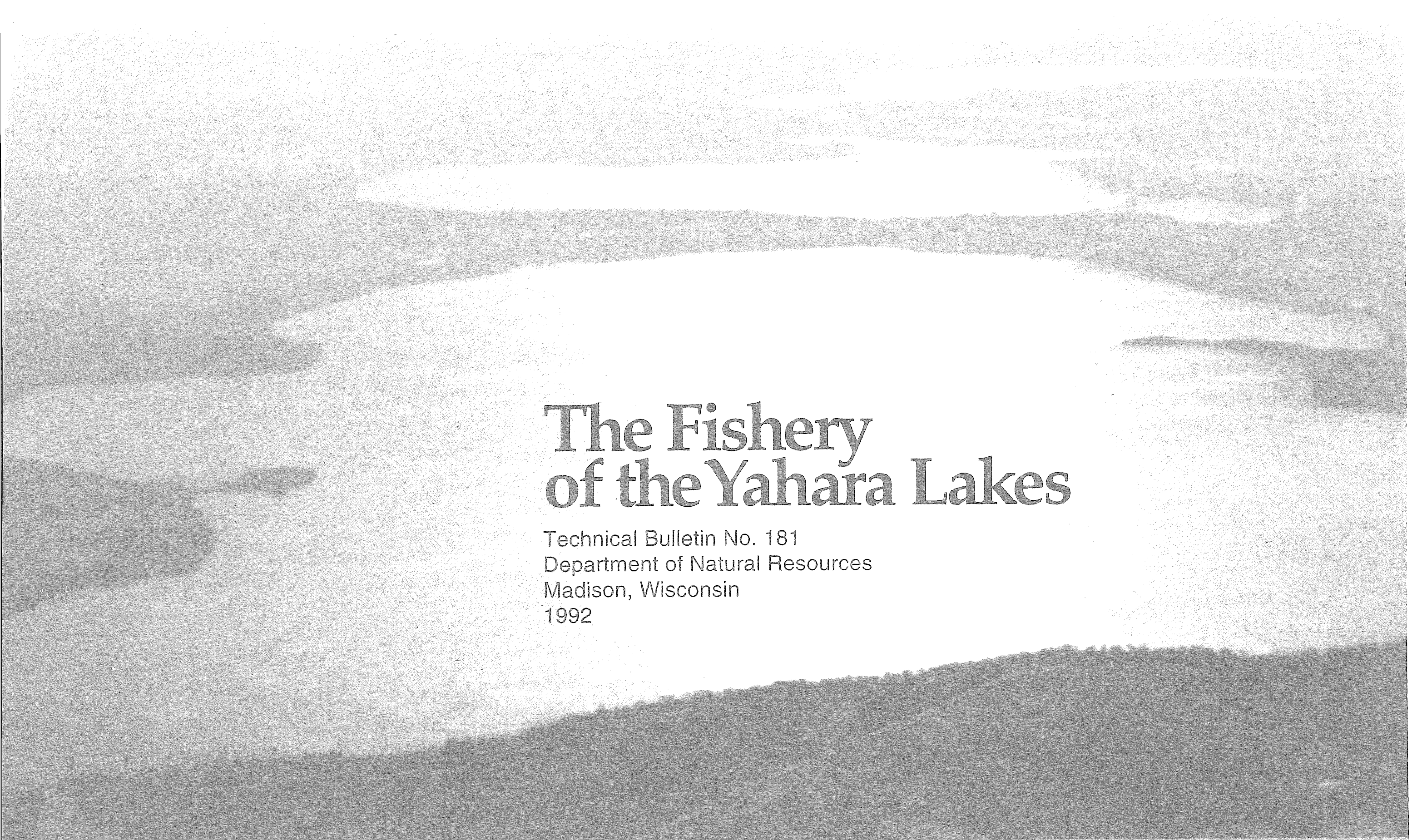

The Fishery of the Yahara Lakes

Technical Bulletin No. 181
Department of Natural Resources
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Cover photos (top to bottom right): Richard Lathrop, DNR Research; Dean Tvedt, DNR Central Office Collection; Eugene Sanborn, DNR Central Office Collection; Ken Christensen, The Capital Times.

ABSTRACT

Part of a larger study on the biology and water quality of the 4 Yahara River lakes—Mendota, Monona, Waubesa, and Kegonsa—this report summarizes fishery data from the extensive amount of published and unpublished surveys and research studies that were conducted from the late 1800s through 1985 on these lakes, which are located in and around Madison, Wisconsin. These surveys and studies were conducted principally by the Wisconsin Department of Natural Resources, its predecessor the Wisconsin Conservation Department, and the University of Wisconsin-Madison. Major data sources include creel surveys, rough fish removal records, fish population surveys (using boom shockers, fyke nets, shoreline seines, and survey seines), stocking records, fish distribution surveys, and research projects focusing on individual species. To gain insight into the lakes' fishery dynamics, lake environment data were also compiled; topics include morphometric characteristics, water temperature, dissolved oxygen, lake fertility, toxics, macrophytes, invertebrate food organisms (zooplankton and macroinvertebrates), wetlands, and water level changes.

The report focuses on ecological requirements and relative abundance of 17 fish species that are or have been major components of the fishery of the Yahara lakes: yellow perch, bluegill, black and white crappie, white and yellow bass, largemouth and smallmouth bass, walleye, northern pike, cisco, common carp, freshwater drum, bullheads (yellow, brown, and black), and white sucker. Other fish species that either have received management attention or were present in past surveys in moderate numbers are also discussed, including rock bass, pumpkinseed, green sunfish, muskellunge, longnose gar, bowfin, lake sturgeon, bigmouth buffalo, channel catfish, and brook silverside. Finally, we summarize records for a number of other fish species from the lakes that are or were rare, have been found infrequently because of inadequate sampling, or are not typically harvested. Many of these species were introduced (both intentionally and unintentionally), and some have been extirpated. Today, 49, 38, 33, and 35 fish species are likely to be present in Mendota, Monona, Waubesa, and Kegonsa, respectively.

The fishery of the Yahara lakes has been dominated by boom and bust populations of certain panfish—bluegills, crappies, white bass, and most notably, yellow perch. Bottom-feeding fish greatly increased during this century, mainly due to the population explosion of carp stocked in earlier years. Predator fish (walleyes and northern pike) have been frequently stocked in order to augment natural reproduction.

Major impacts on the fishery have been related to human activities, including species introductions, increased lake fertility from sewage and nonpoint pollution, and a 30-year program of rough fish removal. Fishkills of yellow perch, cisco, white bass, and yellow bass also had short-term impacts. Other factors such as loss and deterioration of habitat affected some species.

Recommendations to improve the fishery of the Yahara lakes are listed for University of Wisconsin-Madison and Department of Natural Resources research, Department of Natural Resources fisheries management, Dane County, and local fishing clubs.

Key Words: Fishing, panfish, macrophytes, benthic invertebrates, sewage, fertility, stocking, rough fish removal, limnological research, lake environment, Lake Mendota, Lake Monona, Lake Waubesa, Lake Kegonsa, Wisconsin.

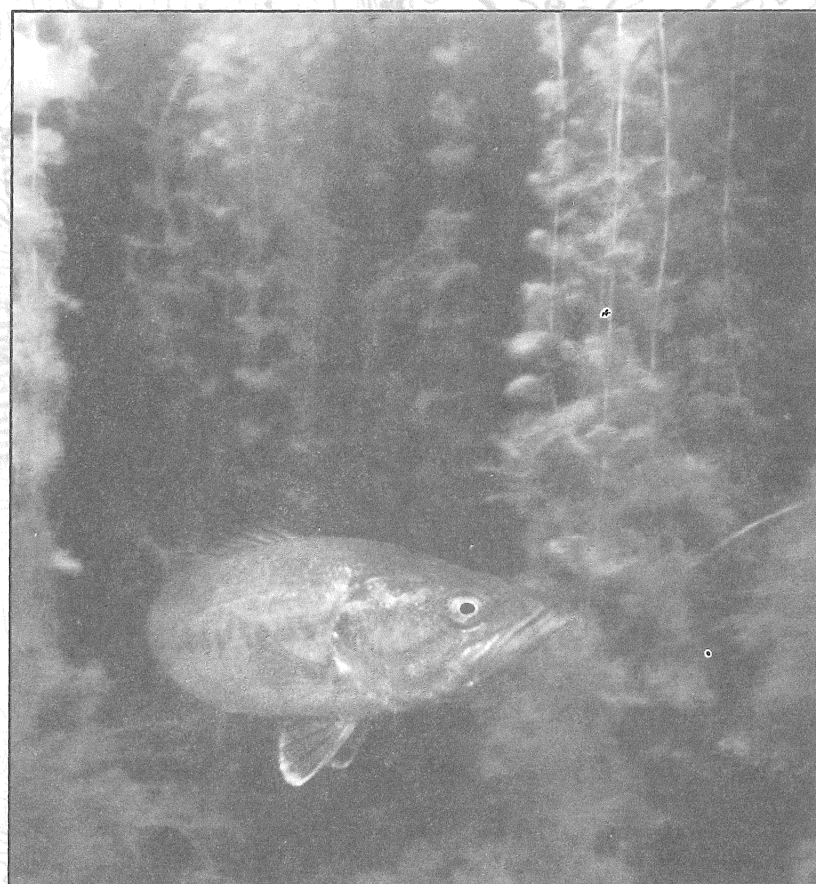

PHOTO: DNR MADISON AREA OFFICE COLLECTION

This report is dedicated to the field biologists, technicians, and students who have worked countless hours, often in less than ideal conditions, sampling the fish populations of the Yahara lakes.

The Fishery of the Yahara Lakes

by
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Clifford L. Brynildson, and Karen R. Plass

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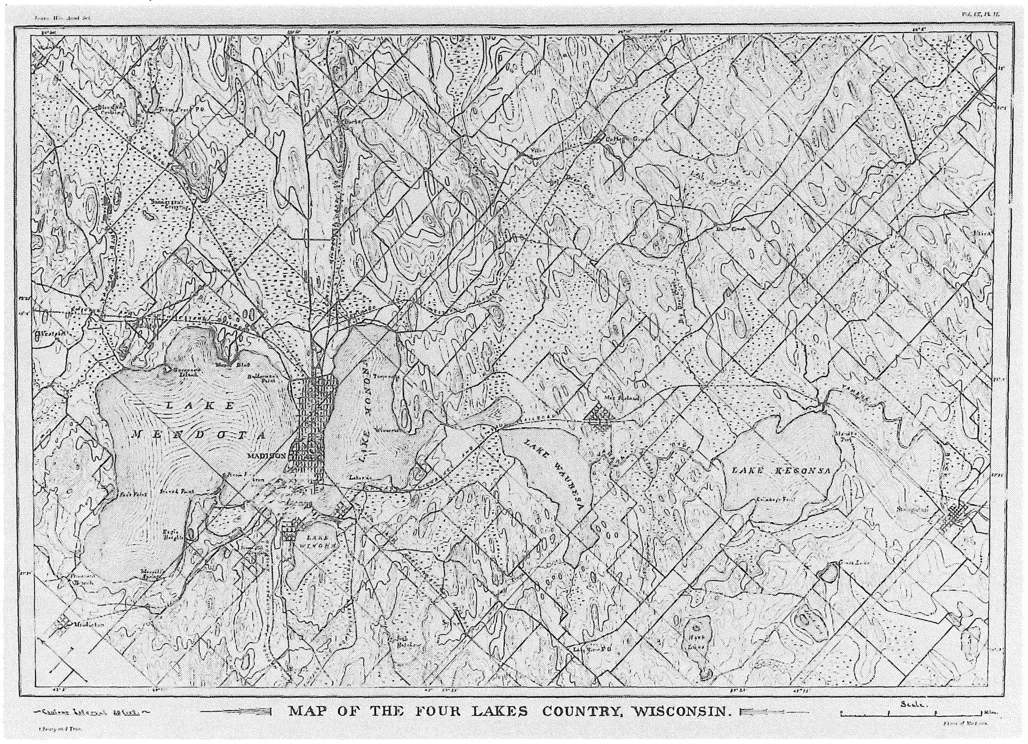

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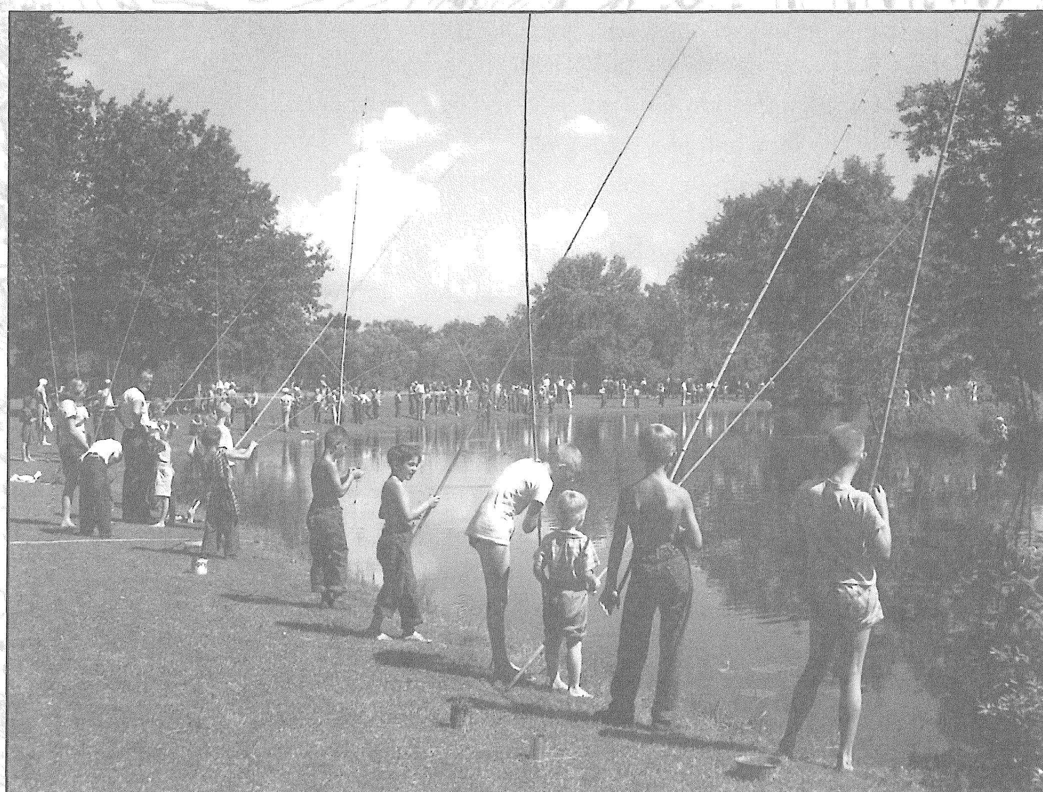


PHOTO: STATE HISTORICAL SOCIETY OF WISCONSIN COLLECTION

INTRODUCTION

The Yahara lakes are a chain of 4 lakes (Lakes Mendota, Monona, Waubesa, and Kegonsa) connected by the Yahara River in and around Madison, Wisconsin. The fishery of the Yahara lakes has been an important asset to humans in the region. For thousands of years prior to Euro-American settlement in Wisconsin, the fishery of these lakes was a vital food resource to the many Indians who camped or settled along the lake shores (Mollenhoff 1982). Accounts of travelers and settlers in the early to mid-1800s described bass, suckers, catfish, pike, perch, and sunfish (bluegills) as abundant in the lakes. Other species mentioned with colloquial names included walleyes and ciscoes.

Beginning in the late 1800s, commercial fishing for ciscoes in Lake Mendota occurred until the cisco population declined in the mid-1940s (John 1954). Commercial fishing for ciscoes was succeeded by commercial fishing for common carp and other "rough fish" because of their increased abundance, particularly in the lower 3 Yahara lakes. In recent years, commercial fishing has been relatively unimportant, principally because of poor market prices for carp.

Recreational fishing on the Yahara lakes and interconnecting rivers has been very popular during the past 100 years. Location of the lakes within or near urban areas makes them readily accessible to anglers. The abundant fishery sustains a thriving local tourism industry, which coupled with fishing by local residents, supports many bait and tackle shops. Fishing provides hours of enjoyment for people of all ages throughout the year, and the fish caught are an important food supplement to many anglers.[1]

History of Research and Management on the Yahara Lakes

The earliest fishery work on the Yahara lakes was conducted by the U.S. Bureau of Fisheries. In addition to stocking various fish species in the lakes as early as the 1880s, they commissioned an evaluation of a massive yellow perch die-off in Lake Mendota during the summer of 1884 (Forbes 1890). The agency also conducted surveys on Lakes Mendota, Monona, and Wingra in the early 1900s that described food preferences and parasite densities of various fish species (Marshall and Gilbert 1905).

The first financial support of fishery research at the University of Wisconsin-Madison (UW) apparently began sometime after 1910. This funding, by the U.S. Bureau of Fisheries, was for a further study of fish food preferences in shore-area fish species of the same lakes (Pearse 1915, 1918). Along with the Wisconsin Geological and Natural History Survey, the U.S. Bureau of Fisheries also supported plankton and macroinvertebrate studies on Lake Mendota (Muttkowski 1918, Juday 1921, Birge and Juday 1922), which dovetailed with a landmark monograph on yellow perch habits in Lake Mendota by Pearse and Achtenberg (1920).

Practical fishery investigations at the UW were also regularly supported not only by the U.S. Bureau of Fisheries but also by the Wisconsin Conservation Department (WCD), which was created in 1927 and assumed fisheries management responsibilities in the state (Frey 1963). However, UW's limnological research emphasis

[1] Based on a creel survey in the early 1980s, about 59% and 74% of the people fishing Lakes Mendota and Monona, respectively, resided in surrounding Dane County (Append. D); most of the remaining people resided in other Wisconsin counties, particularly near Milwaukee. People who fished Lakes Waubesa and Kegonsa were almost equally divided between residences in Dane County and other in-state and out-of-state locations. The annual estimate of people fishing the lakes ranged from 94,000 for Monona to 37,000 for Kegonsa. However, the survey underestimated the total fishing pressure on the Yahara River system, because many lake-shoreline anglers and people fishing the interconnecting rivers were not surveyed.

was shifted to northern Wisconsin during the summer months after 1920, particularly after the building of the Trout Lake Research Station in Vilas County in 1925 (Frey 1963). The only major fishery research conducted on the Yahara lakes during the 1920s and 1930s was Frey's (1940) detailed ecological study of the burgeoning carp populations in Lakes Monona, Waubesa, and Kegonsa.

Because of the importance placed on good recreational fishing, almost all of the past Yahara lakes fishery management by the WCD (incorporated into the Department of Natural Resources [DNR] in 1967) was directed toward maintaining or enhancing important sport fish species and improving public access to these resources. The narrow focus of past fishery management is understandable, since anglers have been the primary historical source of funding for WCD/DNR fisheries management activities and the WCD/DNR's support of UW fishery research. Such funding has come either directly from fishing license fees beginning in 1909 or indirectly from the federal Dingell-Johnson Sport Fish Restoration program beginning in 1951. This program distributes monies to states from revenue collected from the sale of fishing equipment.

Between the mid-1930s and the late 1960s, monies ear-marked for management of the fisheries in the Yahara lakes went primarily to the WCD/DNR's labor-intensive carp removal program. Other than limited sport fish (mostly predator fish) stocking, most of the remaining effort on the Yahara lakes by the WCD/DNR fish management staff was directed at evaluating the effects of the carp removal on improving the shallow-water aquatic vegetation (macrophytes) needed by sport fish species. This habitat evaluation work was directed principally by C. W. Threinen, then Southern Area fish biologist for the WCD, between the late 1940s and late 1950s.

Beginning in the late 1950s, the WCD/DNR's fish management efforts shifted to regular surveys of the fisheries in the 4 lakes. These activities were conducted mainly by C. L. Brynildson, one of the co-authors of this report, during his tenure as WCD Southern Area fish biologist. Emphasis was placed on stocking predator fish to enhance the population densities of some species (walleyes, northern pike, and largemouth bass) and to provide a trophy fishery for others (e.g., hybrid muskellunge). Detailed fishery studies on the Yahara lakes were not regularly done because of the time and staffing required to adequately sample these large lakes.

While the WCD/DNR concentrated on carp management and maintenance of sport fish stocks in the Yahara lakes, in the early 1940s the UW Limnology Laboratory initiated a major research program on the ecology of important pelagic (open-water) fish species in Lake Mendota. Yellow perch received the most attention, followed by white bass and ciscoes. That research emphasis has continued to this day, but with increased emphasis on food-web dynamics and ecosystem research.

Much of this fishery research was under the direction of Arthur Hasler during his nearly 40-year tenure as a professor of limnology at the UW. Hasler developed the UW Limnology Laboratory, which was later renamed the Center for Limnology, into a major center for fish and other limnological research that included work on Lake Mendota. John Magnuson became the Center's director upon Hasler's retirement in 1978 and has continued to expand the Center's interest in limnological and fishery research on Lake Mendota.[2]

During the 1970s, a major study of the distribution and relative abundance of fish species in the Yahara lakes was conducted by the Fish Research Section of the DNR Bureau of Research as part of a larger statewide

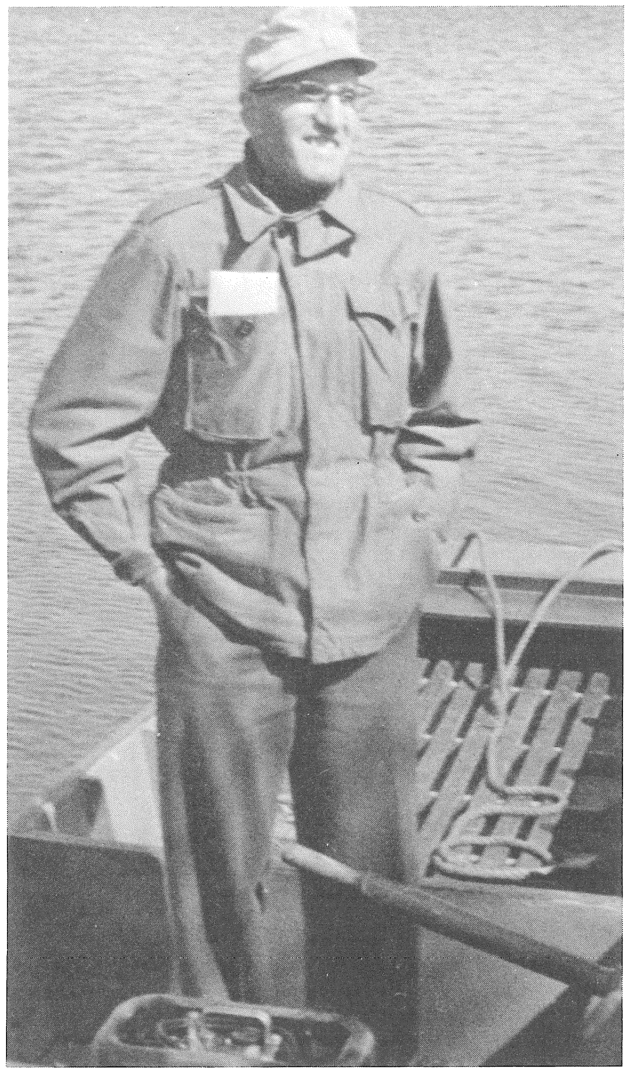


PHOTO: ART HASLER, UW CENTER FOR LIMNOLOGY COLLECTION

Prof. A. D. Hasler, leader of limnological research on Lake Mendota for 4 decades.

[2] Throughout this report, mention of fishery research by the UW refers to studies conducted by the Center for Limnology and/or its predecessor, the Limnology Laboratory.

survey that focused on the lesser known, nonsport fish species such as minnows and other small forage fish. The 4 lakes, their tributary streams, and inter-lake Yahara River were surveyed during this study (Fago 1982). This research complemented the work by McNaught (1963) on the fish species of Lake Mendota.

Recently, the broader role of the fishery in Lake Mendota's ecology has received considerable attention through a joint research/demonstration project conducted by the DNR and the UW. The food web interactions of predator and planktivorous (plankton-eating) fish and the concomitant effect on zooplankton and phytoplankton are being studied in Lake Mendota as large numbers of walleye and northern pike fry and fingerlings are stocked. The hypothesis is that water clarity improvements will be achieved through cascading trophic interactions (e.g., high predator fish densities leading to low planktivorous fish densities, resulting in high zooplankton densities that lead to low phytoplankton densities) (Carpenter et al. 1975, 1987). This effect has previously been reported (Hrbáček et al. 1961, Brooks and Dodson 1965) and has been the focus of biomanipulation lake management strategies in recent years (Shapiro et al. 1982). The results of the first 3 years (1987–89) of the DNR/UW joint research on Lake Mendota were recently published in a book edited by Kitchell (1992). This research is ongoing.

Fisheries research and management have been complemented by limnological research on the Yahara lakes. Lake Mendota was the site of extensive, descriptive research by pioneer limnologists around the early 1900s. Based on their research and that of many others at UW who followed, Lake Mendota has been called one of the most studied lakes in the world (Brock 1985). The 3 lower lakes began to receive attention in the 1920s, when water quality was severely impacted by Madison's sewage effluent. In 1925, B. P. Domogalla, a UW Ph.D. graduate who had conducted water quality research on the Yahara lakes, was hired by the city of Madison to manage its lake problems. He initiated a water quality monitoring program that continued on all 4 Yahara lakes until the late 1940s; unfortunately, complete records from the program were never published.

Other data on the Yahara lakes have been collected since the late 1930s, but the investigations were mostly UW thesis-oriented research covering short time periods. These investigations also marked the beginning of an era of experimental rather than descriptive limnology. In this new era, focus was on specific questions or problems rather than on broad surveys. As a result, routine water quality data were not always obtained. One notable exception was an extensive amount of water chemistry data collected on Lake Mendota by the UW Water Chemistry Program between the mid-1960s and the mid-1970s. That time period was also when water quality monitoring data on the lower 3 Yahara lakes were first regularly obtained by the DNR.

Background on This Report

This report on the fishery of the Yahara lakes is part of a larger study on the biology and water quality of the 4 Yahara lakes. This long-term limnological research project was begun in 1976 by the DNR Bureau of Research. The original purpose of the research was to identify the factors that cause each lake's summer algal blooms, because the public's perception of water quality often is a function of the type and abundance of phytoplankton present.

The research project had several components. Detailed information was obtained about the phytoplankton and their seasonal succession in each lake. Zooplankton were also analyzed, because zooplankton can have a significant effect on phytoplankton through selective feeding. Plankton work on Lakes Waubesa and Kegonsa spanned 12 years (1976–87). Collection and analysis of phytoplankton and zooplankton data for Lakes Mendota and Monona, also begun in 1976, are

PHOTO: BRETT JOHNSON, DNR MADISON AREA OFFICE COLLECTION

Newspaper articles on the joint DNR/UW food web research study initiated in 1987 on Lake Mendota.

ongoing. Detailed information was also collected on water quality to document the effect of nutrients not only on algal growth but also on the long-term fertility of the lakes. Collection and analysis of these physical and chemical data for all 4 lakes are also ongoing. Lastly, short-term surveys on submersed aquatic macrophytes and bottom-dwelling macroinvertebrates were conducted in 1984 and 1987–89, respectively.

After the research project began, it became clear that analyzing the Yahara lakes as a whole ecosystem was just as important as analyzing the algal bloom problem. As a result, a second project objective evolved: to gather and interpret other limnological data, including an analysis of the fishery. This aspect of the lakes' ecosystem was chosen as one of several factors believed to have a role in affecting the lakes' water quality. The primary objective of the fishery analysis was to describe the fishery of the 4 Yahara lakes, including documenting and summarizing historical as well as current information on the fishery. Historical limnological information was included to help put into perspective the more recent data collected by the Bureau of Research.

Historical fishery data were obtained from 2 major sources. Data produced by the UW were extensive but published in separate theses and in a variety of other reports. Fishery data produced by the WCD/DNR, on the other hand, were largely unpublished. These records were often just "memos to the file." They were so transient, in fact, that some records were inadvertently discarded, while others were lost in a fire during the mid-1970s. In the present report, highlights of the published information are summarized in the text for individual fish species, while unpublished records are summarized in appendix tables at the end of the report.

Historical fishery data cover approximately 8 decades, ending in 1985. As data for the fishery report were summarized, 1985 was selected as a convenient cut-off date, since the UW began collecting preliminary data for the biomanipulation study the following year. Also, no fishery surveys were conducted by the DNR on the Yahara lakes in 1986, the year of C. L. Brynildson's retirement as DNR Area fish manager.

In-lake data collected by the Bureau of Research, provided to describe the lake environment of fish species, are based on sampling from 1976–89. Inclusion of limnological data through 1989 (versus 1985, the cut-off for fishery data) was prompted by significant recent changes in the lake environment, particularly water clarity, macrophyte densities, and temperature/dissolved oxygen conditions. We felt that these additional years of data better described the range of environmental conditions affecting the fishery.

For the purposes of this report, the fishery information we collected was merged with other historical information and the limnological data obtained by the Bureau of Research. The report is descriptive, with an emphasis on documenting trends. Historical information has been heavily documented in this report—to correct the historical record in several instances, to put into print unpublished or unsummarized information for use by managers and scientists, and to aid others doing future historical research. An effort has been made to make the technical information understandable to a wide audience of not only scientists but also lake managers and the public concerned about the Yahara lakes. More detailed reports on the physical, chemical, and plankton data and their interrelationships in the 4 lakes have been and will continue to be published.

This report centers around 3 major topics: lake environment, fish species, and fishery perspectives. Other sections describe the Yahara River system, methods of data collection and interpretation, and finally, research and management recommendations.

The Lake Environment Section summarizes a number of factors believed to be important to individual fish species in each lake. Topics include physical and chemical characteristics—morphometry (area and depth characteristics), water temperature, dissolved oxygen, major water chemistry constituents, fertility, and toxics; aquatic macrophytes; invertebrate food organisms; wetlands for spawning (including lake level effects); and inter-lake areas and tributaries. More extensive treatment is made of both macrophytes and bottom-dwelling invertebrates because these important subjects were not adequately summarized before.

The Fish Species Section includes information on the ecological requirements and relative abundance of fish species that are a major component of the fishery of the Yahara lakes. Information about other species is also presented, along with a summary table of all fish species reported for the Yahara lakes. Ecological information is given only for major fish species and only as general background. Although using this information to establish the precise role of each species in the Yahara lakes ecosystem would have been ideal, such a task was beyond the scope of this report. In discussing relative abundance of the major fish species, we first summarize results of relevant surveys, then conclude by interpreting these results to suggest population trends. Other pertinent information (e.g., on the history of carp stocking and removal and on cisco population changes) is also included whenever possible.

The last major section, Fishery Perspectives, describes the fishery and highlights principal factors affecting it, with primary focus on events or changes affecting groups of fish species. Those factors influencing relative abundance of individual species are mentioned in the write-ups for each species.

As this summary of organization may suggest, this report is a compilation of many pieces or groups of data. The relationships among them may not always be initially clear. In addition, some parts are descriptive, whereas others are more quantitative. This variation was dictated in part by a corresponding variation in topics—from general to technical—and by the availability of information. Hopefully, what is lost in the resulting patchwork is offset by the value of a publication that brings together data from a broad range of sources spanning nearly a century.

PHOTO: RICHARD LATHROP, DNR RESEARCH

Water quality sampling on Lake Mendota by DNR Bureau of Research personnel.

Lake Mendota from the northeast.

PHOTOS: RICHARD LATHROP, DNR RESEARCH, SEPTEMBER 1985

Lake Monona from the southwest.

Lake Waubesa from the south.

Lake Kegonsa from the south.

STUDY SITE

Location and Cultural Setting

Lakes Mendota, Monona, Waubesa, and Kegonsa are located in south central Wisconsin within or near Madison, the state capital in Dane County (Fig. 1).[3] The lakes are a chain of lakes connected by the Yahara River, a tributary of the Rock River, and together encompass 7,453 ha. The Yahara River drainage basin (watershed) is only a small part of the Rock River basin, which encompasses much of southern Wisconsin and northern Illinois and drains into the Mississippi River. Three of the lakes (Mendota, Waubesa, and Kegonsa) are elevated by low-head dams, and navigational locks are maintained at the outlets of Lakes Mendota and Waubesa.

The 1990 population of Dane County was approximately 367,000, with 82% of the people residing in Madison or other small cities and incorporated villages (Dane Cty. Reg. Plann. Comm. 1990). Industry in the Madison area can be characterized as light, with major government offices and university-related services supporting much of the local economy. Commercial activities are varied, but heavy industry is not extensive. Agriculture has been important in Dane County since the mid-1800s. In recent years, dairy farming, cattle and hog production, and corn as a cash crop have been dominant. The percentage of corn acreage in the Yahara River drainage system was about 36% in 1986 (Dane Cty. Reg. Plann. Comm. 1988).

Climate

The climate of Madison is typical of interior North America. The annual temperature range is large, and frequent temperature changes are common. Winters are usually long, cold, and snowy, with periodic influxes of arctic air. Summers are warm, with occasional periods of extremely high temperatures and humidity. Spring and fall are sometimes short. The mean annual temperature is 8 C, with an absolute range from 40 C to -39 C. January, the coldest month, averages -8 C, while July, the warmest month, averages 22 C (Natl. Ocean. Atmos. Adm. 1988; Pam Naber Knox, Wis. State Climatologist, pers. comm.).

Average annual precipitation is about 78 cm. About 68% of annual precipitation falls in April–September; average monthly rainfall for that 6-month period ranges from 8–10 cm. Much of the rainfall occurs during heavy thunderstorms. February is the driest month of the year, averaging only about 3 cm of precipitation. Snowfall averages 107 cm/year, with a range of about 32–193 cm/year (Natl. Ocean. Atmos. Adm. 1988; P. Naber Knox, pers. comm.).

Geology and Glacial History

The Yahara watershed, its drainage system, and the 4 Yahara lakes were created during the last period of glaciation, which ended a little more than 10,000 years ago (Martin 1965). The dendritic drainage pattern that was eroded into the sedimentary rocks by the preglacial Yahara River was transformed by the advancing ice sheet. In the Yahara lakes area, the movement of the glacial ice carved rock from the hilltops and valleys. However, the most dramatic change in the topography was wrought by the deposition of a thick layer of glacial till rather than by glacial scouring. Some parts of the Yahara valley were filled with >100 m of unconsolidated debris (Martin 1965).

This deposition created one large lake (Lake Yahara) that later drained when the Yahara River eroded its outlet. This drainage led to the formation of Lakes Mendota, Monona, Waubesa, and Kegonsa, which were separated from one another by dams of glacial debris in the Yahara valley. After the period of glaciation ended, the Yahara River became a stream characterized by a meandering channel, a relatively small number of tributaries, and extensive undrained inter-lake areas with large wetlands.

Beneath the unconsolidated glacial deposits are many different layers of sedimentary rocks. Four formations of sedimentary rock are evident in the surficial topography near Madison: 2 relatively erosion-resistant formations of limestone alternating with 2 weaker formations of sandstone. The tops of the highest hills in the area are capped with the erosion-resistant Black River limestone, while lower hills are capped with Lower Magnesian limestone. The short, steep slopes between these layers of limestone are underlain by St. Peter sandstone, while the valley bottoms are underlain by Cambrian sandstone (Cline 1965, Martin 1965). Beneath the many layers of Cambrian sandstone are much older crystalline rocks—mostly rhyolite, granite, and basalt. These rocks lie 150–300 m below the land surface. They allow little penetration of water and therefore form a floor beneath the overlying, water-bearing sedimentary rocks or aquifers (Cline 1965). Because of the extensive limestone deposits, the waters of the Yahara River system are alkaline. The total alkalinity of the 4 lakes averages 170–180 mg/L as $CaCO_3$.

[3] Much of the information for this section was taken from the Dane County water quality plan (Lathrop and Johnson 1979).

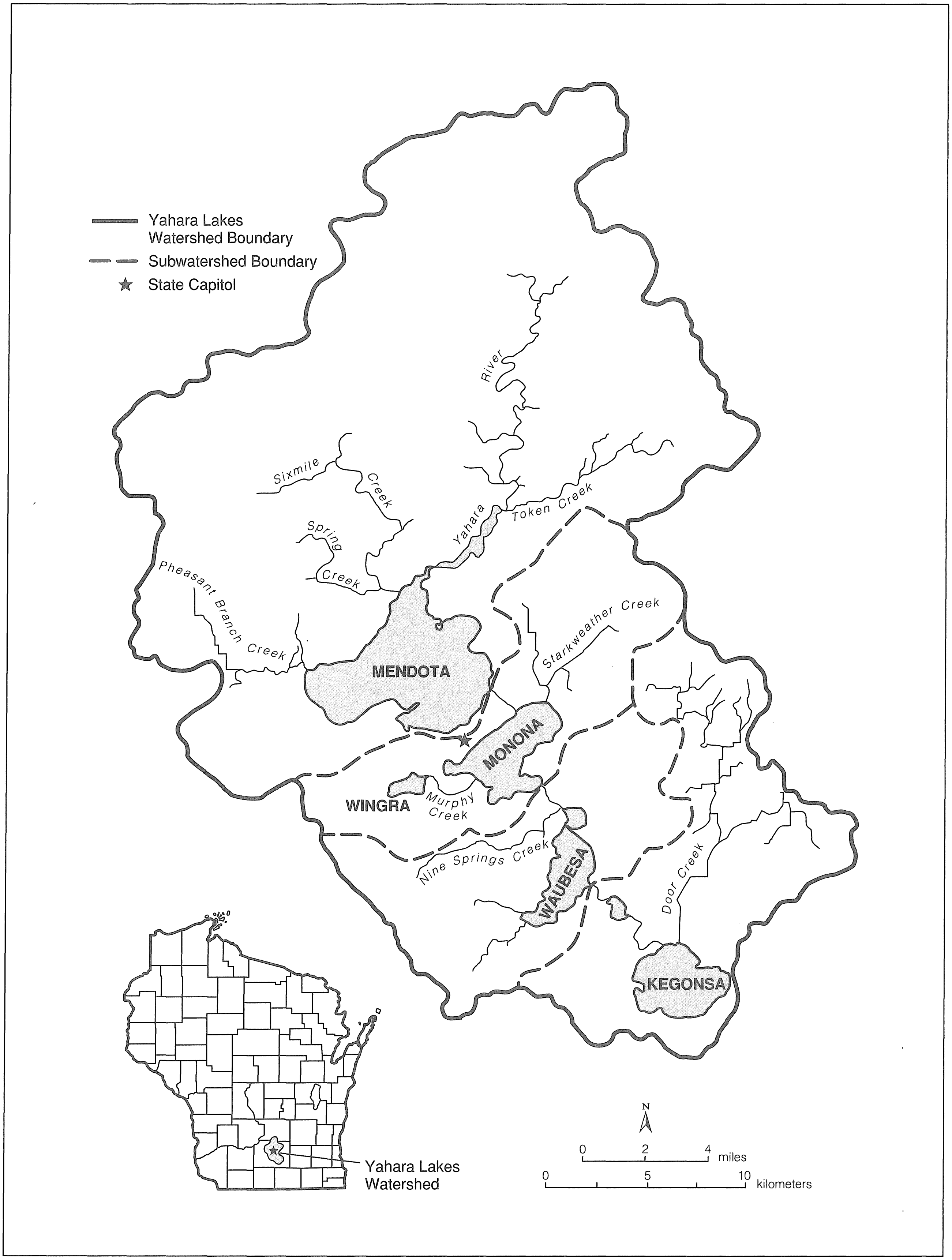


Figure 1. *The Yahara River watershed showing subbasins and adjoining tributaries and wetlands.*

Drainage Basin

The drainage basin or watershed of all 4 Yahara lakes encompasses 996 km^2 (Table 1) of gently rolling to hilly glaciated terrain. The watershed is bounded on the west by moraines and on the east by a region of drumlins and marshes (Martin 1965). Much of the watershed is prime agricultural land because of fertile soils. Upland soils are mostly silt loams or loams characterized as well-drained. Lowland soils are mostly poorly drained silts with mineral and organic material underlain by alluvial deposits (Cline 1965). Wetlands adjacent to the Yahara lakes have extensive peat deposits.

The Yahara River originates in a marshy area in southern Columbia County north of Dane County. Upstream from Lake Mendota, the Yahara River is only a meandering creek of relatively low discharge during baseflow. However, before entering Mendota, the Yahara River joins with Token Creek, which has the highest baseflow of any tributary stream entering the Yahara lakes exclusive of the inter-lake sections of the Yahara River. Other streams entering Lake Mendota are Sixmile Creek and Spring Creek, entering from the north, and Pheasant Branch Creek, entering from the west. Pheasant Branch Creek has much steeper gradients than the other Mendota tributaries because of its origin in the glacial moraines that bound the western edge of the watershed. Other small discharges to Lake Mendota result from urban drainage. However, the majority of Mendota's watershed area (561.8 km^2) is rural, with most of the land in agriculture (Table 1). The urbanized area as identified in the mid-1970s was only about 4.4%, but urban sprawl in recent years has undoubtedly increased its proportionate size. Much of Mendota's hydrologic inputs are via stream and storm sewer discharges during both baseflow and surface runoff from storms.

Table 1. *Watershed and lake areas of the Yahara lakes.*

Lake	Watershed Component	Area (km^2)*	Percentage (%) Urbanized*
Mendota	direct drainage	561.8	4.4
	lake	39.9	-
	total Mendota**	601.7	-
Monona	direct drainage	105.2	36.2
	lake	13.2	-
	total Mendota and Monona**	720.1	-
Waubesa	direct drainage	113.4	9.0
	lake	8.5	-
	total Mendota, Monona, and Waubesa**	842.0	-
Kegonsa	direct drainage	141.2	3.1
	lake	13.0	-
	total Mendota, Monona, Waubesa, and Kegonsa**	996.2	-

* Sources of data:
Areas - computed from watershed map.
Urbanization - determined by planimetry of U.S. Geological Survey topographic maps (printed in 1976).
** Total watershed area at lake outlet.

Various streams discharge to the lower 3 Yahara lakes (Fig. 1), but both their stream gradients and baseflow discharges are relatively low. Most of the water entering these lakes is from the interconnecting Yahara River, the discharge of which is regulated by dams at the outlets of Mendota, Waubesa, and Kegonsa. Surface runoff to Lake Monona via Starkweather Creek (East and West branches) and to Lake Kegonsa via Door Creek can be significant during large rainstorms. Much of Monona's direct drainage area (105.2 km^2) is urbanized (Table 1). Part of the runoff enters Lake Wingra, which discharges to Lake Monona via Murphy Creek. The direct drainage areas to Lakes Waubesa and Kegonsa are 113.4 km^2 and 141.2 km^2, respectively. Almost all of Kegonsa's watershed is rural, whereas Waubesa's watershed is partly urbanized.

Several small shallow lakes and impoundments also are part of the Yahara River system. In the Mendota watershed, there are 3 small lakes: Token Creek has been dammed to create a 9-ha millpond, part of Cherokee Marsh has been dredged to create a small lake, and Sixmile Creek has a widespread called Lake Mary. The Lake Monona watershed has a natural lake, Lake Wingra (140 ha, maximum depth 6.4 m). In addition, 2 large, shallow widespreads exist adjacent to the 2 lower lakes. The first of these is Upper Mud Lake (107 ha), in the Yahara River upstream from Lake Waubesa. In recent years, some areas of this lake have been dredged as part of the construction of the new South Beltline Highway. The second, smaller widespread is Lower Mud Lake (79 ha), upstream from Lake Kegonsa.

The Yahara drainage system, though still similar to its postglacial pattern, has been changed by the agricultural and urban development in the area since the late 1840s. This was also the period when Mendota's water level was raised 1.2–1.5 m by a dam at its outlet. Wetlands have been drained or filled, stream channels have been straightened, and many of the small springs have dried up because of lowered water tables. The impacts of urbanization probably have most severely impacted Lake Monona; its shallow marshy shorelines have been extensively dredged or filled for highways, urban development, and city parks (Mollenhoff 1982). These topics are discussed further later in this report. Specific information about the physical and chemical characteristics of each of the 4 Yahara lakes are discussed in the Lake Environment Section.

PHOTO: BRETT JOHNSON, DNR MADISON AREA OFFICE COLLECTION

METHODS

Study Techniques

Overview of Information Sources

As discussed in the Introduction, the fishery data in this report were obtained mostly from UW theses or published scientific papers and from WCD/DNR management reports or unpublished file memos. The UW research, particularly after about 1940, focused on detailed ecological studies of individual species such as yellow perch, white bass, and ciscoes in Lake Mendota. One additional important source of information was a spring fyke net study of spawning white bass conducted by UW researchers from 1955-71. Detailed information about white bass was contained in 2 theses, but information about other fish species captured in the long-term sampling was not tabulated.

The WCD/DNR information consisted of records of fish stocking and various surveys taken over a number of years on all 4 Yahara lakes, with the goal of improving fishing. The surveys were designed to determine "what was out there" as well as to provide information to evaluate the management of certain fish species such as carp (which were removed) or walleye and northern pike (which were stocked). Many of the surveys were designed for short-term data needs, with less emphasis placed on consistency of sampling methodologies for long-term quantitative comparisons.

Finding the WCD/DNR data was our first problem, and discovering whether or not data existed from other sources was our second. Results of some of the more comprehensive surveys on the Yahara lakes between the late 1940s and early 1950s were reported in mimeographed WCD Fish Management Investigational Reports. These are available in DNR's 2 libraries: the Research Library and the Central Library (both in Madison). Results of less-comprehensive surveys during the 1950s were reported in WCD Southern Area Investigational Memoranda. Other surveys from the WCD's early years through the 1960s may have existed, but a fire at the DNR Southern District headquarters in 1976 destroyed the main file of early information. These records (including the Southern Area Investigational Memoranda) were mostly typed in memo form, with only a few carbon copies made. Original copies were filed at Southern District headquarters, while most of the carbon copies ended up in the files of WCD staff. We found some of the Investigational Memoranda carbon copies in the Research Library, but others were apparently discarded when people retired; a number of them summarizing creel surveys and aquatic macrophyte surveys conducted during the 1950s could not be located. We contacted former employees but were generally unsuccessful in finding these records.

Other lost data included the individual seine haul tallies of the WCD's rough fish removal operation between the mid-1930s and the late 1960s; unfortunately, these records were thrown out after years of storage. While annual summaries of the rough fish removed were available, data on other species captured during the seining were not summarized, except for records for Monona, Waubesa, and Kegonsa from the mid-1930s to the early 1950s. Subsequent records for those lakes and none of the records for Mendota were ever summarized. An exception was an analysis by Wright (1968) of the white bass and yellow bass population changes in the Yahara lakes in the 1950s and 1960s.

Results of DNR surveys conducted in more recent years were all available, as the DNR maintains a central filing system at its state headquarters in Madison, with copies filed at District and Area offices. All memos on surveys that we used (including some copies of earlier WCD surveys) are found in the files of the DNR Madison Area headquarters. These memos all probably had authors, titles, and dates, but that information was not consistently noted when we compiled our own summaries of the data; thus these memos are referenced in this report as unpublished data in the DNR Madison Area files. Most of these surveys were conducted by Cliff Brynildson, then Madison Area fish manager and one of the co-authors of this report, or his assistants.

Personal communications were a final source of fishery data. Mostly anecdotal, these accounts were valuable in providing information for periods when no surveys or research studies were conducted. First, with assistance from members of the Yahara Fisherman's Club, we summarized information on the winning yellow perch weights from their annual winter Percharee contest on Lake Mendota, first held in 1954.[4]

Second, the personal fishing diaries of Robert "Buck" Kalhagen, a retired WCD/DNR Southern District fish technician, provided a valuable creel record of the fishery in Lake Waubesa during 1976–82. Finally, remembrances of many fishery research scientists, biologists, technicians, and avid anglers were useful. Important personal accounts were from Gordon Priegel (WCD/DNR fishery biologist) and Kenneth Christensen (retired outdoor writer for the *The Capital Times*, whose recollections date back to the late 1920s). Additional personal accounts were also used, and all are cited as personal communication in this report. Names and affiliations of persons providing personal recollections and unpublished data are given in Appendix C.

Units of Measurement

The data compiled for our study were originally recorded in either English or metric units. Most of the UW research studies reported data in metric units, while almost all of the WCD/DNR data were collected and reported in English units. For the early fishery, aquatic plant, and bottom insect surveys, lake depth was recorded in feet, while water temperature, dissolved oxygen, and other water chemistry data were reported in metric units. Over the years, fish lengths were recorded mostly in tenths of inches, whereas weights were recorded in grams. Rough fish removal records were in pounds or tons.

Given this potpourri, the choice of how to express measurements in this report was difficult, but after much debate we chose the metric system, to conform to most scientific writing. Exceptions to this metric unit rule were necessary for several groups of data, mostly historical, which we did not convert: (1) *Large-scale fish removals*. These data include records of fishkills that washed up on shore and were removed by shoreline clean-up crews and records of rough fish removed by state and commercial crews. Descriptions of these removals were often approximate (e.g., "several tons were removed"), or field measurements were made roughly because of the vast quantities involved. We have not attempted to convert these rough estimates to more precise metric equivalents, in order to avoid suggesting a degree of accuracy that does not exist. (2) *Carp sizes*. Historical records of carp sizes were left in English units for consistency with rough fish weights and prices (per pound) cited in the early literature. However, metric equivalents for carp sizes and prices are given in parentheses. (3) *Boat sizes*. Where boat lengths were mentioned in gear descriptions, these were left in English units to conform to standard boat descriptions.

Hydrographic Maps

Because of the value of having accurate hydrographic maps of the Yahara lakes, all 4 lakes were remapped, using recording sonar, in the summers of 1980–81.[5] The remapping project was a cooperative effort between the DNR Bureau of Research and the Dane County Public Works Department, which conducted the field work. Eugene Eaton, formerly of the DNR Bureau of Engineering, drafted the official state maps from the new data. The previous map for Lake Monona was known to contain considerable errors, so there were important corrections in the new maps. The new hydrographic maps for Waubesa and Kegonsa had few changes relative to previous maps. The new map for Mendota was very similar to the map prepared by the UW in the 1950s.

These maps are printed with depth contours in feet and area in acres and contain numerous additional shallow water and shoreline information. However, they were too detailed to be reduced for printing in this publication. Consequently another set of lake maps was developed, drafted (again by Eugene Eaton) from the new mapping data, with metric contours and no other map symbols. The lake area and volume information presented in this report were computed from these metric maps. The maps, which were drawn on large sheets, were then adapted by the UW Cartographic Laboratory to the size printed in this report.

Lake Environment

Data for the Lake Environment Section came from many sources, including scientific publications; UW theses; and WCD/DNR memos, mimeographed reports, and other publications, which are all similar to the aforementioned fish data sources. David Frey of Indiana University provided raw data from a survey of benthic macroinvertebrates that he conducted in the Yahara lakes in 1939 and summarized (Frey 1940). J. A. Šapkarev, University of Skopje, Yugoslavia, provided his results of a year-long survey on macroinvertebrates in Lake Mendota conducted during 1964–65; results on the leeches were published in Šapkarev (1967–68). Unpublished records on city weed cutting and county weed harvesting were provided by Bernard Saley (retired), of the City of Madison Public Health Department, and by Howard Hartwig (retired) and Ken Koscik, Director, Dane County Public Works Department. These records were used as a general guide to macrophyte abundance: in years when macrophytes were dense, large amounts were removed. Likewise, in most years when macrophytes were not considered dense, removal was minimal.

Historical macrophyte information also came from observations in published reports and field notes. Such subjective observations have limited usefulness because

[4] This contest, sponsored by the Yahara Fisherman's Club, was called "The Fisheree" from 1951–53 and was then not restricted to Lake Mendota. In 1954, the contest was renamed "Percharee" and was conducted exclusively on Lake Mendota until the early 1980s, when it was extended to include Lake Monona. Contest records for all years were not found.

[5] These hydrographic maps may be obtained from the Information Center of the DNR at the address on the title page of this report.

people perceive macrophyte densities differently. Observations may have missed the less-abundant species, and many species may not have been carefully identified. In addition, observations and surveys were not always simultaneous; thus the reported densities of certain species may have been related to their growth cycle rather than their relative abundance.

Agricultural statistics for Dane County were compiled from 3 sources: the U.S. Department of Agriculture (1953); agricultural censuses published by the U.S. Bureau of the Census[6]; and records found in the Agricultural Statistics Service office of the Wisconsin Department of Agriculture, Trade, and Consumer Protection. Population statistics for Dane County were compiled from census reports published approximately every decade: U.S. Department of the Interior (1892), U.S. Department of Commerce (1921, 1942, 1961, 1982), and Demographic Services (1992).

In addition to these historical data sources, original material, mostly relating to maps of the Yahara lakes, was also used. Data on lake morphometry (i.e., area, volume, depth, and shoreline length and development) were determined from the 1980–81 hydrographic maps discussed earlier. A watershed map of the Yahara lakes was drawn from U.S. Geological Survey topographic maps.[7] Watershed boundaries were then determined in consultation with the Dane County Regional Planning Commission and U.S. Geological Survey. From this watershed map, watershed and lake areas were computed, and a simplified watershed map for this report was prepared. Area of wetlands was also determined by planimetry of maps compiled by Theresa Brasino and Carolyn Johnson, former LTE's for the Bureau of Research, and Adrian Freund, formerly of the Dane County Regional Planning Commission.

Other original material cited consists of water temperature, dissolved oxygen, lake chemistry, and zooplankton data from the Bureau of Research's long-term limnological sampling of the 4 Yahara lakes. Methods for the collection of these data are described in other reports on the Yahara lakes, including Lathrop (1992*a*, 1992*b*) and Lathrop and Carpenter (1992*b*).

The Bureau of Research also conducted surveys of (1) the aquatic macrophytes in Lake Mendota (University Bay) and Lake Monona (Turville Bay) in July 1984 and (2) the bottom-dwelling macroinvertebrates in all 4 Yahara lakes in 1987–89. These surveys were deemed important for a more comprehensive analysis of both the macrophyte and benthos communities and their relationships with each lake's fishery. Complete results of the surveys will be published elsewhere, but summary information is provided in this report along with information from other sources.

The macrophyte survey consisted of sampling (by snorkeling and scuba diving) at set intervals (50–200 m from shore) along a single transect through the center of both bays. Sampling sites were selected because they were areas in which macrophytes had not been treated with herbicides or mechanically harvested. Three replicate plant samples were gathered within a 3-sided aluminum frame (0.1 m^2) dropped on the lake bottom. The plants were later rinsed in dilute acid to remove encrusted carbonates, sorted by species, and dried (at 105 C) to obtain dry weight biomass. Plant distribution by water depth was also noted. Macrophyte surveys have been conducted on Lake Mendota since 1989 and on the lower 3 Yahara lakes since 1990, but the results are not reported here.

For the macroinvertebrate analyses, bottom sediment samples were collected at various depth contours in each lake. In general, 5 replicate Ekman dredge samples were taken at 3-m intervals from 6–24 m of water depth in Lake Mendota and from 9–21 m in Lake Monona and at about 9 m in both Lakes Waubesa and Kegonsa, all during January 1987–89. In August 1987, the same survey was repeated, and samples were also taken at the 6-m depth contour in each lake. Within a few hours of collection, the dredge samples were rinsed with a hose through a 300-μm screen, and the organisms were collected and preserved in 95% ethanol. The organisms were later identified and enumerated. Survey results were reported in Lathrop (1991, 1992*c*).

Although not customarily done in most reports, the source is given for all of the original Bureau of Research material used in this study. This was done in order to distinguish this material from the bulk of the other data cited in this report that come from other unpublished and published sources.

Fish Species

Presence. Sources of data for reports of fish species presence in the lakes included both published and unpublished records. Two primary sources were McNaught (1963) and the computerized data base of Fago (1982). The McNaught reference on the fish species of Lake Mendota was chosen because it summarizes numerous earlier reports, notably Pearse (1918), as well as personal communications and museum records. The Fago reference was chosen because it is the first systematic attempt to survey all the fish species in the 4 Yahara lakes. It also summarizes historical records, including Greene's (1935) report on distribution of Wisconsin fish species. Fago's summary is especially valuable because it bases assessment of Greene's records on the original, oversized distribution maps that Greene used to prepare his book, which itself contains maps of insufficient detail to distinguish which of the Yahara lakes is cited as the source of a record for a particular species. Fago's computerized data base was used instead of his published report because the data base gives more exact information as to where fish were collected. In addition,

[6] The census data appear in reports published approximately every decade, entitled *Census of Agriculture*. Each census is printed in various parts and volumes, and numbering and titling of the parts and volumes varies from census to census.

[7] The topographic maps used as the watershed base map were 1959 map editions (scale 1:24,000; 7.5-min series). These were surveyed in 1959, photo-revised in 1974, and printed in 1976.

the data base contains a few new records added after the publication of the 1982 report.

Other sources of data were also consulted. Primary sources were Lyons' (1988) listing of fish species in Lake Mendota and Lyons' (1989) paper on the shore fish of Lake Mendota. The final source of fish presence information was the set of tables that appear in Appendix A of this report, which were compiled primarily from the WCD/DNR surveys and the personal communication sources described earlier.

In tabulating records from these various sources, we made a number of interpretations about the presence of fish in each of the lakes. Obsolete common names in older reports were traced to new ones via scientific names. Records citing nonexistent common names were not used. All other records we found, even ones unconfirmed by other surveys, were included.

A list was made of all fish species cited in each of the sources named above. Then a code was assigned to each species to indicate whether we found the species reported frequently, occasionally, rarely, or not at all for each of the 4 lakes. We attempted to identify multiple sources citing the same record.

Supplementary information for species that are not discussed in detail in this report is provided in footnotes to the tables on fish species presence, including conclusions as to whether presence is or was at any time likely in any of the Yahara lakes. These conclusions are the opinions of John Lyons (Wis. Dep. Nat. Resour., Bur. Res., pers. comm., 1991). Lyons is a fisheries researcher who not only is knowledgeable about the habitat preferences of Wisconsin fish species but is also very familiar with the many historical fish records for Lake Mendota. As Curator of Fishes for the UW Zoology Museum, he has examined specimens and/or records originating from these early collections. Lyons thus was able to advise us as to which records should be accepted and which ones should not. He also advised us as to the origin of the lakes' fish species (i.e., native, introduced, or stray).

The rationale described above for compiling records of fish species presence in the lakes was also used for compiling a separate table of records of fish from tributaries and water bodies adjoining the Yahara lakes. The same 2 primary data sources were checked: McNaught (1963) and the computerized data base, covering 1974–86, from Fago (1982).

Again, a number of decisions were made in tabulating data from the Fago print-outs. We included only species that were found in tributaries but not found in the adjoining lake, and we excluded species found farther than 3.2 km (2 miles) from the lakes. (Fago's print-outs cite precise sampling locations, and the exact distances of tributary locations from the lakes are given in our summary.) Hybrid fish species were not tabulated, and early records summarized by Fago (from 1900–73) were not included.

Selection and Sequence. This report focuses on 17 fish species that are major components of the fishery of the Yahara lakes. For these major species, we give ecological requirements and information on relative abundance. The sequence in which these species are discussed in the text is as follows: panfish (yellow perch, bluegill, black crappie, white crappie, white bass, and yellow bass); predator fish (largemouth bass, smallmouth bass, walleye, and northern pike); cisco; and bottom feeders and/or rough fish (common carp, freshwater drum, black bullhead, yellow bullhead, brown bullhead, and white sucker). Within this latter group, 3 species—common carp, freshwater drum, and white sucker—are, or have been, regarded as rough fish. In the fish write-ups, the 3 bullhead species are discussed collectively; all other major fish species are discussed individually.

We identified 10 other species as minor species. These species either have received management attention or they were present in past surveys in moderate enough numbers to provide some information about their ecological role. These species are grouped in the Minor Species Section. Relative abundance for each species is discussed, along with a brief summary of pertinent ecological information in the following sequence: panfish (rock bass, pumpkinseed, and green sunfish); predator fish (muskellunge, longnose gar, and bowfin); lake sturgeon; bottom feeders and/or rough fish (bigmouth buffalo and channel catfish); and forage fish (brook silverside).

A number of other species are currently present in the Yahara lakes or were recorded in early surveys. These fish are or were rare, have been found infrequently because of inadequate sampling, or are not typically harvested. A few of these species may at times be an important forage base for other fish, and all the species are an important part of the ecosystem that supports the fishery of the Yahara lakes. However, because little is known about them, they are not discussed individually in this report. Instead, a table listing all fish species reported for the Yahara lakes was compiled from key sources. This master fish table (Table 19) appears in the Other Species Section of this report.

In all tables in this report that deal with presence or relative abundance of fish species, the major species are listed first in the same sequence in which they are discussed in the text, followed by all other species in phylogenetic order.[8] Taxonomy for all species found in the Yahara lakes follows Robins et al. (1991). Scientific names and associated common names are given in Appendix B.

[8] The American Fisheries Society's official list of common and scientific names of fishes was revised during the final writing stage of this report. We changed the order of species within families in our tables to follow the new publication (Robins et al. 1991) but did not conform all our tables to the new sequence of families, leaving them as they appear in Robins et al. (1980).

Ecological Requirements. A limited amount of information other than relative abundance is given for each major and minor fish species. Detailed life history information was not summarized because this information is readily available in the major Wisconsin reference on this topic, *Fishes of Wisconsin*, by George Becker (1983). Instead, key ecological requirements are given—namely, preferred habitat (including depth preference or "zone" of the lake inhabited), food preference, spawning habitat, and any special requirements (e.g., temperature and oxygen level). Scientific publications were the primary source of this information.

Sources of Data on Species Abundance

Major sources of data on species abundance in the Yahara lakes were creel surveys, rough fish removal records, DNR fish population surveys (using boom shockers, fyke nets, shoreline seines, and survey seines), stocking records, DNR fish distribution surveys, and UW research projects. Anecdotal accounts from fishing diaries and newspaper stories provided supplementary information on harvests and fishkills.

Most of these data sources have serious limitations in terms of their accuracy, continuity, comparability, and completeness. No investigation has ever attempted to make population estimates of all fish species in the lakes. In fact, only the DNR fish distribution surveys, conducted during the mid-1970s (Fago 1982), gathered information on relative abundance of all fish species. All other surveys focused on general population trends of certain segments of the fishery.

Factors that may have affected interpretation of the data include period covered (i.e., year and season), location, gear selectivity, effort, lake variables, and fish behavior. In the descriptions of each data source below, only the most significant of these factors are discussed. Obvious factors, such as shore-related gear primarily sampling only shore fish (versus fish of open waters), are not mentioned.

Although the surveys do not give exact abundance data, they are guides that approximate the relative abundance of some of the most important fish species. The best indicator of fish abundance—catch per unit of effort—could be computed only for one source of data: state rough fish hauls. For other surveys (e.g., boom shocker and shoreline seine surveys), effort data were not available, so we had to rely on other indicators, the next best being percentage of the total catch. Percentages were computed for creel surveys, fyke net surveys, survey seine surveys, DNR fish distribution surveys, UW research projects, and some anecdotal accounts. Unfortunately, similar percentages could not be computed for other sources that did not involve a reasonable sampling of the population or enumerate all fish. In the discussion of relative abundance of individual species in this report, heaviest reliance was placed on surveys for which either catch-per-effort or percentages could be calculated, because these were believed to be the best data. Despite brevity of the surveys or limitations in interpreting them, they can be used collectively to highlight changes in the fishery of the Yahara lakes.

Creel Surveys

Results of creel surveys were found in published and unpublished reports for 1952 and 1973 for Lake Mendota (Kuntzelman 1952, Phelan 1973), 1937–39 for Lake Waubesa (Juday et al. 1938, Frey et al. 1939, Frey and Vike 1941), and 1936 and 1938–39 for Lake Kegonsa (Juday and Vike 1938, Frey et al. 1939, Frey and Vike 1941) (Appendix Tables A.1, A.11, A.20, and A.30). No creel survey reports prior to the 1980s were located for Lake Monona. Unpublished data from creel surveys were located in DNR Madison Area files for 1974 for all 4 lakes, 1981–82 for Mendota, and 1982–83 for the 3 lower lakes.

Surveys conducted by the DNR since the 1970s were based on a 40-hour work week including one day every weekend. The 5 weekdays were rotated on a predetermined schedule, whereby each weekday was censused an equal amount of time for each month. An early- and late-hour shift was utilized. Because of its large size, Lake Mendota was divided into 2 parts, east and west

PHOTO: BOB QUEEN, DNR MADISON AREA OFFICE COLLECTION

DNR winter creel survey on Lake Mendota, 1987.

of a line extending from Picnic Point to east of where the Yahara River enters the lake. During the open water season, most of the anglers were contacted at boat launching sites when they were leaving the lake. During the winter, contacts were made on the ice utilizing a snowmobile. Counts of anglers and/or boats were taken every 2 hours.

PHOTO: STATE HISTORICAL SOCIETY OF WISCONSIN COLLECTION

Pulling in the seine used for rough fish removal on Lake Wingra, April 1954.

Both the historical and more recent creel survey data present numerous problems in interpretation: (1) *Years surveyed*. Large gaps exist in the records, and comparable data on all 4 lakes are not available prior to 1974. (2) *Season*. Starting and ending dates varied from survey to survey. Catch rates affected by angler preferences for specific species during certain seasons (e.g., spawning season or ice-fishing season) are therefore not comparable. (3) *Survey method*. The early surveys were primarily voluntary. Unlike later surveys in which anglers were personally interviewed, the early surveys were compiled from cards voluntarily filled out by the anglers themselves and left at boat liveries. Such responses were probably incomplete, e.g., if mention of large fish, exceptionally good fishing, illegal catches, or poor fishing success were omitted. (4) *Species identification*. Large catches of black and white crappies in the creel surveys on all 4 lakes during the 1980s raise the question of whether so many of 2 such similar species could have been accurately separated. The clerk conducting these surveys said he counted dorsal spines on the crappies caught in order to distinguish between the 2 species (R. Kalhagen, pers. comm., 1989), although other clerks assisting in the surveys may not have been as thorough. (5) *Effort*. Most of the early surveys did not record measures of effort or time spent fishing. Some did not even record the number of anglers. Absence of such information makes it impossible to evaluate survey thoroughness. (6) *Time of day*. We presume that most surveys were conducted during the day or early evening. Species such as the walleye, for which the best fishing can be late at night, could be undercounted in a daytime survey if a significant amount of fishing effort occurred during nighttime hours.

Rough Fish Removal Records

Records of rough fish removal provide data on the fisheries of the Yahara lakes for almost 50 years, with few gaps in the chronological record. "Rough fish" were defined by the legislature in 1935 and included these species found in the Yahara lakes: common carp, freshwater drum, white sucker, bigmouth buffalo, longnose gar, and bowfin (Chap. 366, Laws of 1935). This definition was expanded in 1971 to include other species, of which the quillback is found locally (Chap. 226, Laws of 1971).

Prior to the 1930s, rough fish could be removed under licensing arrangements with private individuals. Although large amounts of rough fish were undoubtedly taken from the Yahara lakes in this fashion, systematic records of this effort were not found. Data were found for rough fish removed by state crews of the WCD/DNR beginning in 1934 for Lake Monona and beginning in 1935 for the other 3 lakes (Appendix Tables A.2, A.12, A.21, and A.31). These records continued for most years until 1969, when the state's rough fish removal program ended. In 1976–77, harvest of rough fish resumed, this time under contract with commercial crews. Records of commercial removal of rough fish were found for most years for the next decade (Appendix Tables A.3, A.13, A.22, and A.32). Because of poor prices for the rough fish harvested, commercial fishing was not conducted on all 4 lakes in all years.

For approximately the first 15 years of the state removal program, our primary data sources were Helm (1951) and Hacker (1952*a*, 1952*b*). For later years, records came mainly from unpublished data found in the DNR's central library or DNR Madison Area files. The latter were also the source of all of the commercial rough fish removal records.

Rough fish harvested by the state were typically taken in the spring and fall with long seines pulled by barge-mounted winches (Threinen 1949*b*, Miller et al. 1959), although some seining was also done under the ice (Peterson 1958). Seining was restricted to the cool months because carp congregate then (Helm 1951) and because the lower temperatures reduce the mortalities caused by crowding fish in the seine bags (Frey 1940, Threinen 1949*b*). Commercial crews netted during similar seasons (Gordon Priegel, Wis. Dep. Nat. Resour., South. Dist., pers. comm.). Seines used by state crews varied in reported length from 1,370–1,830 m. Mesh size was approximately 90 mm in the bag to 110 m in the wings, and in depth from 3–4 m. Seines used by commercial crews had to be at least 760 m, with a mesh size ≤150 mm. Seining effort by the state varied from 1–49 hauls/year (1 haul/work day) and by commercial crews from 1–35 days/year.

Another gear type sometimes used by commercial crews was entanglement nets. These nets were similar to long gill nets except that the distance between the lead (weighted) and float lines was shortened to create an area of loose webbing that would catch on sharp areas of fish. Fish entering the bag were caught around their stomachs and held there alive. Nets were 910 m long with a minimum mesh size of 150 mm.

State crews sometimes built fish traps across the entrance to a stream, marsh, or bay, with boards driven vertically into the bottom about 4 cm apart. Traps were left in place all year but were operated only during the carp spawning season. The gates were left open the rest of the time (R. Flemming, *The Capital Times*, 18 Apr 1983). These fish traps apparently were never a significant means of catching large numbers of rough fish; therefore, data from this type of trapping were not included in our tabulations.

Conservation wardens or fish management personnel monitoring the catches of both state and commercial crews estimated the numbers and species of "game fish" that were caught and returned to the water. "Game fish" were first defined by the legislature as including all varieties of fish except rough fish (Chap. 366, Laws of 1935). This definition was revised in 1953 to include all varieties of fish except rough fish and minnows (Chap. 556, Laws of 1953). However, in spite of this legal definition, the term "game fish" is also commonly used by others to refer only to the larger sport fish, such as the predator species walleye and northern pike. In order to avoid confusion in this report we have followed the legal definition and use "game fish" only in connection with data from the rough fish removal records.

Several interpretation problems apply to use of both the rough and game fish data from the rough fish removal records: (1) *Location*. When aquatic macrophytes (weeds) were dense, the seine nets would roll up and some fish would be lost. When few macrophytes were present, seining was more efficient, but game fish may have been sparse. (2) *Gear*. Lengths of the seines used over the 30-year removal period are unclear. Two sources describe the length as being relatively constant from year to year, although actual lengths were not reported (Hacker 1952*a*, 1952*b*). Other sources cite 2 different but overlapping length ranges: 1,370–1,650 m (Black 1945) and 1,520–1,830 m (Helm 1951). While the mesh sizes of the seines were generally large and also relatively constant over the years (Hacker 1952*a*, 1952*b*), occasionally smaller mesh sizes were used, such as in the late 1930s, to catch an abundant carp year class (Frey and Vike 1941). These

PHOTO: EUGENE SANBORN, DNR CENTRAL OFFICE COLLECTION

Captured carp in holding pen and the engine used to haul in rough fish seine, Yahara lakes, mid-1930s.

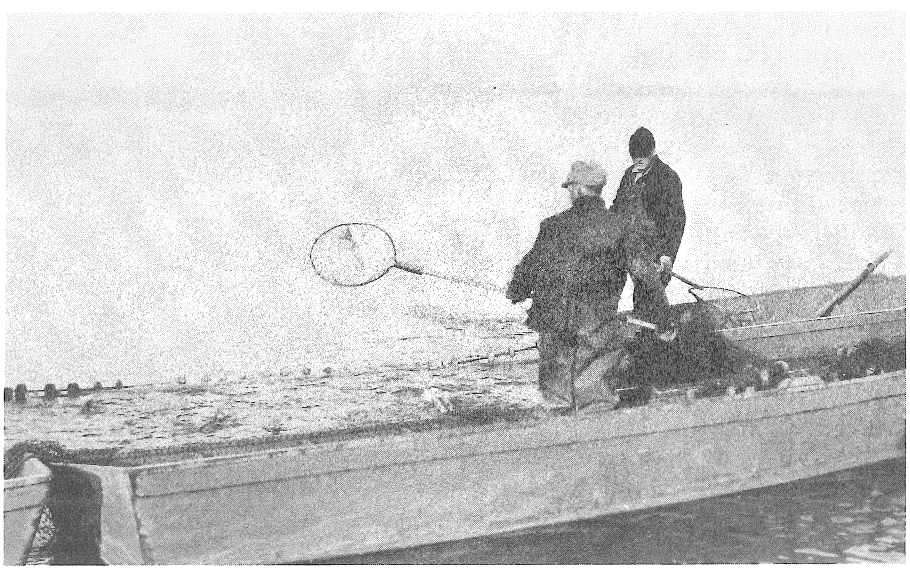


PHOTO: EUGENE SANBORN, DNR CENTRAL OFFICE COLLECTION

Game fish being returned to the lake after capture during rough fish seining.

variations in gear affect the comparability of data. (3) *Effort.* Netting effort (i.e., the number of hauls made) was not summarized for all years; it is thus difficult to draw any conclusions about fish abundance for those years. (4) *Lake size.* Data from Lakes Waubesa and Kegonsa are not directly comparable to data from Lakes Mendota and Monona because smaller, shallower lakes can be seined more efficiently than larger, deeper ones.

Removal records for one species, carp, are affected by additional factors limiting effort of commercial harvests: (1) *Price.* In spring and late fall, when carp were most easily caught, market prices dropped because the market was flooded. As a result, fishing effort was then cut back. Also, a better market price for bigmouth buffalo, although this species was present in the lakes in much smaller numbers, decreased fishing effort for carp. (2) *Fish condition.* In years when carp size and condition were poor, effort was reduced because small, thin carp were less valuable. (3) *Lake size.* The larger surface area and rougher water of Lake Mendota made it harder to fish there; thus it received less effort than Lakes Waubesa and Kegonsa.

Other problems apply solely to the numbers of game fish recorded during the rough fish seining: (1) *Accuracy.* Some of the numbers of game fish recorded were estimates versus actual counts (Threinen 1951). The data available are thus no more than very general indices of relative abundance and should be interpreted with caution. In addition, other records (e.g., Hacker 1952*a*) provide results of seining efforts in graph form only. In order to make lake-to-lake comparisons, we interpolated numbers of fish per haul from these graphs. The averages and totals we computed from these interpolated numbers are therefore only approximations and may differ from corresponding figures reported in the literature. (2) *Missing records.* As described earlier in the Study Techniques Section, no summaries were ever made of all of the game fish caught in Mendota in the rough fish seines or in the other 3 lakes during the 1950s–1960s. The original daily catch reports were later thrown away; thus these data will never be known. (3) *Location.* Nets were sometimes set to avoid large populations of certain game fish (e.g., the abundant white bass in 1945). (4) *Gear.* Nets often roll up in weed beds, where some fish such as bluegills are most abundant. (5) *Fish behavior.* Both largemouth and smallmouth bass are known to be net-shy and would thus be underrepresented in the data.

Finally one specific problem exists in the rough fish records, and that concerns conflicting numbers for some of the data for Lake Waubesa. For the years 1939–47, unpublished records of total pounds of rough fish, which were mostly carp, differ from the recorded pounds of carp for the same period, as reported by Helm (1951). As with descriptions of seine length and mesh size, these inconsistencies in the reported harvest were impossible to reconcile, but may reflect catches by commercial crews.

DNR Fish Population Surveys

After the DNR quit seining carp in 1969, it began conducting more systematic fish population surveys. As before, certain caveats must be mentioned for each set of data collected during surveys using the following types of gear.

Boom Shockers. The most commonly used survey technique was sampling by means of boom shockers. For the period 1968–85, 12 sets of survey results were found for Mendota, 7 for Monona, and 11 each for Waubesa and Kegonsa (Appendix Tables A.4, A.14, A.23, and A.33). All records in this report were summarized from unpublished data in DNR Madison Area files.

The purpose of boom shocking was to collect fish for age and growth measurements and to determine if desired predator fish were present in sufficient numbers. The latter information helped assess the need for stocking the following year. Unlike shoreline seines and fyke nets, which sample certain segments of the fish population, boom shocking stuns most fish that move within its electric field, but only a representative subsample of abundant panfish was collected in the DNR surveys; rough fish and small minnow-sized fish were ignored. Shocking was usually conducted in the fall by means of a 230-v DC generator mounted on an 18-ft boat. Each survey sampled from near the shoreline out to about 1.8 m of water depth.

Several factors need to be considered in order to interpret data from boom shocker surveys: (1) *Location.* Different sections of shoreline were often sampled from year to year. Thus numbers of fish collected could have been affected by shoreline and bottom habitat as well as fish abundance. (2) *Gear.* Shocking is known to be size-

PHOTO: BOB QUEEN, DNR MADISON AREA OFFICE COLLECTION

Fall night boom shocking by DNR personnel, Lake Mendota, late 1980s.

and species-selective. For example, northern pike and muskellunge are quite difficult to capture by electrofishing, in part due to their strong swimming ability and possibly due to a high sensitivity to electrical fields (Novotny and Priegel 1974). In general, larger fish are more easily stunned because they receive more current. Also, larger fish may be overrepresented in the survey because the operators may selectively net the stunned big fish and miss the smaller fish. (3) *Fish collection.* Because of the specific purposes for which boom shocking was conducted, not all fish that floated to the surface were picked up. As stated earlier, rough fish such as carp were routinely ignored. Even panfish, when plentiful, were overlooked if a representative sample had been collected for age and growth data. (4) *Species identification.* In a few cases, original records cited what we believe to be a generalized name for a species (such as mudminnow for central mudminnow). In such cases, the name found in the original field notes is given in this report along with the common name it was interpreted to mean. (5) *Effort.* Recorded shocking times were very general. However, maps of the areas shocked, which were filed with most of the survey results, were very specific. Steve Gilbert (former Madison lakes fish biologist, Wis. Dep. Nat. Resour., pers. comm. 1990) used these maps to determine the number of miles shocked. He then divided these distances by 1.1 miles/hour, which was the average speed for all shorelines shocked on Lake Mendota in 1987 (as well as other area lakes in recent years). This calculation provided a more accurate estimate of actual shocking time. (6) *Lake conditions.* The effectiveness of the shocking varied with the roughness of the lake surface and water and air temperatures. Catches were usually higher in the fall, when most surveys were done, than in the summer, before inshore temperatures began to drop.

Fyke Nets. Records of fyke net surveys were found primarily for Lake Mendota; data for at least one year were located for each of the other 3 lakes (Appendix Tables A.5, A.15, A.24, and A.34). One historical survey is summarized (Mackenthun 1947); all others came from unpublished data in DNR Madison Area files. Recent surveys were conducted mainly during the 1970s but also include 2 from 1957 and one from 1985.

Fyke nets were set in the spring to monitor spawning populations of particular species of adult fish. Hoops varying from 1.0–1.5 m held the mesh bags open. Size of the mesh was usually 50 mm but was sometimes as small as 19 mm, depending on the primary species being sampled. Nets were set in 0.5–2.5 m of water with the 15-m lead anchored to shore. Nets were lifted daily and often moved to new sites if catches diminished.

A couple of problems affect interpretation of fyke net surveys: (1) *Years surveyed.* Fyke net data were extremely limited for the 3 lower lakes, with Kegonsa sampled twice, and Monona and Waubesa only once. (2) *Location.* Monona nets were set only at the extreme southern end of the lake (Squaw Bay and the Yahara River below both the lake and the South Beltline Highway). In Mendota, fyke nets were set in tributaries during the spawning run of walleyes or northern pike and sometimes in the lake itself. Although these catches differed, location cannot always be distinguished in the reports. (3) *Effort.* As with other surveys, incomplete records of effort (i.e., the number of fyke net lifts) affect evaluation of survey duration.

PHOTO: DNR MADISON AREA OFFICE COLLECTION

Bag end of a fyke net being emptied, Lake Mendota, spring 1992.

PHOTO: ART ENSIGN, DNR CENTRAL OFFICE COLLECTION

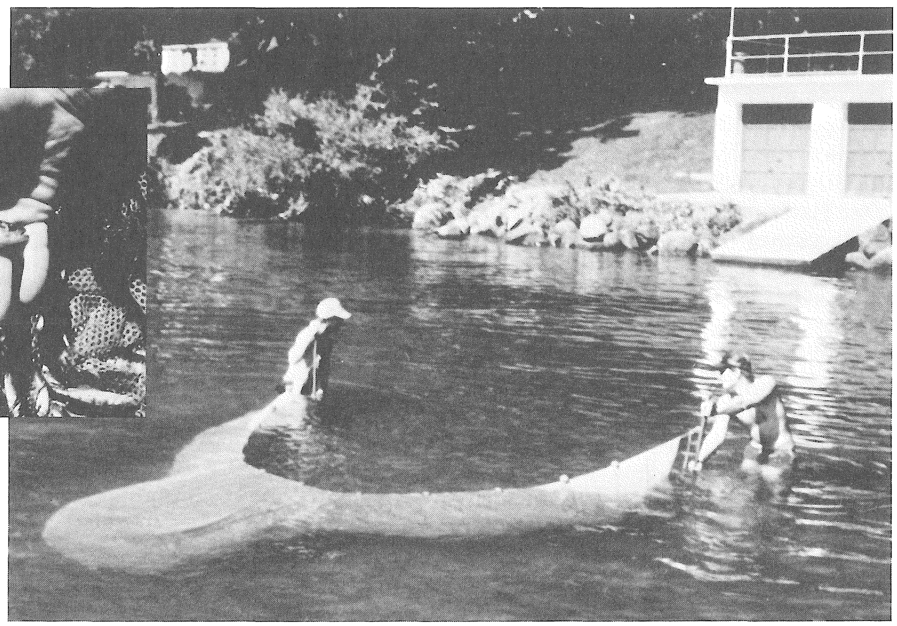
Fyke net set for spawning northern pike in Sixmile Creek, March 1958.

Shoreline Seines. Results of shoreline seining were found in DNR Madison Area files for all 4 lakes for 1966 and 1976–77 through 1980 (Appendix Tables A.6, A.16, A.25, and A.35). Three other shoreline seine surveys were located: two 1939 surveys for Monona and one 1971 survey for Kegonsa.

Usually done in late summer to early fall, shoreline seining assessed reproductive success or year classes produced that year. Shoreline seines were typically 8 m long and 1 m deep with 9-mm mesh. Since the purpose of this survey was to catch young of the year, mesh sizes of 3 and 6 mm were also common. Approximately 45–50 m of shoreline were covered in each haul. Seine hauls were taken at different sites from year to year.

Interpreting shoreline seine surveys requires consideration of these factors: (1) *Season.* Hauls were made from mid-July through September. By late August, however, yellow perch are generally in deeper water and were thus underrepresented in the seine hauls. (2) *Location.* Some reports mentioned that sites were chosen randomly, but generally locations appear to have been distributed around the circumference of each lake. Even at a given site, the vegetation would have varied over time. Lack of macrophytes often meant a haul with no fish, because young fish did not frequent these areas and/or because they saw the seine coming and escaped. On the other hand, if the macrophytes were too dense, the seine could not easily be pulled

Small fish caught during seining.



Shoreline seining, Lake Mendota, summer 1987.

PHOTOS: BRETT JOHNSON, DNR MADISON AREA OFFICE COLLECTION

Survey seining, Lake Mendota, October 1984. Panfish and sport fish were netted from the seine bag and transferred to the crew on shore for length measurements. Carp and bigmouth buffalo were transferred to the boat of the commercial rough fish crew.

PHOTO: SANDY ENGEL, DNR RESEARCH

through the vegetation and many fish would have escaped, thus making the survey results questionable. (3) *Gear.* Seines varied somewhat in length and mesh size. (4) *Fish collection.* Because the purpose of this survey was to catch only young of the year, numbers caught are not necessarily representative of the entire population present. (5) *Fish behavior.* An important portion of the seining catch consisted of small forage fish (such as brook silversides and bluntnose minnows) and fingerling sunfish (panfish and bass). These fish are found in schools distributed unevenly along the shoreline. The catches, therefore, tended to be hit-or-miss. The smaller the number of hauls per year, the more schooling behavior would bias the data.

Survey Seines. Sampling with survey seines was the least common survey technique, probably because of the intensity of the effort involved. Only 5 records of this type of survey were found: 2 for Monona and one for each of the other lakes (Appendix Tables A.7, A.17, A.26, and A.36). All surveys took place between 1974 and 1984 and were summarized from unpublished data in DNR Madison Area files.

Survey seines were used when a lot of data on fish populations were needed. Although this technique can be used anytime from spring through autumn, the surveys done on the Yahara lakes were done in September–October. Unlike shoreline seines, which were short enough that 2 people could lift them, survey seines were long (460–1,370 m), requiring a large crew of people plus an engine on a barge to pull them. Mesh size varied from 32–50 mm, often with more than one mesh size in the same seine. The depth at which the seine was used ranged from 3–5 m. A lake area of 4–8 ha could be sampled, depending on the length of the seine. Survey seines could not be used where macrophyte beds were dense because the seines would roll up, losing fish.

Stocking Records

While fish stocking records do not provide guides to species abundance as do some of the surveys previously discussed, they are useful summaries of WCD/DNR efforts to influence the fishery in the lakes. Fish have been stocked in the lakes primarily to introduce new species and to augment existing populations. During the 1930s and 1940s, the lakes were also stocked with rescued fish that had been stranded in the shallow backwaters of the Mississippi River.

We compiled stocking records for 1852–1986 for each of the 4 Yahara lakes (Appendix Tables A.8, A.18, A.27, and A.37). Although fish were also stocked in tributary streams, Upper Mud Lake, Lower Mud Lake, and the Yahara River at various times, we limited our summary to records for the Yahara lakes for purposes of comparison with other data summarized in this report. All numbers of fish stocked were coded to identify the developmental stage of the fish, i.e., eggs, fry, fingerlings, yearlings, adults, or a combination of fingerlings and adults.

Early stocking data were found in WCD memoranda in the State Historical Society archives, ledgers in the DNR's central library, and Mackenthun (1947). Data from 1959 to 1986 came from the stocking receipts in DNR Madison Area and Southern District files. In the early years (1852–1935), stocking was sporadic. After 1935, stocking became more regular, and records were found for every year except 1955 and 1966.

Some interpretation of the names of fish found in the original stocking records was necessary. Fish recorded as "crappies" and "bullheads" were considered crappie spp. and bullhead spp. In the early years (1901–19), largemouth and smallmouth bass were not separated and were described as "black bass." We agree with McNaught's (1963) opinion that these were likely largemouth bass; however, we list these in the tables as bass spp. or *Micropterus* spp. Fish labeled "sunfish" we considered to be *Lepomis* spp.

The only published summaries of stocking records for the Yahara lakes that we found were in Mackenthun (1947) covering 1937–47 and in McNaught (1963) covering 1852–1962. Both reports were primarily about Lake Mendota. Unpublished WCD records agree with Mackenthun's but differ in a few cases from McNaught's. Without knowing which specific data sources McNaught used as a basis for his figures, it is impossible to identify reasons for the differences.

Some inaccuracies would be unavoidable in any compilation of the historical stocking records. This is likely, considering the difficulty of counting the large numbers of eggs or fish actually stocked, the large span of years covered (135) and the possibility that some early records have disappeared, the generalization of some records that listed fish stocked by county rather than by water body, the involvement of both state and federal agencies in stocking prior to 1941 (Noland 1951), the variety of records kept, the poor legibility of original field notes, and the likelihood of transposition and/or mathematical errors when field notes were copied into more permanent records. However, we believe the tables in this report represent as complete a summary of stocking in the Yahara lakes as is possible from records currently available.

Aside from the inaccuracies in data reporting listed above, the stocking data need to be interpreted with caution. The relationship between number of fish eggs stocked and survival to adults is not known, and there is little in the fisheries literature to indicate what percentage of stocked fry survive to adults (John Klingbiel, Wis. Dep. Nat. Resour., Bur. Fish. Manage., pers. comm.). The percentages of fingerlings stocked statewide that survive and are caught by anglers have been estimated (largemouth bass 3%, walleye 2%–5%, and northern pike 20%) (Klingbiel 1983), but not all fisheries biologists agree with these percentages. Given this uncertainty, assumptions linking numbers stocked statewide to population abundance should be avoided. Conclusions should instead be limited to those relating to a history of stocking in the Yahara lakes (e.g., changes in numbers or species stocked from decade to decade or lake to lake) and, in some cases, to a perceived need for more adult fish of the species being stocked.

DNR Fish Distribution Surveys

The only survey that attempted to sample all fish species in all 4 Yahara lakes was made by the DNR in 1975–76. This survey was part of a larger statewide sampling program that assessed distribution and relative abundance of individual fish species, emphasizing but not limited to nonsport species. Results for the entire Rock River basin, which encompasses the Yahara lakes, are presented in Fago (1982). In addition to presenting results of the 1975–76 sampling, Fago also summarized data from other surveys in prior years. In his report, specific data are reported by basin, and presence only is summarized on maps in an appendix.

Because the data on which Fago's 1982 report were based are computerized and sortable by water body, we ran detailed print-outs for each of the 4 Yahara lakes. Summaries of these print-outs are given in Appendix Tables A.9, A.19, A.28, and A.38.

Two decisions were made at the time the print-outs were run: (1) to list occurrence only of fish species at each sampling station (multiple occurrences were not listed) and (2) to exclude records from 2 sources on the advice of Don Fago (Wis. Dep. Nat. Resour., Bur. Res., pers. comm., 1987). Records from the literature that were not based on any particular survey (e.g., County Surface Water Resources Reports published by the DNR) were excluded because the information was based on hearsay only, not on any actual sampling. Records were also excluded for fish restocked after chemical treatment.

To facilitate use of these appendix tables, further explanation is needed about certain groups of data: (1) *Periods.* The periods listed in the fish distribution tables in this report differ slightly from those in Fago (1982). Additional records found by Fago since his 1982 report have broadened the ranges of 2 periods: from 1900–28 to 1900–59 and from 1974–81 to 1974–83. (2) *Percentages.* Because the amount of sampling and number of stations varied considerably between periods and lakes, the percentage of the total number of stations sampled at which each species occurred is included. No percentages are given where too few data exist to make percentages meaningful. (3) *Gear.* Gear type only is listed in our tables, even though data on effort are given in the print-outs for nearly all the records for the 1974–83 sampling. Including these data would have required separately listing each occurrence at each station; we did not feel this level of detail was necessary for the purposes of this report. Gear used in 1974–83 were primarily small-mesh seines. These consisted of bag seines 1 m deep, 9 m long, with 5-mm delta mesh. Areas sampled by this method averaged 280 m^2 for all stations in Fago (1982). DC boom shockers were occasionally used on the Yahara lakes, sampling an average of 72 ha or 1.9 km of shoreline/station for all stations in Fago (1982). (4) *Collector.* As with gear type, identification of collectors is given for the total occurrences for each species rather than for the individual records. Of the 8 collectors of fish in the Yahara lakes, the most reliable records are those identifications reported by ichthyologists. These include identifications by Greene (1935), DNR Fish Distribution Study personnel, and personnel from the University of Wisconsin-Waukesha under the direction of Prof. Marlin Johnson. (5) *Unspecified species.* In some cases, data recorded in the field were generalized to genus or family, or identifications of some species were not accepted by Fago (1982) and were generalized by him to genus or family. We have excluded all of these records from our data tables. These exclusions involved 4 families (trouts, carps and minnows, temperate basses, and sunfishes) and 9 genera (gar, chubs, suckers, buffaloes, bullheads, sunfishes, crappies, darters, and sculpins).

As we have indicated, the fish distribution tables in this report list only highlights of information from the actual print-outs. Other information contained in the print-outs is described by Fago (1982). This includes data on numbers of fish caught, date, gear and effort, and location of the sampling stations within each lake. All print-outs on which our appendix tables were based are on file with the Bureau of Research in Madison.

University Research Projects

A variety of research projects conducted by the UW provided information on fish species found in the Yahara lakes, especially Lake Mendota. As described earlier in the overview of information sources, many theses and papers on individual species resulted from this research and are cited in this report.

The best long-term fish population data for Lake Mendota are from a fyke net survey of spawning white bass conducted by the UW each spring in 1955–69 and in 1971 (Horrall 1961, Voigtlander 1971). Although white bass was the target species, numbers of other fish caught were recorded in the field notes as tick marks. A summary of the catches of these other species was compiled from original field records loaned to us by John Magnuson (UW Cent. Limnol., unpubl. data collected in 1956–69 and 1971) (Appendix Table A.10). Although the University survey began in 1955, our summary starts with 1956 because the 1955 lab book was not found. We tabulated the catch of each species, converted these numbers to a standard catch-per-effort for 50 fyke net lifts. This conversion was done to avoid the problem of reporting tenths and hundredths of fish in our tables. Fifty was selected as the number of net lifts for the conversion because it was approximately the average number of lifts per year. From the numbers of fish per 50 net lifts, we computed percentages for each species caught. White bass was excluded from these percentages so that its representation in the sample did not overshadow that of other fish species.

The sampling method for this survey used fyke nets set on the firm shelves of sand, gravel, and rubble off Maple Bluff and Governor's Island in Lake Mendota. A complete description of the gear used is given in Horrall

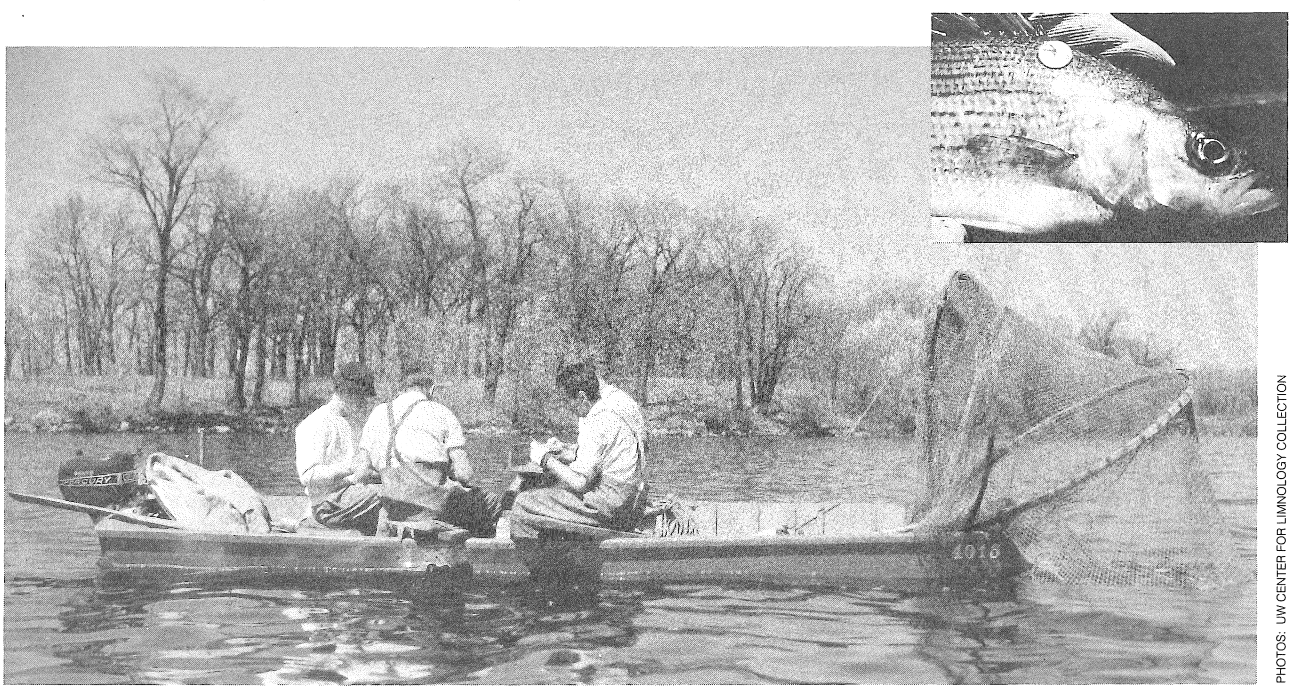
(1961) and Voigtlander (1971). A number of other fish species were caught in the fyke nets, but Horrall (1961) saw no evidence of active exclusion of these species from the spawning grounds by the more numerous white bass.

Several factors need to be considered in order to interpret data from this survey: (1) *Years surveyed.* Little information exists from other sources that could corroborate possible population trends. (2) *Season.* Because the peak of the white bass spring spawning period changed from year to year, actual sampling dates varied accordingly. (3) *Location.* Although direct competition may not have forced other fish off the spawning ground, it must be remembered that catching species other than white bass was not an objective of the survey. Thus species preferring other types of habitat in the lake would be underrepresented by this survey. (4) *Gear.* Gear changes affect comparisons even within the 15-year period covered by the survey. In 1971 the fyke net was changed from a standard to a double-ended fyke net, which operates differently. With a standard net, the lead is attached to the shore and the net is set perpendicular to shore. Fish swimming along the shoreline encounter the lead and follow it out until they enter the funnel and the net itself. The double-ended net, on the other hand, has one lead set parallel to shore in deeper water, with a hooped fyke net on each end. It is designed to catch fish that are moving on and offshore (J. Magnuson, pers. comm.). (5) *Effort.* Duration of sampling, as reflected by the number of fyke net lifts, varied from year to year. (6) *Lake variables.* For years in which white bass spawning was intensified by a rapid rise in water temperature, white bass may be overrepresented. Because the spawning season and thus netting duration would have been shortened in such years, other species may have been undersampled.

In addition to these long-term spring fyke netting data, recent survey data were provided to us from another UW project, Long Term Ecological Research in Northern Temperate Lakes (UW-LTER). The data consist of numbers of fish caught in shoreline seine hauls on Lake Mendota during 1981–85. As with the fyke netting records, the UW-LTER data were made available to us by John Magnuson (unpubl. data collected in 1981–85).

Anecdotal Accounts

Numerous personal communications on fish abundance were reviewed during the course of compiling this report. Of these, we summarize pertinent records from only 2. The first of these sources was the personal fishing diaries of Robert Kalhagen, a retired WCD/DNR fish technician. From these diaries we summarized numbers of fish caught in Lake Waubesa for a 7-year period, 1976–82. The second source was a summary of winning yellow perch weights from annual Percharee contests conducted by the Yahara Fisherman's Club since the early 1950s. The summary of the Percharee data has several limitations: (1) *Years surveyed.* While the Percharee has been held every year, results of the contests have not been consistently recorded. Contest winners were not recorded in early years, and no records were found for a few other years. (2) *Accuracy.* Because of the popularity of this contest, it is highly likely that some anglers fished together and pooled the heaviest fish in their catches to submit one entry. Likewise, some anglers may have included yellow perch caught from other lakes. Thus, the recorded weights were undoubtedly not representative of the average weights of yellow perch caught for any given year.



PHOTOS: UW CENTER FOR LIMNOLOGY COLLECTION

UW researchers conducting white bass spawning study off Governor's Island in Lake Mendota, 1950s–1960s. Inset shows tagged white bass.

PHOTO: RICHARD LATHROP, DNR RESEARCH

Winter's Breath

Autumn morning's dance
Of the lake clouds.
Water body exhales summer breath
With misty gusts,
Like ghosts of restless sails
Blown to infinity.
Winter beds my memories
Beneath icy sheets.
A sleep
Only spring's tepid breath
Will arouse.

—Inga Brynildson Hagge

LAKE ENVIRONMENT

The diverse and abundant fishery of the Yahara lakes is a function of many factors that collectively influence which fish species are important in each lake. Physical and chemical lake characteristics (including morphometry, temperature, dissolved oxygen, and water chemistry), macrophytes, wetlands, inter-lake areas, and tributary streams dictate the habitat important to different fish life stages and to invertebrate food organisms (zooplankton and macroinvertebrates). In addition, the nutrient enrichment of the Yahara lakes from sewage effluent discharges and from agricultural and urban runoff since the late 1800s (also called "cultural eutrophication" by Hasler [1947]), has increased overall lake fertility and enhanced the abundance of many fish species. Competition for food resources affects the relative abundance of different fish species.

Actions directed at various water quality and water use problems in the lakes have not always benefited the fishery. For example, dredging of shorelines and filling of wetlands has eliminated habitat important to the fishery. Such dredging and filling has been done in urban areas to create more usable land for parks, buildings, etc., and in rural agricultural areas to increase drainage on lands that were then converted to crop production. Lowering of lake levels to prevent winter ice damage and spring flooding have reduced fish spawning in the wetlands during spring months. Public concerns about excessive macrophytes restricting swimming and boating have resulted in major weed eradication and removal programs, emphasizing chemicals in earlier years and mechanical harvesting more recently. Dense algal blooms resulting from sewage pollution in prior years were also treated with large quantities of chemicals. Toxicants from industrial and municipal sources have also raised concerns about their impacts on the fishery, particularly in Lake Monona. Finally, agricultural herbicides and insecticides washed into the lakes could negatively affect macrophytes and aquatic invertebrates important to the fishery, but no direct impact has ever been proven for the Yahara lakes.

Some of the lake environment factors can be considered fixed determinants of the fishery in each lake, as these factors are a product of the region's geology and glacial history. Other factors are variable determinants that have been affected by cultural eutrophication, biological community changes, or complex limnological interactions in the lakes. Some factors, such as zooplankton populations, exhibit large annual and seasonal variability. Historical data about these factors or the fishery data themselves often are too scanty to discern any direct relationship. In some cases, the short-term variability of chemical and biological parameters requires analyses beyond the scope of this report, even if the fishery data were available.

What we have attempted in this section is to provide as much information as possible about the Yahara lakes as complete ecosystems. Much of the discussion of the actual relationship to individual fish species or to the entire fishery is left for the Fish Species, Fishery Perspectives, and Recommendations Sections. In cases where not enough is known about a particular factor, we make recommendations for future research, data gathering, and management activities.

Physical and Chemical Characteristics

Morphometry

Lake morphometry is one of the most important factors affecting the fishery of the 4 Yahara lakes. Besides indicating the relative importance of nutrient recycling rates from littoral versus profundal lake sediments, morphometry dictates the relative proportion of habitat in the littoral, sublittoral (littoriprofundal), profundal, and pelagic regions in each lake. The high level of primary production in lake surface waters expresses itself as aquatic macrophytes and associated filamentous and attached algae in the littoral region and as phytoplankton in the pelagic region. Each region has a complex biological community of organisms utilizing this production, including invertebrates that are important as fish food. The macrophytes also provide cover for fish, particularly in their early life stages. Furthermore, the littoral, sublittoral, and profundal bottom sediments receive settled detrital material, which supports rich communities of bottom-dwelling organisms that are an important food resource to the fishery. Bacterial decomposition of this detritus consumes dissolved oxygen from the overlying water, which causes anoxia in the deep-water regions where thermal stratification during the summer and ice cover during the winter prevent oxygen replenishment. This reduces the amount of habitat suitable for fish and many food organisms.

Morphometric characteristics of each of the 4 Yahara lakes are distinctly different. Lake Mendota, the upstream lake in the Yahara River chain, is both the largest and deepest lake (Table 2, Figs. 2–5). While Mendota is only slightly deeper than Monona, Mendota's total surface area is about 3 times as large. The surface area of Monona, Waubesa, and Kegonsa are more similar, with Waubesa the smallest lake in the chain. However, Waubesa is only about half as deep as Mendota and Monona, and Kegonsa is slightly shallower than Waubesa. The "shoreline development factor" (D_L), which assesses the degree of irregularity of a

Table 2. *Physical characteristics of the Yahara lakes.**

Characteristic	Mendota	Monona	Waubesa	Kegonsa
Area (ha)	3,985	1,326	843	1,299
<3 m	697 (17%)	339 (26%)	341 (40%)	365 (28%)
3–9 m	682 (17%)	343 (26%)	378 (45%)	827 (64%)
>9 m	2,606 (65%)	644 (49%)	124 (15%)	107 (8%)
Volume ($m^3 \times 1{,}000$)	505,300	109,600	39,500	66,800
0–9 m	281,900 (56%)	82,600 (75%)	38,300 (97%)	66,500 (100%)
>9 m	223,400 (44%)	27,000 (25%)	1,200 (3%)	300 (0%)
Depth (m)				
Maximum	25.3	22.6	11.6	9.8
Mean (V/A)**	12.7	8.3	4.7	5.1
Hypolimnetic V/A (>9m)	8.6	4.2	1.0	0.3
Shoreline length (km)	35.2	21.2	15.1	15.4
Shoreline development (D_L)[a]	1.57	1.64	1.47	1.21
Water res. time (V/Q[b] in yrs)	6.5	1.1	0.31	0.45

* Sources of data:
Lake morphometry - DNR 1980–81 hydrographic maps.
Water residence time - Lathrop and Johnson (1979).
** Volume:area ratio.
[a] Ratio of the length of the shoreline to the length of the circumference of a circle of area equal to that of the lake. A value of 1.0 indicates a perfect circle. Values increase as shoreline irregularity increases.
[b] Q = average annual outlet discharge.

lake shoreline and hence its potential for biological diversity, also indicates that Monona, Mendota, Waubesa, and Kegonsa have the most to the least irregular shorelines, respectively, although none of the D_L values is particularly high. Kegonsa's D_L is relatively close to 1.0, the value obtained when a lake is a perfect circle. More irregular lake shapes usually provide more diversity of shallow water habitat for the fishery.

These differences in lake area and depth characteristics create large differences in habitat among the 4 lakes. Three regions of lake bottom delineated from depth contours on the hydrographic maps can be defined: (1) <3 m, representing the littoral region where dense stands of aquatic macrophytes can grow; (2) 3–9 m, representing the sublittoral region that has no macrophytes and is overlain with warm, oxygenated water throughout the summer months; and (3) >9 m, representing the profundal region where the water immediately above the sediments is anoxic after early summer and much colder than the surface waters during the summer. This latter region is also the lake's depositional zone, which causes its sediments to be more organic than those in shallower water.

However, the boundaries of these regions are not absolute. The maximum depth of macrophyte growth is governed by the amount of light penetration in the water column, and light penetration is reduced significantly by algal blooms. Also, water to depths of 11–12 m is sporadically mixed with overlying oxygenated water during summer windstorms (Stauffer 1974, Lathrop and Lillie 1980), particularly on Lake Mendota with its longer fetch. For Lake Mendota, Lathrop (1991, 1992*c*) used boundaries of <4 m, 4–10 m, and >10 m for the littoral, sublittoral, and profundal regions, respectively. For the purposes of depth comparisons between lakes, the boundaries of <3 m, 3–9 m, and >9 m are used in this report.

The lake bottom area in each of these 3 depth regions indicates that Mendota has about double the area <3 m compared to the other 3 lakes, which have similar areas <3 m (Table 2). However, when this littoral area is expressed as a percentage of total area, Mendota has the smallest relative area (17%) and Waubesa has the greatest (40%). The amount of bottom area within the 3-m to 9-m contour is similar to the bottom area <3 m in each lake except in Kegonsa, which has more than twice the area within 3–9 m. Kegonsa has even more sublittoral area than larger Mendota. For the depth region >9 m, Mendota has the most area (65%). Monona has 49% of its bottom area in water depths >9 m. In contrast, Waubesa and Kegonsa have very little bottom habitat at >9 m of water depth.

The volumes of lake water within the <9-m and >9-m depth ranges are markedly different in the 4 lakes (Table 2). Mendota, because of its larger size and greater maximum depth, has more than 3 times the <9-m water volume of Monona, the next largest lake. However, the volume of the profundal zone (>9 m) is about 8 times greater in Mendota than Monona, because much of Mendota's deep-water region is >18 m while most of Monona's is <18 m. The volume of water >9 m in Waubesa and Kegonsa is negligible because of their shallow maximum depths. These relative differences in water volumes of the 4 lakes are also reflected in the water residence times of the lakes—the amount of time it takes to flush the entire volume of each lake (Table 2).

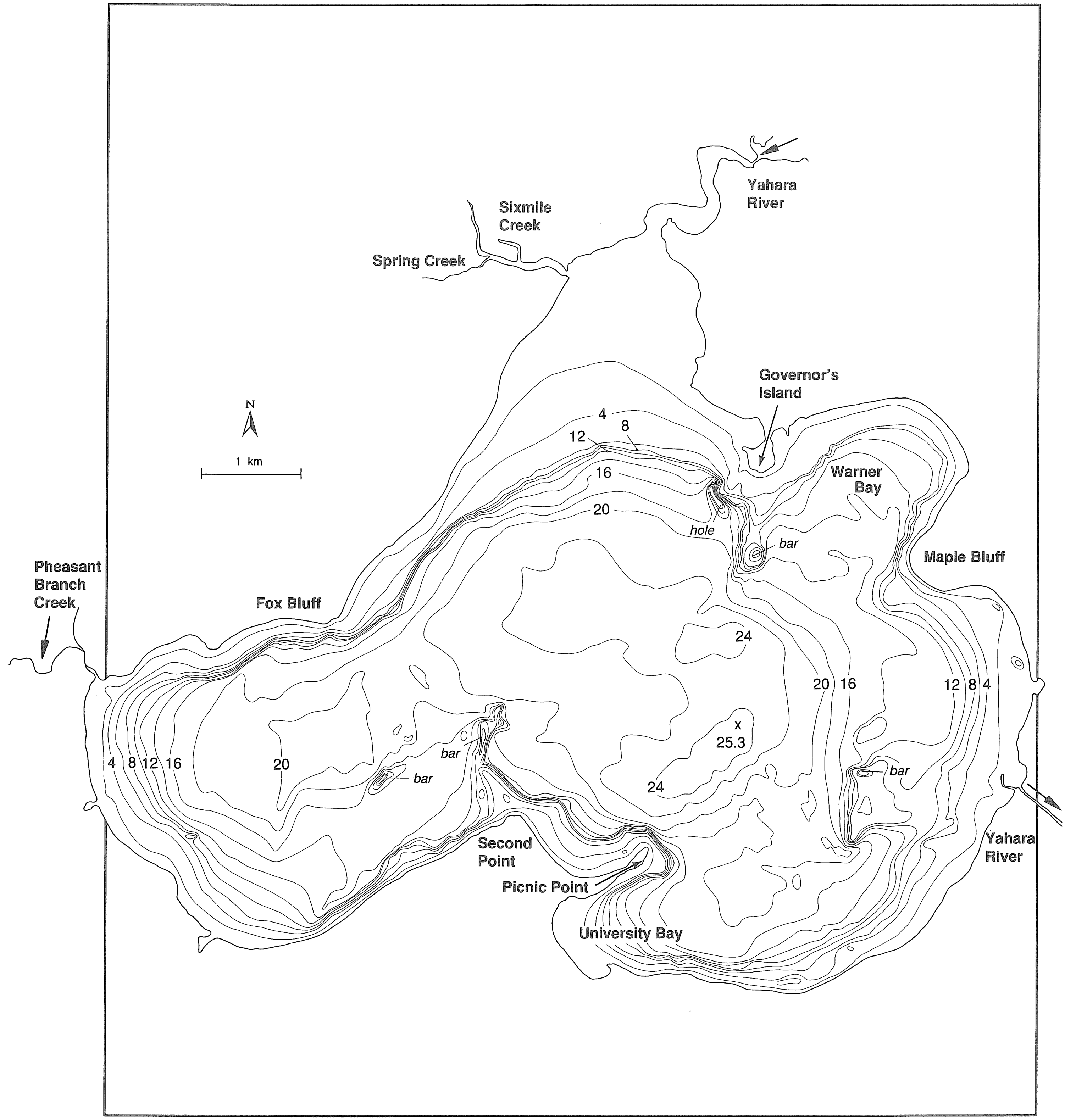


Figure 2. *Hydrographic map of Lake Mendota (depth contours in meters).*

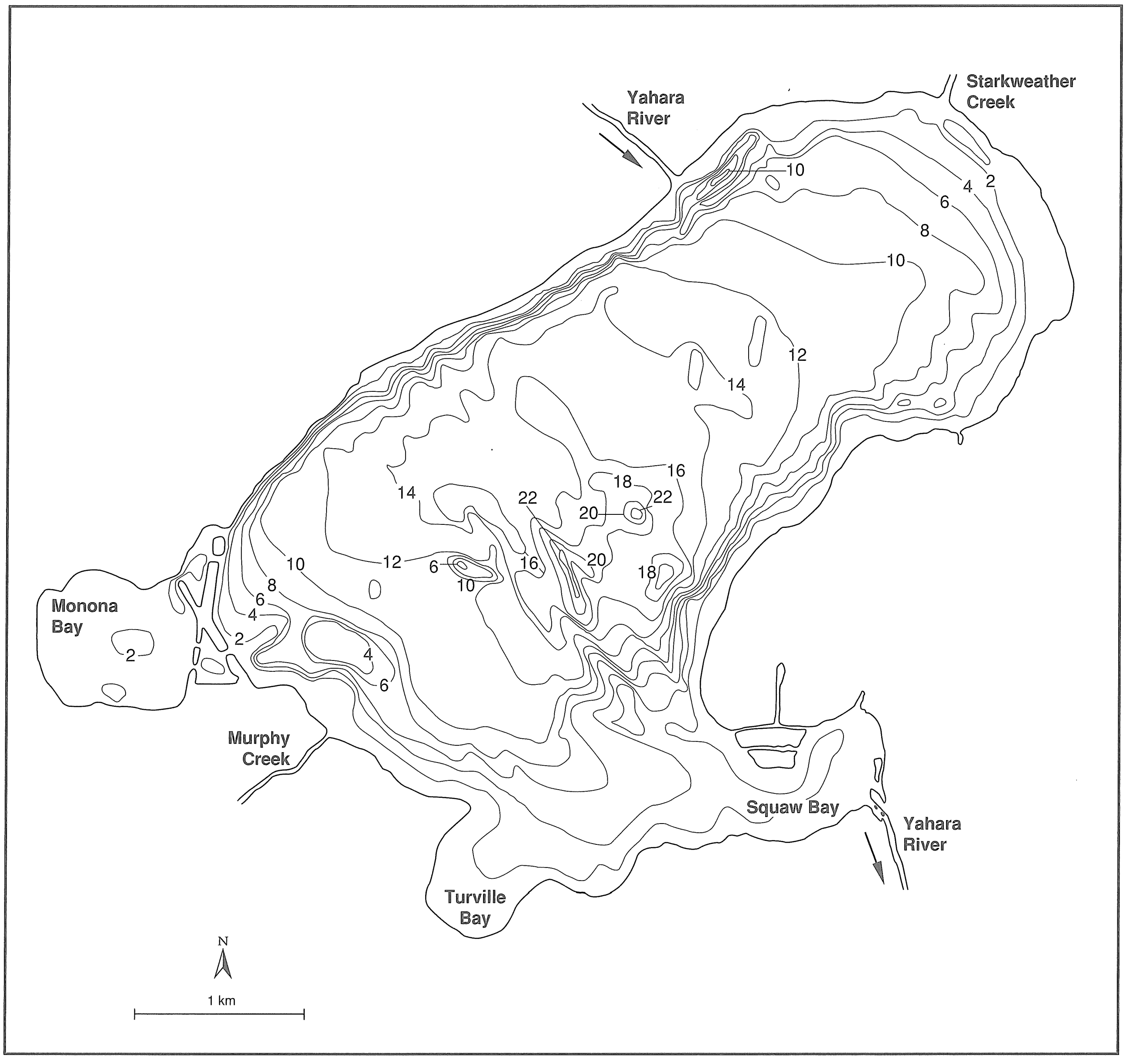


Figure 3. *Hydrographic map of Lake Monona (depth contours in meters).*

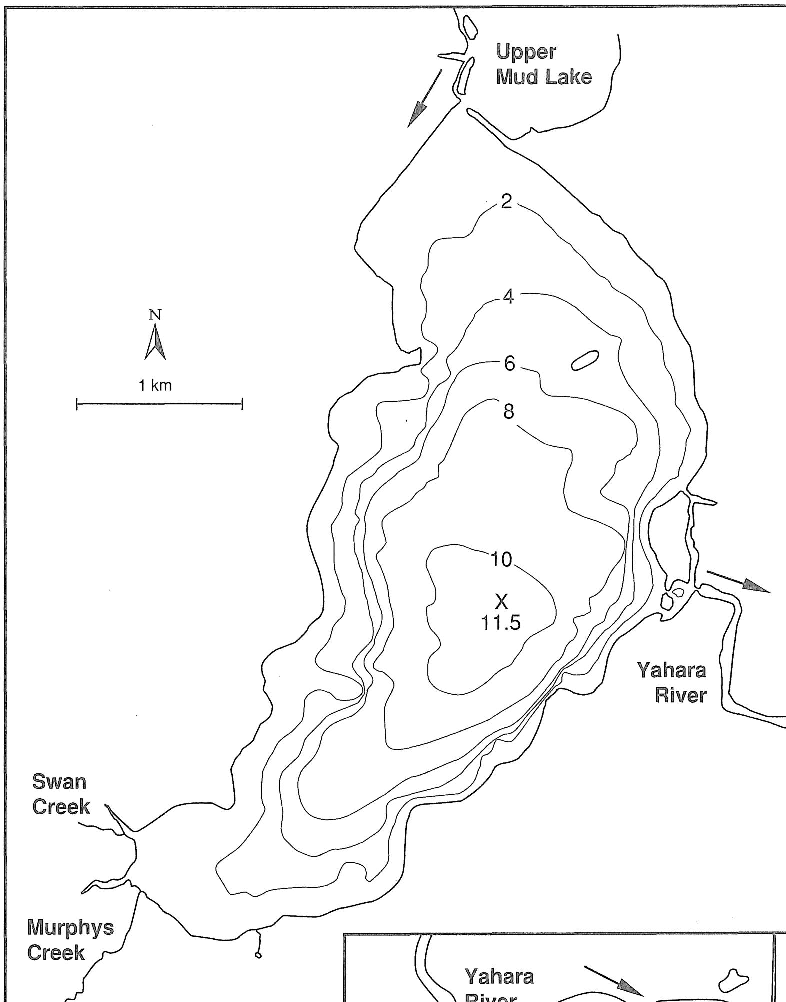


Figure 4. *Hydrographic map of Lake Waubesa (depth contours in meters).*

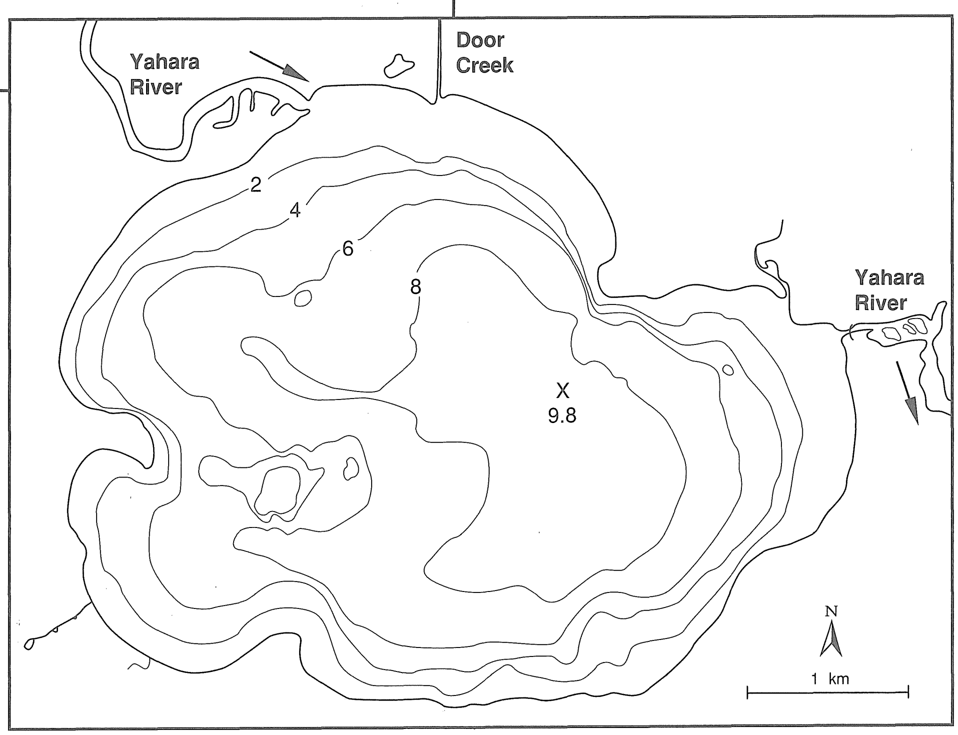


Figure 5. *Hydrographic map of Lake Kegonsa (depth contours in meters).*

Mendota flushes an average of every 6.5 years and Monona flushes every 1.1 years, while Waubesa and Kegonsa flush 2–3 times/year.

Other influences of lake morphometry on the fishery result from structural diversity of bottom habitat, particularly in the shallower regions of the lake. Reefs and bars are well known for their congregations of fish such as yellow perch. Gravel bottoms are also important for successful spawning of certain fish species. When the field surveys for the hydrographic maps were conducted in 1980–81, some attention was given to further defining this bottom structure by sounding with a long cane pole. Although many areas were undoubtedly missed, some of the more obvious bars, reefs, and holes were delineated and are shown on the maps developed for this report (Figs. 2–5), which are simplified versions of the official state maps. These maps indicate that even Lakes Waubesa and Kegonsa have bottom structural diversity. This diversity is probably most pronounced in Lake Mendota. While some information is available on the importance to fish of certain areas in each lake (noted in the Fish Species Section), a more complete site-specific analysis is not possible.

Table 3. *Estimated surface water temperatures of the Yahara lakes on 1 May, 1976–87.**

Year	Temperature (C) Mendota	Monona	Waubesa	Kegonsa
1976	10	12	14	14
1977	11	13	-	-
1978	7	9	-	-
1979	7	10	12	11
1980	8	12	11	11
1981	10	11	12	11
1982	8	10	13	12
1983	7	9	12	12
1984	7	9	11	11
1985	11	13	16	16
1986	9	11	-	-
1987	10	12	14	15

* Sources of data:
1976 and 1978 Mendota - estimated from Brock (1985).
1977 Mendota - estimated from Fallon (1978).
All other data - Wis. Dep. Nat. Resour., Bur. Res. (unpubl. data).

Water Temperature

Water temperatures in the Yahara lakes affect the fishery in many ways. Based on their preferred temperatures, the fish that inhabit the Yahara lakes can be considered as either cool-water (18–26 C) or warm-water ($\geq$27 C) species, except for cisco, which is a cold-water (10–17 C) species. Some species avoid the higher surface temperatures that occur on some summer days. These temperatures are not warm enough to be lethal, but some species seek cooler temperatures in deeper water if oxygen supplies are adequate.

In addition to affecting fish movement from one depth to another, water temperatures also affect fish growth. Metabolic rates increase during warmer temperatures, which ultimately affect fish growth rates. When metabolic rates are too high and food availability is low, fish growth for certain species may actually be negative (Luecke et al. 1992).

Fish spawning occurs within relatively narrow temperature ranges, which vary between species. Rapid water temperature changes in a given spring may hamper successful reproduction of some fish species, while more uniform temperature increases may enhance reproduction in other years.

Lake depth directly affects spring and summer water temperatures in each lake. Surface (0–2 m) temperatures estimated for 1 May for 1976–87 indicate that the shallower lakes, Waubesa and Kegonsa, warm up sooner than Lake Monona, followed by Lake Mendota, the deepest lake (Table 3).[9] Because of their greater maximum depths, Mendota and Monona each thermally stratify around mid-May into a distinct epilimnion (warm, overlying water), thermocline or metalimnion (zone of rapid temperature change with depth), and hypolimnion (deeper, cooler water) (Fig. 6). This temperature stratification adds an extra refuge for fish that prefer cooler summer temperatures than those found in the surface waters, although the lack of dissolved oxygen in the hypolimnion restricts the available refuge to the upper part of the thermocline in most years (further discussed in the next section on dissolved oxygen).

When Monona stratifies, its hypolimnion is usually 2–3 C warmer than Mendota's, because Monona's smaller deep-water volume allows it to warm up faster during the spring mixing period before stratification is established. Because of their shallower depths, Waubesa and Kegonsa have no stable summer hypolimnia, although periods of stratification can occur between June and mid-August (Fig. 6). Summer bottom water temperatures in Waubesa and Kegonsa are only a few degrees cooler than surface temperatures during stratification; heavy winds can destratify the lakes in some summers.

Based on temperature data collected from 1976–87, mid-summer daytime surface temperatures generally ranged between 22 C and 26 C on Mendota and Monona. Surface temperatures were sometimes 1–2 C warmer than that on Waubesa and Kegonsa on the same sampling date. These higher temperatures can be attributed to the shallower depths and smaller volumes of Waubesa and Kegonsa, which had no cooler thermoclines for surface waters to mix with. The higher temperatures could also be a result of the lakes having been sampled later in the afternoon, when daily water temperatures were the warmest.

[9] The observations about lake temperatures discussed in this section and about dissolved oxygen discussed in the next section are consistent with data for Lakes Mendota, Monona, and Waubesa collected during the early 1960s (Stewart 1965, Stewart and Hasler 1972). These authors also found similar conditions for Lake Mendota around the early 1900s, based on data collected by E. A. Birge and others.

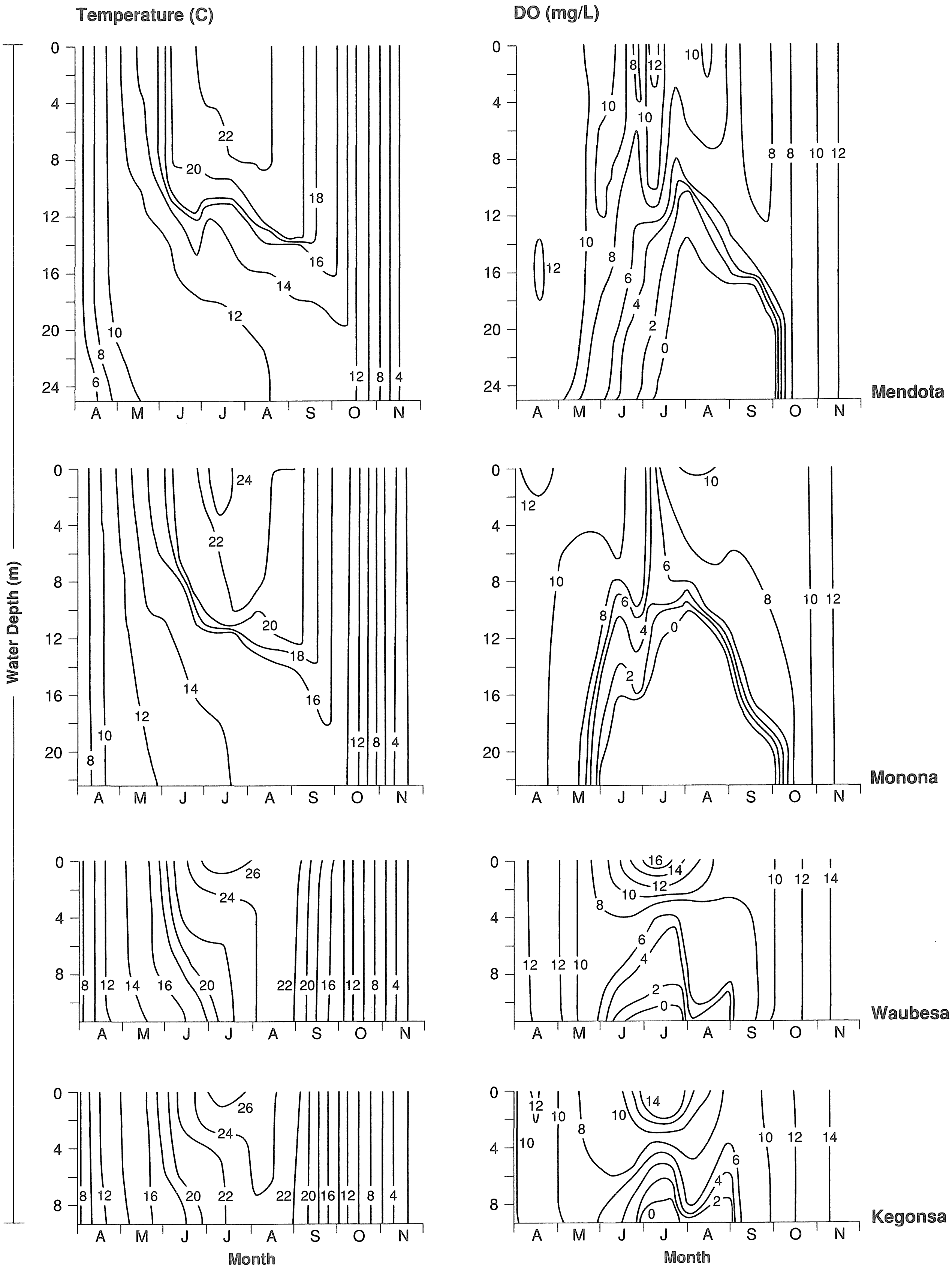


Figure 6. *Temperature and dissolved oxygen isopleths for Lakes Mendota, Monona, Waubesa, and Kegonsa, 1976.*

A comparison of water temperatures obtained at the 4-m depth eliminates some of the bias from short-term heating of the lake surface. Typical epilimnetic summer temperatures at 4 m were 20–24 C for Mendota and Monona and 22–26 C for Waubesa and Kegonsa. However, water temperatures were notably higher in 1983 and 1987 during particularly warm summers. Surface temperatures of 28–29 C were recorded on the lakes during those years. Mid-depth temperatures were correspondingly warmer also.

In late summer, as air temperatures cool and solar radiation declines, epilimnetic temperatures also start to cool (Fig. 6). In Mendota and Monona, this cooling causes an erosion of the thermocline; water from greater depths mixes with surface waters. Monona and Mendota normally are completely mixed by early and mid-October, respectively. Waubesa and Kegonsa are usually completely mixed by late August. Mixing continues in all 4 lakes throughout the fall, as the lakes lose heat.

Ice generally forms on a calm, cold night when water column temperatures are about 1 C (or slightly less) in Mendota, 1–2 C in Monona and 2–3 C on Waubesa and Kegonsa. Wind fetch and lake depth dictate these temperature differences. Because of their smaller lake volumes and smaller heat storage, Waubesa and Kegonsa freeze over earlier than the deeper lakes. Average ice cover dates are 7–8 December for Waubesa and Kegonsa, 16 December for Monona, and 20 December for Mendota. Dates for ice formation have varied by as much as 3 weeks earlier or later than the average date for each lake, depending on weather conditions in a given year. Average spring ice-out dates are 5 April, 2 April, 31 March, and 31 March for Mendota, Monona, Waubesa, and Kegonsa, respectively. Ice-out dates also vary considerably from one year to the next. However, Robertson (1989) determined that the total period of ice duration for Lake Mendota has declined since 1856 as a response to warmer air temperatures. Thus current ice-out dates are often earlier than and rarely exceed the long-term average for each lake.

In addition to natural factors influencing lake water temperatures, humans have also played a part by creating thermal discharges. The biggest of these, Madison Gas and Electric's discharge to Lake Monona, has had only a minor effect on the lake environment. Although this discharge used to cause earlier spring ice-out, now a barrier installed every winter restricts this response to a small area of the lake (Stewart and Hasler 1972). Likewise, the outfall has only a localized effect on lake temperatures throughout the open-water period (Jack Mason, formerly with Wis. Dep. Nat. Resour., Bur. Res., unpubl. data collected in the late 1960s). Numerous studies have been made of the outfall and its possible relationship to the fishery (e.g., to fish production, distribution, and mortality). The outfall apparently was beneficial to some species such as bluegills, which congregate in the outfall area during winter (Neill and Magnuson 1974, Magnuson et al. 1979). Negative effects on the fishery were negligible.

Dissolved Oxygen

Dissolved oxygen concentrations (DO) dictate the water depths habitable by fish. Freshwater fish other than trouts generally start to exhibit symptoms of stress when DO concentrations drop to around 4.0 mg/L (Davis 1975). Concentrations $\leq$2.5 mg/L often produce a severe deleterious effect after an exposure of a few hours. Lethal concentrations for short-term exposures are lower for some species, with concentrations decreasing slightly as temperatures also decrease (Rudstam and Magnuson 1985). Davis (1975) separated aquatic invertebrates into 2 general groups, those requiring high levels of DO and those tolerant of very low levels. Marked differences in the habitat suitable for fish food organisms are thus possible.

During the spring and fall mixing periods, the DO is >8.0 mg/L throughout the entire water column on all 4 lakes (Fig. 6). Concentrations $\geq$12 mg/L occur early in the spring and late in the fall because of the inverse relationship between oxygen solubility and water temperature. Surface water (0–9 m) DO concentrations during the summer months are usually adequate for warm-water fish species, even though the DO saturation concentration is less in warmer water. Supersaturation frequently occurs when algal blooms are dense on sunny days, particularly on Waubesa and Kegonsa, which generally have more extensive algal blooms than Mendota and Monona. Algal respiration and re-equilibration with the atmosphere (degassing) reduce the high DO levels during the night.

In mid-May, when Mendota and Monona thermally stratify, the bottom waters (hypolimnion) are sealed off from further oxygen replenishment from the atmosphere, and light levels are too low for photosynthesis. Biological respiration (principally from bacterial decomposition of organic matter) and chemical reduction consume hypolimnetic oxygen, particularly at the sediment-water interface (Brock 1985). Because Monona has less hypolimnetic water volume per unit sediment area than Mendota (Table 2) and because Monona's hypolimnetic temperatures are usually 2–3 C warmer than Mendota's, the DO is depleted more rapidly in Monona. Based on lake sampling data collected since 1976, Monona's hypolimnion starts to become anoxic about early June, while Mendota's does not become anoxic until early July (Fig. 6). Mendota's hypolimnetic DO depletion rate apparently has not changed since the early 1900s, when DO measurements were first made (Stewart 1976, Brock 1985). Oxygen depletion in the bottom waters of Waubesa and Kegonsa during the summer months is rapid, due to very low hypolimnetic volume:area ratios (Table 2) and much warmer water temperatures. These relatively shallow bottom waters can be re-oxygenated during periods of destratification caused by high winds.

DO depletion of Mendota's and Monona's bottom waters also occurs during the winter but to a much lesser extent than during the summer. Colder water temperatures cause lower bacterial metabolic rates (less oxygen consumed) and also allow higher DO levels to be present in the water column when the ice forms. Anoxia usually develops by March in Monona and Mendota but only in the deepest part of the lakes. In Waubesa and Kegonsa, DO concentrations are also depleted by March in the bottom waters and are sometimes depressed up to a depth of 5 m. In many years, DO supersaturation occurs under the ice because low snowfall allows good light penetration, triggering algal blooms. Algal blooms often occur just before ice-out after the surface snow has melted and after incident sunlight has increased due to longer day length and higher angle. In Lake Waubesa, one such supersaturation of oxygen was reported to have caused a sudden fishkill (Woodbury 1941). However, evidence for this event was mostly circumstantial, as late-night DO depletion and other factors were not considered.

Major Water Chemistry Constituents

Concentrations of the major water chemistry constituents in the Yahara lakes reflect the geochemistry of the surrounding drainage basin (Table 4). As discussed earlier in the Study Site Section, the large deposits of limestone and dolomite cause the lake waters to be alkaline; concentrations of calcium and magnesium are relatively high. The lakes are thus considered hard-water lakes and are not sensitive to acid deposition; this contrasts with the many soft-water lakes in northern Wisconsin.

The high sulfate concentrations in the Yahara lakes are significant, because sulfate in anoxic conditions is reduced to sulfide, which combines with reduced iron to form insoluble iron sulfide. Iron is therefore unable under anoxic conditions to form hydrous iron-oxides, which could adsorb/coprecipitate inorganic phosphorus (P) and thereby restrict its recycling. (P is the primary plant nutrient causing the excessive fertility in the Yahara lakes, a topic discussed in the next section.) Consequently, the Yahara lakes have high capacities for internal recycling of P, as compared to other lakes where sulfate levels are lower and iron is not tied up as iron sulfide (Holdren 1977, Stauffer 1987).

Fertility

Phosphorus (P) has been identified as the primary nutrient stimulating eutrophication in most lakes (Vollenweider 1968, Hutchinson 1975, Schindler 1977). Excessive loadings of P and other nutrients from a lake's watershed or drainage basin result in part from agricultural and urban runoff (nonpoint source pollution). They also come from sewage discharges and certain industrial/manufacturing wastes (e.g., food processing) that enter the lakes (point source pollution). This excessive fertilization has been called "cultural eutrophication" (Hasler 1947) and has resulted in overabundant algal and macrophyte growth in the Yahara lakes since at least the early 1900s. Aside from the recreational and water use problems associated with dense algal blooms and overabundant macrophytes, the fertility of the Yahara lakes has provided abundant food organisms that have allowed many fish species to proliferate.

Sewage Pollution. Nutrients contained in sewage and other discharges to Madison's sanitary sewers have heavily fertilized the lakes during past decades. In 1885, the city of Madison began construction of a sanitary sewer system that delivered raw sewage to Lakes Mendota and Monona (Alvord and Burdick, Eng. 1920; Flannery 1949). Prior to that, the sewage from Madison and outlying villages in the watershed went into privies and cesspools or private sewers that flowed directly into the Yahara lakes or its river and wetland system. Beginning in 1898, Madison's first sewage treatment plant was built east of the Yahara River. The effluent entered Lake Monona at the Yahara inflow.

Various changes in Madison's sewage treatment facilities were made throughout the 1900s as Madison's population grew. These changes began with the building of the Burke plant on the east side of the city in 1914, which continued to discharge Madison's effluent to Lake Monona after treatment consisting of primary settling tanks and trickling filters (Sonzogni 1974). In 1928, the first portion of the Nine Springs treatment plant was built, and it received about half of Madison's sewage (Flannery 1949). This treatment consisted of Imhoff tanks followed by trickling filters and final clarifiers (Sonzogni 1974). The effluent entered Nine Springs Creek immediately upstream from Lake Waubesa. The other half of Madison's sewage was still treated at the Burke plant until all of the sewage from Madison and adjacent communities was sent to an expanded Nine Springs plant in 1936, when an activated sludge system was added (Sonzogni 1974). (By that time the Madison

Table 4. *Major water chemistry constituents of the Yahara lakes, 1980–88.**

	Mean Concentration			
Constituent**	**Mendota**	**Monona**	**Waubesa**	**Kegonsa**
pH	8.5	8.5	8.6	8.6
Alkalinity (mg/L as $CaCO_3$)	172	170	176	179
Calcium (mg/L)	32	31	32	33
Magnesium (mg/L)	32	32	33	34
Potassium (mg/L)	3	3	3	3
Sodium (mg/L)	11	15	15	14
Chloride[a] (mg/L)	22	28	28	28
Sulfate (mg SO_4/L)	22	24	24	25
Specific conductance (µmhos/cm)	412	434	439	442

* Sources of data:
Specific conductance - Mary Ellen Testen, City of Madison Dep. Public Health, pers. comm.
All other constituents - Wis. Dep. Nat. Resour., Bur. Res. (unpubl. data).

** All analyses except for specific conductance were performed at the State Laboratory of Hygiene in Madison. Means cover 1980–88 except for calcium, magnesium, potassium, and sodium which are based on 1987–88 data, and specific conductance which is based on averages for June 1984–May 1989.

[a] Chloride has had a steady increase in concentration (see Lathrop 1988*b*).

Metropolitan Sewerage District had been formed.) The Burke plant was closed in 1936 but was reopened during the 1940s for army training facilities that were not connected to the treatment plant at Nine Springs. The Burke plant was used again later during this period for temporary treatment of part of Madison's east-side sewage, allowing an overloaded interceptor to be replaced and improvements to be completed at the Nine Springs plant by 1950. The Nine Springs treatment plant effluent continued to enter Waubesa until 1958, when the effluent was diverted around the Yahara lakes to the Rock River via Badfish Creek (Sonzogni and Lee 1974).

Other treated sewage effluents also entered the Yahara lakes over the years. The villages of Deforest and Waunakee built their first systems in 1923 and 1928, respectively. In 1962, the town of Windsor completed a treatment facility. All 3 effluents entered Lake Mendota via inflowing streams until 1971, when the systems were connected to the Madison Metropolitan Sewerage District (Sonzogni and Lee 1974). Finally, in 1962, the village of Cottage Grove began discharging treated sewage effluent to Lake Kegonsa via Door Creek. In 1982, Cottage Grove's sewage was connected to Madison's Nine Springs treatment facility. Other isolated sewage effluents that previously entered the Yahara lakes were diverted to various treatment systems in recent years.

The discharge of sewage effluents to the Yahara lakes constituted one of the most important impacts on the fishery over the past hundred years. As Madison's and the surrounding communities' populations grew, the quantity of the effluent increased tremendously. Also, the treatment systems were frequently overloaded because of this population growth. But more importantly, because the sewage treatment primarily was designed only to reduce the solids and biological oxygen demand, most of the nutrients in the sewage still entered the lakes.

Long-term trends in dissolved reactive (inorganic) P (DRP), one of the most important nutrients for causing excessive plant growth, depict the impact of the sewage in the lakes (Fig. 7). The elevated summer DRP concentrations in Lake Monona prior to the 1936 diversion and the subsequent increasingly high levels in Waubesa and Kegonsa until soon after the diversion in 1958 indicate

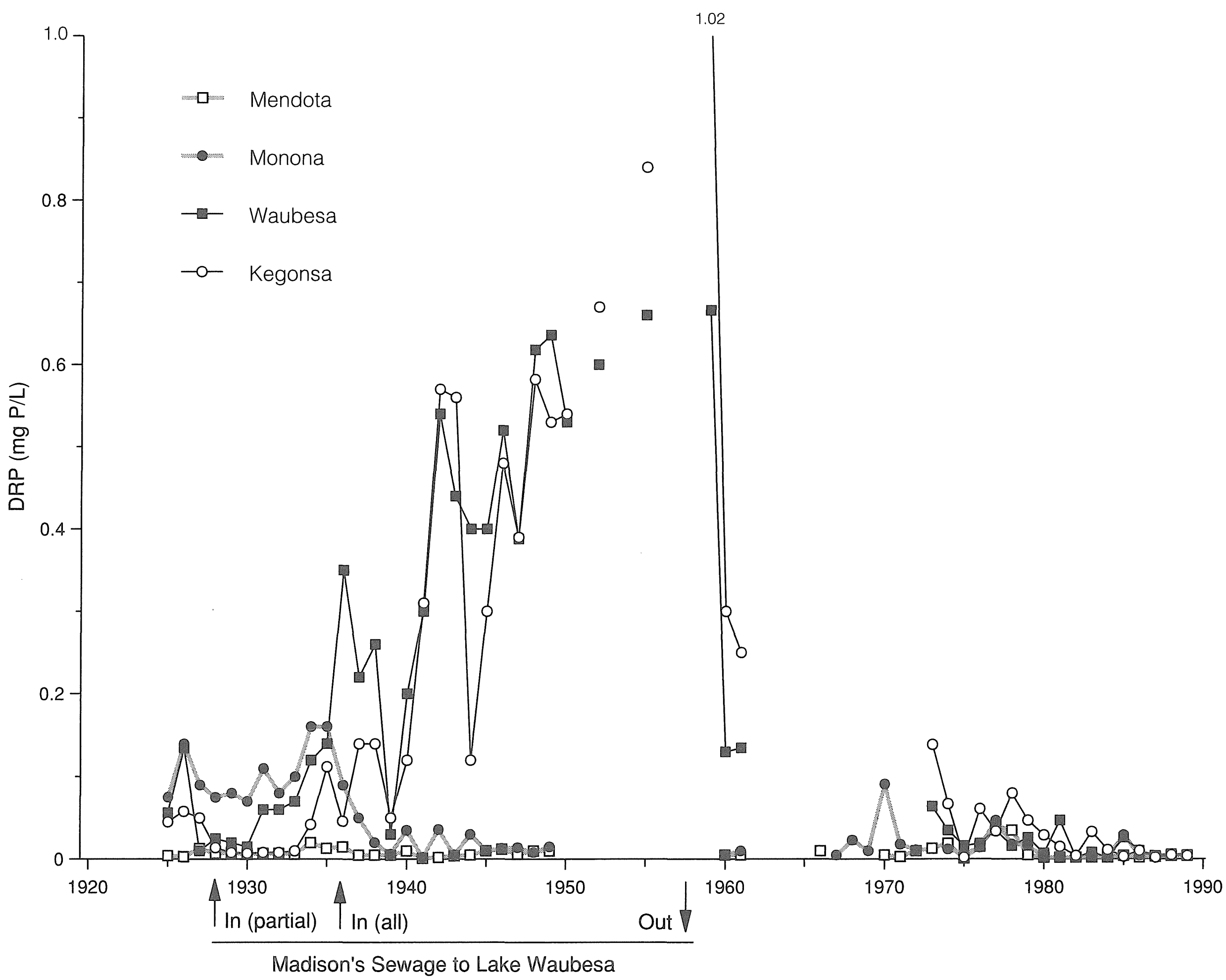


Figure 7. *Long-term trends in concentrations of dissolved reactive phosphorus (DRP) in the Yahara lakes, July–August, 1925–89.*

the massive enrichment of the lower Yahara lakes from Madison's sewage discharges. This enrichment was particularly pronounced in Waubesa and Kegonsa because of their relatively shallow depths and small lake volumes as compared to Mendota and Monona. In these early years, the nutrient-rich sewage led to severe water quality problems caused by excessive algal blooms. DRP was so high that the dense algae could not utilize it all, a condition typical of hypereutrophic lakes (Barica 1980, Lathrop 1988*c*).

In more recent years, summer DRP concentrations generally have been relatively low in all 4 Yahara lakes, although concentrations were higher in Waubesa and Kegonsa in the 1970s and early 1980s. When DRP was low and below analytical detection, then P may have been limiting to algal growth. A further analysis of P concentrations in all 4 lakes since 1976 is included in the Lake Trophic Condition Section, below.

Nonpoint Pollution. In addition to pollution from sewage and other wastes, nonpoint source pollution from agricultural and urban runoff has contributed large quantities of both nutrients and sediments to the Yahara lakes. While Madison's population did not grow significantly until after the early 1900s, crop production in Dane County expanded rapidly from 1850–70 (Figs. 8, 9). Since then, the biggest changes have been a decrease in small grain production (mostly wheat in early years, oats and other small grains after 1880), and an increase in corn production since the 1960s. Beginning in the mid-1900s, the use of artificial fertilizers also increased dramatically, particularly to increase the yields of corn as a cash crop.

The rapid development of the agricultural community in the Yahara lakes watershed between 1840 and 1870 subjected the land to increased erosion as the fields were plowed. This erosion was intensified as the production of grain crops decreased and as corn increased in more recent years. Much of these eroded sediments were deposited in the lower stream channel reaches or at the lake inlets. Nutrients contained in these deposited sediments would have leached out, thereby increasing the fertility of the lakes. The use of artificial fertilizers also has increased the nutrients in runoff.

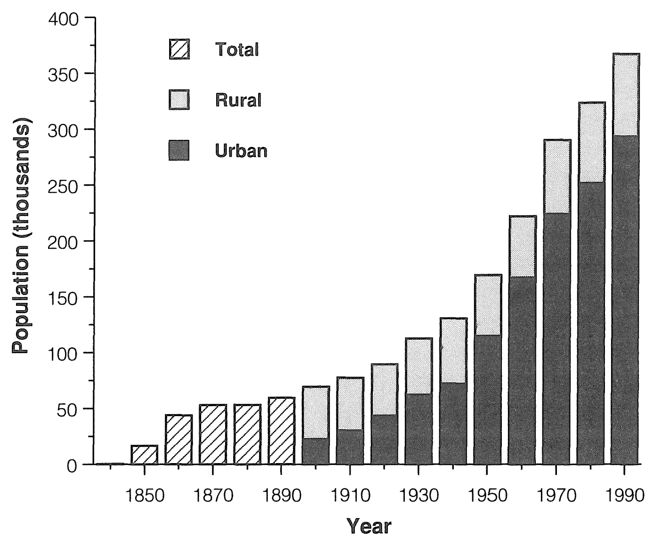


Figure 8. *Population of Dane County, 1840–1990, showing urban and rural populations for 1900–90.*

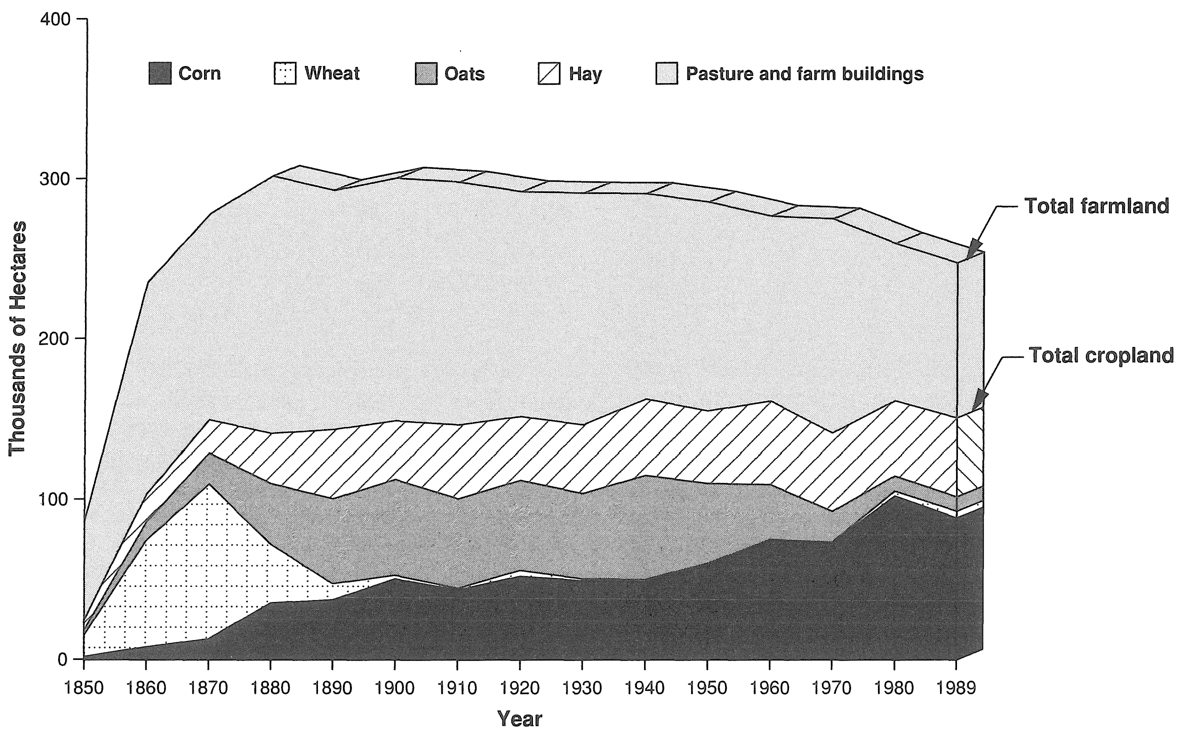


Figure 9. *Area of crop production and total farmland in Dane County, 1850–1989. Note that this is a stacked area graph, showing relative proportions of farmland use.*

As the farming community expanded, the number of farm animals also increased (Fig. 10), which resulted in large amounts of manure. While an assessment of total manure production and manure-handling practices is beyond the scope of this report, the numbers of each major manure-producing animal (i.e., cattle, horses and mules, hogs, and sheep) for the period 1850–1980 indicate that manure production probably has not changed appreciably since the early 1900s. High quantities of soluble nutrients from manure have entered the Yahara lakes, particularly during the spring runoff after manure had been spread during the winter on frozen ground (Lathrop 1986). Barnyards and animal feedlots in close proximity to drainage courses also may have been a major source of nutrients from manure.

Urbanization has been another significant source of sediments and nutrients from runoff to the Yahara lakes, particularly in more recent decades as the population of Madison and the surrounding communities has grown. One of the major sources of sediments in urban runoff is construction site erosion (Freund et al. 1979). The sources of nutrients from urban areas are many, including leaves, grass clippings, lawn fertilizers, and dust on impervious surfaces (e.g., roads, driveways, and rooftops). In fact, even though the total rural area is greater than the urban area in the Mendota watershed, the amount of P delivered per unit area of urban land is greater than that for the rural land (Lathrop 1979). In Lake Monona's direct drainage area, the contribution of P from urban sources is much greater than from the rural area. However, the major source of P to Monona, Waubesa, and Kegonsa is the Yahara River, discharging from the corresponding upstream lake.

Lake Trophic Condition. One of the best indicators or measures of eutrophication from both point sources and nonpoint sources is lake trophic condition. This state or condition of a lake refers to its degree of fertility resulting in overabundant aquatic plants (macrophytes and/or algae). Vollenweider (1968) defined a lake's trophic state in terms of total P concentrations (including both dissolved and particulate P). Eutrophic lakes have summer total P concentrations >0.03 mg/L. Mesotrophic lakes have total P between 0.01 and 0.03 mg/L, and oligotrophic lakes have total P <0.01 mg/L.

Total P data for the periods prior to the mid-1960s for Mendota and prior to the early 1970s for the other 3 Yahara lakes were either nonexistent or less reliable than DRP data. However, based on total P data collected since 1976 by the DNR Bureau of Research from all 4 Yahara lakes (Fig. 11), the lakes can all be classified as highly eutrophic, with shallower Lakes Waubesa and Kegonsa having the highest total P. Models that predict the threshold between permissible and dangerously

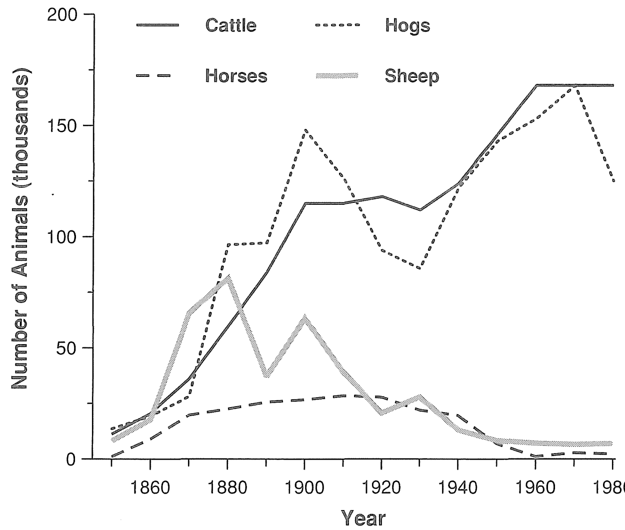


Figure 10. *Dane County farm animals, 1850–1980. Data for horses include mules for 1850–1960 and ponies for 1970–80.*

PHOTO: STATE HISTORICAL SOCIETY OF WISCONSIN COLLECTION

Cattle wading in Lake Mendota in early years prior to water quality concerns.

Storm runoff sediments entering Lake Mendota from Sixmile Creek, June 1978.

PHOTO: RICHARD LATHROP, DNR RESEARCH

PHOTO: STATE HISTORICAL SOCIETY OF WISCONSIN COLLECTION

Construction site erosion—a major source of sediment and nutrients to the Yahara lakes—on Madison's west side, early 1950s.

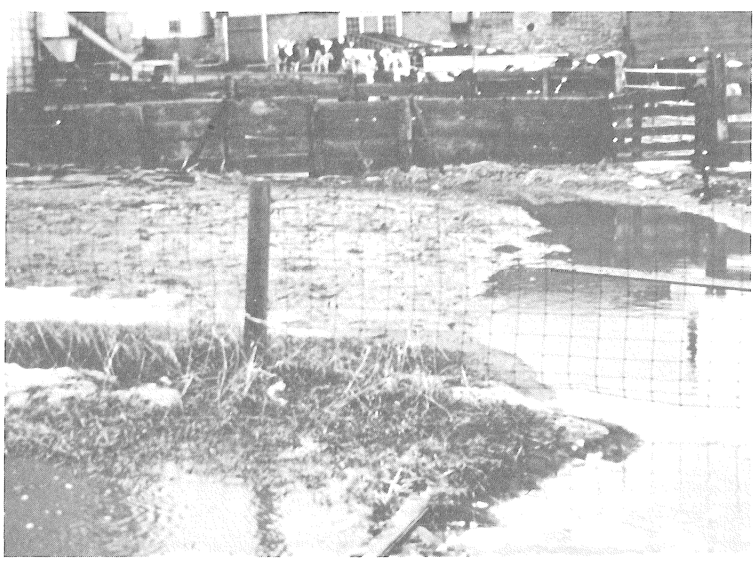


PHOTO: DANE COUNTY REGIONAL PLANNING COMMISSION COLLECTION

Early spring runoff from a barnyard, a major source of nutrients entering the Yahara lakes since the late 1800s.

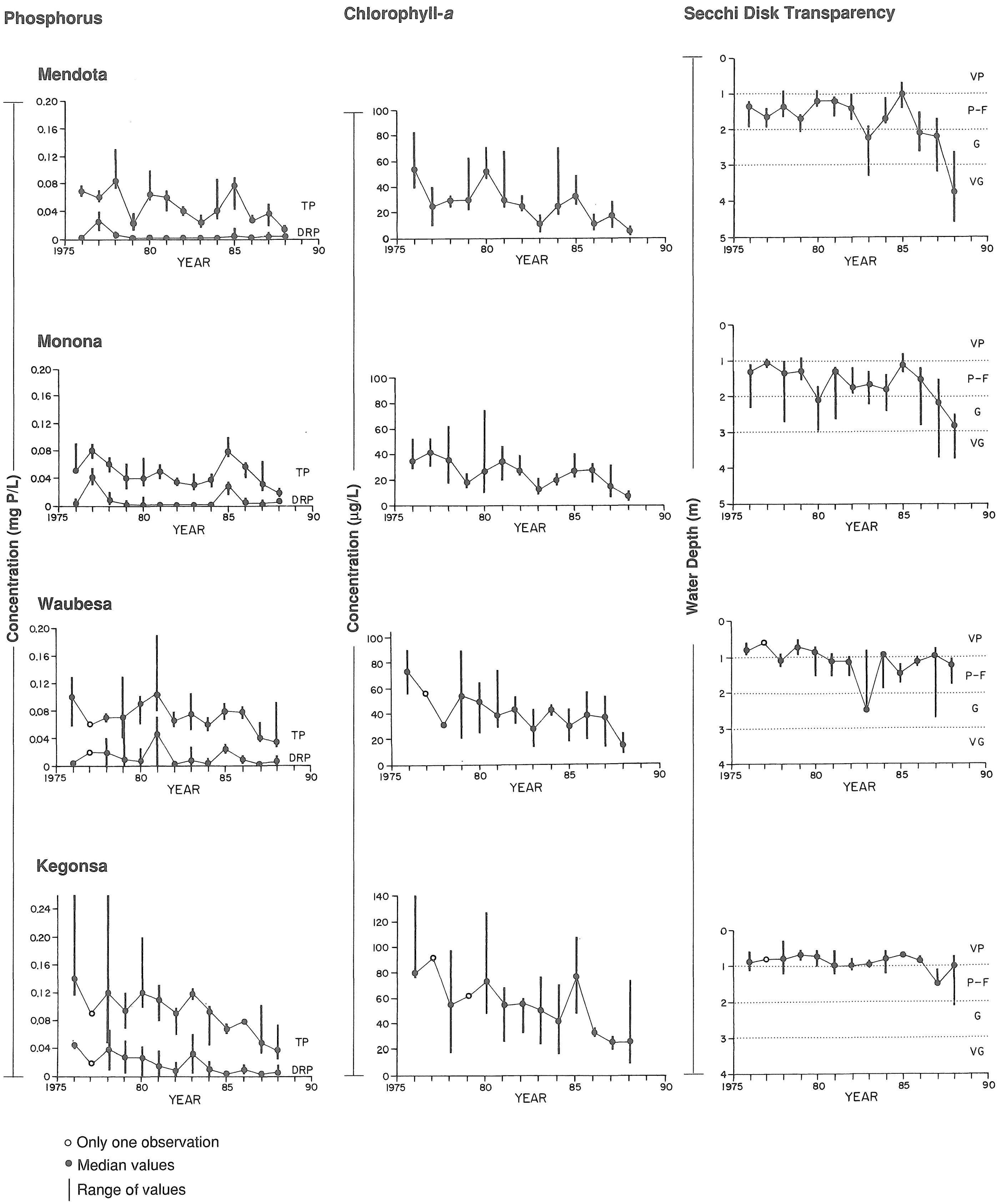


Figure 11. *Trends in summer phosphorus (total phosphorus and dissolved reactive phosphorus), chlorophyll-*a, *and Secchi disk transparency for the Yahara lakes, 1976–88. For Secchi disk transparency, VP = very poor, P-F = poor–fair, G = good, and VG = very good.*

high P loadings also indicate that Mendota and Monona are very eutrophic, based on average annual loadings determined in the late 1970s (Lathrop 1979).

However, total P concentrations have declined since the late 1970s, because spring runoff for most years since then has been below normal (Lathrop 1988*a*). This has caused Mendota's P concentrations to decrease, which has reduced loadings and in-lake P concentrations in Monona. The same effect has been observed in Waubesa and Kegonsa. In Mendota during the summer of 1988, total P concentrations declined to mesotrophic levels. (These low concentrations also may have been caused by lowered phytoplankton populations from increased zooplankton grazing.) In Monona, a similar decrease to mesotrophic levels was also observed in 1988. However, total P concentrations during the rest of the year suggest that Mendota and Monona should still be considered eutrophic (R. Lathrop, unpubl. data).

Two other indices of lake trophic condition are chlorophyll-*a* concentrations, the direct measure of algal biomass, and Secchi disk depths, a measure of water clarity or transparency. Trends in these 2 indices since 1976 also indicate that summer algal blooms in the Yahara lakes have been declining, although shallower Waubesa and Kegonsa have had much poorer water clarity than Mendota and Monona (Fig. 11). Secchi disk depths in Waubesa during the late 1970s and in Kegonsa since 1976 were generally <1.0 m, which prevented adequate light penetration for aquatic macrophyte (weed) growth, a topic to be discussed in a later section. Based on the data presented in Fig. 11, we computed the median summer Secchi disk depths for 1976–88 for Mendota, Monona, Waubesa, and Kegonsa to be 1.7 m, 1.5 m, 1.1 m, and 0.9 m, respectively.

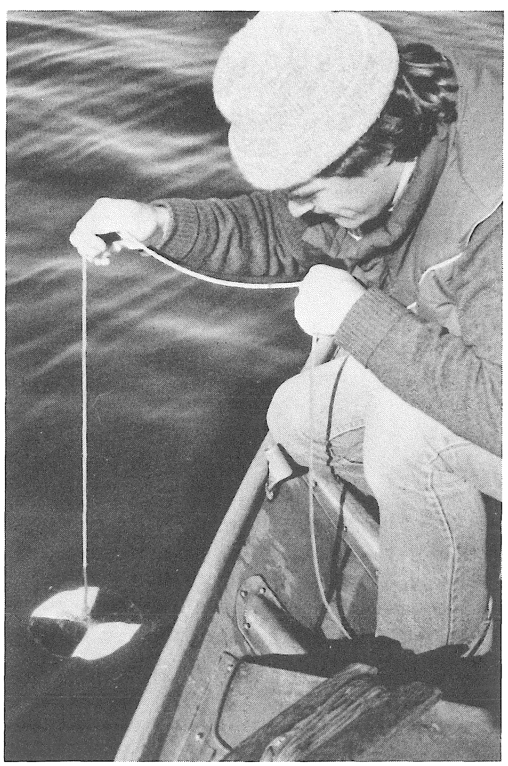


PHOTO: RICHARD LATHROP, DNR RESEARCH

Secchi disk used by DNR Bureau of Research personnel to measure water clarity of the Yahara lakes.

In summary, nutrient loadings from the sewage effluent discharges and from agricultural and urban runoff have produced eutrophic (fertile) symptoms in the Yahara lakes and, in some cases, hypereutrophic symptoms since the late 1800s. Cores taken from the bottom sediments in Lake Mendota, the lake least affected by sewage discharges, convincingly show the increase in overall fertility since Euro-American settlement (Bortleson 1970). The removal of Madison's sewage effluent discharges has reduced the hypereutrophic symptoms in the lower Yahara lakes, particularly Waubesa and Kegonsa. However, all 4 lakes should remain eutrophic for the foreseeable future because of the difficulty, particularly from a political and economic standpoint, of reducing nonpoint pollution.

Fishery Productivity. Another indicator of lake fertility is fishery productivity. Whereas excessive nutrients are considered detrimental by lake managers concerned about water quality, fisheries biologists have long recognized the value of nutrients passing up the food chain and ending up as fish biomass.

Although total fish production in the Yahara lakes cannot be measured, it can be predicted by means of a model called the morphoedaphic index. This index compares lake depth with lake fertility as expressed by the total dissolved solids in the lake water. A formula is then used to relate the index to fishery yield (Ryder 1965, Ryder et al. 1974).

Table 5 shows the results of these calculations for the Yahara lakes. Because total dissolved solids are similar in all 4 lakes, the yields are mainly affected by differences in mean depth between the lakes. Shallower Lakes Waubesa and Kegonsa thus have the highest predicted fishery yields per unit area of lake surface. Because of its larger surface area, Mendota has the highest predicted total yield.

Table 5. *Predicted yearly fish yields for the Yahara lakes using the morphoedaphic index (MEI).**

Parameter	Mendota	Monona	Waubesa	Kegonsa
Total dissolved solids—TDS (mg/L)	261	269	276	292
Mean depth $\bar{z}$ (m)	12.7	8.3	4.7	5.1
MEI	21	32	59	57
Yield (kg/ha/year)	4.4	5.5	7.4	7.3
Total yield (kg/year)	17,500	7,300	6,200	9,500

* Sources of data: TDS data were obtained from Mary Ellen Testen, City of Madison Dep. Public Health, pers. comm., and are averages for June 1984–May 1989. Computations were done by the Bureau of Research according to formulas in Ryder et al. (1974) (yield = $0.966\sqrt{MEI}$; MEI = TDS/$\bar{z}$).

Toxics

In addition to receiving domestic sewage, the Yahara lakes also received various industrial and commercial wastewater discharges via both the storm and sanitary sewers and the inflowing streams, although data on these discharges are scarce except for recent years. While many of the discharges contributed nutrients to the lakes (e.g., from sugar beet processing, canning, and meat-processing plants), some of the discharges contained heavy metals and other toxic substances. Lake Monona received the majority of these contaminants because of the location of much of Madison's industry. By the mid-1950s, efforts were made to identify the industrial/commercial discharges to the storm sewers and to eliminate many of the discharges via the sanitary sewer system (Fitzgerald et al. 1955). Most major sources of industrial wastewater discharges to the Yahara lakes were eliminated by 1978, except for cooling water discharges, which have been monitored (Dane Cty. Reg. Plann. Comm. 1978).

The long-term effects of these heavy metal toxicants on the fishery have probably been minimal, although localized effects on the biota may have been significant near the discharge outfalls. Many metals readily bind to calcareous, organic lake sediments (such as occur in the Yahara lakes) as metal carbonates, metal sulfides, or various organic complexes, and these metals apparently do not cause any long-term toxicity to the fish or benthic invertebrates. However, the free uncomplexed metal ions dissolved in the water are often highly toxic. Because Lake Monona received the largest quantities of these discharges, its sediments contain much higher levels of many metals than Mendota or Kegonsa (Iskandar and Keeney 1974). Waubesa also contains moderately high levels of some metals (Iskandar and Keeney 1974), due to discharges from the sanitary sewer system to Nine Springs Creek and discharges from industry on Waubesa's northeast side.

In addition to industrial discharges, heavy metals have also entered the lakes through other means. One such source was the massive copper sulfate treatments used for algal control from the mid-1920s to the mid-1950s (Mackenthun and Cooley 1952). These treatments resulted in high levels of copper in the muds of Lakes Monona, Waubesa, and Kegonsa (Nichols et al. 1946, Iskandar and Keeney 1974). Bio-assay experiments could not demonstrate any toxic effect on the profundal macroinvertebrates from high levels of complexed copper in the sediments (Mackenthun and Cooley 1952). However, others have noted that the copper sulfate treatments had a direct deleterious effect (most likely due to uncomplexed copper ions) on fish in treated areas (Hein 1940, Black 1945), particularly if copper concentrations were too high (Domogalla 1935). Sensitive invertebrates such as snails also were noticeably absent in Waubesa, which had been treated with copper sulfate (Frey 1940). What effect the treatments had on the littoral macroinvertebrates in the Yahara lakes was never fully evaluated, but the direct toxicity from the uncomplexed copper may have reduced the food resources during the years of heavy copper sulfate treatment (1925–46) on Monona, Waubesa, and Kegonsa.

While copper sulfate was used extensively to control algal blooms in the 3 lower lakes, herbicides were used as early as 1926 to control shore area macrophytes, particularly in Lake Monona (Domogalla 1926). Arsenic compounds were the primary chemicals applied in early years, but their use was discontinued after 1964 because of concerns about the cumulative toxic effect in the environment (Lathrop and Johnson 1979). Beginning in the 1960s, organic compound herbicides such as 2,4-D [(2,4-Dichlorophenoxy) acetic acid], diquat [6,7-dihydrodipyridol (1,2-a: 2′,1′-c) pyrazdiium ion], and a variety of endothall products (7-Oxabicyclo [2,2,1]heptane-2,3-dicarboxylic acid) were the primary chemicals used for weed control until the early 1980s, when diquat became

PHOTO: BERNARD SALEY, MADISON PUBLIC HEALTH DEPARTMENT

Barge used in copper sulfate treatments of Lake Monona, 1930s. An inboard motor boat was used to tow the barge along the lake shoreline during spraying.

the only organic herbicide allowed for the Yahara lakes. However, the amount of organic herbicides used in the Yahara lakes in more recent years has never been as extensive as the amount of arsenicals used in early years, since the primary method for aquatic weed control has become mechanical harvesting. The use of large amounts of herbicides for aquatic plant control was never adequately studied to determine its impact on the littoral zone biota. Current practices are to spray in very limited areas after the period of most fish spawning, to reduce the impact on fish. Research on the effects of diquat on spawning fish in the Yahara lakes is currently being conducted by UW researchers.

Mercury is another heavy metal that in recent years has become a concern, in this case regarding the consumption of fish from Wisconsin lakes. While mercury is not directly toxic to fish, it accumulates in fish tissue and becomes sufficiently concentrated in older, larger predator fish such as walleyes or northern pike to pose a human health hazard if these fish are ingested in large quantities. Normally, elevated mercury levels are of concern only for predator fish from soft-water lakes, such as those found in northern Wisconsin (Lathrop et al. 1989, 1991). Fish from hard-water lakes such as the Yahara lakes contain much less mercury, due to less availability of the mercury to the fish.

However, because Lake Monona historically received large quantities of sewage and industrial effluents that were contaminated with mercury, its sediments contain abnormally high levels of mercury (Syers et al. 1973; Marshall 1989; R. Lathrop, unpubl. data collected in 1985–86). The greater availability of mercury in Lake Monona has resulted in walleyes >46 cm from the lake being placed on a joint advisory (updated semi-annually) from the DNR and the Health Division of the Wisconsin Department of Health and Social Services. This advisory limits consumption, particularly for pregnant or breast-feeding women, women who plan to have children, and children under 18 years old (Wis. Div. Health and Wis. Dep. Nat. Resour. 1991). Mercury levels in the sediments of Lakes Mendota and Kegonsa are much lower, indicating they have received little mercury-contaminated discharge. Fish from these lakes have not been placed on any health advisory. Sediments in Lake Waubesa have moderate mercury levels, but only walleyes >66 cm have been placed on the advisory for that lake (Wis. Div. Health and Wis. Dep. Nat. Resour. 1992). Because panfish have much shorter life spans and because their diets are lower in the food chain, they rarely contain high levels of mercury, even in northern Wisconsin lakes. Panfish are not considered a health hazard for mercury in any of the Yahara lakes.

Fortunately for the fishery, the Yahara lakes have not received any industrial discharge of significant quantities of pollutants such as polychlorinatedbiphenyls (PCBs), dioxin, or other pesticides that plague the fisheries of a number of the state's waters in major industrial areas such as in the Lower Fox River, the Sheboygan harbor, or the Milwaukee harbor. Most of the industrial discharges to the Yahara lakes occurred in years before such organic compounds were synthesized. However, PCBs have been found in relatively low concentrations in the sediments of Lake Monona (Marshall 1989).

PHOTO: DNR WATER RESOURCES MANAGEMENT COLLECTION

DNR personnel preparing walleyes for mercury testing by the State Laboratory of Hygiene. Such tests led to a health advisory for eating large walleyes from Lake Monona, site of historical sewage and industrial effluents.

Macrophytes

Aquatic macrophytes, more commonly known as lake weeds, play a key role in the fishery of the Yahara lakes. Macrophytes provide cover for many fish species, particularly during early life stages when fish are most vulnerable to predation. Certain fish species require extensive beds of macrophytes in order to successfully spawn. Macrophytes also support abundant invertebrates; many fish species are often found in or around macrophyte beds, utilizing this food resource. As a result of their roles as habitat for fish and fish foods, macrophytes may influence the successful competition of one fish species over another in a given year.

Densities of macrophytes in the Yahara lakes have been affected by a number of factors. Key to enhancement of weed growth has been the eutrophic nature of the lakes. Invasion of new plant species has also contributed to the dense weed beds that have characterized the lakes for decades. Weed growth has been limited, on the other hand, by dense algal blooms that have reduced sunlight needed for growth, by carp that have uprooted macrophytes while feeding, and by extensive weed control programs. Weed control, through chemicals or mechanical cutting, has been attempted in the Yahara lakes since at least the 1920s (Domogalla 1926). All of these factors, along with species changes and natural differences in plant densities and bottom coverage, have resulted in both short- and long-term changes in the macrophytes in each of the Yahara lakes.

In the following sections, we highlight trends in macrophyte abundance in each lake, based on the major plant species. Many macrophytes are similar in leaf size, shape, and area of leaf dissection, and they can be grouped into functional types. The major submersed macrophytes, grouped to show these leaf relationships, are listed by their scientific and common names in Table 6. This list is composed of those species most frequently reported as abundant in the Yahara lakes. Numerous other species, especially pondweeds, have been reported in various surveys, but these species were either not considered important enough to include here or were common only in isolated areas.

Lake Mendota

Trends. Although Mendota's water level was raised 1.2–1.5 m to its current level by construction of a dam in 1847 (Kanneberg 1936), aquatic macrophytes probably soon invaded the new lake shallows. Accounts from the late 1800s to the 1920s described these plants as abundant. In 1884–85, Mendota was said to have a "large area of weedy shallows" (Forbes 1890:480). Juday (1914:15) described the whole bay at the inlet of the Yahara River as "filled with dense growths of vegetation." These descriptions are consistent with detailed macrophyte surveys of Mendota made in 1912 (Denniston 1922), 1914–15 (Muttkowski 1918), and 1920 (Rickett 1922). The major species present there were wild celery and pondweeds (primarily largeleaf pondweed and Richardson pondweed), the maximum depth of plant growth was about 5.5 m, and the area of coverage was about 25% of the total lake area.

Between the 1920s and the 1950s, Mendota's macrophytes did not change significantly. A 1942 survey showed generally the same major species as were found earlier, although largeleaf pondweed was not mentioned and coontail was listed as abundant (Zimmerman 1953). Surveys conducted in University Bay in 1939–41 and 1946 found weed beds to be still diverse and extending to relatively deep waters (Andrews and Hasler 1943, Andrews 1946). Major species were generally the same as in earlier accounts. One difference was the first record in 1946 of curlyleaf pondweed, an exotic to North America. In addition, Andrews studied plant succession throughout the year and noted that wild celery grew mainly in late summer. The fact that past surveys were conducted at this time may account for the reported abundance of this species.

Dominance of wild celery and pondweeds continued throughout the late 1940s and 1950s, according to surveys by Threinen (1949*a*) in 1948, Threinen and Helm (1952*b*) in 1951, and an account by Cooke (1962) for the late 1950s. In 1951, the maximum depth of the dense beds was about 4.8 m, indicating that the area of coverage had not declined significantly since the early 1900s. However, coontail and water milfoil had become more abundant. Macrophytes were also richer in variety and density in the main lake basin than in the bays where turbidity caused by carp activity may have restricted plant growth (Threinen and Helm 1952*a*). Similar diversity of species was recorded in one other survey in 1961 (Clifford Brynildson, Wis. Dep. Nat. Resour., Madison Area files, unpubl. data collected in 1961).

The first dramatic change in the macrophytes in Mendota took place in the mid-1960s with the invasion of Eurasian water milfoil, an exotic to North America.[10]

Table 6. *Taxonomy of some of the major submersed macrophytes in the Yahara lakes, by functional group according to leaf characteristics.**

Functional Group and Scientific Name	Common Name
Highly dissected leaf structure	
Ceratophyllum demersum	coontail
*Myriophyllum exalbescens***	northern water milfoil
Myriophyllum spicatum	Eurasian water milfoil
Potamogeton pectinatus	sago pondweed
Moderately dissected leaf structure	
Elodea canadensis	American elodea
Potamogeton crispus	curlyleaf pondweed
Potamogeton richardsonii	Richardson pondweed
Undissected, ribbonlike, or broad leaf structure	
Potamogeton amplifolius	largeleaf pondweed
Vallisneria americana	wild celery

* Evaluation of significance of species and assignment of species to each group were subjective and not absolute. Taxonomy follows Winterringer and Lopinot (1966) except for the common name for *Vallisneria americana,* for which the more widely used name of wild celery is given instead of eel grass.

** *Myriophyllum exalbescens* was recently renamed *M. sibiricum* (Gleason and Cronquist 1991).

[10] Some confusion has occurred in the species identification of the genus *Myriophyllum* in the various surveys. Lind and Cottam (1969) recorded the explosion of milfoil as being the native species, *M. exalbescens,* but this was later accepted to have been Eurasian water milfoil, *M. spicatum.* Based on examination of voucher specimens collected, Nichols (1975) found only *M. exalbescens* in Lake Mendota in 1962 and only *M. spicatum* in 1966. Other species of *Myriophyllum* were also recorded in earlier surveys. *M. exalbescens* was recently renamed *M. sibiricum* (Gleason and Cronquist 1991).

By 1966, this species accounted for 98% of the biomass of submersed plants in University Bay (Lind 1967, Lind and Cottam 1969). The maximum water depth of plant growth had also decreased to 4.0 m. The ability of Eurasian water milfoil to outcompete other species may have been due to several of its characteristics: (1) trailing surface stems and leaves, which can form a canopy in shallow water, thus blocking light to other submersed plants, (2) a strong root system, which bottom feeders such as carp do not easily uproot, and (3) an ability to spread prolifically from plant cuttings.

Eurasian water milfoil was very dense in Mendota until about 1976, after which declines were observed in many area lakes within the next few years (Carpenter 1980, Andrews 1986). In 1978–79, Andrews (1980:9) studied the causes of the decline of milfoil in University Bay. During this time period, he found a "precipitous general decline of species" numbers and apparent plant densities. Coontail and American elodea had become the dominant species. Andrews (1980:33) attributed the decline in species and densities to "unusually turbid water" and not to plant pathogens.

In the summer of 1980, Vander Zouwen (1982) found that the maximum depth of plant growth in University Bay had declined to 3.0 m, which resulted in a 30% loss of littoral area in the bay since 1966. Eurasian water milfoil was again the dominant species, but it was not extensive and was found covered with dense mats of filamentous algae. Similar conditions were recorded during a macrophyte survey in late July 1984, except that coontail was more abundant than in 1980. Plants were generally sparse between 2.0 m and 3.0 m. By 1989, the macrophyte community had increased and extended into water depths of 3.5–4.0 m, although coontail had replaced milfoil as the dominant species (Nichols et al. 1992). In 1990, because of poor water clarity, the macrophyte community again declined (R. Lathrop, unpubl. data), another example of the dynamic nature of the macrophytes in the Yahara lakes. The densities of milfoil present in Lake Mendota between the mid-1960s and mid-1970s have currently not returned.

Management. Since the 1920s, the city of Madison has removed weeds with a weed cutter, allowing the weeds to float to nearby shorelines where they are loaded by hand and hauled away. However, prior to the mid-1950s, most of this effort was directed to isolated areas because the weed cutters were inefficient, and the city relied heavily on aquatic herbicides[11] to control weeds during these early years (Bernard Saley, formerly with City of Madison Dep. Public Health, pers. comm.). In the mid-1950s, the city began emphasizing weed cutting and shoreline cleanup in both Mendota and Monona because of the purchase of more efficient cutting machines and concerns about the use of chemicals in the lakes (B. Saley, pers. comm.). Records for the tonnage of debris (mostly weeds) picked up from Mendota's shoreline during 1955–69 indicate that the amounts of weeds removed remained fairly steady prior to 1964 (Fig. 12). Quantities increased in 1964, and from 1965 through 1969 almost twice the amount of weeds were removed each year. During this period, weed harvesting was geared almost exclusively toward removal of

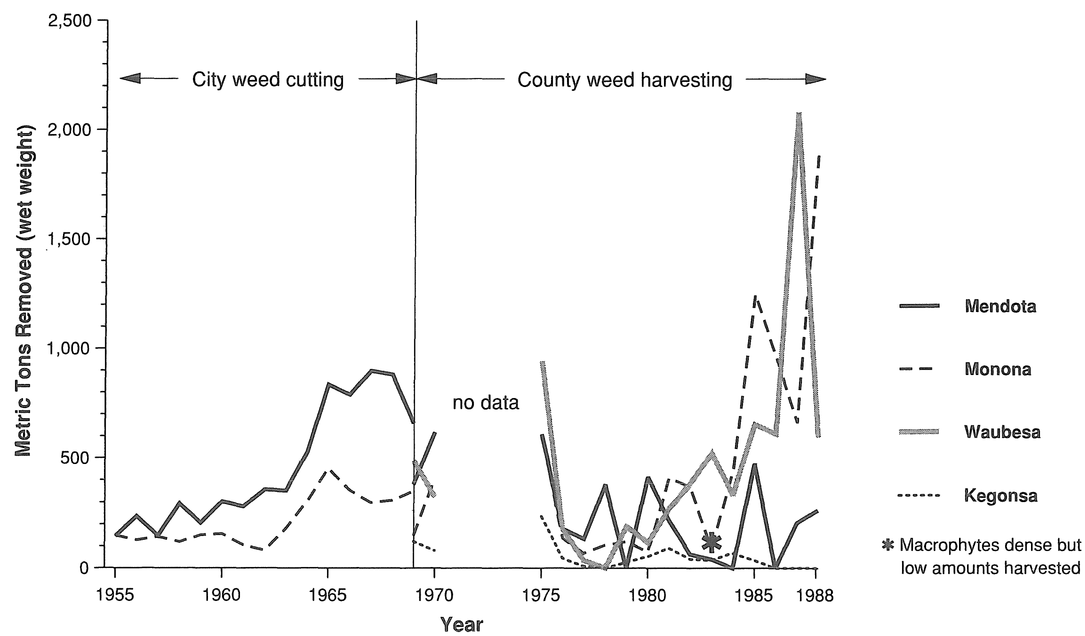


Figure 12. *Trends in weed cutting and harvest on the Yahara lakes, 1955–88.*
(Note: tons removed by the city versus the county are not directly comparable because effort was different.)

[11] See Lueschow (1972), Lathrop and Johnson (1979), and Andrews (1986) for summaries of chemicals used.

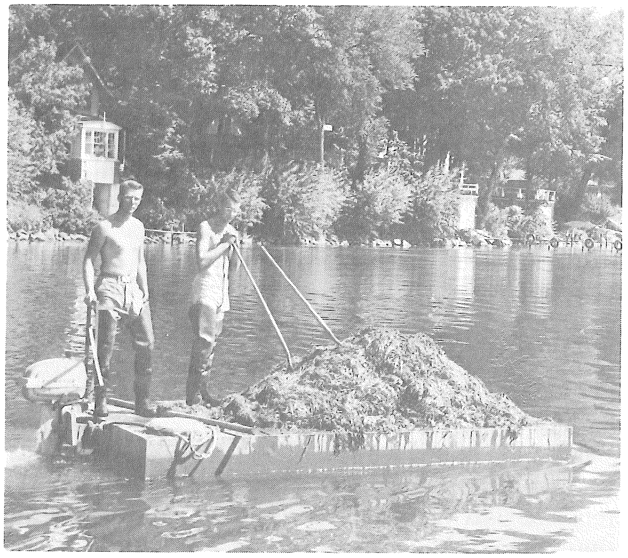


PHOTO: BERNARD SALEY, MADISON PUBLIC HEALTH DEPARTMENT

City weed cutter used on Lakes Mendota and Monona beginning in the mid-1950s.

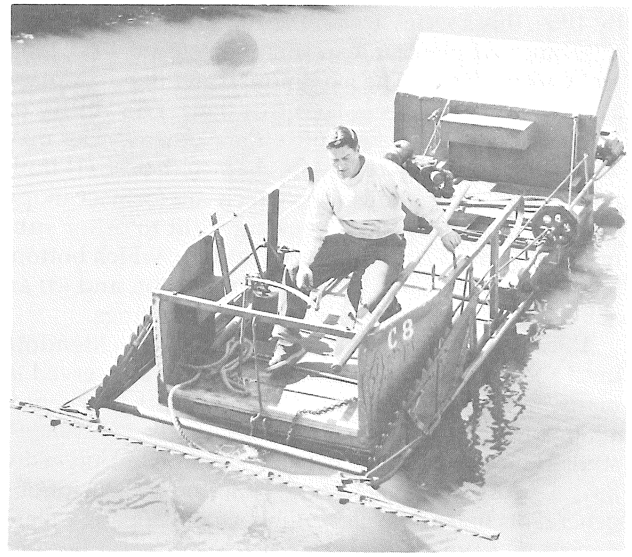


PHOTO: BERNARD SALEY, MADISON PUBLIC HEALTH DEPARTMENT

Barge of cut weeds collected from the shoreline by City of Madison, 1955.

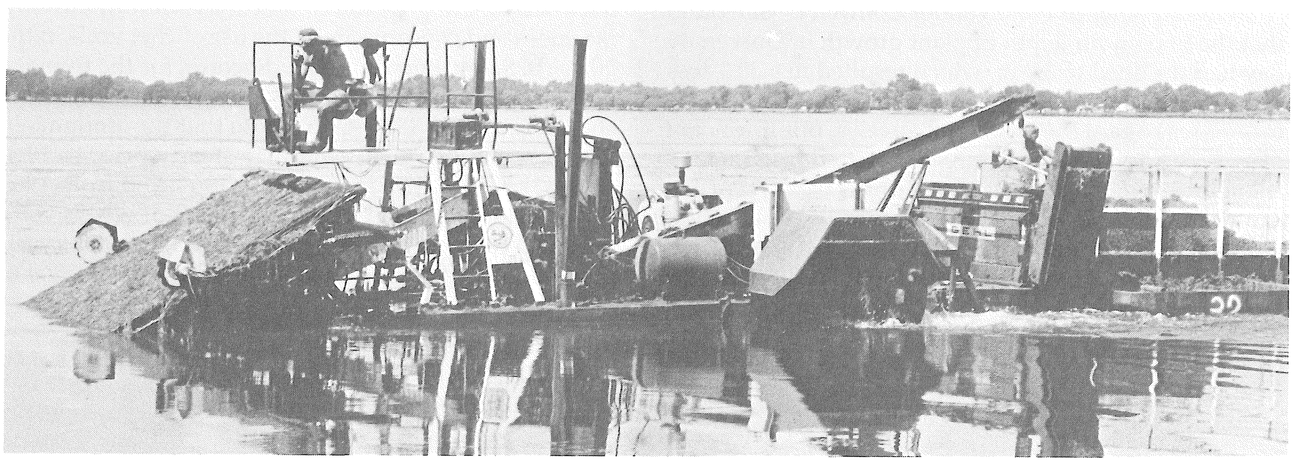


PHOTO: KEN CHRISTENSEN, THE CAPITAL TIMES

Dane County weed harvester used on Yahara lakes, 1985.

Eurasian water milfoil. Ironically, since this species reproduces easily from vegetative cuttings, early removal methods that only cut weeds and left them floating may have increased the spread of this plant.

In 1965, the Lake Mendota Problems Committee was formed because of the objectionable plant growth of rooted weeds, associated filamentous algae, and free-floating algae that formed shoreline scums that summer (Nutr. Sources Subcomm. 1966, Livermore and Wunderlich 1969). That same year, a weed harvester was purchased by the city as part of an emergency remedial action to the overabundant weed growth. This machine not only cut weeds but gathered up the cuttings at the same time. Both weed cutting/shoreline cleanup and weed harvesting continued through 1969 (Saley 1987). During 1969, the city began to phase out its weed removal program. Shoreline cleanup effort decreased, records of the amount of debris removed were discontinued, and some of the city's responsibilities for weed harvesting were transferred to Dane County. Finally in 1970, the weed harvesting was completely turned over to the county in order to expand harvesting to Waubesa and Kegonsa.

The weed harvesting program conducted by the Dane County Public Works Department expanded in the early 1970s with the purchase of new harvesting equipment (Howard Hartwig, formerly with Dane Cty. Public Works Dep., pers. comm.). But a quantitative picture of the county's early efforts is not clear for several reasons. First, the amount of weeds harvested in 1969–70 is not certain. During this transition period, when both city and county agencies were harvesting weeds, each agency kept its own records and some quantities of removed weeds may have been counted more than once. Secondly, no records were found for 1971–74. Nevertheless, we know that macrophyte densities were very high in Lake Mendota during this period and that large amounts of weeds were removed (H. Hartwig, pers. comm.). Since 1975, the highest weed harvests—although only moderate amounts—were in 1978, 1980, 1985, and 1988 (Fig. 11). Growth in 1988 was actually more extensive than the harvest record reflects, since lush growth of weeds in Lakes Monona and Waubesa tied up equipment and personnel and delayed harvesting on Mendota until midseason.

Summary. Lake Mendota had a diverse and moderately dense community of macrophyte species growing to depths of 5.0–5.5 m around most of its shoreline from soon after the lake level was raised in the mid-1800s through the late 1950s and early 1960s. Plant species changes during these years were relatively minor, and the 3 main functional groups of plants were well represented. By the early 1960s, Eurasian water milfoil had invaded the lake and by the mid-1960s had exploded to nuisance levels that dominated the entire macrophyte community. Many previously important macrophyte species were eliminated or severely reduced. However, even though plant densities of the milfoil beds increased, the maximum depth of macrophyte growth was reduced to about 4.0 m, thereby decreasing the area covered by submersed macrophytes. Heavy densities of milfoil beds continued in Mendota until about 1976, when a general decline in milfoil occurred there and in other area lakes. By the early 1980s, depth of plant growth had dropped to about 3.0 m. Since then, Mendota has had variable densities of macrophytes, with Eurasian water milfoil and a few other species being moderately dense in some years and not in others. An increase in water clarity during 1986–88 extended the depth limit of growth to deeper water and allowed coontail to replace milfoil as the dominant species. Data since 1989 indicate year-to-year variation in Mendota's macrophyte community.

The major change in functional groups has been increased densities of plants with highly dissected leaves relegated to relatively shallow water. This has been accompanied by loss of plants with less-dissected leaves (including the broad-leaved plants) as well as loss of all macrophytes in deeper water. These changes occurred mainly during the mid-1960s.

Lake Monona

Trends. Early accounts of the macrophytes in Lake Monona describe them as abundant. In one of the first of these descriptions, Juday (1914:22) noted that Turville Bay was "filled with dense growths of vegetation" and that Monona Bay behind the railroad tracks had been "filled with a large amount of vegetation" until a few years earlier, when the bay was dredged. In another report, Lake Monona was described as having a "practically continuous belt" of weeds to a depth of about 3.0 m. These weed beds covered "considerably" more than 20% of the lake area (Alvord and Burdick, Eng. 1920:17).

In 1925, Monona was still "infested with rooted weeds" (Domogalla 1935:119). Because of citizen complaints, the city began systematically removing the weeds from swimming beaches and around boathouses by means of a weed cutting machine, steel cables, and chemicals. Use of chemicals, initially white arsenic, became the preferred treatment method and eliminated many macrophytes, particularly in shallow waters. However, copper sulfate, which was used extensively on Lake Monona beginning in 1925 to control dense summer algal blooms, improved water clarity considerably, with Monona having the best clarity of all the Yahara lakes (Domogalla 1935). Resulting increased light penetration apparently allowed the weeds to flourish and spread to deeper water, even though the weeds in certain areas were being eradicated. In treated areas, weeds grew "luxuriantly" offshore at depths of 3.0–5.5 m; Domogalla (1935:119) wrote: "This finding pleases the fishermen, who first thought the chemical treatments through these years would kill every weed in the lake."

The end of the massive copper sulfate treatments after 1946 probably marked a major decrease in the

PHOTO: STATE HISTORICAL SOCIETY OF WISCONSIN COLLECTION

Dredging of Monona Bay and filling of shoreline, circa 1907. Prior to this dredging, dense macrophytes filled this bay.

distribution of macrophytes in Lake Monona. In 1948 and 1951, algal turbidity reduced light penetration and restricted macrophytes to maximum depths of 1.7 m (Threinen 1949*a*, Threinen and Helm 1952*a*). Within this shallow-water zone, macrophytes were still "abundant and varied" (Threinen and Helm 1952*a*:9). Macrophyte species diversity was also high. Sago pondweed was predominant, with other abundant species including coontail, American elodea, Richardson pondweed, other pondweeds, and wild celery. All functional groups of submersed macrophytes, from plants with highly dissected leaves to those with undissected leaves, were thus represented in the lake during the late 1940s through early 1950s.

Surveys a decade later found macrophytes restricted to the same 1.8-m depth (C. Brynildson, Wis. Dep. Nat. Resour., Madison Area files, unpubl. data collected in 1960 and 1961). A few species differences were noted: sago pondweed was not as abundant, while the native northern water milfoil was more abundant. It is not clear if this was really native milfoil or Eurasian milfoil. (See footnote, p. 48.)

By the mid-1960s a second and dramatic change in Monona's macrophytes took place. Records of debris (mostly weeds) removed by the city showed that larger amounts were taken out in 1964–69 than in 1955–63 (Fig. 12). Although no surveys identified the species involved, it is common knowledge that the predominant plant was Eurasian water milfoil, which had increased dramatically in Lake Mendota at the same time.

Macrophytes continued to be very dense in Lake Monona until milfoil densities declined in 1976. The relative lack of macrophytes inflamed controversy between anglers, who felt that chemical spraying and harvesting were removing too much of the remaining fish habitat, and boaters and shoreline residents, who wanted most of the weeds removed. This public concern led to a study by the DNR's Bureau of Fish Management on the amount of invertebrates and fish fry and fingerlings removed by the harvesters (Wis. Dep. Nat. Resour., Bur. Fish. Manage. files, unpubl. rep. Dec 1978). While large numbers of invertebrates were removed, almost no fish were found in any of the samples of weeds cut by the harvesters. However, a survey of 23 lake harvesting operations in Wisconsin showed that young fish have frequently been removed during harvesting (Sandy Engel, Wis. Dep. Nat. Resour., Bur. Res., pers. comm.).

The low densities of milfoil in Lake Monona lasted through about 1980. However, starting in 1981 weed growth generally increased, as indicated by the large tonnages removed, especially since 1985 (Fig. 12). A survey in Turville Bay in late July 1984 recorded Eurasian water milfoil as very dense from the shore to 1.5 m and then as gradually declining out to 3.0 m, the limit of plant growth. Coontail was also dense in the same depth ranges where milfoil was most abundant. Little filamentous algae was observed on plants, which was just the opposite of survey findings for Mendota in the same year. However, surveys conducted in 1990–91 confirmed observations that macrophyte densities declined since the late 1980s (R. Lathrop, unpubl. data).

Summary. In the early years of this century, Lake Monona apparently had an extensive macrophyte community, which was probably similar in species composition to Lake Mendota's diverse community. Dredging and shoreline filling in Monona eliminated some of the bottom habitat for macrophytes, but algal blooms caused by Madison's sewage effluent restricted the maximum depth of growth to <3.0 m by 1920. Worsening water quality problems in Monona from greater amounts of sewage effluent precipitated an era of intensive algae and weed management by the city of Madison. Copper sulfate was continuously applied throughout the summer from 1925 through the late 1940s to control the algal blooms. In the early years of treatment, low algal densities in the open water were apparently achieved at times, which allowed light penetration for the macrophytes to grow in deeper water depths of 3.0–5.5 m. Shallow water macrophytes were chemically eradicated.

By the late 1940s and through the early 1960s, macrophytes were moderately abundant, but growth was limited to water depths of 1.7 m. The deep-water macrophyte community had been eliminated, because the water clarity during this era was not as good as in previous years when the lake was being chemically treated. Pondweeds and coontail were common species until the early 1960s, when milfoil started to dominate. Similar to the situation in Mendota, densities of Eurasian water milfoil became extensive in Monona by the mid-1960s. Weed beds, dominated by milfoil, continued to be dense through the mid-1970s, decreased dramatically in 1976, but then increased steadily since 1981. The maximum depth of macrophyte growth was about 3.0 m in 1984, but with the clearer water in 1986–88, the depth limit for growth probably increased. A shift to plants with more highly dissected leaves started at the time of the milfoil dominance. The apparent decline of macrophytes in the early 1990s indicates the dynamic nature of Monona's macrophyte community.

Lake Waubesa

Trends. As in Lakes Mendota and Monona, Lake Waubesa had extensive macrophyte beds in early years. Juday (1914:25) wrote: "abundant growths of the larger aquatic plants [occur] in the shoal water [along the west shoreline]. In fact, a fairly large amount of vegetation is found in the shallow water all along the edge of the lake but these growths are not so dense and continuous elsewhere as along the above shoreline."

However, the weed beds declined in Lake Waubesa after Juday's initial description. During the summer of 1939, Frey (1940) found macrophytes growing only to a maximum depth of 0.6–1.5 m in isolated areas occupying <3% of the lake. He noted that up until 1936, the weed beds were dense enough that anglers "sometimes had difficulty in rowing boats through [them]" (Frey

1940:63). Sago pondweed was the only important species, whereas leaf fragments found in bottom deposits indicated wild celery had been more abundant earlier. Frey also noted Juday's surprise that Upper Mud Lake, which had been described by Thwaites (1902) as having dense growths of macrophytes in 1887, had no submersed macrophytes by the late 1930s.

The macrophyte decline described by Frey (1940) probably occurred soon after 1936, when massive algal blooms were likely caused by the additional discharge of Madison's sewage effluent to Waubesa via Nine Springs Creek. This combination of intense algal blooms and less-than-abundant macrophytes was also described in 1949 and 1951 (Threinen 1949*a*, Threinen and Helm 1952*a*). These authors found that macrophyte growth was still restricted to shallow waters (1.2 m). Sago pondweed remained the only important species, occurring in moderate abundance. Very little macrophyte growth was recorded again in WCD surveys in 1955 and 1960–61 (C. Brynildson, Wis. Dep. Nat. Resour., Madison Area files, unpubl. data).

A major change in Waubesa's macrophytes took place sometime after the mid-1960s when the lake no longer received sewage effluent and macrophytes began to flourish again. As in the 2 upriver lakes, this increase was undoubtedly associated with the spread of Eurasian water milfoil. In a 1972 survey (C. Brynildson, unpubl. data) and in notes by the DNR Bureau of Research lake monitoring field crew for 1972–75, milfoil growth descriptions ranged from "abundant" to "a nuisance."

In 1976, macrophyte growth in Lake Waubesa declined dramatically, as indicated by county weed harvesting records (Fig. 12). During the late 1970s, few weeds were removed because of poor water clarity resulting from dense summer algal blooms (Fig. 11).

Both water clarity and macrophytes increased again in the early 1980s; macrophytes were dense in Waubesa through the summer of 1988. Macrophyte growth in 1987 was particularly extensive; macrophytes then were probably as dense as they had been for decades. Eurasian water milfoil has continued to be the predominant species. The milfoil has also been dense in downstream Lower Mud Lake throughout the 1980s; harvesting was required in many years to maintain a channel allowing adequate discharge from the Waubesa outlet (Ken Koscik, Dane Cty. Public Works Dep., pers. comm.).

Summary. Lake Waubesa had dense macrophyte beds in the early 1900s. However, soon after Madison began discharging its sewage effluent to Waubesa in 1936, water clarity decreased substantially because of algal blooms. Macrophytes also decreased in area and maximum depth of growth. Sago pondweed was the only species found in any abundance from the late 1930s through the early 1950s. Macrophytes were sparse in the early 1960s. By the late 1960s, Eurasian water milfoil spread throughout the lake shallows. Densities of milfoil were high in the early 1970s and then declined in 1976, as in the other Yahara lakes. Eurasian milfoil became abundant again in the early 1980s and became very abundant by the end of that decade. While no actual measurements have been made, the maximum depth of plant growth probably increased somewhat during the 1980s. Since at least the 1930s, the macrophyte community has been composed of mostly highly dissected plant species.

Lake Kegonsa

Trends. Lake Kegonsa apparently did not historically have the dense macrophyte beds that formerly characterized the upper 3 Yahara lakes. Juday (1914:26) stated that because Kegonsa was relatively large and circular in shape, "the lake is free from bays, . . . [which] permits a freer circulation of the water and tends to prevent the growth of vegetation in the shallow water."

Frey (1940:6) stated that Kegonsa also had "reduced" macrophytes in 1939; the main species then was sago pondweed. Whether this small amount of macrophytes was substantially less than that noted by Juday is not clear, but there was probably some reduction because of the increasing water quality problems in Kegonsa. Domogalla (1935:115) stated that both Waubesa's and Kegonsa's water quality was "in very bad condition" in 1935. This was one year prior to the diversion of all of Madison's sewage effluent from Lake Monona to Lake Waubesa via Nine Springs Creek, although a part of Madison's sewage had entered Lake Waubesa since 1928. Light penetration to weed beds in Waubesa and Kegonsa throughout the 1920s and 1930s was probably reduced by shading from algal blooms.

During the 1940s and 1950s, macrophyte densities remained low. Surveys in 1948 and 1951 found macrophytes not abundant and growing only to depths of 1.6–1.8 m (Threinen 1949*a*, Threinen and Helm 1952*a*). Sago pondweed and coontail were the principal species. These were also the most common species in 1952 and 1955, according to observations by C. W. Threinen (formerly with Wis. Dep. Nat. Resour., Bur. Fish. Manage.) that were mentioned in subsequent WCD Fish Management surveys. By 1960, no macrophytes were recorded at various stations sampled around Kegonsa's shoreline, and in 1961, macrophyte growth was generally sparse (C. Brynildson, Wis. Dep. Nat. Resour., Madison Area files, unpubl. data collected in 1960 and 1961).

No macrophyte surveys were made on Lake Kegonsa from 1961–90, but we suspect that Eurasian water milfoil became established and began to increase to moderate densities in the mid-1960s at the same time that it increased in Mendota and Monona and, probably, in Waubesa as well. Eurasian water milfoil was first recorded in Kegonsa in 1972, at which time this species was described as abundant and 4 other species were described as common (C. Brynildson, unpubl. data collected in 1972). Observations recorded by DNR Bureau of Research lake monitoring personnel during July 1973–75 indicated that Eurasian water milfoil was moderate to heavy around most of the shoreline and that it was covered with filamentous algae in 1973.

From 1976–88, annual weed harvesting was minimal or nonexistent on Kegonsa (Fig. 12), as macrophyte growth has been sparse. During these years, dense summer algal blooms were common, and water clarity was poor, thus suppressing macrophytes. However, even during the early 1970s when the county was harvesting weeds in Kegonsa, the milfoil was never as extensive as in the other Yahara lakes (H. Hartwig, pers. comm.).

Summary. The macrophytes in Lake Kegonsa have never been extensive. Even though the lake has a large, shallow water area, the circular shape of the lake allows significant wave action to maintain relatively hard bottom conditions in the lake shallows by redepositing the organic sediments in deeper water. Macrophyte rooting would be disturbed by the wave action. Kegonsa also has had severe algal blooms dating back to the 1920s, which have restricted light penetration for macrophyte growth. Sago pondweed was the main species recorded in surveys from the late 1930s through the 1950s. In the early 1970s, when Eurasian water milfoil became overabundant in the other 3 Yahara lakes, it was also moderately abundant in Kegonsa. Since the mid-1970s, macrophytes (mostly milfoil) have been relatively scarce in Kegonsa. The milfoil growth in the late 1960s and the early 1970s probably represented the largest extent of macrophytes in Kegonsa since early times. When macrophytes were common, they were composed of mostly highly dissected species.

Invertebrate Food Organisms

Zooplankton

Zooplankton (littoral and pelagic) are the principal food organisms for almost all fish in their early life stages (fry and fingerlings), and they remain an important food source for a number of fish species throughout their lives. Because of the large pelagic area of the Yahara lakes, the pelagic zooplankton in the lakes are considered the most numerically important, and most available information pertains to these species. Species found in the littoral zone are often different from those found in abundance in the open water, but almost no information exists on these littoral zooplankton in the Yahara lakes.

Only a brief summary of the zooplankton is given below. The most numerically important pelagic zooplankton of the Yahara lakes consist of crustaceans; rotifers are generally not abundant. The most important crustaceans are represented by 6 species of copepods and 7 species of cladocerans (Lathrop and Carpenter 1992*b*). While these species exhibit regular seasonal patterns, all species do not occur in large numbers in all years. Different life stages of juvenile and adult crustaceans also occur, with the smaller individuals in immature or juvenile life stages often being more numerous. The zooplankton communities are constantly changing as the various organisms mature and reproduce. The presence of food organisms, which is also dynamic, and planktivory by higher life forms—including fish and larger zooplankton—also contribute to the dynamic changes in the zooplankton communities in the lakes.

In general, zooplankton densities are much greater in the spring months than in summer or fall (Lathrop and Carpenter 1992*a*). In the spring, phytoplankton populations consist of mostly edible species, which are a food source for the herbivorous zooplankton. Copepods (adults and, especially, the immature copepodites and nauplii) are usually the most numerous zooplankton species in spring, particularly *Diacyclops bicuspidatus thomasi* (Lathrop and Carpenter 1992*b*). (Cyclopoid copepods in their later life stages feed on smaller zooplankton.) Although not most numerous, *Daphnia* (cladocerans), commonly known as water fleas, are particularly efficient filter feeders that graze on algae, thus causing a clear-water period in the lakes each spring. In turn, *Daphnia* is a highly preferred food of such fish species as yellow perch and cisco (Luecke et al. 1992).

These large zooplankton densities in the spring occur throughout the water column of each of the Yahara lakes when the entire water body is oxygenated. The timing of this spring population abundance is critical for newly hatched fish fry to survive and grow (Post et al. 1992). By early summer, the deeper lakes have thermally stratified, and blue-green algal blooms have developed on all 4 lakes. Because blue-green algae are a poor food source for zooplankton and because the anoxic hypolimnion restricts the zooplankton mostly to the epilimnion and thermocline, total lake zooplankton numbers are usually the lowest of the open-water period. Summer is also the season in which planktivory by fish can effectively suppress zooplankton populations (Luecke et al. 1992).

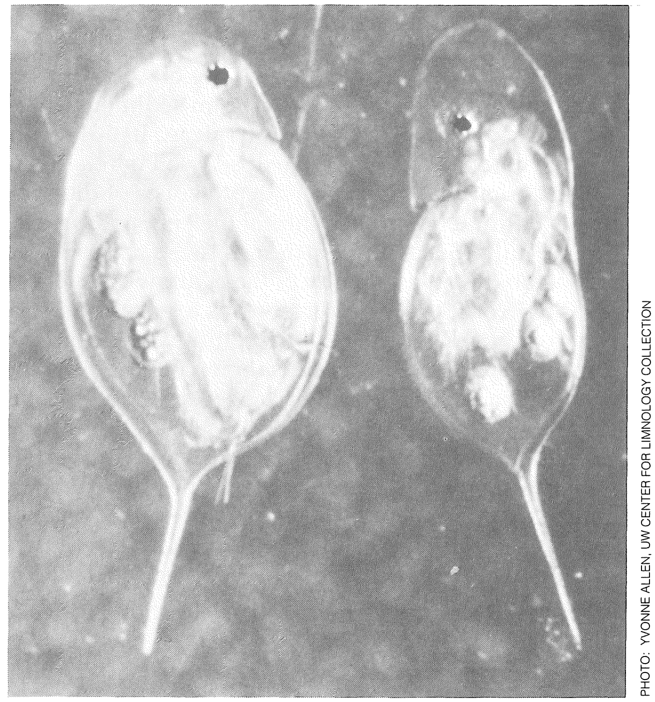
Much has been written about fish predation on zooplankton by fish and the resulting effects on algal populations (Hrbáček et al. 1961, Brooks and Dodson 1965, Shapiro et al. 1982, Carpenter et al. 1987). When planktivory by fish is high, larger species of zooplankton (particularly *Daphnia*) are reduced and smaller species predominate. Smaller zooplankton generally have reduced filtering rates and can ingest only small algal species, thereby affecting the amount and type of phytoplankton in a lake.[12]

Besides the obvious effect of planktivory by fish causing suppressed zooplankton population abundance, more subtle and complex interactions also occur. One example is the effect on 2 different species of *Daphnia*: *D. pulicaria* and *D. galeata mendotae*. Under minimal planktivory by fish, the larger *D. pulicaria*

[12] The interaction of zooplankton and phytoplankton in the Yahara lakes is beyond the scope of this report. It is treated more fully in a recently published book on Lake Mendota's food web edited by Kitchell (1992).

predominates, whereas under heavier planktivory, the smaller *D. galeata mendotae* becomes the dominant species (Mills et al. 1987, Lathrop and Carpenter 1992*b*, Rudstam et al. 1993). Both species have been present in the Yahara lakes since 1976, but generally in most years only one species reaches large population densities each spring (Fig. 13). Which *Daphnia* species predominates has also had implications for water clarity. Because the larger *D. pulicaria* is a more efficient filter feeder than the smaller *D. galeata mendotae*, and because *D. pulicaria* reproduces at colder temperatures (Burns 1969, Leibold 1990), Lake Mendota has exhibited a more extensive spring clear-water period when *D. pulicaria* has predominated (Lathrop 1992*b*).

In recent years, Mendota was dominated by *D. galeata mendotae* during 1978–85 and 1987 and by *D. pulicaria* in 1976–77 and 1988–89. Both species co-dominated in 1986. A similar shift from *D. pulicaria* to *D. galeata mendotae* occurred in the other 3 Yahara lakes between 1976 and 1978–81, but the 2 species have varied as the dominant species throughout the 1980s. The lack of *D. pulicaria* in Lake Mendota during 1978–85 and 1987 coincides with a period of abundant ciscoes prior to a massive summerkill in August 1987 (Rudstam et al. 1992) (discussed later in the section on ciscoes). However, the more complex *Daphnia* picture in the lower 3 lakes suggests that other planktivorous fish species (ciscoes there are either absent or low in numbers) can also regulate the relative abundance of these 2 *Daphnia* species.



Two species of zooplankton, the larger-bodied Daphnia pulicaria *and smaller-bodied* D. galeata mendotae, *which are an important source of food for fish and can also affect lake water clarity due to their different potential for grazing on phytoplankton. Actual body lengths (excluding tail spines) about 1.7 mm.*

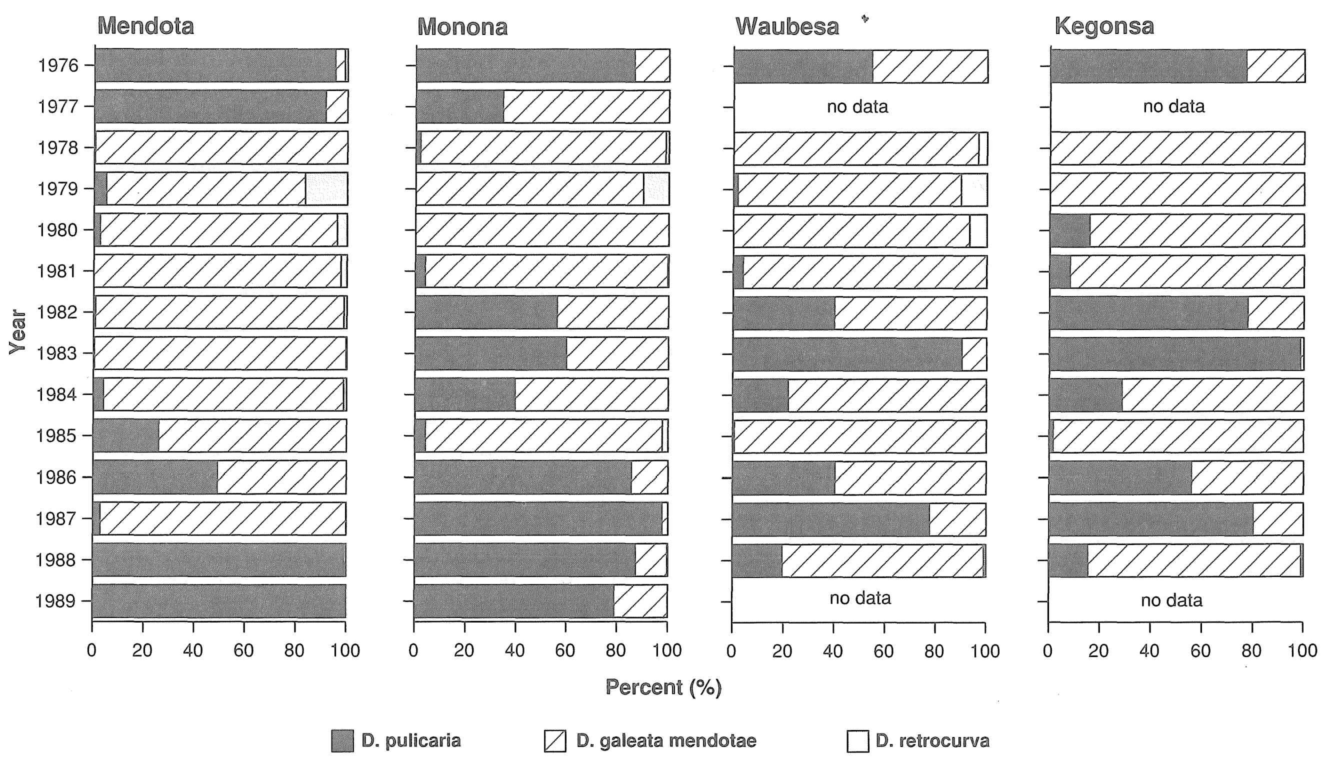


Figure 13. *Relative proportion of the 3 major* Daphnia *species in the 4 Yahara lakes during April–June, 1976–89.*

Macroinvertebrates

Benthic macroinvertebrates can be classified as to whether they live in or on the bottom sediments or on aquatic macrophytes or filamentous algae. In this report, benthic macroinvertebrates are discussed in relation to 3 lake regions based on water depth zones of the sediments: littoral (<3 m), sublittoral (3–9 m), and profundal (>9 m). (See a description of these zones in the section on the morphometry of the lake environment.)

The littoral macroinvertebrates are composed of hundreds of different plant-dwelling and sediment-dwelling species. Because this region of a lake's water column is mixed throughout the open-water season, the organisms present do not have to be tolerant of low oxygen levels for prolonged periods, as is the case in the profundal sediments during summer stratification and late winter. Because of the complexity of the ecological niches in the littoral zone, a great diversity of organisms is present (Wetzel 1983). In contrast, the profundal sediments have fewer niches, and hence are inhabited by a few species tolerant of low oxygen. However, because the deeper lake sediments are highly organic, the numbers of a particular species utilizing this energy source can be very large at times (Brinkhurst 1974).

While most macroinvertebrate species are associated with sediments or macrophytes, 2 species that have been found at different times in the Yahara lakes are planktonic, living at least part of their life cycle in the open water. One of these is *Leptodora kindtii*, a large-bodied predacious crustacean, and the other is *Chaoborus punctipennis*, an insect that spends part of its larval stage in the profundal sediments and migrates up in the water column during the night to feed on smaller zooplankton. Both organisms have been observed in the diet of fish such as yellow perch (Pearse and Achtenberg 1920, Luecke et al. 1992). *Leptodora* is a major component of the yellow perch diet in late summer, when the invertebrate is most abundant (Luecke et al. 1992). A more detailed treatment of *Leptodora* dynamics in Lake Mendota is given by Lunte and Luecke (1990). Because *Leptodora* is only periodically important to the fishery in the Yahara lakes, it will not be discussed further. *Chaoborus* will be discussed along with the benthic macroinvertebrates of the profundal zone.

Littoral. Because of the complexity of these organisms, only a few studies have been made of the littoral macroinvertebrates; most of these studies were done on Lake Mendota. Probably the first account of these invertebrates was from dredge samples collected in 1884–85 (Forbes 1890). Forbes found large numbers of a small white chironomid and a small amphipod and various other types of invertebrates in Mendota's shallow-water sediments. One of the most comprehensive surveys of the macroinvertebrates in Mendota was conducted by Muttkowski (1918) throughout 1914–15 in water depths <7 m. Numerous organisms were found, with their densities affected by bottom type and water depth. A caddisfly (*Leptocella*) dominated his collection in terms of biomass, but small oligochaetes, a mollusc (*Amnicola*), and the amphipod *Hyalella* all had larger numerical densities. Chironomids were also numerically important. The total number of species (excluding leeches) recognized by Muttkowski was 98.

About 2 decades later (1939–41), Andrews studied the macroinvertebrates associated with macrophytes in Lake Mendota's University Bay. He found that the plants with the most highly dissected structure had the largest densities of invertebrates and that the plants with the least structure had the smallest densities (Andrews and Hasler 1943, Andrews 1946). Densities ranged from 29,000–52,000 organisms/kg (dry weight) for northern water milfoil and coontail, about 20,000/kg for sago pondweed and *Chara* sp., 10,000–18,000/kg for more moderately dissected pondweed species, about 5,000/kg for largeleaf pondweed, to only 3,000/kg for the ribbonlike wild celery, one of the most abundant macrophyte species in Lake Mendota prior to 1960. *Hyalella*, followed by chironomids, was the most numerous organism on the plants, but many other invertebrate species were found. The total number of invertebrates on mixed plant populations averaged about 2,500/m^2 of lake area. However, *Hyalella* was found in densities of about 10,000/m^2 in beds of *Chara* during late summer. These invertebrate densities on the plants with highly dissected leaf areas are consistent with recent data from dense Eurasian water milfoil beds in nearby Fish Lake (Richard Narf, Wis. Dep. Nat. Resour., Bur. Res., pers. comm.).

In late summer of 1939, David Frey (Indiana Univ., unpubl. data) took bottom samples in all 4 Yahara lakes at various water depths. In shallow-water depths of Mendota, *Chironomus* larvae (mostly small-sized), the chironomid *Procladius*, and the oligochaete *Limnodrilus* each had densities of 400–1,000/m^2, while total littoral macroinvertebrate densities were 1,200–2,400/m^2. Kegonsa had 1,800–5,000/m^2 small-sized *Chironomus* in water depths of 1–4 m; other organisms there had much lower densities. Total littoral densities in Kegonsa were 2,300–7,700/m^2, with densities much lower in 6 m of water. Waubesa had *Chironomus* densities in between Mendota's and Kegonsa's for water depths <2 m; total littoral densities there averaged 3,400/m^2. The number of chironomids decreased dramatically in Lake Waubesa beyond 3 m in depth; total macroinvertebrate densities averaged 1,300/m^2 in water depths of 3–8 m. In Monona, shallow-water densities were <1,000/m^2.

The most recent study of littoral macroinvertebrates in Lake Mendota was conducted by J. A. Šapkarev (1967–68), University of Skopje, Yugoslavia, while a visiting professor in 1964–65. He took numerous dredge samples in Lake Mendota from all depth ranges, but he published information only about leeches. His unpublished data for other organisms are summarized in Lathrop (1992*c*). Average yearly densities of water mites, oligochaetes, chironomid larvae, hydras, and amphipods were much greater (900–4,000/m^2) than corresponding densities of other organism groups (<450/m^2). Water mites and oligochaetes were particularly abundant in late spring, with maximum densities of 20,200 and 11,200/m², respectively. Densities of turbellarians, leeches, amphipods, water mites, and chironomids were all notably greater than densities recorded by Muttkowski (1918). Other organisms that were recorded in both surveys had relatively similar densities except for caddisflies, which were more abundant in Muttkowski's survey. However, the plant-dwelling caddisflies may have been underrepresented in the 1964–65 survey because an Ekman dredge was used for sampling.

Because of taxonomic changes and the listing of newly discovered species for many types of shallow-water macroinvertebrates, historic comparisons of organism densities require a highly specialized analysis beyond the scope of this study. Studies conducted on Lake Mendota during the 1950s further documented the complexity of the chironomid speciation and population dynamics in the shallow waters of the lake (Dugdale 1955, Cooke 1962). Muttkowski (1918), Andrews (1946), Dugdale (1955), and Šapkarev (Lathrop 1992*c*) each gave densities of various organisms in their studies, but differences in sampling techniques and habitat sampled (sediments versus plants) also make quantitative comparisons of any of the shallow-water macroinvertebrates difficult. For example, Andrews collected 10–1,000 times the density of *Hyalella* as did Muttkowski, but Andrews sampled the plants with a special bag sampler. Other researchers usually used different types of bottom dredges. In addition, individual species densities are often highly variable during different times of the year. Some researchers only reported annual averages, while others sampled only in certain seasons, making comparisons invalid. Finally, individual studies that sampled in consecutive years reported large yearly differences in some organisms. However, density changes for certain macroinvertebrates may have occurred over a larger span of years. For example, Šapkarev (1967–68), in his 1964–65 study of the leeches in Lake Mendota, found an average of 360/m² in water depths from 0–5 m, as contrasted to Muttkowski's (1918) work in 1914–15, when densities ranged from 0.8–14/m². The data from all the studies/surveys suggest that the littoral zone of Lake Mendota supports large densities and a great diversity of aquatic organisms.

Sublittoral. Long-term trends in densities of the major benthic macroinvertebrates in the sublittoral sediments of Lakes Mendota and Monona and the corresponding sediments of Waubesa and Kegonsa are summarized in Tables 7 and 8. The data are from studies that used dredges for sampling bottom sediments during either winter or late summer in water depths of about 6–9 m. While some studies reported samples taken at approximately 6 m and 9 m, other studies only reported the average number of organisms sampled within the 6-m to 9-m depth range. Total densities of invertebrates were less than those reported for the littoral zone. Order of magnitude decreases in invertebrate densities from 6m to 9m were common, which may indicate that oxygen conditions in the sediments restrict some organisms at 9 m. Mendota has had more chironomids than the lower 3 Yahara lakes within this depth range during the winter months; oxygen conditions at 6–9 m are much better in Mendota because of its greater total depth.

Many animal groups recorded in the littoral zone of Lake Mendota were found only occasionally or in small abundance in the sublittoral zone in Šapkarev's 1964–65 survey (Lathrop 1992*c*). Oligochaetes and chironomids were the most abundant sublittoral benthos. Ostracods and water mites were also present in moderate densities (Lathrop 1992*c*). Similar findings were found by Muttkowski's (1918) survey at depths of 0–7 m.

Long-term benthos density data for winter and summer months indicated that sublittoral and profundal sediments of Lake Mendota were inhabited by similar organism groups, but densities have differed during this century (Tables 7, 9). In the winters of 1917–18, phantom midge larvae (*Chaoborus punctipennis*) occurred in moderate densities in water depths of 8–9 m, although their densities were much higher in deeper waters (Juday 1921). Only annual averages were given by Juday for all depths, so sublittoral data for larval insects are not listed in Table 7. They were not found in more recent surveys in sublittoral sediments. Both *Chironomus* spp. and *Procladius* spp. were important sublittoral species (Juday 1921). In 1965 and 1987–89, *Procladius* was much more abundant in sublittoral sediments than in profundal sediments (Lathrop 1992*c*). Conversely, oligochaetes generally were more abundant in profundal sediments than in sublittoral sediments in most of the past surveys. The fingernail clam *Pisidium* sp. also was abundant in sublittoral sediments in 1917–18 and 1951 (Lathrop 1992*c*). Densities had declined dramatically by 1965; the clam was not found in 1987–89.

Of interest is the lack of *Pisidium* in Monona, Waubesa, and Kegonsa. Its absence in the 1940s was related to the use of copper sulfate in those lakes (Sawyer et al. 1945). However, numerous mollusc shells were found at depths of 4–7 m in Waubesa in 1939 (D. Frey, unpubl. data collected in 1939).

Profundal. The profundal benthic macroinvertebrates provide a better long-term indicator of changes in the fish food organisms in deeper Lakes Mendota and Monona (Table 9). A description of the profundal benthos in Lake Mendota was first given by Forbes (1890) from dredge samples taken in August 1884–85. He recorded "a good collection of *Pisidium* [mollusc]..., several large deep red *Chironomus* larvae, and a species of a tube-making worm *Limnodrilus*" from water depths >21 m (Forbes 1890:480). He noted an occasional *Chaoborus* larva (formerly called *Corethra*) found only in a sample collected in 6 m of water on a rocky reef, although the total number of dredge samples taken at all depths was small.

Using a vertical tow net, Birge regularly collected the dipteran *Chaoborus* in summer hypolimnetic samples from Lake Mendota in the late 1890s (Birge 1895, 1898, 1904). Few other zooplankton were present because of anoxia. Birge noted the larvae's nocturnal migration to the surface waters for feeding. He also noted that copepods and "a few worms" inhabited the deep-water muds,

Table 7. *Macroinvertebrate densities in the sublittoral sediments of Lake Mendota.**

		Macroinvertebrate Densities (no./m²)							
Organism	**Depth (m)**	**1914–15****	**1917–18**	**1939**	**1951**	**1954[a]**	**1961[a]**	**1965**	**1987–89[b]**
Chironomus									
winter	6	-	-	-	-	-	-	-	1,255
	6–9	-	-	-	2,190	2,700	-	1,998[d]	-
	9	-	-	-	-	-	-	-	1,445
summer[c]	6	15	-	-	-	-	46	-	1,400
	6–9	-	-	460	-	340	-	2,042[d]	-
	9	-	-	-	-	-	69	-	59
Procladius									
winter	6	-	-	-	-	-	-	-	1,592
	6–9	-	-	-	220	-	-	-[d]	-
	9	-	-	-	-	-	-	-	1,248
summer[c]	6	24	-	-	-	-	-	-	640
	6–9	-	-	670	-	-	-	-[d]	-
	9	-	-	-	-	-	-	-	33
Chaoborus									
winter	6	-	-	-	-	-	-	-	58
	6–9	-	-	-	5	-	-	0	-
	9	-	-	-	-	-	-	-	0
summer[c]	6	10	-	-	-	-	-	-	0
	6–9	-	-	0	-	-	0	0	-
	9	-	-	-	-	-	-	-	0
Oligochaetes									
winter	6	-	-	-	-	-	-	-	-[f]
	6–9	-	-	-	280	-	-	1,566	-
	9	-	805[e]	-	-	-	-	-	-[f]
summer[c]	6	10	-	-	-	-	-	-	-[f]
	6–9	-	-	810	-	-	160	1,611	-
	9	-	-	-	-	-	-	-	-[f]
Pisidium									
winter	6	-	-	-	-	-	-	-	0
	6–9	-	-	-	1,020	-	-	23	-
	9	-	374[e]	-	-	-	-	-	0
summer[c]	6	19	-	-	-	-	-	-	0
	6–9	-	-	0	-	-	-	15	-
	9	-	-	-	-	-	-	-	0

* Sources of data:
1914–15 - Muttkowski (1918)
1917–18 - Juday (1921)
1939 - David Frey, Indiana Univ. (unpubl. data)
1951 - Mackenthun and Cooley (1952)
1954 - Dugdale (1955)
1961 - Stewart (1965)
1965 - J. A. Šapkarev, Univ. Skopje, Yugoslavia, unpubl. data for 1964–65 summarized in Lathrop (1992*c*)
1987–89 - Wis. Dep. Nat. Resour., Bur. Res. (unpubl. data).

** Data are averages for 3 seasons (spring, summer, and fall) and were collected at 5–7 m.

[a] Number/m² estimated from graphs.

[b] Winter data are averages of 1988–89 for 6 m and 1987–89 for 9 m; summer data for 1987 only.

[c] All summer samples were taken in August.

[d] All chironomids (including *Procladius*) reported here as *Chironomus*.

[e] Only annual averages were reported for those species with no emergence cycle.

[f] Oligochaetes were not counted in 1987–89 because they were broken apart during sieving.

Table 8. *Macroinvertebrate densities in the sublittoral sediments of Lakes Monona and deep-hole sediments of Lakes Waubesa, and Kegonsa.**

		Macroinvertebrate Densities (no./m²)									
		Monona			Waubesa			Kegonsa			
Organism	Depth (m)	1939	1951	1987–89**	1939	1944	1987–89[a,b]	1939	1944	1962[c]	1987–89[b]
Chironomus											
winter	6	-	-	766	-	-	-	-	-	-	-
	6–9	-	160	-	-	-	-	-	-	130	-
	9	-	-	380	-	-	257	-	-	-	482
summer[d]	6	410	-	38	350	-	110	180	-	-	10
	6–9	-	-	-	-	-	-	-	-	100	-
	9	260	-	54	0	214	0	40	331	-	5
Procladius											
winter	6	-	-	585	-	-	-	-	-	-	-
	6–9	-	250	-	-	-	-	-	-	750	-
	9	-	-	664	-	-	154	-	-	-	277
summer[d]	6	35	-	140	130	-	290	530	-	-	160
	6–9	-	-	-	-	-	-	-	-	180	-
	9	130	-	11	88	-	0	0	-	-	16
Chaoborus											
winter	6	-	-	5	-	-	-	-	-	-	-
	6–9	-	0	-	-	-	-	-	-	160	-
	9	-	-	56	-	-	898	-	-	-	573
summer[d]	6	0	-	43	0	-	0	0	-	-	5
	6–9	-	-	-	-	-	-	-	-	160	-
	9	0	-	110	0	214	220	0	0	-	43
Oligochaetes											
winter	6	-	-	-[e]	-	-	-	-	-	-	-
	6–9	-	380	-	-	-	-	-	-	-	-
	9	-	-	-[e]	-	-	-[e]	-	-	-	-[e]
summer[d]	6	430	-	-[e]	3,400	-	-[e]	1,200	-	-	-[e]
	6–9	-	-	-	-	-	-	-	-	-	-
	9	264	-	-[e]	88	0	-[e]	44	58	-	-[e]
Pisidium											
winter	6	-	-	0	-	-	-	-	-	-	-
	6–9	-	0	-	-	-	-	-	-	-	-
	9	-	-	0	-	-	0	-	-	-	0
summer[d]	6	0	-	0	-	-	-	-	-	-	0
	6–9	-	-	-	-	-	-	-	-	-	-
	9	0	-	0	0	0	-	0	0	-	0

* Sources of data:
1939 - David Frey, Indiana Univ. (unpubl. data)
1944 - Survey by E. Jones reported in Sawyer et al. (1945); samples collected at deep hole
1951 - Mackenthun and Cooley (1952)
1962 - Hilsenhoff and Narf (1968)
1987–89 - Wis. Dep. Nat. Resour., Bur. Res. (unpubl. data).

** Winter data are averages of 1988–89 for 6 m and 1987–89 for 9 m; summer data for 1987 only.

[a] Waubesa sampled at 10.5 m instead of 9 m in 1987.

[b] Summer data for 1987 only.

[c] Number/m² estimated from graphs.

[d] All summer samples were taken in August, except in 1944, when they were taken in July.

[e] Oligochaetes were not counted in 1987–89 because they were broken apart during sieving.

Table 9. *Macroinvertebrate densities in the profundal sediments of Lakes Mendota and Monona.**

		Macroinvertebrate Densities (no./m²)											
		Mendota								Monona			
Organism	Depth(m)	1917–18	1939	1942–43	1944	1951	1954	1965	1987–89**	1939	1944	1951	1987–89**
Chaoborus													
winter	>9[a]	15,500	-	10,500	-	940	-	122	35	-	-	120	512
	deep hole[b]	24,700	-	21,000	-	2,440	-	0	53	-	-	890	1,749
summer[c]	>9	1,320	1,590	-	-	-	-	22	0	89	-	-	350
	deep hole[b]	1,980	1,360	-	2,280	-	-	44	0	160	702	-	310
Chironomus													
winter	>9	-	-	610	-	3,490	2,310	273	129	-	-	140	189
	deep hole[b]	750	-	440	-	5,330	500	0	3	-	-	170	11
summer[c]	>9	-	140	-	-	-	2,540	70	31	29	-	-	65
	deep hole[b]	550	44	-	1,870	-	1,460	89	10	0	117	-	35
Procladius													
winter	>9	650	-	-	-	280	-	210	267	-	-	200	223
	deep hole[b]	290	-	-	-	200	-	0	163	-	-	290	46
summer[c]	>9	110	63	-	-	-	-	385	3	67	-	-	4
	deep hole[b]	50	22	-	-	-	-	0	0	0	-	-	0
Oligochaetes													
winter	>9	2,700[d]	-	1,210	-	2,320	-	2,196	-[e]	-	-	410	-[e]
	deep hole[b]	4,290	-	1,940	-	2,420	-	2,242	-[e]	-	-	72	-[e]
summer[c]	>9	2,700[d]	3,950	-	-	-	-	1,611	-[e]	175	-	-	-[e]
	deep hole[b]	3,080	3,760	-	429	-	-	1,066	-[e]	0	175	-	-[e]
Pisidium													
winter	>9	-	-	-	-	460	-	4	0	-	-	0	0
	deep hole[b]	-	-	-	-	420	-	0	0	-	-	0	0
summer[c]	>9	470[d]	-	-	-	-	-	6	0	0	-	-	0
	deep hole[b]	570[d]	33	-	429	-	-	0	0	0	0	-	0

* Sources of data:
1917–18 - Juday (1921)
1939 - David Frey, Indiana Univ. (unpubl. data)
1942–43 - Hasler (1945)
1944 - Survey by E. Jones reported in Sawyer et al. (1945)
1951 - Mackenthun and Cooley (1952)
1954 - Dugdale (1955)
1965 - J.A. Šapkarev, Univ. Skopje, Yugoslavia, unpubl. data for 1964–65 summarized in Lathrop (1992*c*)
1987–89 - Wis. Dep. Nat. Resour., Bur. Res. (unpubl. data).

** Winter data are averages for 1987–89; summer data are for 1987 only.

[a] Mean, weighted by area.

[b] Deep hole samples for Lake Mendota were from >20 m, and for Lake Monona from >18 m.

[c] All summer samples were taken in August, except in 1944, when they were taken in July.

[d] Annual average.

[e] Oligochaetes were not counted in 1987–89 because they were broken during sieving.

but *Chaoborus* was not mentioned (Birge 1904:25). It is not known how extensive his bottom sampling was during those early years, because no data were published. However, the copepods Birge described are known to enter a resting stage in the deep-water sediments during the summer months (Wetzel 1983), suggesting that Birge's benthos observations were made at that time.

In 1917–18, Juday (1921) conducted the first quantitative survey of the profundal macroinvertebrates of Lake Mendota. Total densities were 48 kg/ha. By far the most abundant organism was *Chaoborus punctipennis*, the phantom midge, with densities averaging 25,000/m^2 during the winter in the deepest region of the lake (Table 9). Densities remained high until June, when adults first began to emerge. However, the greatest emergence occurred later, in July and August, such that the minimum number of *Chaoborus* larvae were found in early August.[13] The August densities in water depths >20 m were about 2,000/m^2; densities in the deepest station (23 m) were around 900/m^2. *Chaoborus* was abundant in the entire profundal region of Mendota in water depths >9 m, although densities were generally smaller in 9–15 m than in the deeper regions. Winter profundal mean densities (weighted by area for depths >9 m) were around 16,000/m^2. In water depths <7 m, few *Chaoborus* were found. For the entire profundal zone of Lake Mendota as we have defined it (>9 m), about 400 billion *Chaoborus* inhabited the sediments in the winter months during those years!

While *Chaoborus* was by far the most numerically abundant benthic macroinvertebrate in Lake Mendota during Juday's (1921) survey, oligochaetes (*Limnodrilus* and *Tubifex*) and chironomids (*Chironomus* and *Procladius*) were also numerically important throughout the year, along with the mollusc *Pisidium*. On a dry weight basis, *Chaoborus*, then oligochaetes, followed by *Chironomus* were the most abundant organisms in the deeper regions (>20 m) of the lake (Juday 1921). *Chironomus* was slightly more abundant than *Chaoborus* in depths of 8–20 m. Although only annual averages were given, *Pisidium* was relatively uniform in distribution in depths >9 m (Juday 1921). The clam was only about 4% as dense in 5–7 m, based on data reported in Muttkowski (1918).

Surveys conducted in 1939 (D. Frey, unpubl. data), in 1942–43 (Hasler 1945), and in 1944 (Sawyer et al. 1945) indicated that Mendota's profundal benthos was similar to that found in 1917–18. Differences could easily be attributed to either normal annual variability or less extensive sampling in the later surveys.

However, by 1951 major changes had occurred. Winter densities of *Chaoborus* were only 10% of earlier densities, while *Chironomus* densities had increased from nearly 800/m^2 to over 5,000/m^2 in the deep-hole region[14] (Mackenthun and Cooley 1952). Larger densities of *Chironomus* were also recorded in 1954 by Dugdale (1955) while studying Mendota's benthic diptera. Densities for other organisms were not given, but *Chaoborus* (also a dipteran) apparently was even more reduced in 1954 than in 1951. Dugdale (1955:94) wrote that the chironomid larvae "make up almost the entire bulk of the dipterous larvae" in Lake Mendota in depths >6 m.

By the early 1960s, this large density of profundal chironomids in Lake Mendota had apparently decreased. In 1957–58 while collecting chironomids for his university class, W. L. Hilsenhoff (UW-Madison, Dep. Entomol., pers. comm.) found very few chironomids in the profundal sediments as compared with the early 1950s, when densities were high. Stewart (1965) sampled the lake between 6 m and 14 m on 29 August 1961 to determine the response of the benthos exposed to anoxic water during thermocline oscillation. Chironomid densities at depths of 12–14 m were 200–300/m^2, which was substantially less than densities recorded by Dugdale in August 1954 at those depths. Stewart (1965) found no *Chaoborus* in any of his dredge samples in August 1961. He did, however, record densities of nematodes or roundworms as high as 9,700/m^2 in depths between 10 m and 14 m; densities were much less at 6–10 m.

Stewart (1965) felt that it was unusual to have such large numbers of roundworms in the mid-depth sediments of Lake Mendota. Other published surveys had not recorded any roundworms. However, in August 1939, 1,900 roundworms/m^2 were found in 2 samples taken at a depth of 13 m (D. Frey, unpubl. data). A few roundworms were also collected at 8 m, but none were collected at other depths between 4 m and 23 m.

Šapkarev's data for the winter and late summer (August) of 1965 (Lathrop 1992*c*) document the decline of *Chironomus*, *Chaoborus*, and *Pisidium* since the early 1950s. The only organisms that had not declined since earlier surveys were oligochaetes and *Procladius*, except in the deep-hole region. Similar macroinvertebrate densities were found in DNR surveys made in both January and August of 1987 and January–February of 1988–89 in order to document current densities in the deeper regions of all the Yahara lakes. In Mendota, very low densities of *Chaoborus punctipennis* and *Chironomus* were found in both surveys in water depths >9 m. The chironomid *Procladius* was the most numerous macroinvertebrate recorded, found in winter densities of about 200/m^2; summer densities were very low. Also,

[13] Juday (1921) mentioned that during the day, young *Chaoborus* larvae only inhabited the hypolimnetic water and not the bottom sediments where the older larvae were found, a finding that is common knowledge today. Presumably this is the reason that the surveys in the late 1800s did not record any *Chaoborus* in the deep-water sediments in August, when Juday also found the fewest in the sediments. Birge's early accounts of relatively large numbers of larvae inhabiting the hypolimnion during the day imply that *Chaoborus* was historically abundant in the sediments throughout the fall, winter, and spring, as was found in 1917–18 by Juday.

[14] Lake Mendota's deep-hole region is >20 m. See Fig. 2.

the mollusc *Pisidium* was not found. Oligochaetes were not quantitatively assessed in 1987–89, but densities were large (4,700/m^2) in 2 unsieved samples collected at 22 m in May 1991. Further study is needed to confirm current densities.

Unlike Lake Mendota, few profundal benthic surveys have been made in Lake Monona over the years. A 1939 survey was conducted in summer (D. Frey, unpubl. data), a 1944 survey was conducted in early summer (E. Jones, cited in Sawyer et al. 1945), and a 1951 survey was conducted in winter (Mackenthun and Cooley 1952), making direct comparison difficult. Generally, however, changes in the benthos of Lake Monona between 1939 and 1951 were not substantial. *Chaoborus* densities were much lower than in Mendota in 1939 and 1944, and somewhat lower in 1951, when densities in Mendota had decreased from earlier years. *Chironomus* densities were also low in Monona and reflected only small increases in the early 1950s, as compared with the large increases in Mendota. *Procladius* densities were similar for Monona and Mendota for the surveys in 1939 and 1951. (*Procladius* was not separated from *Chironomus* in the 1944 summer survey.) *Pisidium* was not found in the deep-water sediments of Monona during any of the surveys. Finally, the densities of oligochaetes were much less in Monona than in Mendota in 1939, 1944, and 1951.

The 1987–89 surveys in Monona indicated similar low densities of chironomids when compared to earlier years, while showing an increase of *Chaoborus*. An average of 1,700/m^2 was found at 18–21 m in Monona during the winters of 1987–89. These *Chaoborus* densities were significantly higher than those found in the Mendota surveys.

Summary. Macroinvertebrates provide a picture of the food resources available to and utilized by the fishery of the Yahara lakes. In Lake Mendota, an extensive littoral zone of macrophytes dominated by broad-leaved or ribbonlike species had moderate densities of plant-associated invertebrates from early years until the late 1950s. Although invertebrate density data for the dense Eurasian water milfoil beds occurring in Lake Mendota since the mid-1960s are not available, as the macrophyte community became dominated by Eurasian milfoil, which is a species with highly dissected leaves, invertebrate densities may have increased on the plants. This supposition is based on data collected on native milfoil during the 1940s that showed higher densities of invertebrates on milfoil than on broad-leaved macrophytes (Andrews and Hasler 1943). In contrast, Keast (1984) found fewer invertebrates in a Eurasian milfoil community than in a pondweed-wild celery (broad-leaf) community in a Canadian lake.

The maximum depth of plant growth decreased from around 5 m to 3 m or less after the milfoil invasion in the 1960s, due to shading. Although sediments underneath the macrophyte canopy also have large numbers of invertebrates, an expanded sublittoral zone due to less macrophyte coverage would expose invertebrates to benthivorous fish feeding in the open water where macrophytes are absent. Invertebrate densities between 6 m and 9 m apparently have not changed appreciably over the years, but data are not extensive. These same shallow-water sediments in the lower 3 Yahara lakes have had similar densities of invertebrates in the few studies recorded, but densities were lower than in Mendota. Given the fertile nature of the lower 3 lakes, particularly shallower Waubesa and Kegonsa, low densities may signify intense fish predation.

The biggest change in Lake Mendota's macroinvertebrates occurred in its profundal benthos (>9 m water depth), a finding recently reported by Lathrop (1992, 1992*c*). In years prior to the mid-1940s, an extremely large population of the phantom midge *Chaoborus punctipennis* was found in the sediments. Moderate populations of *Chironomus* were also present. In the early 1950s, the *Chaoborus* population decreased by one order of magnitude, but the chironomids increased by almost as much. However, by the mid-1960s, both populations were reduced to very low densities. In 1987–89, *Chaoborus* densities were nearly 400 times less than in the earlier period of population abundance. *Chironomus* was also very low in 1987–89. Finally, the small clam *Pisidium*, which had originally been present in moderate numbers, drastically declined by the mid-1960s. It was not found in the profundal sediments of Lake Mendota during 1987–89. Oligochaete and *Procladius* densities had not declined from earlier years. These organisms are often the only profundal macroinvertebrates present in lakes with prolonged hypolimnetic anoxia (Wiederholm 1980, Kajak 1988).

In general, the total profundal benthos in Mendota has been sparse since the mid-1960s. While no change occurred in hypolimnetic oxygen conditions since the early 1900s (Stewart 1976, Brock 1985), this decrease in the profundal benthos may have been due to an increase in hypolimnetic ammonia and hydrogen sulfide concentrations (Lathrop 1992, 1992*c*). However, the presence of greater densities of *Chaoborus* in Monona's profundal sediments during 1987–89 does not confirm this conclusion, because hypolimnetic concentrations there are even higher than in Mendota, due to more prolonged anoxia. Lathrop (1991, 1992*c*) evaluated other factors such as food availability, fish predation, and toxic insecticides and determined that they were less likely to have caused this decline in Lake Mendota's profundal macroinvertebrates. Further study is needed to verify the causes for the decline, but the current lower densities of fish food organisms in the deeper regions of Lake Mendota are significant for certain fish species such as yellow perch.

Wetlands

Loss

The Yahara lakes historically had large areas of shoreline wetlands, particularly around the in-flowing streams and the inter-lake sections of the Yahara River. These wetland areas undoubtedly were very important for northern pike spawning and other fish habitat, as well as for trapping sediments and nutrients entering the lakes. The loss of these wetlands around each lake can be documented from land use inventories made in 1935, 1938, and 1974 (Table 10).

The first disturbance to the Yahara lakes wetlands occurred in 1849 when Mendota's level was increased 1.2–1.5 m by a dam at its outlet. As a result, many wetland areas were submerged while others were created by the lake backwaters farther up the tributary streams. The Yahara widespread/Cherokee Marsh area was created from this increase in water level. Sixmile Creek also now enters directly into Lake Mendota and has its own extensive wetland system, whereas the creek previously discharged into the Yahara River just upstream from Mendota.

The earliest loss of wetlands occurred mostly in Lake Monona's watershed as a result of Madison's initial growth on the isthmus, the near east side, and the west side in the late 1800s. During that time, much of Monona's marshy shoreline was dredged and filled, and many wetlands were either ditched and drained or filled, providing new land for development (Mollenhoff 1982). Even though most of the Yahara lakes' rural watershed was under cultivation by 1870, the formation of the agricultural drainage districts in the early 1900s was the real beginning of the ditching and drainage of the upstream rural wetlands. By 1938, 63% of the wetland area in the direct watershed of Monona had been lost, while about 25% of Mendota's, Waubesa's, and Kegonsa's wetland areas had been lost (Table 10). Between 1938 and 1974, wetlands in the Yahara River watershed continued to decline, particularly in the rural areas. By 1974, only about 50%, 8%, 27%, and 30% of the original wetland areas remained in the watersheds of Mendota, Monona, Waubesa, and Kegonsa, respectively.

Stream Channelization

While wetland loss by urban filling and agricultural drainage has had a major detrimental impact on the fishery, the poor quality of some of the remaining wetlands also contributes to poor fish spawning habitat.

Table 10. *Wetland area in watersheds of the Yahara lakes between 1835 and 1974, with percentage lost since 1835 shown in parentheses.**

	Wetland Area (ha)			
Year	**Mendota**	**Monona**	**Waubesa**	**Kegonsa**
1835	4,120	1,980	2,510	2,360
1938	3,190 (-23%)	740 (-63%)	1,940 (-23%)	1,720 (-27%)
1974	2,060 (-50%)	150 (-92%)	680 (-73%)	710 (-70%)

* Sources of data:
1835 - Township survey maps (published by the U.S. Surveyor General's Office in 1851 and 1855)
1938 - Wisconsin Conservation Department (1961)
1974 - U.S. Geological Survey topographic maps (printed in 1976).

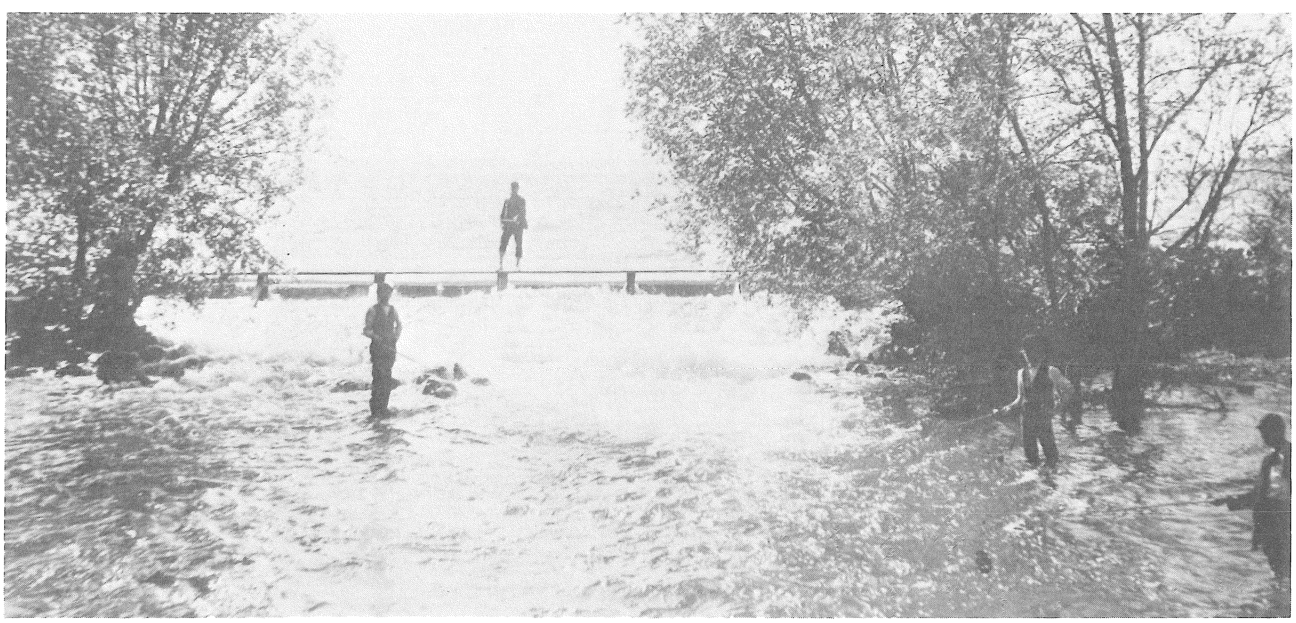


PHOTO: STATE HISTORICAL SOCIETY OF WISCONSIN COLLECTION

Dam near mill at outlet of Lake Mendota, late 1800s. The Tenney Park locks were later constructed at this site.

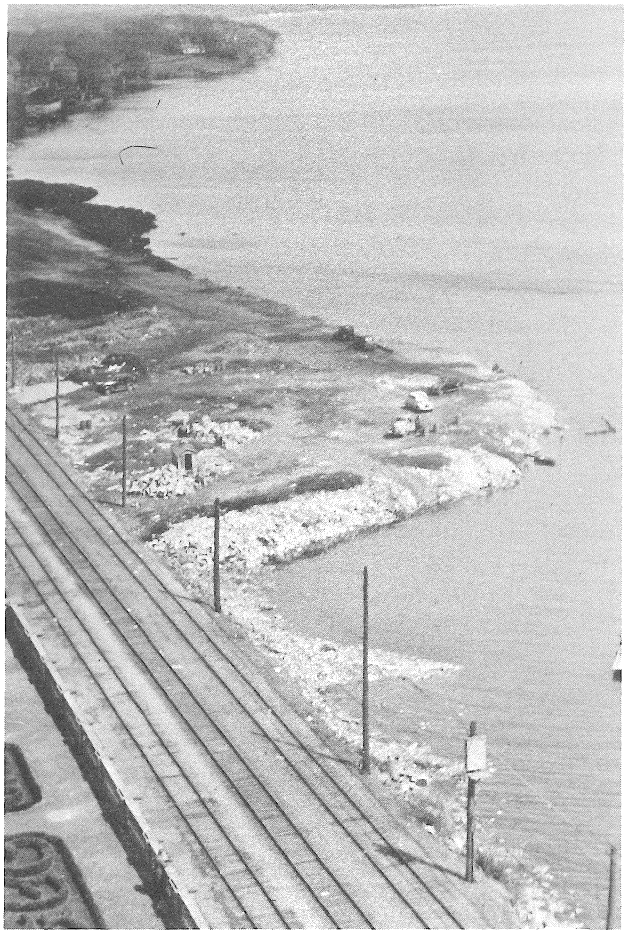


PHOTO: EUGENE SANBORN, DNR CENTRAL OFFICE COLLECTION

Filling of Lake Monona's western shoreline along Olin Terrace, 1943. Filled area in later years became John Nolen Drive and Law Park.

Some of the wetlands actually are dysfunctional hydrological systems of wet-meadow type vegetation with dredged and straightened stream channels (with dredge spoil banks), which carry stream water directly to the lakes. Examples of these dysfunctional wetlands are the Nine Springs Creek wetland upstream from Lake Waubesa, the wetland north of Upper Mud Lake, and the Door Creek wetland along the north shore of Lake Kegonsa. Straightened stream channels bypassing the wetlands provide poor access to flooded marshes for spring spawning by northern pike and other marsh spawners. These straightened channels also prevent the wetlands from acting as sediment and nutrient filters during periods of runoff. The Door Creek wetland is a good example of this, because heavy loads of sediment from its large agricultural watershed have been observed bypassing the wetland and directly entering Lake Kegonsa (Richard Lathrop, unpubl. data).

Restoration of these types of dysfunctional wetlands in the Yahara River system has begun, but the process is slow. Work has begun on the Nine Springs Creek wetland, and interest is just starting on the Door Creek wetland. Fortunately other wetland areas have been preserved (e.g., the wetlands south of Lake Waubesa and the wetlands surrounding Lake Wingra), and major preservation work has been done on the large Cherokee Marsh wetlands upstream from Lake Mendota. During the mid-1980s, a major controversy accompanied the construction of the South Beltline Highway around Madison. Many wanted the highway constructed, but environmentalists were determined to lose no more wetlands. One of the compromises reached was the

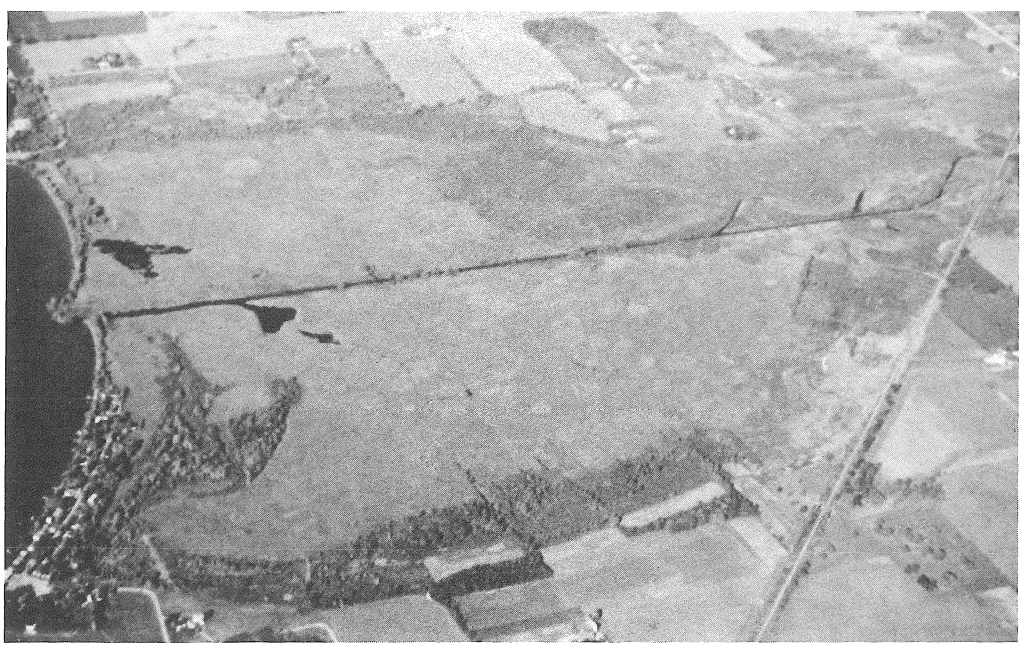


PHOTO: RICHARD LATHROP, DNR RESEARCH

Door Creek wetland showing straightened stream channel, 1985. Such channels carry runoff water directly to the lakes, bypassing the beneficial effects of filtering sediments and nutrients through adjacent wetlands.

reclaiming of wetland area that had been previously filled to offset the loss of wetlands to the new highway.

Water Level Fluctuations

Another problem has been the loss of function of the wetlands during the spring spawning season because of low or variable lake water levels. Low levels cause the nearby wetlands to have inadequate water in the channels for spawning fish to reach vegetation. In certain cases, a tidal flat appearance results when the emergent wetland vegetation is left high and dry. This has been observed in the wetlands along the south end of Lake Waubesa. Low water levels in the spring are a problem because fish eggs deposited on dead vegetation are exposed and because vulnerable fry lose their protective vegetative cover.

Mendota's level is controlled at the Tenney Park locks (outlet), both Monona's and Waubesa's levels (relatively the same for both lakes) are controlled at Waubesa's outlet, and Kegonsa's level is controlled at its outlet. Beginning in 1974, the city of Madison began lowering Lake Mendota in the fall primarily to minimize ice expansion damage to the shoreline and to accomodate spring floods. This practice was continued by the Dane County Public Works Department in 1979 when it took over control of lake level management for all the Yahara lakes. Mendota's level was allowed to rise again in the spring at a rate that was dependent on spring runoff. In years with little runoff, the lake levels would not reach the higher summer levels until well past the spring fish spawning season.

Current lake levels for the 4 Yahara lakes are compared to past lake levels in Table 11. Changes in lake levels for Mendota and Monona/Waubesa from 1 March to 30 April 1961–85 are depicted in Figures 14 and 15, based on automatic lake level gauging stations run by the U.S. Geological Survey on Mendota and Monona. Level changes of 0.3–0.6 m were common, particularly since the early 1970s. In recent years, the Dane County Public Works Department has been working with fishery managers to try to maintain adequate water levels for fish spawning during the spring months.

Table 11. *Past and present lake levels of the Yahara lakes.**

	Lake Level (m above mean sea level)	
Lake	**Past**	**Present Average**
Mendota	257.5	259.0
Monona	257.4	257.5
Waubesa	257.4	257.5
Kegonsa	256.8	257.0

* Sources of data:

Past - Mendota level was estimated from Kanneberg (1936); levels for other lakes were based on a 1937 ruling by the Wisconsin Public Service Commission (State of Wis. 1937).

Present - Levels were determined by the Bureau of Research from 1980–81 hydrographic maps and U.S. Geological Survey water level records.

PHOTO: STATE HISTORICAL SOCIETY OF WISCONSIN COLLECTION

Ice expansion along Picnic Point, circa 1900. Minimizing damage from such ice is one reason lake levels are now lowered during the winter months.

Inter-lake Areas and Tributaries

The fishery of the Yahara lakes utilizes not only the habitat provided by the 4 lakes themselves but also the inflowing streams, wetlands, and particularly the large inter-lake stretches of the Yahara River (see Fig. 1). Upper Mud Lake and Lower Mud Lake, which are shallow widespreads upstream and downstream from Lake Waubesa, support abundant populations of fish that probably spend much of their lives in these areas. The fishery of Lake Wingra, which is now part of Lake Monona's direct drainage basin, represents an important local recreational fishing resource.

Formerly separated from the 4 Yahara lakes, Wingra did not become joined to Monona until 1907–08 when Murphy Creek, the connecting waterway, was dredged (Baumann et al. 1974). This created a well-defined channel through the marsh between the 2 lakes and permitted the first free movement of fish from one lake to the other. Although it is not known how many species from one lake may have migrated to the other, one species that was introduced to Lake Wingra, the yellow bass, probably migrated to Lake Monona (Wright 1968). Other fish not native to the Yahara lakes also may have entered the lakes through fish rescue stockings to Lake Wingra. Fish migration between the 4 Yahara lakes has also occurred, as evidenced by observations of marked predator fish (particularly in the lower 3 lakes) and by the spread of yellow bass throughout all of the lakes (see the Yellow Bass Section).

Only a few fishery surveys have been conducted in the inter-lake areas and tributaries of the Yahara lakes, except near the lakes proper. Despite this lack of information, it is common knowledge that those fish species found in the lake shallows also occur in the inter-lake areas and tributaries. The wetlands and tributary streams are particularly important for fish spawning. However, upstream in the tributaries, the stream

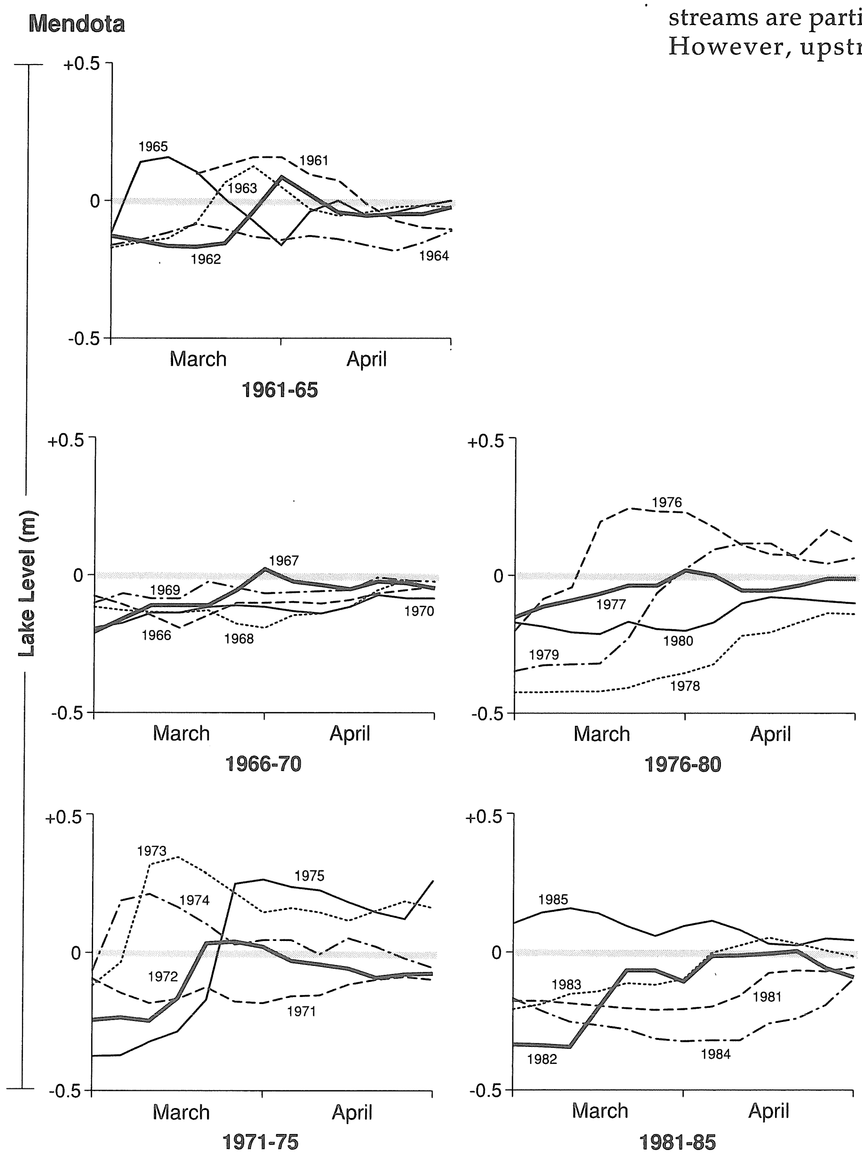


Figure 14. *Changes in spring lake levels for Lake Mendota, 1 March–30 April, 1961–85. The present average lake level, 259.0 m above mean sea level, is indicated by the grey line.*

baseflow is generally too low and water temperatures are too warm to support more than forage fish species (Lathrop and Johnson 1979). One exception is Token Creek (upstream from Lake Mendota), which has a large baseflow discharge and hence cool water temperatures that support a small trout fishery (stocked in earlier years). Only one other stream, Nine Springs Creek, taps sufficient groundwater in its headwaters to support trout, which are mostly escapees from the Nevin State Fish Hatchery.

Historically, summer flow in the lower Yahara River was probably greater than it is today. A decrease took place in 1958 when sewage effluent was diverted from Lake Waubesa to Badfish Creek. Although low summer flows in the river would presumably not affect spawning activities in the spring, they would result in higher summer water temperatures and lower dissolved oxygen levels. The decrease in summer flow in the lower Yahara River may have reduced the value of the river as fish habitat during extremely dry years.

In addition, the baseflow of tributary streams and the ground water discharging directly to the lakes have also declined because of increased ground water pumping by Madison for its drinking water. The pumping has caused a cone of depression in the deep aquifer, but a smaller depression has also occurred in the shallow aquifer due to leakage to the deep aquifer. The shallow aquifer is the source of ground water that discharges to the lakes. As a result, the discharge of the Yahara River during periods of low flow must be augmented by lake water stored during periods of surface runoff. During droughts, river flow cannot be augmented as much because of low lake levels.

Because of the limited amount of data available about the fish populations of the inter-lake areas and tributaries and the general similarity of their fishery with the fishery of the shallow lake areas, these regions will not be discussed further.

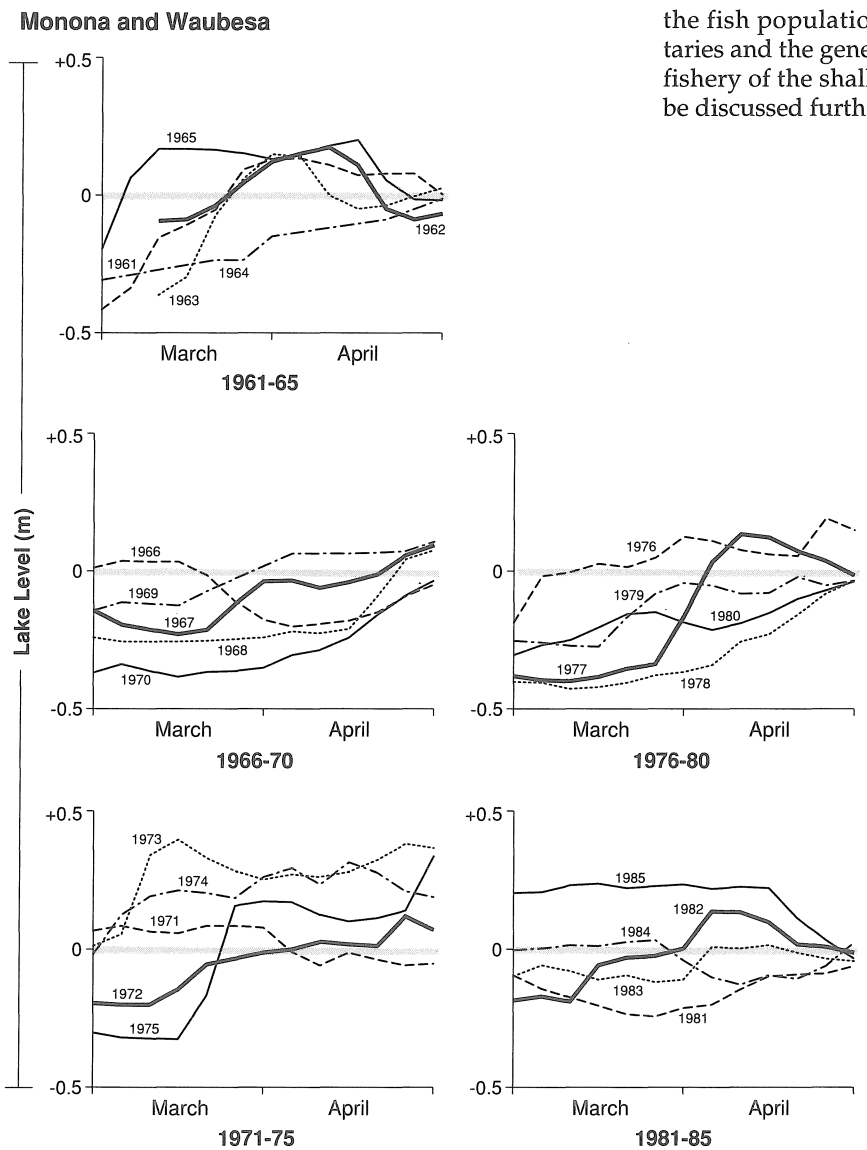


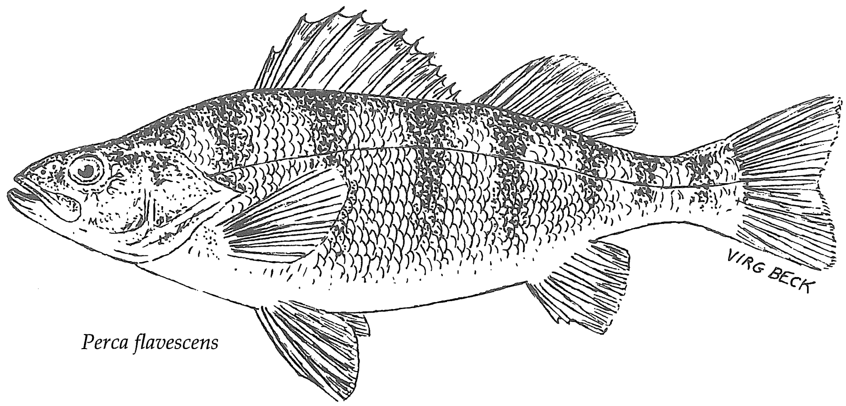
Figure 15. *Changes in spring lake levels for Lakes Monona and Waubesa, 1 March–30 April, 1961–85. The present average lake level, 257.5 m above mean sea level, is indicated by the grey line.*

PHOTO: KEN CHRISTENSEN, THE CAPITAL TIMES

FISH SPECIES

In the sections that follow, fish species that are a major component of the fishery of the Yahara lakes are discussed first, followed by species that are a more minor component, followed by other species that have been reported to occur in the lakes. Quantity of information presented on the various species reflects the emphasis placed on those species through the years. For example, the famed yellow perch fishery in Lake Mendota has received much study; consequently, the section of the report on yellow perch is more detailed than others.

Information presented on the ecological requirements of each major fish species is not lengthy, as this information is readily available in sources such as Becker (1983). Magnuson and Lathrop (1992) also provide information on the thermal guilds (preferred temperature ranges) and reproductive guilds (preferred spawning habitat) for Lake Mendota's fish species.



Perca flavescens

Yellow Perch

Ecological Requirements

Yellow perch prefer cool waters. They are well equipped to survive low oxygen levels for brief periods because they are able to use some oxygen from their swim bladders (Pearse and Achtenberg 1920). They also are able to cross thermoclines to anoxic bottom waters in search of food (Tibbles 1956). In Lake Mendota, part of the population migrates inshore during the night, while another part remains offshore both day and night (Tibbles 1956, McCarty 1990, Rudstam and Johnson 1992).

Yellow perch do not seek out particular substrates for spawning, thus they are able to spawn in most slow-moving waters within their range (Collette et al. 1977). Neither are yellow perch restricted to a specific zone or habitat for feeding; they can feed on invertebrates in vegetation, on zooplankton in open water, or on macroinvertebrates in bottom sediments. Larger yellow perch also eat small fish. Because of this wide diet diversity, yellow perch compete successfully with other fish in both shallow- and deep-water habitats where food sources are quite different (Pearse and Achtenberg 1920).

In Lake Mendota, a long-term change in food availability for yellow perch has occurred. An early food study revealed that macroinvertebrates, especially chironomids and *Chaoborus*, as well as zooplankton were important foods in all seasons (Table 12). Since then, numbers of macroinvertebrates have declined drastically in the profundal sediments (Lathrop 1992, 1992*c*). The effect of this loss on yellow perch is unknown because densities of chironomids and other invertebrates in shallow-water sediments have not declined and because zooplankton have remained abundant.

Table 12. *Food habits of yellow perch in Lake Mendota, 1915–16.**

	Percentage (%) of Diet **			
Year and Season	**Chironomids**	***Chaoborus***	**Zooplankton**	**Other Animals**
1915				
Jan–Mar	9	17	57	17
Apr–Jun	35	4	18	43
Jul–Sep	29	10	37	24
Oct–Dec	12	4	65	19
1916				
Jan–Mar	12	35	21	32
Apr–Jun	26	19	9	46
Jul–Sep	33	25	18	24
Dec[a]	9	7	72	12

* Source of data: Pearse and Achtenberg (1920).
** Percentages were based on animal matter in stomach contents.
[a] No data were available for Oct–Nov.

Relative Abundance

Numerous early records of abundant yellow perch indicate that this species is native to the Yahara lakes. Because of the extensive amount of research and surveys on yellow perch in Lake Mendota, their relative abundance in this lake is discussed separately. However, because yellow perch are not effectively sampled by shoreline gear except during the spawning season in the spring, few DNR surveys captured them. Most of the work on yellow perch in Lake Mendota was conducted by the UW, with financial support from various sources, including the WCD/DNR. The majority of the UW research over the years was conducted with vertical gill nets and sonar.

Survey Results—Mendota. One of the earliest accounts of the abundant yellow perch fishery in Lake Mendota came from a description of an 1884 fish epidemic that affected mainly perch (Forbes 1890). Even before the die-off had ended, the city had hauled away roughly 200 tons of dead fish, and it was thought that at least another 200 tons had already died and piled up on shorelines outside the city. As many as 38 workers with wagons and teams of horses were employed in the cleanup at one time (Dunning and Others 1884). Most of the dead perch were full grown (Forbes 1890). The freshly dead specimens were in good condition, often plump, with bright color and fungus-free skin. However, the dead fish represented a population of yellow perch from deeper water, because their stomachs contained mostly large red midges (*Chironomus*) found only in the deep-water muds. Healthy yellow perch were seined in the shallow waters near shore where they had eaten other organisms common to that region. While the cause of the fishkill was never determined, the above evidence suggests that low oxygen conditions were a contributing factor.

Probably the most telling example of the early importance of the yellow perch fishery in Mendota and other local lakes was the commission of a detailed account of yellow perch feeding habits and other life history information (Pearse and Achtenberg 1920). The authors estimated that about 420,000 yellow perch/year were harvested by anglers on Lake Mendota around 1916–17. Fishing for yellow perch was heaviest in the winter. This annual harvest represented about 75 times the combined number of northern pike, white bass, rock bass, crappies, largemouth bass, pumpkinseeds, and bluegills caught, although the authors' estimate for fish caught during the open-water season seemed more speculative than scientific. They also noted that anglers claimed to have caught as many as 800 yellow perch/day ice fishing in the early 1900s, while the "usual catch of a professional fisherman [in 1917], fishing through the ice with a line and two hooks, is from 200 to 400 per day" (Pearse and Achtenberg 1920:338). The average catch per angler-day during the winter of 1917 was estimated at about 70 yellow perch. Pearse and Achtenberg attributed this large abundance of yellow perch in Mendota to the species' feeding versatility.

The next source of information about yellow perch in Lake Mendota was intensive research conducted by the UW during the 1940s through the 1960s under the direction of Prof. A. D. Hasler. Doctoral theses by Bardach (1949), Tibbles (1956), and Hergenrader (1967) as well as numerous scientific papers by Hasler, his students, and others (e.g., Hasler 1945; Hasler and Bardach 1949; Mackenthun and Herman 1949; Bardach 1951; Hasler and Wisby 1958; Hergenrader and Hasler 1966, 1968) provide a detailed record about yellow perch life history for those years.

From 1939–46 (and on a smaller scale, through 1949), annual summer mortalities of yellow perch occurred, particularly of older fish. These mortalities were attributed to the myxosporidian *Myxobolus*, an infectious disease causing visible sores on the sides of the fish. *Myxobolus* reached epizootic proportions in 1939, with the worst outbreaks occurring in 1939 and 1946. In 1946, one city official estimated that about 10 tons of yellow perch had been removed from a 10-block area in a week (Mackenthun and Herman 1949). The total amount of perch killed during these years was not estimated.

The main result of the 1939 and 1946 summer mortalities appeared to be a dramatic decrease in yellow perch numbers in Lake Mendota, with a concomitant increase in the average size and growth rate (Table 13) of the remaining yellow perch because of reduced competition. Bardach (1951) compared the average length and weight of yellow perch captured in gill nets (with a range of mesh sizes) for various years before, during,

PHOTO: UW CENTER FOR LIMNOLOGY COLLECTION

Vertical gill net used by UW researchers to catch yellow perch from Lake Mendota, mid-1950s. Because of the yellow perch's importance to the local fishery, much research was conducted on this pelagic species.

Table 13. *Age-growth comparisons for yellow perch from Lake Mendota, primarily for the 1940s and early 1980s.**

	Average Total Length (cm) at Age[a]			
Year**	II	III	IV	V
1939[b]	19	-	-	-
1942	20	23	24	-
1943–44	21	23	-	-
1946	20	24	25	26
1946–47	-	19	21	24
1948	22	24	27	28
1981–85	20	21	22	25

* Sources of data:
1939 - Bardach (1949)
1942 - Hasler (1945)
1943–44 - Bardach (1949)
1946 - Bardach (1949)
1946–47 - Mackenthun and Herman (1949)
1948 - Bardach (1949)
1981–85 - Lars Rudstam, UW Center for Limnol. (unpubl. data).

** Fish were collected during fall or winter; winter data were combined with data from the fall of the previous year.

[a] Length of perch of unspecified sex or average length of males and females combined when sex was given.

[b] Fish were collected in August.

Table 14. *Average total length and weight of adult yellow perch collected by gill nets in Lake Mendota between 1916 and 1948.**

Year	No. Fish	Average Total Length (cm)	Average Weight (g)
1916	169	16	50
1931	261	20	84
1932	51	18	76
1939	25	19	86
1943	297	21	128
1946	375	22	137
1948	210	24	180

*Data from various sources listed in Bardach (1951).

and after the *Myxobolus* infection period (Table 14). In 1916, the yellow perch averaged 16 cm in length and 50 g in weight. In the early 1930s, the average length was 18–20 cm and the average weight was 76–84 g. But during the mid-1940s, yellow perch size had increased such that by 1948 the length and weight averaged 24 cm and 180 g.

Large changes in average length or weight can be the result of variable age structure in the population (see recent data for 1981–89, Table 15). However, anecdotal information indicates that perch were indeed smaller in the early part of the century. The record of large numbers of small yellow perch present in Lake Mendota prior to the 1939 die-off is corroborated by the personal recollections of Kenneth Christensen, retired outdoor writer for the *The Capital Times*. He remembers catching thousands of small-sized yellow perch (about 80–90 g) from around 1922 until the early 1930s. As a boy, he and others sold their catch from door to door for "two dozen for a quarter." He also remembers that the lower 3 lakes contained bigger yellow perch.

Table 15. *Average weight of yellow perch caught in gill nets in Lake Mendota during August–September, 1981–89.**

Year	Mean Weight (g)
1981	145
1982	81
1983	87
1984	65
1985	112
1986	103
1987	107
1988	151
1989	168

* Source of data: Rudstam et al. (1992).

Catch rates and estimates of the total number of perch in Lake Mendota also showed the change in yellow perch numbers before and after the large summer mortalities. Pearse (1934) estimated 15 million yellow perch as a result of his 1916–17 survey (Pearse and Achtenberg 1920). Bardach 1951 estimated a maximum of 4 million yellow perch in 1949 after the years of the *Myxobolus* epidemic, although his estimate was later considered to be low (Tibbles 1956, Hasler and Wisby 1958). Even if it was low, a presumed decrease in the yellow perch population was reflected in another indicator, namely gill net catch rates for the different periods (Bardach 1951). In 1947, Bardach caught only 4 and 14 yellow perch/hour/30 m of gill net for the spring spawning and summer seasons, respectively, whereas in 1916, Pearse and Achtenberg (1920, as cited in Bardach 1951) had captured 16 and 34 yellow perch/hour using gill nets for the same seasons.

In addition to these open-water catch rates, catches in winter creel surveys reflected a change in yellow perch numbers (Table 16). In the winter of 1917, the catch per angler-hour averaged 23.6 and amounted to about 283,000 yellow perch out of an estimated annual harvest of 425,000 yellow perch. In the winter of 1947 the catch per angler-hour was 1.8, and in 1948 the rate was 0.7. Bardach (1951) estimated the 1947–49 winter harvest at 60,000–100,000 yellow perch/season and the annual harvest at 150,000.

Low catch rates of yellow perch (around 2/angler-hour) continued on Lake Mendota in the winters of 1953, 1959, and 1960 (Table 16). However, numerous other statistics for the 1950s indicate a different picture of yellow perch fishing for this period. For example, yellow perch dominated the 1952 summer creel survey (78% of total fish) (Kuntzelman 1952). Likewise, even though the 1953 winter catch rate was only 1.9/angler-hour, the total yellow perch harvest for that winter was estimated to be 770,000 yellow perch and at least 17 kg/ha (Brynildson 1954). Yellow perch were abundant in Tibbles' (1956) vertical gill nets during the summer of 1954. Yellow perch were also considered abundant enough in 1955 that their bag limit was removed. Good yellow perch fishing in the summers of 1954–55 was corroborated by Kenneth Christensen (*The Capital Times*, 15 Jun 1954 and 5 Jul 1955). In 1956, the winter yellow

Yellow perch creel survey conducted by the UW on Lake Mendota, mid-1950s.

PHOTO: UW CENTER FOR LIMNOLOGY COLLECTION

Table 16. *Reported catches of yellow perch during winter creel surveys on Lake Mendota.**

	Fishing Statistics**						Fish Size	
					Catch			
Year[a]	No. Surveys	No. Perch Caught[b]	No. Anglers Interviewed	No. Hours/Angler	Per Angler-day	Per Angler-hour	Average Length (cm)	No. Fish Measured
1917	-	283,000	-	-	-	23.6	-	-
1947	-	24,909	2,287	5.9	10.9	1.8	23	339
1948	2	2,376	655	5.5	3.6	0.7	-	-
1953	15	10,872	1,869	3.0	5.8	1.9	22	-
1960	32	16,689	2,720	3.5	6.1	1.8	-	-
1961	7+	14,242	583	3.8	24.4	6.5	21	171
1974	-	15,276	2,983	-	5.1	-	-	-
1980	1	1,008	99	1.7	10.2	6.0	19	233
1981	1	205	49	1.1	4.2	3.8	21	137
1982	-	72,461	31,906	-	2.3	-	-	-

* Sources of data:
- 1917 - Pearse and Achtenberg (1920)
- 1947 - Mackenthun and Herman (1949)
- 1948 - Bardach (1949)
- 1953 - Brynildson (1954)
- 1960 - Clarence Zimmerman, Wis. Dep. Nat. Resour., Madison Area files (unpubl. data)
- 1961 - Clarence Zimmerman and Spencer Chapman of Wis. Dep. Nat. Resour. and members of Yahara Fisherman's Club, Madison Area files (unpubl. data)
- 1974 - Len Marty and Robert Kalhagen, Wis. Dep. Nat. Resour., Madison Area files (unpubl. data)
- 1980 - Students directed by James Kitchell and John Magnuson, Univ. Wis.-Madison, Cent. Limnol. (unpubl. data)
- 1981 - Students directed by James Kitchell and John Magnuson, Univ. Wis.-Madison, Cent. Limnol. (unpubl. data)
- 1982 - Clifford Brynildson, Wis. Dep. Nat. Resour., Madison Area files (unpubl. data).

** All statistics are actual counts except for 1982 which are projections for January–March.

[a] Surveys were conducted during January–March.

[b] Of the years summarized in this table, a bag limit of 25 perch was in effect in 1947–48 and 1953. No bag limit was in effect for the other years listed.

PHOTO: STABER REESE, DNR CENTRAL OFFICE COLLECTION

Ice fishing for yellow perch on Lake Mendota in February 1956, during the period called the "perch heydays." Note the airplane in photo to the right of center.

perch harvest was estimated at nearly 1.5 million, a level suggesting that the perch population continued to be abundant (Hergenrader and Hasler 1966). A WCD creel survey conducted in February 1956 recorded a catch rate of 4 yellow perch/angler-hour or 14/angler-day (Russ Pyre, *Wisconsin State Journal*, 12 Feb 1956). These rates were higher than those recorded in the late 1940s and early 1950s (Table 16).

This period from the late 1940s to the mid-1950s has been considered Lake Mendota's heyday as a perch capital. Winter yellow perch fishing was so popular in the 1950s that people flew into Madison and landed their planes on the ice. Catches of yellow perch were high enough that "many careless anglers discarded their surplus on the ice and at the various access points to the lake" (K. Christensen, pers. comm., quoting Yahara Fisherman's Club records).

For the late 1950s, some data sources suggest that yellow perch fishing was only average, while others suggested it was very good. According to Kenneth Christensen, yellow perch fishing in 1957 was moderate (*The Capital Times*, 14 Feb 1957 and 8 Aug 1957). However, in the winter of 1958, anglers began complaining about the poor yellow perch fishing and the lack of a bag limit (K. Christensen, *The Capital Times*, 9 Jan 1958 and 16 Jan 1958). The total winter catch was much lower than in previous years, but 3-year-old yellow perch were frequently caught (Hasler and Wisby 1958). Yellow perch fishing improved on Lake Mendota in March of that year, with one 5-day survey recording 10,000 yellow perch caught at a rate of 30/angler-day; this represented 20% of the total surveyed catch all winter. Yellow perch fishing was apparently good in 1959 and in 1960. In 1961, the winter creel survey of 6.5 yellow perch/angler-hour suggests excellent yellow perch fishing (Table 16). By 1963, a 50-perch bag limit was adopted as a result of concerns about overfishing.

Between 1961 and the early 1970s, no surveys conducted by the DNR gave indications of yellow perch abundance in Lake Mendota. Furthermore, because yellow perch cannot be effectively surveyed by electroshocking or by seine hauls, DNR data on yellow perch populations are limited to creel surveys and spring fyke net surveys. Spring fyke net surveys recorded relatively large numbers of yellow perch in 1971, but few were captured in 1972–73. However, in the 1973 summer creel survey, yellow perch composed 74% of the total catch, which suggests that the spring fyke net surveys are not always a good indicator of yellow perch abundance. In 1974, yellow perch were also the dominant fish (75%) caught during the year-long creel survey. January–March 1974 ice fishing creel surveys showed yellow perch were caught at a rather low rate of 5.1/angler-day.

The next major development recorded for the yellow perch fishery in Lake Mendota was the large yellow perch hatch in 1977 (Woolsey 1986; Wis. Dep. Nat. Resour., Madison Area files, unpubl. data). Small yellow perch were the dominant species in the DNR spring fyke nets in 1978. This large year class of yellow perch increased by an order of magnitude the catch per effort of ice fishing anglers, as recorded by UW students during one weekend day in February (Woolsey 1986). This yellow perch catch per line-hour was 2, 0, and 12 for 1977–79, respectively. In 1977, yellow perch were from various year classes; in 1979, the catch was almost exclusively from the 1977 year class. Excellent ice fishing for yellow perch from this same year class continued on Mendota in 1980, as evidenced by Robert Kalhagen's personal fishing journal. Normally fishing on Lake Waubesa near his home, he switched to Lake Mendota in 1980, where he frequently caught his limit of 50 yellow perch/day. For the total 1980 winter season on Mendota, he caught 1,105 yellow perch in 23 days of fishing (48/angler-day). The total yellow perch harvest for all anglers that year probably was comparable to the large harvests in the 1950s.

Data in the July 1981 to June 1982 DNR creel survey show that yellow perch continued to be important in Lake Mendota's fishery, although the catch rate per angler-day during the winter was quite low (Table 16). While yellow perch were still numerically the most important species caught during the year-long survey, both black and white crappies were almost equally as important, except during the ice fishing season. However, the estimated winter and year-long harvests of yellow perch were only about 72,500 (Table 16) and 126,000, respectively, which are comparable to the low estimates given by Bardach (1949) for the late 1940s. In 1982, the 1977 year class of perch would have been 5+

years, which is considered old for yellow perch (Herman et al. 1959). Subsequent hatches occurred in 1981, 1982, 1983, and 1985, although all were much smaller than the 1977 hatch based on recruitment.

Further information about Lake Mendota's yellow perch fishery from 1954 through 1985 is available in records from the annual Percharee contest sponsored by the Yahara Fisherman's Club (K. Christensen, pers. comm., and Mike Michaels, Yahara Fisherman's Club, unpubl. data). The contests awarded first, second, and third place prizes to the 3 heaviest buckets of 25 yellow perch each. Prizes were also awarded for the heaviest buckets of smaller numbers of yellow perch. To compare yearly variations in yellow perch size, the average weight of the fish in each of the 3 top-prize buckets and the average weight of the 75 fish from all 3 top-prize buckets are summarized in Table 17.

Conclusions that can be made about Mendota's yellow perch fishery based on the Percharee data are limited. The records do suggest that some changes in yellow perch sizes have occurred. The prize yellow perch averaged around 200 g each in the only 2 early years with complete records (1954 and 1957), but yellow perch sizes increased to over 300 g/fish in 1975–77. Sizes were much smaller in 1979–81 and 1985–87. Many of the contest winners were from Lake Monona in the 1980s, because of poor yellow perch fishing on Lake Mendota.

No strong year class of perch occurred in Lake Mendota between 1986 and 1989. Sonar estimates of the yellow perch populations in the lake during those years varied from <1,000,000 to 3,000,000 (Luecke et al. 1992, Rudstam et al. 1993), an estimate much lower than Pearse and Achtenberg's (1920) estimate for the early 1900s. The estimate of the yellow perch population based on a mark-recapture study in 1988 was around 900,000 fish (Rudstam and Johnson 1992). Annual yellow perch abundances, after the 1977 year class became large enough to survey, were 10–20 times higher (Rudstam et al. 1992). The UW's record of yellow perch abundance in Lake Mendota since 1976 indicates the importance of strong year classes in maintaining the fishery. Heavy angler exploitation coupled with poor recruitment can result in low yellow perch abundance.

Survey Results—Lower Lakes. Much less is known about the early yellow perch fishery of the lower 3 Yahara lakes. Kenneth Christensen (pers. comm.) recalls that these lakes contained large yellow perch during the 1920s through the early 1930s, as contrasted to the much smaller yellow perch in Lake Mendota. Yellow perch were generally not captured in the DNR's rough fish seine hauls because the mesh size was too large. In Lake Waubesa, yellow perch were abundant in the 1937 open-water creel survey; they represented 28% of the total catch. Yellow perch fishing declined dramatically in 1938–39; yellow perch represented ≤2% of the total catch for those years, coincident with an increase in crappies. During the 1936 and 1938–39 creel surveys on Lake Kegonsa, yellow perch represented 9%, 22%, and 5% of the catch, respectively. However, the Waubesa and Kegonsa creel surveys were not conducted during the ice fishing season.

Black (1945) described the yellow perch fishery in the lower 3 lakes for 1944–45. He stated that yellow perch were abundant in Lake Monona, based on ice fishing and gill netting records (data not given), but the sizes were small. Black (1945:20) wrote, "The large perch formerly so common in Lake Monona seem to have disappeared and fishing for perch for several years prior to the 1944–45 winter season was virtually non-existent." Summer fishing on Waubesa and Kegonsa was generally poor in 1944–45, but yellow perch sizes were large; the combination of these statistics suggests that the perch populations in these lakes may have been low.


PHOTO: DEAN TVEDT, DNR CENTRAL OFFICE COLLECTION

The headquarters tent for the Percharee on Lake Mendota, February 1959. This annual contest for the heaviest perch has been conducted by the Yahara Fisherman's Club since the early 1950s.

Table 17. *Average weights of yellow perch in the annual Percharee ice fishing contest held on Lake Mendota, 1951–87.**

	Average Individual Weights (g) of the 25 Perch Winning First, Second, and Third Places**							
	Lake Mendota				Lake Monona			
Year	1st	2nd	3rd	Avg.	1st	2nd	3rd	Avg.
1951	254	-	-	-	-	-	-	-
1952	-	-	-	-	-	-	-	-
1953	-	-	-	-	-	-	-	-
1954	220	207	200	210	-	-	-	-
1955	-	-	-	-	-	-	-	-
1956	-	-	-	-	-	-	-	-
1957	210	203	200	204	-	-	-	-
1958	-	-	-	-	-	-	-	-
1959	-	-	-	-	-	-	-	-
1960	-	-	-	-	-	-	-	-
1961	-	-	-	-	-	-	-	-
1962	-	-	-	-	-	-	-	-
1963	224	-	-	-	-	-	-	-
1964	254	-	-	-	-	-	-	-
1965	199	195	190	195	-	-	-	-
1966	-	-	-	-	-	-	-	-
1967	287	280	210	259	-	-	-	-
1968	-	-	-	-	-	-	-	-
1969	-	-	-	-	-	-	-	-
1970	345	278	227	283	-	-	-	-
1971	-	-	-	-	-	-	-	-
1972	204	199	194	199	-	-	-	-
1973	248	236	227	237	-	-	-	-
1974	251	244	219	238	-	-	-	-
1975	310	302	301	304	-	-	-	-
1976	352	323	308	328	-	-	-	-
1977	370	396	257	324	-	-	-	-
1978	-	-	-	-	-	-	-	-
1979	204	176	154	178	-	-	-	-
1980	283	129	98	170	-	-	-	-
1981	142	141	141	141	-	-	-	-
1982	227	221	-	-	-	-	-	-
1983	-	-	-	-	196	185	183	188
1984	198	-	-	-	237	207	-	-
1985	125	124	122	124	211	207	154	191
1986	168	155	143	155	115	115	109	113
1987	163	161	154	159	177	150	-	-

* Sources of data: Mike Michaels, Yahara Fisherman's Club (pers. comm.) and Kenneth Christensen, *The Capital Times* outdoor writer (pers. comm). Contest was called Fisheree in 1951–53. Perch fishing from Lake Monona was also allowed in contest since 1983.

** Weights for individual fish were averaged from the 3 highest total weights of 25 fish recorded in the contest. Where data were found, highest average weights recorded for both Mendota and Monona are given after 1983.

Little information on the yellow perch fishery of Monona, Waubesa, and Kegonsa exists for the 1950s and 1960s. The 1974 creel surveys, which included part of the ice fishing season for Monona and Waubesa, recorded yellow perch as 58%, 10%, and 45% of the total yearly catch for the 3 lakes, respectively. However, the catches per angler-day were much higher in the open-water season than during the winter. Summer catch rates were 12, 19, and 11 yellow perch/angler-day for Monona, Waubesa, and Kegonsa, respectively, and winter catch rates were 3 and <1 yellow perch/angler-day for Monona and Waubesa, respectively, with no data recorded for Kegonsa.

The personal fishing record of Robert Kalhagen also indicated high catch rates of yellow perch from Lake Waubesa in 1976–78. Most of his yellow perch catch was in July–October of those years. The following winter he also caught numerous yellow perch, but few were caught in the remainder of 1979 (99% of the yellow perch were taken in winter). Yellow perch continued to represent only a minor proportion of his open-water catches for 1980–82 on Waubesa.

The 1982–83 DNR creel survey on Lake Waubesa recorded 7% yellow perch. A strong hatch had occurred in the mid-1970s, but perch numbers were greatly reduced after the ice fishing season of 1979. Yellow perch represented 10% of the annual catch in 1974 for Waubesa. The 1982–83 creel surveys on Lakes Monona and Kegonsa recorded yellow perch as 52% and 2%, respectively, of the total catch. This catch rate for Kegonsa was dramatically lower than it had been in the 1974 open-water creel survey, when yellow perch represented 45% of the total catch. The catch for Monona during 1974 was 58%. The catch rates of yellow perch in the winter creel surveys for 1974 and 1983 indicate much lower fishing success on Waubesa and Kegonsa than on Monona (Table 18).

Unfortunately, the routine DNR shoreline boom shocker surveys during the 1970s–1980s did not adequately sample the yellow perch populations. Thus, there is a void of information between the 1974 and 1982–83 creel surveys. Many of the Percharee contest winners fished Lake Monona in the winters of 1983–86 because of poor yellow perch fishing on Lake Mendota (Table 17). Winning weights were not exceptionally large, but they were greater than most weights from Mendota during those years except for 1986, when yellow perch weights from Monona were quite low.

Population Trends. The public has shown more interest in the population abundance of yellow perch throughout this century than any other species in the Yahara lakes. The numerous surveys and special studies that were conducted attest to the interest in yellow perch by managers and researchers. However, even with all this information, long-term trends in yellow perch abundances are sketchy and sometimes contradictory. Conclusions based on infrequent surveys extrapolated over long periods of time may be erroneous because of the highly variable year class strength that has been shown in studies spanning several years.

Based on early accounts and a detailed study conducted in 1916–17, catches of yellow perch from Mendota were apparently very large. The significantly smaller average size of Mendota's yellow perch reported for the period from 1900 through the 1930s could also mean that the yellow perch population was stunted. However, it could also mean that the population of yellow perch was so large that the more numerous smaller fish caused the average size to be smaller. The lack of a systematic long-term survey through these years may have also missed normal ups and downs in the yellow perch population. Unfortunately, little information has been published about yellow perch growth rates from this early period. One thing is clear, though—the yellow perch population was drastically altered during the late 1930s and the 1940s, due to massive die-offs. The increase in growth rate and in average yellow perch size during those years seems to be related to a smaller but faster-growing population.

During the 1950s, the accounts of excellent yellow perch fishing on Mendota were not always substantiated by the winter creel surveys. However, the early 1950s was the period when profundal chironomids were most dense. The drastic decline and sustained low densities that began in the late 1950s and early 1960s of both chironomids and *Chaoborus* populations, which are important as fish food, should have had some impact on yellow perch growth and abundance. Conversely, the high insect densities (particularly of *Chaoborus*) for decades prior to the 1950s should have resulted in good growth rates of yellow perch during the early 1930s, unless the smaller-sized yellow perch were not extensively utilizing this food resource.

Since the 1960s, occasional periods of excellent yellow perch fishing on Mendota were related to successful year classes of yellow perch. Likewise, poor yellow perch fishing appears to be related to poor recruitment for a few successive years after heavy exploitation by anglers had reduced the yellow perch population. The factors causing reproductive success and recruitment have not been elucidated.

For the lower 3 Yahara lakes, the relatively little data that exist on yellow perch abundance must be gleaned from the few creel surveys that were conducted over the years, as no gill netting studies were ever conducted. Yellow perch fishing was reported as very good at various times, often followed by reports of years when fishing success was poor. This suggests that year class strength has been highly variable, particularly in Lakes Waubesa and Kegonsa, which have exhibited boom and bust yellow perch fisheries. At certain times (prior to the 1940s and during the mid-1980s), yellow perch in Lake Monona were larger than those in Mendota. The abundance of yellow perch in all of the Yahara lakes is a variable but important component of each lake's fishery.

Table 18. *Reported catches of yellow perch during winter creel surveys on Lakes Monona, Waubesa, and Kegonsa.**

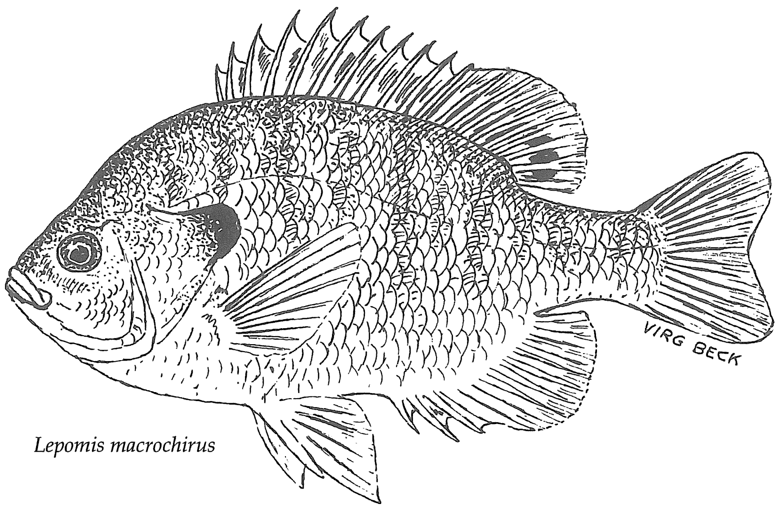
	Fishing Statistics**		
Lake and Year[a]	No. Perch Caught[b]	No. Anglers Interviewed	Catch per Angler-day
Monona			
1974	4,440	1,547	2.9
1983	92,566	38,275	2.4
Waubesa			
1974	107	827	0.1
1983	6,086	11,896	0.5
Kegonsa			
1974	-	-	-
1983	1,131	4,584	0.2

* Sources of data:
1974 - Len Marty and Robert Kalhagen, Wis. Dep. Nat. Resour., Madison Area files (unpubl. data)
1983 - Clifford Brynildson and Ron Benjamin, Wis. Dep. Nat. Resour., Madison Area files (unpubl. data).

** Statistics for 1974 are actual counts; those for 1983 are projections for January–March. The 2 surveys summarized did not provide information on the other topics for which data were available for Lake Mendota (see Table 16).

[a] Surveys covered January–March. Although the 2 lower lakes ice over earlier than January, December data were not included in order to make this table more comparable to Table 16.

[b] No bag limit was in effect for the years listed.



Lepomis macrochirus

Bluegill

Ecological Requirements

Bluegills do not tolerate low oxygen levels as well as some other fish (Snow et al. 1978). They are encountered most frequently in clear water at varying depths, usually in warm-water habitats with moderate amounts of rooted vegetation (Becker 1983). In spring, bluegills seek out macrophytes inshore—a source of cover for feeding and spawning. Density of bluegills is generally reduced in the absence of such cover. Spawning occurs in shallow water at water temperatures of 20–27 C.

Bluegills are able to feed on a variety of items from algae and zooplankton to insects. However, their gill rakers are rather inefficient, so large zooplankton need to be available if bluegills are to do well on a zooplankton diet (El-Shamy 1973). In addition, movement of young bluegills to open water for feeding leaves them vulnerable to predation, which can significantly affect their subsequent population densities.

Relative Abundance

Survey Results. Numerous early records of bluegills from Lakes Mendota, Monona, and Wingra confirm that this widespread species is native to the Yahara lakes. Because bluegills are easily captured by fyke nets, seines, and boom shockers, all of which are designed for shallow water, their relative abundance is more easily noted than abundance of many other species. Creel surveys are also a good indicator of bluegill relative abundance, because bluegills are easily caught by anglers along weedy shorelines.

Creel surveys indicated that bluegills decreased from 31% of the catch to 4% in Lake Waubesa between 1937 and 1939 and from 34% to 2% in Lake Kegonsa between 1936 and 1939. These decreases occurred at the same time that the sewage effluent caused massive algal blooms and macrophyte declines, particularly in Waubesa. A major carp hatch also occurred in 1936 (see the Common Carp Section).

Rough fish seine hauls provided information on the catch of "sunfish" (probably mostly bluegills) from the lower 3 lakes for the mid-1930s to early 1950s (Fig. 16). However, these data may not be good indicators of bluegill numbers. The large mesh used in the seines captured only the largest bluegills; in addition, the seines often rolled up in dense macrophyte beds where the bluegills would have been most abundant. Because of this, dense macrophyte beds were often avoided during the seining, although Waubesa and Kegonsa did not have dense macrophytes during those years. The record for Waubesa from the mid-1930s to the early 1950s indicates relatively minor annual differences in the sunfish catch per seine haul (average = 239/haul; range = 70–552/haul) (Threinen 1951). Thus the large differences reported in the creel surveys during the late 1930s are not reflected in the seine haul data. For Kegonsa, the average catch rate was 117/haul (range = 40–268/haul) (Hacker 1952*b*). The catch was lowest during 1940–43, 1948, and 1951.

For Lake Monona, where no creel surveys were conducted, large fluctuations in the annual catch data appear (Fig. 16). Large catches occurred in 1937 (1,189/haul), 1943 (823/haul) and 1944 (700/haul), and low catches occurred in 1939 (38/haul), 1940 (29/haul), 1946 (51/haul), and 1951 (52/haul). We computed the average annual catch of sunfish to be 322/haul; Hacker

(1952*a*) reported the same average as 269 fish/haul. (See the Methods Section for a discussion of reasons for these differences.) Black (1945), comparing the spring rough fish seine haul data for 1939–40 and 1944–45, also noted a large increase in 1944. These bluegills were large, averaging about 340 g each, and they were similar in size to those being routinely caught by anglers (Black 1945). In 1945 the seine catch decreased, and the average size also decreased, because a large number of bluegills from the smaller-sized 1943 year class were also captured. To reflect the discrepancy in interpretation of the seine haul data, Black (1945) noted that the 1945 angling for bluegills in Lake Monona was the best it had been in years, and yet the seine haul catches were much lower than in 1943–44. In one other survey on Monona during the summer of 1939, large numbers of bluegills were captured with a finer-mesh shoreline seine. These were probably mostly small-sized fish, indicating good reproduction.

Information on early bluegill numbers for Lake Mendota is scarce, but because macrophyte beds were extensive during these years, bluegills probably were abundant. Pearse (1918) collected numerous bluegills along the shoreline as part of his fish food study. Andrews and Hasler (1943), summarizing seining results for University Bay, show large numbers of centrarchids (mostly bluegills) in 1939, followed by sharp reductions in 1940–41 because of poor bluegill hatches. In 1947, 16% bluegills were recorded during a June fyke net survey on Mendota.

Data on bluegills in Mendota during the 1950s and 1960s show fluctuations. A creel survey conducted in 1952 reported a bluegill catch of only 2%. Horrall's (1961) and Voigtlander's (1971) spring fyke net survey indicated low catch rates (2%–9%) of bluegills in 1959–61, 1965, 1967, and 1971; the highest catch rates (26%–41%) were recorded in 1957 and 1962–63. However, because the fyke nets were set in areas that were usually weedless, the bluegill catch was probably not a good representation of the population.

Information on bluegill catches from the lower 3 lakes during the 1950s and 1960s is scarce. A shoreline seine survey on Monona in 1966 caught no bluegills. In Waubesa, a similar survey in 1966 recorded large numbers of crappies but few bluegills. In Kegonsa, only 3% of a 1957 spring fyke net survey were bluegills. Bluegills were well represented in the summer 1966 shoreline seining, but they were relatively unimportant in the 1968 fall boom shocker survey, as compared with other species captured.

The record on bluegill catches for all of the Yahara lakes since the early 1970s is more complete. For Lake Mendota, 1973 and 1974 creel surveys recorded moderate catches of bluegills (8% and 9%, respectively). Spring fyke net surveys averaged 126, 25, and 15/lift in 1970–72, respectively. Low numbers were recorded in the springs of 1973, 1977–78, and 1985, when other surveys were conducted. The 1981–82 creel survey recorded only 1% bluegills, indicating that they had declined since the early 1970s. However, bluegills were the most numerous fish captured in the DNR shoreline seines from 1977–80. Shoreline seining for the UW-LTER Project caught significant numbers of bluegills in 1981 and 1983, but few bluegills were caught in 1982 and 1984–85 (J. Magnuson, unpubl. data collected in 1981–85). In the DNR survey seining on Mendota in the fall of 1984, bluegills were the species most frequently captured (32%). Whereas catches of crappies were high for Lake Mendota from 1979–82, catches of bluegills were correspondingly lower. From 1983–85, more bluegills were caught than crappies.

Few bluegills were taken from Lake Monona in a 1970 daytime summer boom shocker survey. Bluegills represented a large percentage of the catch during the 1974 creel survey (32%) and 1976 spring fyke net surveys (39%). The summer 1976 and 1978–80 shoreline seining recorded few bluegills, but large numbers of bluegills were captured in 1977. Fall boom shocking recorded bluegills to be numerous in 1978–79, less numerous in 1980, and relatively unimportant numerically in 1981. Bluegill catches increased somewhat toward the mid-1980s: they represented 10% of the 1982–83 creel survey catch and 43% of the 1984 survey seine sample.

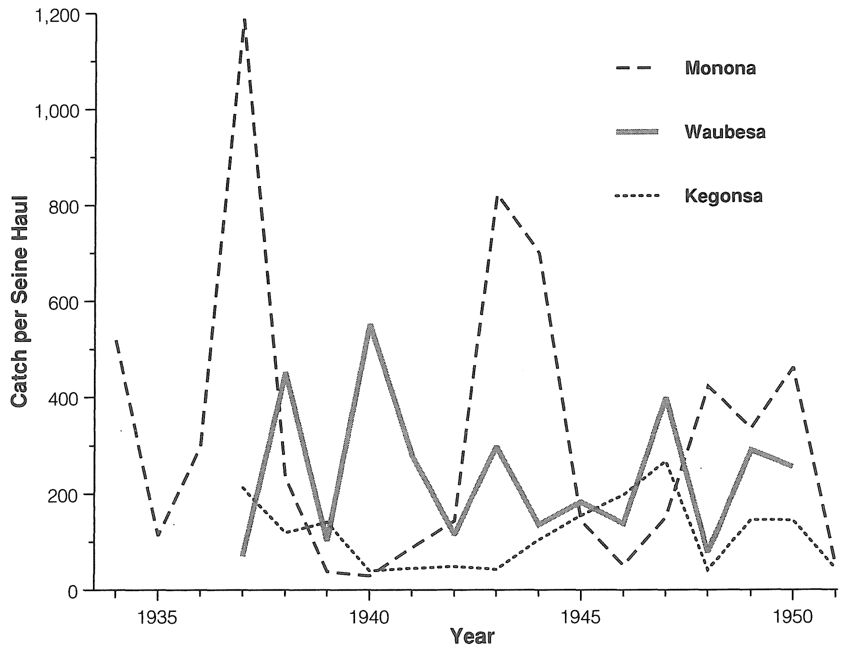
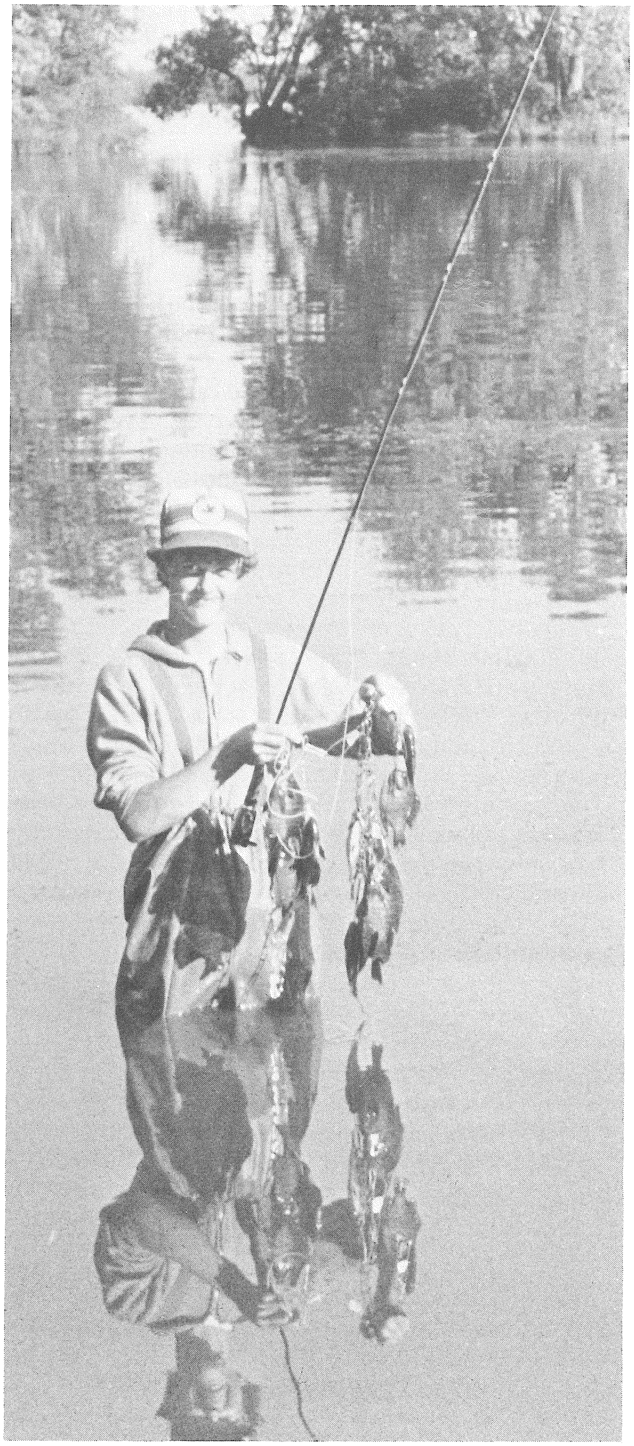


Figure 16. *"Sunfish" caught in the state rough fish hauls in Lakes Monona, Waubesa, and Kegonsa, 1934–51.*



Bluegills caught near outlet of Lake Waubesa, June 1985.

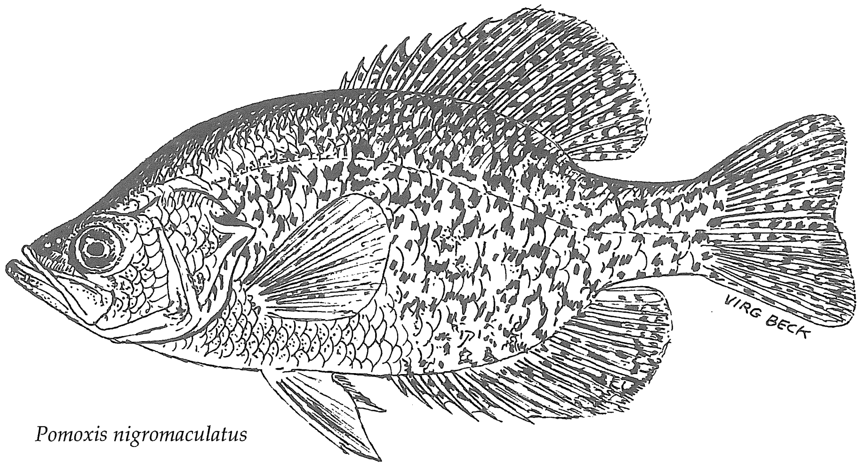
PHOTO: KEN CHRISTENSEN, THE CAPITAL TIMES

On Lake Waubesa, bluegills were relatively unimportant in the 1968–71 boom shocker surveys, but their numbers increased in the 1973 survey. They were abundant in the 1974 spring fyke netting and represented 71% of the catch in the 1974 fall survey seining. Over 33,000 bluegills were captured in 2 seine hauls that fall. Anglers caught 56% bluegills in the 1974 creel survey. Shoreline seining recorded no bluegills in 1976, large numbers in 1977–78, and small numbers in 1979–80. Boom shocking recorded bluegills to be numerous in 1978–80, somewhat less numerous in 1981, then abundant in 1982–84. The 1982–83 creel survey recorded only 11% bluegills because of the large number of crappies caught by anglers. The personal fishing diaries of Robert Kalhagen for 1976–82 further indicate that bluegills were abundant in 1976–77 catches, but they represented a very small proportion of his catch in 1979–82, when crappies were frequently caught.

On Lake Kegonsa, bluegills were not captured in large numbers during boom shocker surveys in 1968–73 but were more frequently caught during 1976–84. Bluegills represented 7% of the 1974 creel survey catch and 6% of the 1975 survey seine haul. Very few bluegills were captured in the spring 1975 fyke netting. Shoreline seining in 1971 and 1976–80 recorded few bluegills, except for 1977 when over 1,000 were captured. Finally, the creel survey in 1982–83 found 9% bluegills, again reflecting the large number of crappies caught by anglers.

Population Trends. Bluegills are considered one of the most abundant panfish in the Yahara lakes, but true abundance cannot be ascertained from available data. Because the area of macrophyte growth represents a greater percentage of lake area in Waubesa and Monona, bluegills appear to have been relatively abundant in those lakes when macrophyte growth was extensive, particularly in the early 1970s and after the early 1980s.

Historically, bluegill catch rates appeared to decline for the lower lakes in the late 1930s, when macrophytes declined because of algal blooms caused by sewage effluents. Catch rates also declined in the late 1970s during a decline in milfoil, which had until then dominated the macrophyte beds. During the early 1980s, following the decline of milfoil, catch rates of crappies increased in all 4 lakes. Now that macrophytes (mostly milfoil) have returned in Monona and Waubesa, bluegills are more frequently caught in those lakes, particularly in Waubesa. Bluegill fluctuations over the years in all 4 lakes may indicate strong year classes or inadequate sampling.



Pomoxis nigromaculatus

Black Crappie

Ecological Requirements

Black crappies and white crappies are both pelagic, but black crappies prefer cleaner, deeper, and cooler water than white crappies, and they are more often found over sand and gravel bottoms (Schneberger 1972). Spawning occurs near vegetation in shallows or to depths of 2 m or more (Becker 1983). Favorable spawning temperatures range from 18–20 C. Black crappies are able to consume zooplankton, macroinvertebrates, and small fish, a factor that allows the species to adapt successfully to many waters. Relatively little is known about the different ecological niches of white and black crappies.

Relative Abundance

Survey Results. The black crappie is native to the Yahara lakes, based on evidence from early records of Pearse (1918) and others for Lakes Mendota, Monona, and Wingra and on the species' widespread occurrence throughout Wisconsin. A few crappies were stocked in the 4 Yahara lakes during the late 1930s and the 1940s, although species were not identified in the stocking records. Some of these fish may have come from fish rescue operations; other stockings of moderate numbers of fingerlings were undoubtedly deliberate. Most early surveys listed only black and no white crappies in the lakes, or else they lumped both species as crappies. However, white crappies may not have been present in the lakes prior to the fish rescue stockings in the 1930s. (See the White Crappie Section.) The rough fish seine haul summaries from the mid-1930s to the early 1950s for the lower 3 lakes as well as the 1936–39 creel surveys on Lakes Waubesa and Kegonsa only recorded total crappies. However, Black (1945) stated that black crappies composed 95% of both crappie species in Lakes Waubesa and Kegonsa and 85% in Lake Monona, although he provided no data to support these conclusions. Consequently, the following discussion about crappies in the lower 3 lakes assumes that most of the major crappie population changes involved black crappies. White crappies began to be recorded in large numbers in the Yahara lakes only after 1976, although Black (1945) stated that white crappies were more abundant in Lake Mendota in the 1940s. (This was not confirmed by other surveys.)

The rough fish seine hauls and the creel surveys indicate major changes in the crappie catches from the lower 3 lakes during the 1930s and 1940s. On Lake Waubesa, large numbers of crappies were caught in the rough fish seine hauls in 1938 (about 3,500/haul) through 1940 (Fig. 17). The numbers of crappies caught after 1941 were much smaller, with very few crappies caught in 1942, 1944, and 1948–50. The 1937–39 creel surveys on Waubesa also indicated the increasing importance of crappies in the fishery. Crappies represented 11%, 81%, and 93% of the catch in the 3 years, respectively. Frey and Vike (1941) attributed the large increase in crappies in Lake Waubesa to crappie response to the exceedingly large carp hatch in 1936. Most of the crappies caught in 1938–39 were of the 1936 year class. Black (1945) compared rough fish haul catches from 1939–40 with those from 1944–45. He felt that there was an error in the 1939 records, because only a total of 717 crappies had been captured in 14 out of 15 hauls, whereas 20,000 crappies were captured in the 15th haul. Although an additional 21 hauls (total 36) for 1939 (spring and fall) were summarized by Threinen (1951), the average number of crappies (1,380/haul) was similar to the 15 spring hauls reported by Black (1945).

The catches of crappies were never as large in the Lake Kegonsa seine hauls as in the peak years for Lake Waubesa. Low crappie numbers were recorded from 1948–51. In the creel surveys during the late 1930s, the crappie catch increased from about 1% in 1936 to 14% and 31% in 1938–39, respectively. A large carp hatch also occurred in Lake Kegonsa, but the crappies apparently did not increase as much as the white bass. Black (1945), summarizing spring rough fish hauls, noted a drop in crappie catch from 149/haul in 1939–40 to 53/haul in 1944–45. He felt the decrease was due to competition from white bass.

In the Lake Monona rough fish hauls, crappies were frequently caught in 1937 (7,144/haul), but this large number was the result of an estimated 100,000 crappies taken in one haul in late June (Hacker 1952*a*). Crappie catches were reduced in the succeeding years. Crappies were caught in low numbers in 1935–36, 1945–46, and 1951 (Fig. 17). Black (1945) also discussed the variability in seine haul data during the spring of 1939. About 17,000 crappies were caught in 20 hauls, of which 15,000 were reported in one haul. He felt, as in the above discussion for Lake Waubesa, that the large numbers were in error. However, they may not have been, and the overall interpretation would not change anyway.

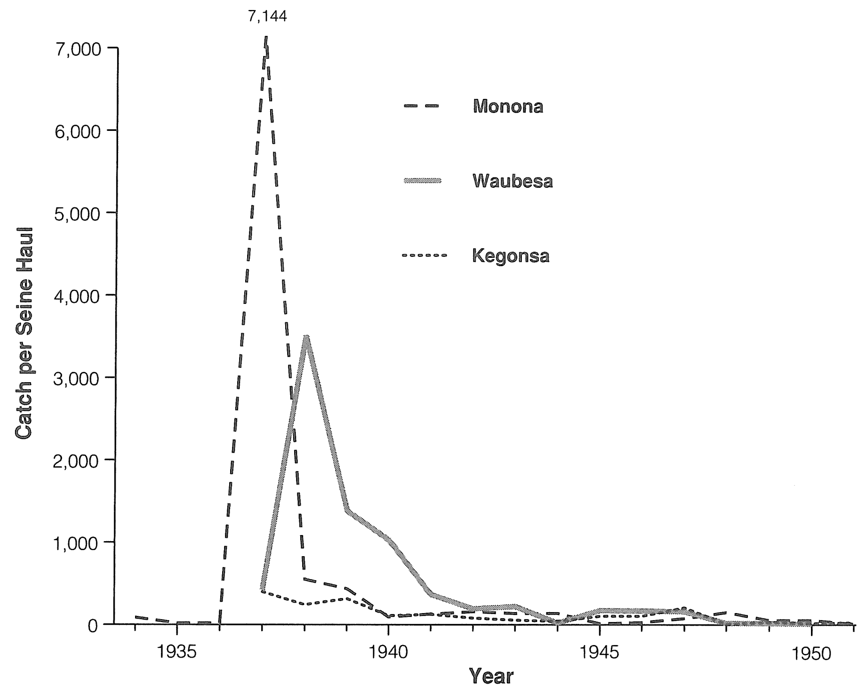


Figure 17. *Total crappies caught in the state rough fish hauls in Lakes Monona, Waubesa, and Kegonsa, 1934–51.*

The early black crappie catches from Lake Mendota are difficult to assess. Mackenthun's (1947) fyke net survey recorded 18% black crappies, second only to bullheads (27%). In a creel survey during 1952, crappies represented only 1% of the total catch. The long-term UW fyke net study during the 1950s and 1960s averaged about 1,000 crappies/50 fyke net lifts in 1956 and 1964 and about 2,800/50 lifts in 1963. About 400–1,000 black crappies/50 lifts were captured in 1957, 1959, 1962, and 1964. Less than 400 black crappies/lift were recorded in other years. Very few crappies were caught in 1967, 1969, and 1971. These low numbers were also followed by low numbers of crappies caught in the 1973 and 1974 creel surveys on Mendota. However, crappies represented 23% and 34% of the catch in DNR fyke net surveys in the springs of 1970 and 1971, respectively.

The fyke net surveys in the late 1970s and the boom shocker surveys from 1977–82 reflect the large catches of black crappies from Lake Mendota during those years. In addition, large numbers of black crappies were captured in the UW-LTER shoreline seine hauls in late summer 1981; smaller numbers were captured in 1983 (J. Magnuson, unpubl. data collected in 1981–85). The DNR shoreline seine surveys from 1978–80 also captured black crappies. But the strongest evidence of a large crappie population in Lake Mendota during those years was provided by the 1981–82 creel survey, which recorded large numbers of both black and white crappies. Black crappies represented 28% of the total catch, behind white crappies (32%) and yellow perch (37%), while bluegills represented only 1% of the catch. However, John Lyons (Wis. Dep. Nat. Resour., Bur. Res., pers. comm.) feels that most of the crappies were black, based on extensive sampling he conducted for the UW during those years. In 1984, survey seining captured 14% black crappies and almost no white crappies, but bluegills represented more than twice the crappie catch. The 1985 boom shocker survey indicated that the crappie catches may have been declining for Lake Mendota, as few black or white crappies were captured in proportion to other fish species.

Crappies were not frequently caught from Lake Monona during the 1974 creel survey, representing only 1% of the total catch. Very few crappies were recorded in a boom shocking survey in 1970. However, the spring 1976 fyke net survey captured 16% black crappies and very few white crappies; the fall survey seine captured 8% black crappies. The black crappie catches apparently had increased prior to the yellow bass and white bass die-off in the fall of 1976. Black crappie catches were high in 1977–83, based on boom shocking and shoreline seine data. The 1982–83 creel survey on Lake Monona recorded large numbers of black crappies (27%); black crappies outnumbered white crappies 3:1.

Black crappies have also been frequently caught at various times from Lake Waubesa since the 1960s. Large numbers of small crappies were captured in summer shoreline seining in 1966, although few crappies were netted during the fall boom shocking in 1970–71. Numerous black crappies were again captured in the fall 1974 survey seining, but the percentage of crappies (12%) was affected by the extremely large number of bluegills also captured. The 1974 creel survey on Lake Waubesa indicated that the crappies were well represented in the catch (5%), but that other species were even more numerous.

In the summer of 1976, very large numbers of crappies were recorded during shoreline seining on Lake Waubesa, indicating that a major crappie hatch had occurred. Both black and white crappies increased in importance after the yellow bass and white bass die-off in the fall of 1976. Crappies were frequently recorded as abundant in the boom shocker surveys during the late 1970s and early 1980s. The 1982–83 creel survey on Lake Waubesa recorded large numbers of black crappies (38%), second only to white crappies (43%). This same increase in crappies from Waubesa following the temperate bass die-off in the fall of 1976 was evident in the personal fishing diaries of Robert Kalhagen (Fig. 18). In 1976, prior to the die-off, 63 black crappies were caught per 50 fishing trips in the open-water season. This number increased to 168, 362, and 853 in 1977–79, respectively. Black crappies were the dominant fish caught in 1980–82, when 766, 877, and 1,197/50 trips were caught. White crappies were equally as dominant in 1979–80, but they composed a smaller proportion of the catch in the other years.

The black crappie had similar population responses in Kegonsa since the 1960s. Black crappies were scarce or absent in the 1968, 1970, and 1973 boom shocker surveys. The 1974 creel survey recorded only 2% crappies. In 1975, crappies composed 6% of a fyke net survey and 11% of a survey seine catch. During the late 1970s and early 1980s, both black and white crappies were frequently caught in boom shocker surveys. The 1982–83 creel survey recorded large numbers of crappies; 44% were black crappies and 43% were white crappies. Boom shocking in 1984 indicated that black crappies were still present in substantial numbers.

Population Trends. Perhaps less is known about the black and white crappies in the Yahara lakes than any other major panfish species. We know of 2 distinct periods in which catches were dominated by crappies. The first was in the late 1930s on Monona and Waubesa (data on Mendota are not available). The second period occurred for all 4 lakes from the late 1970s through the early 1980s. Other years had much lower black crappie catch rates, although records are incomplete. However, black crappie catches from Mendota were higher for many years during the late 1950s and early 1960s than in the late 1960s. There is some indication that when catches of crappies increased, catches of bluegills or other fish species declined. Both black and white crappies were recorded in large numbers during the late 1970s to early 1980s in all 4 lakes, although some scientists believe that most of these crappies were black, at least in Lake Mendota. The fact that these 2 species were generally not separated in earlier surveys makes a more detailed analysis of either species difficult.

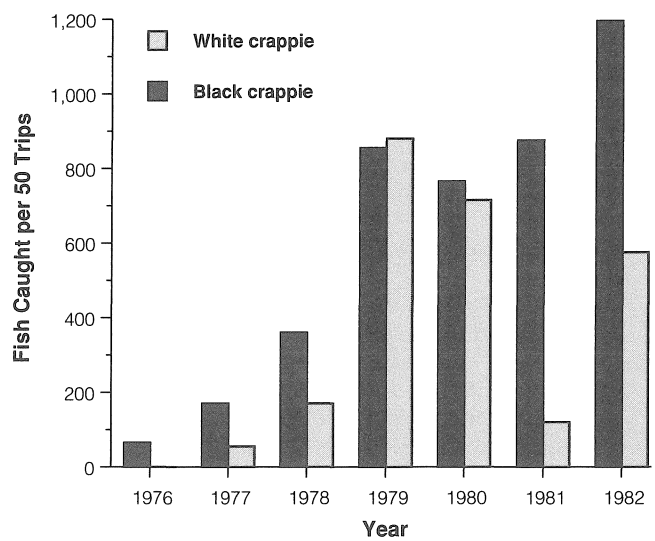
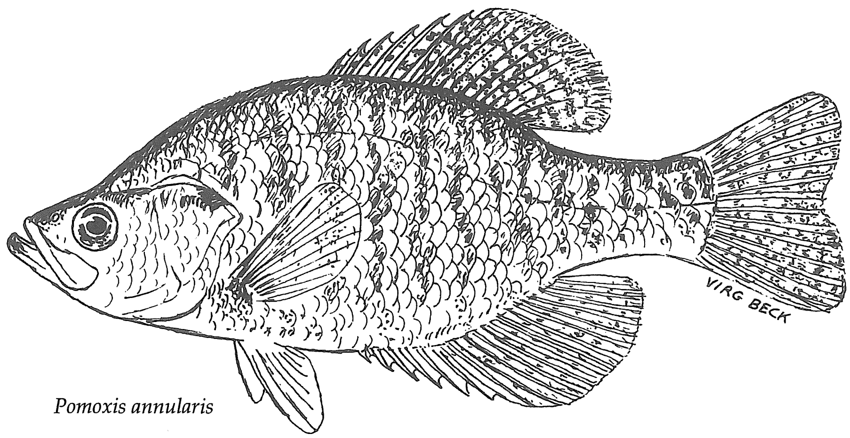


Figure 18. *Black and white crappies caught by Robert Kalhagen in Lake Waubesa, 1976–82.*



Pomoxis annularis

White Crappie

Ecological Requirements

Like black crappies, white crappies are pelagic. They prefer slightly turbid to turbid water with sparse vegetation (Becker 1983). During their first year, zooplankton are almost the only food eaten (Carlander 1977); the diet of larger crappies also includes macroinvertebrates and small fish. Spawning occurs at water temperatures of 14–23 C. The white crappie nests at depths of up to 2 m, generally within 10 m of the shore, on hard clay or gravel, or on the roots of aquatic or terrestrial plants (Hansen 1951, 1965).

Relative Abundance

Survey Results. Only the black crappie and not the white crappie was listed in early surveys of the fish of the Yahara lakes (Marshall and Gilbert 1905, Pearse 1918). Greene (1935) indicated that it was found in the Rock River prior to the 1930s but not in the Yahara River system. White crappies, although less widespread than black crappies, may still have been native to the Yahara lakes. They may also have been introduced to Lake Wingra and the other Yahara lakes during the fish rescue operations in the 1930s. The white crappie was abundant in the sloughs of the Mississippi River at that time (Greene 1935).

The 1936–39 creel surveys on Lakes Waubesa and Kegonsa recorded only total crappies, with no distinction between the 2 species. Similarly the rough fish seine haul records from the mid-1930s to the early 1950s recorded only total crappies. Black (1945) mentioned that it was impractical to separate the 2 species during these seine hauls, but he stated that in general white crappies composed only about 15% of the crappie population in Lake Monona and only about 5% each in Lakes Waubesa and Kegonsa. However, he stated that the white crappie was more common than the black crappie in Lake Mendota and that the white crappie was much more common in Lake Wingra. Unfortunately, he provided no evidence to support these statements, particularly after mentioning that crappies were not separated by species during the rough fish hauls. In contrast, only 11% of the crappies were found to be white crappies during a June 1947 fyke net survey in Lake Mendota; white crappies represented only 2% of the total catch of fish. White crappies were also generally caught in much lower numbers than black crappies in the UW's fyke net survey from the mid-1950s through the 1960s.

During the late 1970s and early 1980s, the ratio of white crappies to black crappies and their percentage in the total catch in the Yahara lakes appear to have increased. This increase followed the massive die-off of yellow bass and white bass in the Yahara lakes in the fall of 1976. In the 1973 creel survey on Lake Mendota, 28% of the crappies were white, but they represented only <1% of the total catch. The 1974 creel surveys did not separate the 2 crappie species, but total numbers were low. The 1981–82 creel survey on Mendota recorded slightly more white crappies (53%) than black crappies, with the white crappies representing 32% of the total catch. In the Mendota shoreline boom shocker surveys, white crappies were recorded as abundant in 1979–80. They were virtually absent in the Mendota survey seine hauls in 1984. In shoreline seine surveys conducted by the DNR from 1978–80 and the UW-LTER project from 1981–85, black crappies were much more frequently caught than white crappies (J. Magnuson, unpubl. data collected in 1981–85). In one of these surveys in late August 1981, black crappies outnumbered white crappies 19:1.

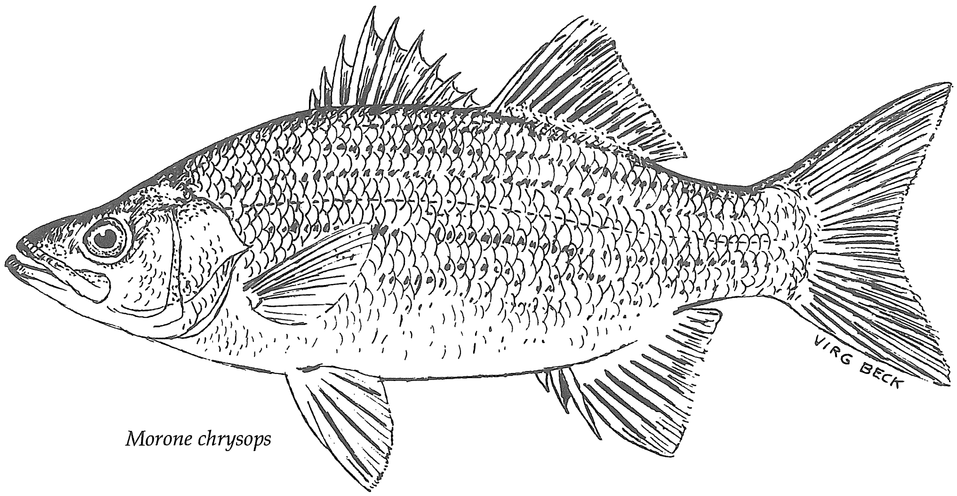
In Lake Monona, white crappies were caught in relatively equal proportion to black crappies in surveys from 1981–84, and white crappies were listed as abundant in 1981 boom shocker survey records. In the 1982–83 Monona creel survey, white crappies represented only 25% of the total crappie catch and 9% of the total catch of all species. Shoreline seine hauls from 1977–80 recorded numerous black crappies but few white crappies.

On Lake Waubesa, white crappies were frequently caught in the late 1970s but were more scarce earlier. The 1974 survey seine haul recorded <1% of the crappies as white crappies, although the large number of fish processed may have prevented a true separation by species of the crappies caught. In the 1982–83 creel survey, the dominant species caught was white crappie (43%), followed by black crappie (38%). Robert Kalhagen's personal fishing diaries recorded steadily increasing numbers of white crappies caught, from none in 1976 to a high of 881/50 trips in 1979. Numbers of white crappies stayed high in 1980, declined in 1981, and then rebounded in 1982. Fewer white crappies were caught than black crappies in all years of Kalhagen's diaries except for 1979–80, when the numbers were about equal. The 1984 boom shocker survey found more black than white crappies.

For Lake Kegonsa, a similar increase in catches of both black and white crappies occurred after the 1976 temperate bass die-off. White crappies were either absent or scarce in the earlier boom shocker surveys, fyke nettings, and survey seine hauls. Catches of crappies increased in the boom shocker surveys from 1978–84, with white crappies and black crappies present in similar proportions except in 1984, when the catch of white crappies decreased. In the 1982–83 creel survey, crappies represented 87% of the total catch of all species. White and black crappies were caught in similar numbers. The shoreline seining did not record many crappies in 1977–80.

Population Trends. Except for Black's (1945) statement that white crappies were more abundant than black crappies in Lake Mendota and Lake Wingra by the 1940s (a statement not confirmed by other surveys), it appears that white crappies were not abundant in the 4 Yahara lakes until the late 1970s and early 1980s. Because black and white crappies were often not separated during early WCD/DNR surveys, the presence and relative importance of white crappies in the Yahara lakes in early years may never be known. Because white crappies were not found in surveys prior to the 1930s, they may have increased in abundance after introduction via fish rescue operations in the 1930s.

Also, for some unknown reason shoreline boom shocking and seining may not have adequately sampled the population. The seining frequently recorded a large proportion of black crappies, even though the creel surveys and boom shocking found a more equal distribution of white and black crappies. Early abundance of total crappies is further discussed in the Black Crappie Section.



Morone chrysops

White Bass

Ecological Requirements

The white bass is a pelagic species. From early spring to fall, white bass inhabit surface water, either singly or in large active schools. Limited data suggest that they move into deeper water for the rest of the year (Becker 1983). They typically spawn in rivers such as the Yahara (Calhoun and Coon 1940). In Lake Mendota, they also use rocky shorelines off Governor's Island and Maple Bluff (Horrall 1961). Natal homing to these 2 spawning grounds occurs, thus distinct stocks of white bass may exist (Horrall 1961, Wright and Hasler 1967).

Young white bass in the Yahara lakes are strictly planktivorous and do not eat other foods until their second year (Voigtlander 1971). Because pelagic forage fish are not numerous in the Yahara lakes, zooplankton continue to be a major component in the diet of adult white bass, although small fish are also eaten (Voigtlander 1971).

Relative Abundance

Survey Results. White bass are evidently native to the Yahara lakes. According to an 1867 newspaper article, they were plentiful in Lake Mendota but seldom seen in the lower lakes (Neuenschwander 1946). However, accounts for the downstream lakes, particularly Lake Kegonsa, may not have been as reliable, given the distance of these lakes from population centers at that time. Limited stocking of white bass was done in Monona in 1891 (McNaught 1963); white bass were stocked in Mendota in 1899 and twice during the early 1940s. No stockings were recorded for Waubesa or Kegonsa.

The first survey records for Lakes Waubesa and Kegonsa indicate that white bass were an important component of the fishery. This was true by the 1930s, although catches fluctuated, probably as the result of variable year class strength. The 1937–39 creel surveys found that 18% of the catch were white bass in 1937 on Waubesa, whereas only 5% and 2% were white bass in 1938 and 1939, respectively. The creel surveys on Kegonsa recorded an increase in white bass percentages, from 27% in 1936 to 48% in 1938 and 57% in 1939. White bass fishing was also apparently very good on Kegonsa in 1937, a year when no creel survey was conducted (Frey and Vike 1941).

The rough fish seine haul records for the mid-1930s to the early 1950s show that white bass catch rates for Waubesa and Kegonsa changed dramatically during this period (Fig. 19). For Lake Waubesa, few seinable white bass were captured during 1937 and 1939, but large numbers per seine haul were captured in 1938 and 1940. Numbers per seine haul were low from 1941–44, but a large increase occurred in 1945 and remained through 1950, the last year of Threinen's (1951) summary. For Lake Kegonsa, the number of seinable fish increased from 1937 through 1939 and decreased somewhat for the next few years. A major increase occurred in 1945, when over 7,300 white bass/seine haul were captured (Hacker 1952*b*). White bass were also frequently caught in 1946; catches were moderately high from 1948–51. In general, more white bass were caught per seine haul during the 1930s and 1940s in the rough fish removal operations on Kegonsa than on Waubesa.

Frey and Vike (1941) considered the large successful hatch of white bass in Lake Kegonsa in 1936 to be a response to the tremendous hatch of carp that same year. They noted that a similar but smaller response occurred in 1931 in Kegonsa. They felt that in 1939 the large white bass population was preventing successful recruitment of other fish species. Black (1945) mentioned that in the spring of 1944, the Yahara River was full of white bass just under seinable size. By 1945, tremendous numbers of white bass were caught during the spring rough fish seine hauls on Lake Kegonsa. In 5 consecutive hauls, over 27,000 white bass/haul were captured, such that the seine crews began laying the large seine closer to shore to avoid catching white bass as much as possible. The numbers of white bass per haul decreased thereafter, probably because the bass moved to deeper water to avoid the summer copper sulfate treatments. Similar to the situation in 1939, Black (1945) stated that the large white bass population in 1944–45 had eliminated most of the young of the other fish species.

The rough fish seine records for Lake Monona from 1934–51 indicate much more stable catches of white bass, but the number of white bass per haul was frequently much less than the number caught from Lakes Waubesa and Kegonsa, particularly during 1938–40 and 1945–51. The largest catch per haul of white bass from Monona occurred in 1934; this catch represented more than twice as many fish as were caught in 1935–51.

Wright (1968) provided a continuous record of the white bass in the lower 3 lakes for 1958–66 (1959–66 for Lake Kegonsa) when he summarized the rough fish seine haul records. (These data were never summarized for all fish species; the records have since been destroyed.) Similar numbers of white bass per haul, compared with those in the earlier years, were caught from Lake Monona. For Lake Waubesa, the numbers of white bass per seine haul were much lower than in the late 1940s and more similar to catches in the early 1940s. For Lake Kegonsa, a 1957 fyke net survey that recorded 39% of the catch as white bass marked the beginning of an apparent change in white bass numbers. According to Wright's (1968) records, catches of white bass were low in 1959–60, moderate in 1961–62, and very low from 1963–66. Additional data obtained for 1967–69 indicated that numbers of white bass per haul continued to be very low for Kegonsa. The decline in catch of white bass from Waubesa and Kegonsa was thought to be partly from competition with the newly prominent yellow bass, which began dominating catches in the mid-1960s in those lakes. The relationship between these 2 species will be discussed further in the Yellow Bass Section.

Less is known about the white bass in Lake Mendota during the early years. In 1947, 13% white bass were recorded in a fyke net survey. White bass represented 9% of a 1952 creel survey catch. Wright (1968) found that numbers in the rough fish seine hauls from Lake Mendota from 1963–66 (the only years he summarized) were similar to those for Lakes Monona, Waubesa, and Kegonsa during the 1960s. However, the large proportions of yellow bass recorded for the lower 3 lakes during the mid-1960s were not recorded for Mendota.

The importance of white bass in Lake Mendota's fishery during the 1950s and 1960s was exemplified by the effort made by the UW to study its population during those years. The spring fyke netting surveys off Maple Bluff and Governor's Island conducted by R. Horrall during 1955–62, 1969, and 1971 and by C. Voigtlander during 1963–68 recorded large numbers of white bass. When the data from these studies were tabulated based on the number of fish per 50 fyke net lifts (roughly the average yearly effort), catch rates were highest in 1960–61, 1964, and 1966, when over 7,000 white bass were caught. Catch rates between 3,000 and 7,000 each were recorded in 1956–57, 1963, 1965, and 1969. Catch rates were 1,000–3,000/50 fyke net lifts for the other years between 1956 and 1969. Yellow bass were never caught frequently during the UW's intensive sampling, and there was no apparent decline in the white bass

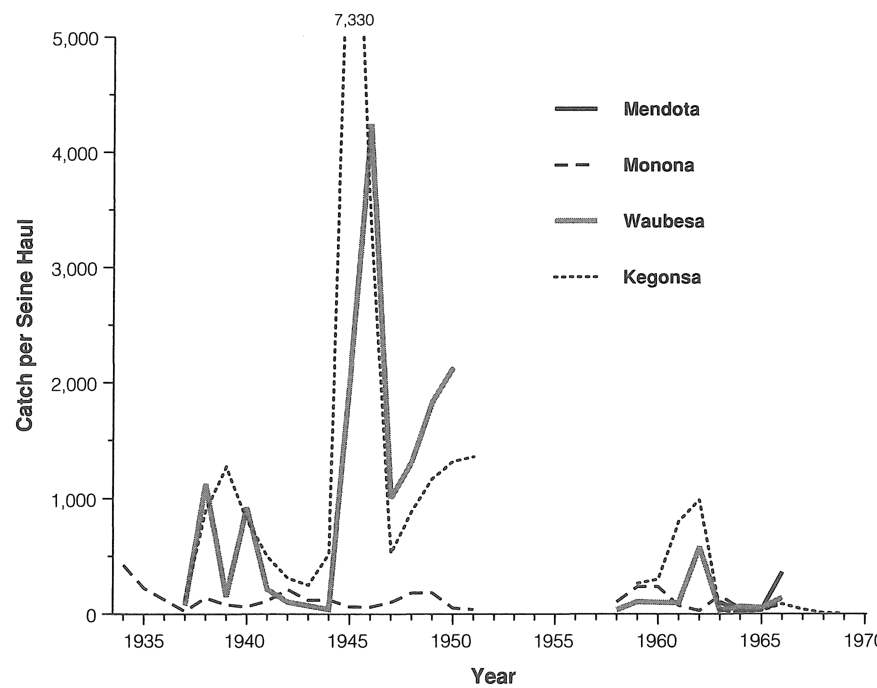


Figure 19. *White bass caught in the state rough fish hauls in the Yahara lakes, 1934–51 and 1958–69.*

population during those years. Of all the years sampled, the fewest bass captured (<1,000) were taken in the last year of the study. This may have been because a different style of fyke net was used that year.

In the early 1970s, when the first DNR surveys were conducted, white bass populations appeared to be relatively low in the lower 3 lakes. This occurred after catches of yellow bass increased in the 1960s (Wright 1968). In the 1974 creel surveys, white bass represented only 2% and 3% of the catches in Monona and Kegonsa, respectively (none found in Waubesa), compared with 2% and 5%, respectively, for yellow bass. In Mendota, the 1973 and 1974 creel surveys recorded 7% and 8% white bass and 2% and 1% yellow bass, respectively, indicating that the white bass was still numerically more important than the yellow bass. Boom shocking and fyke net surveys in Mendota during the early 1970s captured white bass but suggested little about their abundance. White bass represented 85% of the catch in an October 1970 fyke net survey, but numbers were much lower in similar surveys the previous spring and during the springs of 1971–73. However, the purpose of these surveys was to assess the abundance and spawning success of northern pike and walleye.

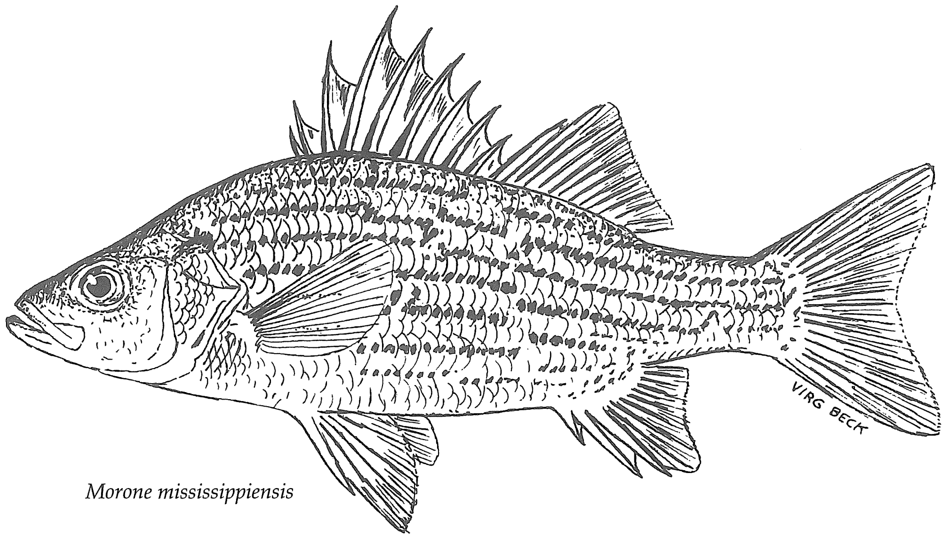
Boom shocking and fyke net surveys on the lower 3 lakes did not record many white bass during the early to mid-1970s. In fact, most evidence suggests that yellow bass may have been the more abundant of the 2 bass species. A 1976 survey seine haul on Monona recorded 2,505 yellow bass and only 10 white bass. A fall boom shocker survey on Waubesa in 1971 recorded 2,000 yellow bass and 50 white bass, but a 1974 survey seine haul had more white bass (3% of total catch) than yellow bass (1%). For Lake Kegonsa, yellow bass were listed as abundant in a 1968 boom shocker survey, whereas few white bass were captured. Similar findings were recorded in 1976. More yellow bass (4% of total catch) were also recorded in a 1975 survey seine haul on Kegonsa; only a few white bass were recorded.

In the fall of 1976, a severe die-off of white bass and yellow bass occurred, particularly in the lower lakes. Boom shocker surveys in Mendota during 1977–80 recorded almost none of these 2 species. White bass represented <1% of the 1981–82 creel survey. However, white bass began to be regularly caught in the boom shocker surveys after 1981. They represented 7% of 2 survey seine hauls during 1984. In recent years, white bass catch rates in Mendota are much higher.

In the lower 3 lakes, white bass did not rebound as quickly after the massive mortality in 1976 as they did in Mendota. In the 1982–83 creel survey, only a few white bass were recorded on Monona, and none were recorded on Waubesa and Kegonsa. Almost no white bass were captured during the boom shocker surveys on the 3 lower lakes during the early 1980s prior to 1984. In ensuing years, white bass were very numerous in Kegonsa catches as a result of one good year class, but they were not caught frequently from Monona and Waubesa.

Population Trends. White bass have been an important and apparently abundant component of the pelagic fishery in Lake Mendota, certainly since the 1940s and probably since early settlement times, except for a few years after the 1976 die-off. No accounts were found of a similar die-off in earlier years. The rough fish removal records beginning in the mid-1930s suggest that white bass were also important in the other 3 Yahara lakes. The large catches of white bass in the late 1930s and for a number of years beginning in the mid-1940s in Waubesa and Kegonsa indicate the tremendous reproductive potential of this species when spawning conditions are right and food availability is good. Successful hatches in 1931, 1936, and around 1943 dominated the pelagic fishery in Kegonsa for the next few years.

Beginning in the mid-1960s, competition from an increasing yellow bass population in the lower 3 lakes apparently caused a decline in white bass such that by the mid-1970s white bass were probably not very abundant. Catches of white bass from Mendota were more stable during those years, as yellow bass apparently were never very abundant there. The massive mortality of both bass species in all 4 lakes in the fall of 1976 caused catches of white bass to decline considerably, even in Mendota. However, catches of white bass have been increasing in Mendota since the early 1980s and have also increased in Lake Kegonsa during the late 1980s. This suggests that the white bass can successfully occupy an important niche in the fish community of the Yahara lakes.



Morone mississippiensis

Yellow Bass

Ecological Requirements

Yellow bass prefer open, clear to turbid waters (Becker 1983), similar to the habitat that white bass prefer. However, unlike the white bass, the yellow bass is not native to the Yahara lakes. A southern species, the yellow bass is tolerant of warm water. For example, yellow bass were observed congregating in summer near the power plant discharges in Lake Monona where water temperatures approach 35 C (Neill and Magnuson 1974). For spawning, they seek out sand, gravel, or rubble bottoms with few macrophytes. Yellow bass feed primarily on zooplankton and macroinvertebrates but also eat small fish (Helm 1964). Unlike white bass, yellow bass do not regularly feed on the surface, but usually hunt for food at mid-depths or near the bottom (Helm 1958).

Relative Abundance

Survey Results. The first accepted record of yellow bass in area lakes was from Lake Wingra in 1944–45, when WCD crews were using large carp seines (Noland 1951, Baumann et al. 1974).[15] The species is believed to have been introduced to Lake Wingra through stocking of fish salvaged from shallow sloughs of the Mississippi River in the 1930s–1940s (Helm 1964). Yellow bass were discovered in Lake Monona in 1953 and in Lake Waubesa around the same time (Helm 1964). WCD records documented the presence of yellow bass in Lake Kegonsa in 1959 (Wright 1968); a 1957 fyke net survey on Kegonsa did not record any yellow bass. Helm (1964) concluded that the yellow bass had entered the Yahara lakes from Lake Wingra rather than by migrating up the Yahara River from the south. This conclusion was based on the fact that a large population existed in Wingra and that the invasions were first detected in Monona, adjoining Wingra, 6 years before they were found in Kegonsa, the downstream end of the chain. Furthermore, he noted that yellow bass had not invaded Lake Koshkonong (even further down the Yahara/Rock River system) as of 1964. Such an invasion would be expected had the species been extending its distribution northward on its own.

For Lake Mendota, the first known catch of yellow bass occurred in 1957 in a fyke net set on a white bass spawning ground during the breeding season (Horrall 1961). No more yellow bass were caught from Lake Mendota until 1960, when more than 100 were taken. They were mostly males ready to spawn, from the 1957 year class (Horrall 1961). Yellow bass continued to be captured in ensuing years of the fyke net sampling, but the numbers were never large.

In contrast, yellow bass did well in the lower 3 Yahara lakes. Their increase largely coincided with an apparent decrease in white bass, a native species. These simultaneous events were documented with data from the state's rough fish seine hauls, first by Noland (1951) for Wingra (1936–49), and then by Wright (1968) for Monona and Waubesa (1958–66), Kegonsa (1959–66),

[15] The earliest record of yellow bass is from Lake Mendota in 1905, according to the fish collections of George Wagner, whose field notes are on file in the University of Wisconsin-Madison Zoology Museum. An examination of this record, however, showed the scientific name written on the back of the record card actually to be that of the smallmouth bass (see photos on pg. 91).

and Mendota (1963–66). Yellow bass made up 90% or more of the total annual temperate bass (white/yellow bass) catch in these seine hauls in Monona and Waubesa by 1965 and in Kegonsa by 1966. In Mendota hauls in 1966, only 7% of the temperate bass were yellow bass, but the percentage was increasing rapidly. Yellow bass did not appear in the seines until 1963, yet in the first haul of 1967, the large temperate bass catch was 23% yellow bass (Wright 1968). The catch of yellow bass in the remainder of 1967 is not known because the records were never tabulated.

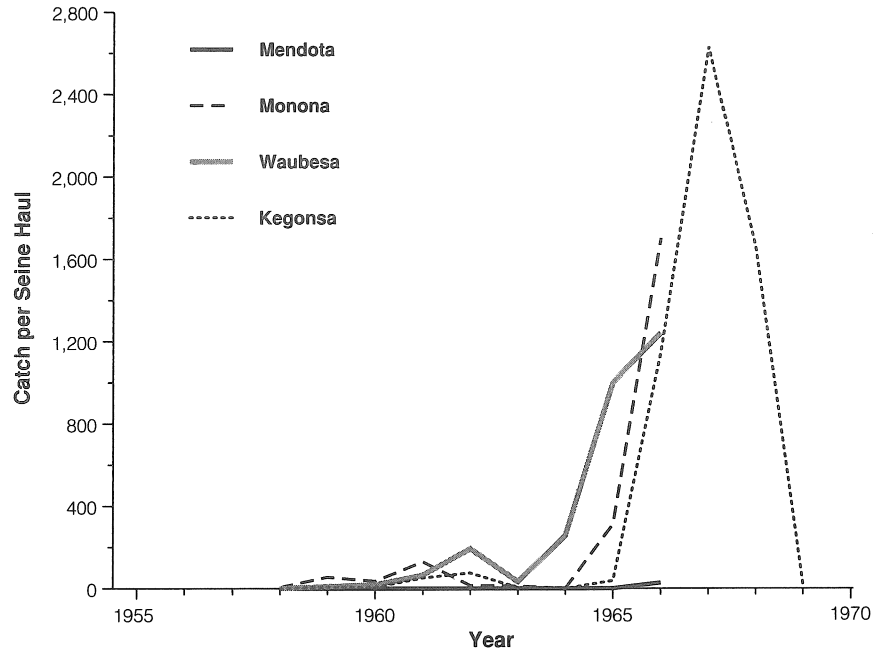


Figure 20. *Yellow bass caught in the state rough fish seine hauls in the Yahara lakes, 1958–69.*

During the mid-1960s, when the catch of yellow bass exceeded 1,000 fish/haul on the lower 3 lakes (Fig. 20), the catches were similar to the large catches of white bass from Waubesa and Kegonsa during the late 1940s. The large catch of yellow bass from Monona documented in 1966 was about 10 times greater than the average catch of white bass from that lake for 1934–51. The reason is not known for the large decrease in yellow bass caught from Kegonsa during 1969 following 3 years of high catches, although 1969 was the last year of rough fish seining by the WCD, and effort was significantly reduced. Also, a population dominated by small-sized fish would have escaped the large-mesh seines.

This trend toward more yellow bass and fewer white bass was never as pronounced in Lake Mendota as in the lower 3 lakes. In Mendota, yellow bass were rarely caught in fyke net surveys during 1970–73 and represented $\leq$2% of the creel surveys in 1973 and 1974.

Catches of yellow bass in the lower 3 lakes continued to be high throughout much of the early 1970s, according to various DNR surveys, although records are not complete enough to suggest whether the populations were stable or fluctuating during that period.

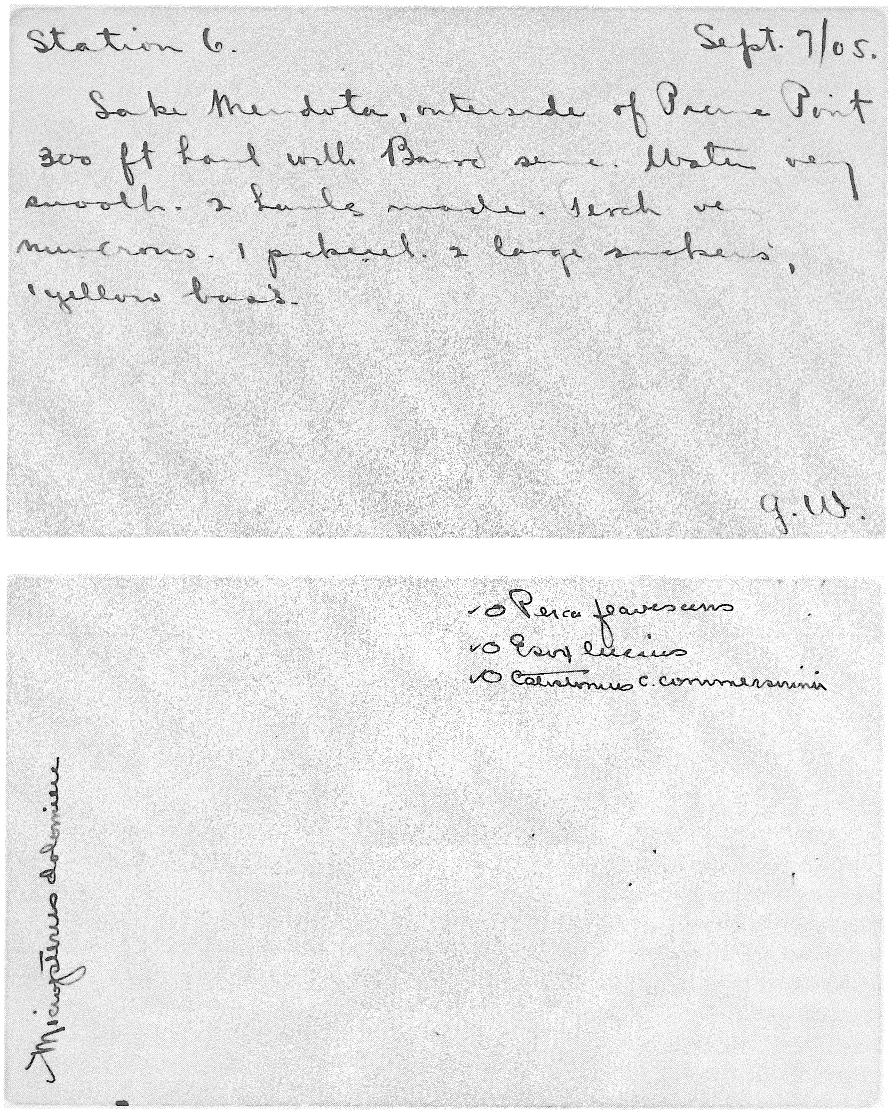
Yellow bass represented only 2% of the 1974 creel catch on Monona, but a 1976 survey seine haul had over 2,500 yellow bass, representing 71% of the total catch. A 1970 boom shocker survey and a 1976 fyke net survey recorded the presence of yellow bass, but the numbers recorded were not high. The 1974 creel surveys on Waubesa and Kegonsa recorded 5% and 29% yellow bass, respectively. Approximately 2,000 yellow bass were caught during 30 minutes of boom shocking on Waubesa in October 1971. A 1974 survey seine recorded 536 yellow bass, which represented only 1% of the total catch because of the exceedingly large catch of bluegills.

In Kegonsa, yellow bass were listed as abundant in the 1968 and 1976 boom shocker surveys. Yellow bass were numerically unimportant in a 1975 fyke net survey, and only 165 yellow bass were caught in a survey seine haul that year.

Between August and November 1976, a massive die-off of yellow and white bass occurred in all 4 lakes. After that fall, DNR records reveal only scattered references to a few yellow bass for several years. The fishkill was apparently fairly local, for yellow bass were still common in lakes in nearby counties. The personal fishing record of Robert Kalhagen for Lake Waubesa also reflects the die-off. During the open-water season in 1976, 23% of the fish he caught were yellow bass. During the same season in 1977, not a single yellow bass was caught.

The extent of the die-off is indicated by survey records during the early 1980s. No yellow bass were reported in the 1981–83 creel surveys on all 4 lakes. In the fall 1985 boom shocker survey on Lake Mendota, 10 yellow bass were captured. While a slow recovery may be occurring, yellow bass were still not numerous in any of the Yahara lakes by the late 1980s (Brett Johnson, Wis. Dep. Nat. Resour., pers. comm.).

Given the close taxonomic relationship between yellow bass and white bass, it is not surprising that occasional hybrids between the 2 species have been reported. A few such hybrids were captured in Wingra and Mendota by W. Helm and R. Horrall during the 1950s (Ross Horrall, UW Environ. Stud., pers. comm.). During the fish distribution surveys of the Yahara lakes in 1975–76, hybrids were found at 5% of the total stations in Mendota. However, none were found during the same surveys in the 3 lower lakes, and none have been recorded in any of the other surveys summarized in this report. The evidence suggests that extensive hybridization between yellow and white bass probably has not occurred.



Station 6. Sept. 7/05.

Lake Mendota, outerside of Picnic Point 300 ft haul with Baird seine. Water very smooth. 2 hauls made. Perch very numerous. 1 pickerel. 2 large suckers, 1 yellow bass.

G.W.

✓O Perca flavescens
✓O Esox lucius
✓O Catostomus c. commersonii

Micropterus dolomieu

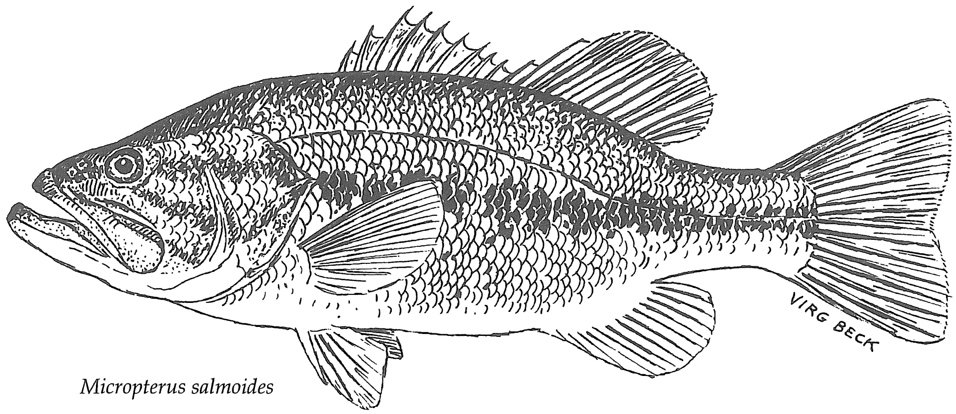
PHOTO: UW-MADISON ZOOLOGY MUSEUM COLLECTION

Original data card of George Wagner's 1905 fish collections on Lake Mendota. Front side of card (top) was cited for many years as the first record of yellow bass in Lake Mendota. The back side of the card (bottom) proved the fish to be a smallmouth bass instead (note scientific name at left).

Population Trends. The yellow bass is an exotic species that was apparently introduced to Lake Wingra by fish rescue operations in the late 1930s or early 1940s. By the 1950s, yellow bass had spread to the 4 Yahara lakes and was abundant in catches in the lower 3 lakes by the mid-1960s. This species was an important component of the fish community in those lakes until a massive die-off occurred in the fall of 1976. Yellow bass were never frequently caught in Lake Mendota, quite likely because its fish community is more diverse, and there never was a major yellow bass hatch there.

Since the 1976 die-off, yellow bass have only recently been recorded in various surveys but in low numbers. It is not known if yellow bass will again increase in any of the Yahara lakes, but a rapid increase in the 1960s indicates that it is possible.

Despite some public interest, the DNR does not intend to stock the exotic and potentially disruptive yellow bass in the Yahara lakes. Thus its recent place in the sport fishery may be occupied once again by the native white bass.



Micropterus salmoides

Largemouth Bass

Ecological Requirements

Largemouth bass are found mainly in shallow waters with sparse to abundant vegetation. Their habitat is similar to that in which bluegills occur (Becker 1983). Largemouth bass prefer stable, warm water temperatures of 27–30 C (Clark 1969). They are mainly sight feeders and feed extensively on forage fish as well as small panfish. They prefer shallow, protected spawning sites among emergent vegetation in quiet bays. Spawning occurs when water temperatures reach about 16 C.

Relative Abundance

Survey Results. Largemouth bass are native to the Yahara lakes, although some stocking (mostly of fingerlings) regularly occurred in the 4 lakes from the 1930s until the mid-1950s. Stocking has been much less extensive since then.

One of the main problems in describing largemouth bass catch rates in early years is that in the rough fish seine haul data from the mid-1930s to the early 1950s, largemouth and smallmouth bass were combined as black bass (Fig. 21). Average numbers of black bass per haul for those years were 9, 4, and 3 for Monona, Waubesa, and Kegonsa, respectively. To further complicate the historical record, in descriptions of each game fish species caught during that period, smallmouth and largemouth bass were both listed as largemouth bass (Threinen 1951; Hacker 1952*a*, 1952*b*).

Black (1945), in his 2-year analysis of rough fish removal records for 1944–45, reported both species in the spring seine hauls for the lower 3 lakes. In Monona in 1944, the 2 species were captured in similar numbers (6–7/haul) (Black 1945). In the following year, the same number of smallmouth bass were captured as in 1944, but no largemouth bass were captured. In the spring hauls on Lake Waubesa, 4 times as many smallmouth bass as largemouth bass were captured in 1944 (4/haul versus 1/haul), but only a few largemouth bass were captured in 1945 (Black 1945). On Lake Kegonsa, smallmouth bass dominated the spring hauls of 1944 (21/haul versus 5/haul for largemouth bass) and 1945 (2/haul versus 0/haul).

In contrast, the creel surveys on Lakes Waubesa and Kegonsa in the late 1930s indicated that the largemouth bass were slightly more numerous than smallmouth bass, especially in the large catch from Waubesa in 1937. In the 1936 creel survey on Kegonsa, 161 largemouth bass were caught, and in the 1937 creel survey on Waubesa, 980 were caught. However, only about 60 largemouth bass were caught on each of these lakes during the 1938 survey, and even smaller numbers were caught in 1939.

The apparent decline in largemouth bass in Waubesa may have also been reflected in the rough fish haul records for black bass. The highest numbers recorded were 20 black bass/haul in 1937 and 17/haul in 1938; numbers were much lower from 1939 on, except for a slight increase in 1944 (5 black bass/haul).[16] Numbers of black bass were not tabulated for Kegonsa, but largemouth bass were described as constituting <1% of the total number of all game fish caught (Hacker 1952*b*).

[16] The data for 1944–45 differ from those cited earlier from Black (1945) because of the period covered. Black believed predator fish and panfish tended to be more onshore in spring than in fall, therefore he used haul data only from spring. In contrast, the state rough fish haul records we cite are annual totals.

The rough fish seine hauls for Lake Monona from 1934–51 indicated large fluctuations during that period (Hacker 1952*a*). In 1935, <5 black bass/haul were recorded, but by 1937, about 70/haul were caught (Hacker 1952*a*). The number of recorded largemouth bass dropped precipitously in 1938 and stayed low until 1943, when 24/haul were recorded. The catch also declined during the late 1940s until 1950, when 46/haul were captured (Hacker 1952*a*). Numbers declined again in 1951, the last year of summarized data. Because the large mesh size used in the rough fish seines would not catch small fish, greater numbers of smaller fish were probably present in the years before the peaks in the catch.

The early bass record for Lake Mendota is less complete. A 1947 fyke net survey recorded much larger numbers of largemouth than smallmouth bass. Largemouth bass represented about 3% of the total catch. However, the 1952 creel survey recorded 79 smallmouth bass but no largemouth bass. The UW's 1956–71 spring fyke net sampling averaged only 3 largemouth bass/50 net lifts for the study years, probably because the nets were set on rocky shoreline areas.

More recent DNR records indicate that most of the bass captured on the Yahara lakes have been largemouth bass, although smallmouth bass were recorded in slightly greater numbers in the 1973, 1974, and 1981–82 creel surveys on Mendota. The 1974 and 1982–83 creel surveys on Monona, Waubesa, and Kegonsa recorded more largemouth bass than smallmouth bass. However, because of the large numbers of panfish caught from the Yahara lakes, the total largemouth bass catch in the 1981–83 surveys was <1% of each total catch from Mendota, Waubesa, and Kegonsa, respectively, and only 1% of Monona's catch.

Largemouth bass were not caught frequently during the boom shocker surveys on each of the 4 lakes during the late 1970s, but more fish have been shocked since 1982. In these surveys, almost all bass caught on the lower 3 lakes were largemouth bass. On Mendota, smallmouth bass represented a higher percentage of the catch than on the lower 3 lakes but were still outnumbered by largemouth bass. Largemouth bass also were recorded in shoreline seine surveys conducted sporadically during 1966–80, indicating their reproductive success in all 4 lakes, particularly Monona and Waubesa. Smallmouth bass were generally not captured in the shoreline seines during this period. One problem with comparing the relative densities of the 2 bass species is gear selectivity. For example, largemouth bass are more easily caught in fyke net and boom shocker surveys that are conducted near the shoreline, where this species tends to be more prevalent.

Population Trends. The largemouth bass is probably one of the most abundant predator fish in the Yahara lakes. The early emphasis on stocking largemouth bass suggests that predator densities were perceived to be below desired levels for fishing. However, the lack of largemouth bass stocking since the 1950s implies that successful reproduction was occurring, most likely when aquatic macrophyte densities were high. The apparent decline of bass in Waubesa and the relatively low catches of bass in Kegonsa after the late 1930s, when these lakes had few macrophytes, indicate the need for good macrophyte cover for abundant largemouth bass populations. The lack of good survey data recording actual numbers of fish caught, plus the tendency of certain gear types to inadequately capture these fish, make more detailed analyses about largemouth bass in the Yahara lakes impossible.

Stocking of "black bass" fry in Sixmile Creek, a tributary to Lake Mendota, July 1939. Milk cans were frequently used for transporting young fish.

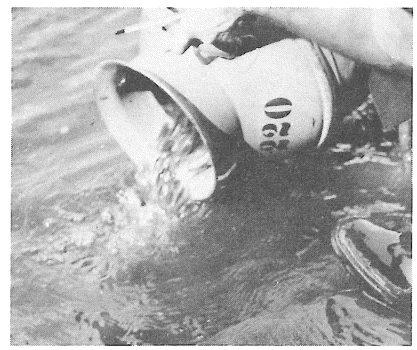


PHOTO: CARROL HANSON, DNR CENTRAL OFFICE COLLECTION

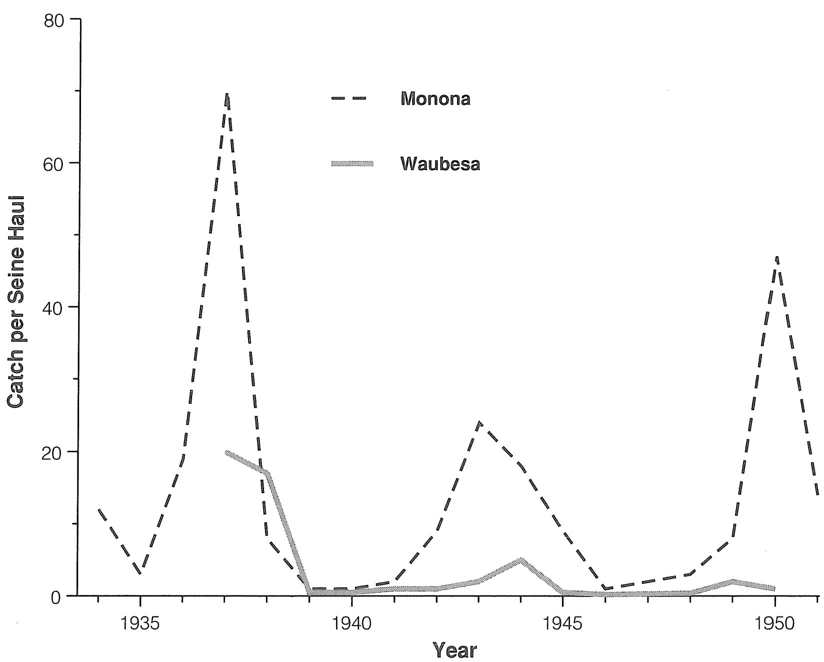
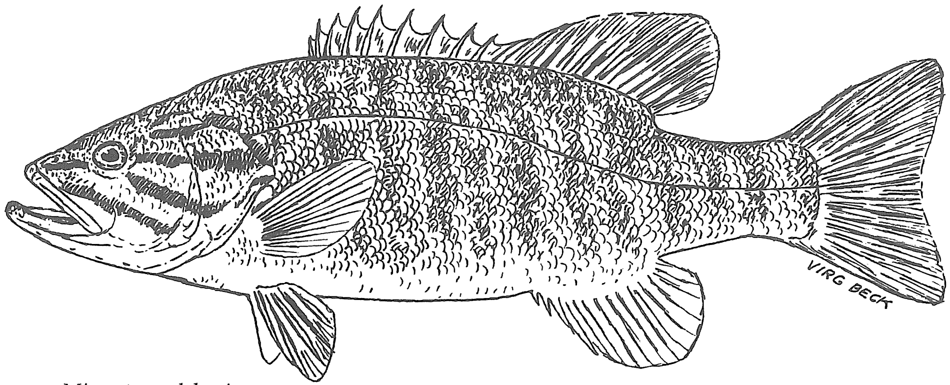


Figure 21. *"Black bass" caught in the state rough fish seine hauls in Lakes Monona and Waubesa, 1934–51.*



Micropterus dolomieu

Smallmouth Bass

Ecological Requirements

Smallmouth and largemouth bass prefer different habitat. Whereas largemouth bass seek out floating and submersed plants of warm bays and shallows, smallmouth bass prefer cooler water and appear to avoid dense weed beds (Hubbs and Bailey 1938). Instead they find shelter near or under objects such as boulders, rock ledges, or submerged logs (Becker 1983). Smallmouth bass are found most frequently in shallow waters of the epilimnion, although during the day, adults retreat to fairly deep water. Spawning occurs in nests over gravel substrate, usually beside a natural or artificial obstruction, in water temperatures ranging from 13–24 C. Smallmouth bass feed mainly on fish, crayfish, and insects from the time the young leave the nest (Becker 1983).

Relative Abundance

Survey Results. Smallmouth bass are native to the Yahara lakes, although they were also stocked in early years. As discussed in the Largemouth Bass Section, both smallmouth and largemouth bass were lumped as black bass in most of the early fishery records, including rough fish removal summaries and stocking records prior to the 1930s.[17] Most of these stockings were believed to have been largemouth bass. Smallmouth bass were sporadically stocked as fingerlings from the late 1930s and early 1940s through the early 1950s in the 4 Yahara lakes. Total numbers of smallmouth bass fingerlings stocked were less than that of largemouth bass in Mendota, Waubesa, and Kegonsa and were about equal to numbers of largemouth bass stocked in Monona during these years. Smallmouth bass have not been stocked since then.

Creel surveys in the late 1930s on Waubesa and Kegonsa recorded small numbers of smallmouth bass. Smallmouth bass were also recorded in small numbers in each rough fish seine haul during the springs of 1944 and 1945 in the lower 3 lakes (Black 1945), with the largest catch from Kegonsa in 1944 (see description in the Largemouth Bass Section).

DNR surveys in more recent years recorded small catches of smallmouth bass in the lower 3 lakes, although gear selectivity against the smallmouth bass, which prefer deeper water, may have affected catch quantity. Creel surveys during 1974 and 1982–83 recorded very few smallmouth bass, particularly from Waubesa. Boom shocking from the late 1960s and early 1970s through the mid-1980s recorded few smallmouth bass on the lower 3 lakes, with most years having no smallmouth bass. Other surveys had similar results but, again, gear avoidance may have been a problem.

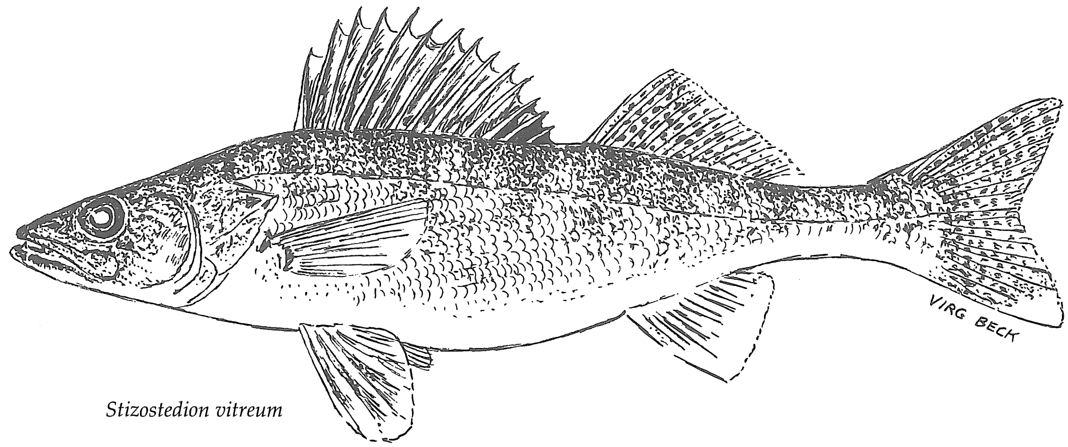
Smallmouth bass were more frequently caught in Mendota, which contains more rocky substrate and deeper habitat than the other 3 lakes. Although numbers were not large, more smallmouth than largemouth bass were recorded in the 1952, 1973, 1974, and 1981–82

[17] Because smallmouth and largemouth bass were combined in the early rough fish removal records, discussion of the catch rates from these records is presented in the Largemouth Bass Section and not repeated here.

Mendota creel surveys, the opposite of what occurred in the other lakes. The UW's fyke net survey on the white bass spawning grounds (rocky substrate) in Mendota recorded many more smallmouth bass than largemouth bass. Smallmouth bass represented $\leq$2% of the catch of all species, excluding white bass, during 1956–64, but smallmouth bass increased to 2%–4% of the catch in 1965–71. DNR boom shocker surveys recorded no smallmouth bass in 1970, 1972, and 1977. Smallmouth bass were caught during 1978–85 surveys, with relative numbers higher since 1982.

Population Trends. Little can be said about changes in smallmouth bass relative abundance because of the lack of good survey data. Smallmouth bass may have been less abundant in the lower 3 lakes, particularly in Waubesa, in more recent years than they were in the 1930s and 1940s. Habitat in the shallower, more eutrophic lakes is not suitable for smallmouth bass.

In Mendota, smallmouth bass are more abundant and appear to reproduce successfully, given that their population seems stable and that stocking has not occurred in recent years. Early records of smallmouth bass in Mendota were not available to suggest whether or not this species was more numerous when the fish were stocked in the 1940s. With its greater diversity of habitat, Mendota is probably much more suited for smallmouth bass than any of the other Yahara lakes.



Stizostedion vitreum

Walleye

Ecological Requirements

Walleyes are generally associated with large rivers and drainage lakes (Becker 1983). Although they prefer moderately fertile water, they are found in all types of lakes, ranging from clear or darkly stained soft-water lakes to eutrophic hard-water lakes like the Yahara lakes. Walleyes are usually found in deep or dark water during the day, but they migrate in the evening to bars or shoals to feed. However, in Lake Mendota, walleyes appear to inhabit the near-shore areas most of the time and are generally associated with the bottom of the lake at water depths <5 m (D. Fago, Wis. Dep. Nat. Resour., Bur. Res., pers. comm.).

Walleyes have sensitive eyes that may restrict their daytime activity (Ryder 1977), but tolerance of low oxygen levels enables them to move through the thermocline to feed (Kitchell et al. 1977). Walleyes consume almost all species of fish as well as many of the larger invertebrates (Niemuth et al. 1959). Spawning occurs soon after ice-out. Primary spawning grounds are rocky shorelines, rocky wave-washed shallows, and inlet streams or gravel bottoms.

Relative Abundance

Survey Results. While the walleye is considered native to the Yahara lakes, more walleyes have been stocked in the lakes than any other fish. Records indicate that stocking began as early as the 1880s in Mendota and Kegonsa and around 1900 in Monona and Waubesa. Most of the walleyes stocked prior to the 1940s were fry (Fig. 22). Since the mid-1940s, fingerlings have been the preferred developmental stage for stocking.

For the decades prior to 1987, the year that massive stocking of walleyes began as part of the Lake Mendota biomanipulation study, Mendota received about 93 million fry and about 1.3 million fingerlings in total. Most of the fingerlings were stocked between 1967 and 1977. Large stockings were made in 1967, 1969, and 1973; smaller stockings were made in 1971, 1977, and 1985–86. The total numbers of walleye fry and fingerlings stocked in Mendota during the first century of stocking (1885–1986) were similar to numbers stocked during the next 3 years (1987–89), the period of intensive stocking in the lake.

Records indicate about 35 million fry and 980,000 fingerlings were stocked in Monona through 1986. Much of the fingerling stocking occurred during the 1950s. Large stockings were also done in 1967, 1974, 1978, and 1986. Waubesa received 49 million fry and almost 300,000 fingerlings, with fingerlings most regularly stocked during the 1950s. Lastly, Kegonsa received 52 million fry and 3.8 million fingerlings, the most walleye fingerlings stocked in any of the 4 lakes through 1986. Fingerlings were stocked in most years between 1945 and 1976. The largest stocking of fingerlings in Kegonsa (2.0 million) occurred in 1945.

Unfortunately, little information is available to document the effect of these stockings on walleye densities in the lakes. Apparently, Waubesa and particularly Kegonsa were historically known as good walleye fishing lakes (Frey et al. 1939). Large walleyes were consistently captured in the state's rough fish removal seine hauls on Monona, Waubesa, and Kegonsa from the

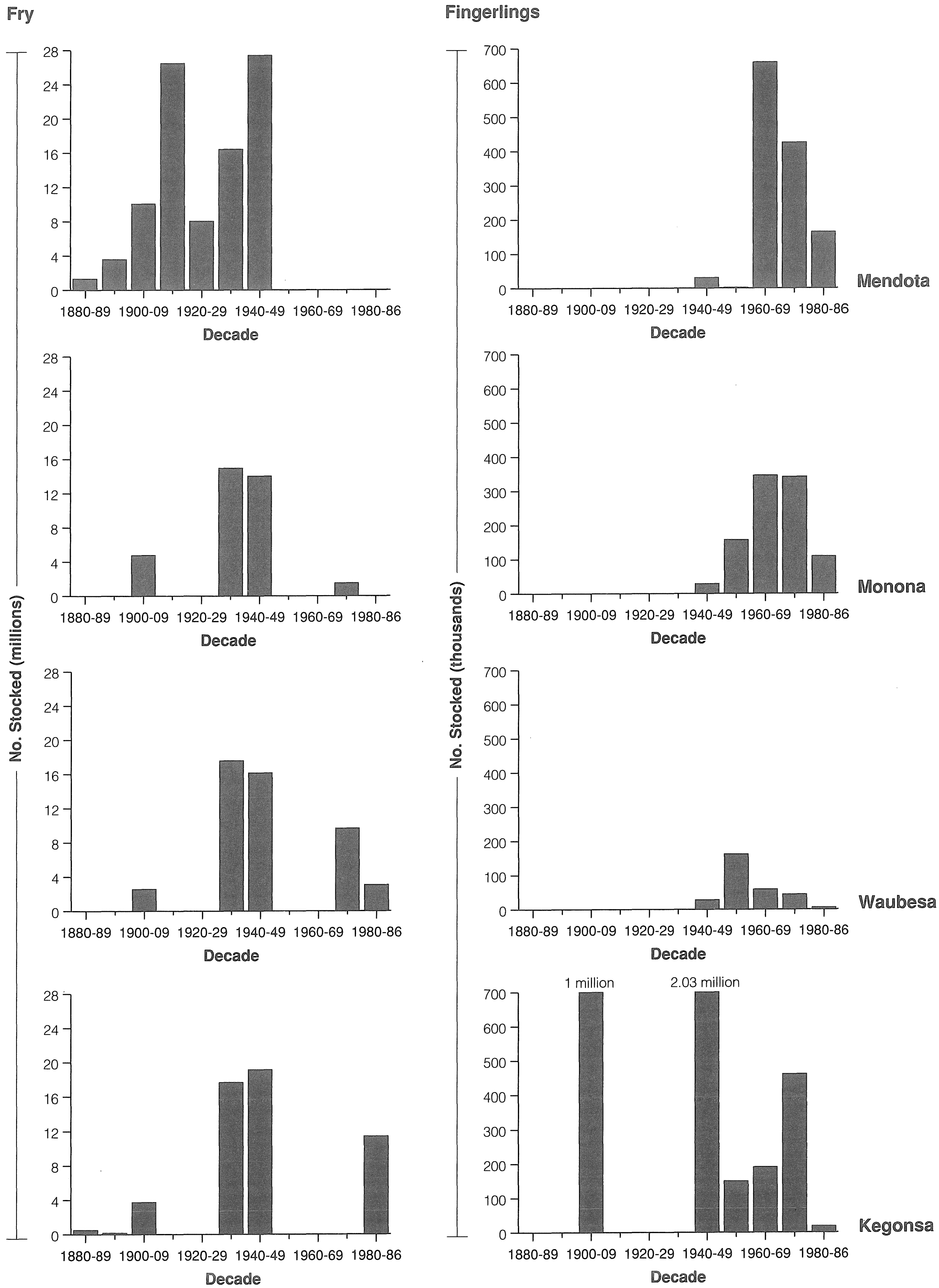


Figure 22. *Numbers of walleye fry and fingerlings stocked in the Yahara lakes, 1880–1986. Not included are the massive numbers of fry and fingerlings stocked in Lake Mendota beginning in 1987 as part of the UW biomanipulation study. Also not included are small numbers of yearlings stocked in Lake Monona in 1950–59 (1,706 total) and in 1970–79 (6,730 total).*

PHOTO: KEN CHRISTENSEN, THE CAPITAL TIMES

Members of the Mendota Fishing Association collecting walleye fingerlings reared for stocking in Lake Mendota, June 1986.

mid-1930s through the early 1950s. However, wide fluctuations in the catch per haul were evident (Fig. 23). The greatest number of walleyes per haul were captured in 1944 in all 3 lakes. Large numbers of walleyes were also caught from Waubesa in 1943 and from Kegonsa in 1937 and 1942. In creel surveys during 1936 on Kegonsa and during 1937 on Waubesa, walleyes were a significant part of the catch (Frey et al. 1939). Walleyes declined somewhat in the 1938 creel surveys on both lakes but were still numerous in the catches. However, in 1939, numbers were much lower, although many undersized 1- and 2-year-old fish were caught by individual anglers (Frey and Vike 1941). This decline is also evident in the seine haul data. Although no creel surveys were conducted during the 1940s, Black (1945) noted that fishing for walleyes was unusually good in 1944 and 1945 in all 3 lakes and especially in Waubesa. He believed that these fish were from the highly successful 1941 year class. The records are not clear as to what became of the large undersized population from the late 1930s.

No walleyes were recorded during a summer creel survey in 1952 on Lake Mendota (Kuntzelman 1952), although the voluntary survey may have had poor participation, especially during the late evening hours when walleye fishing is usually best. In the UW's spring fyke net sampling for white bass, only about 3 walleyes/50 fyke net lifts were caught during the springs of 1956–68. Between 1950 and 1966, only one small stocking of walleyes in Lake Mendota took place, hence populations may have been low. As discussed earlier, stocking of walleyes began again in earnest in 1967, when about 360,000 fingerlings were stocked in Mendota. In the UW's fyke netting during 1969 and 1970, 33 and 15 walleyes/50 lifts were recorded, respectively.

The effect of fingerling stocking in the lower 3 lakes during the 1950s cannot be assessed because of the lack of survey data. However, it was generally felt by fishery managers that populations were low, except possibly in Kegonsa. In a 1957 spring fyke net survey on Kegonsa, about 8 walleyes/net lift were captured.

More survey data are available for all 4 lakes to indicate the effect of the walleye stockings in the 1970s and 1980s. In Mendota, the fall nighttime boom shocker surveys captured 23–39 walleyes/hour of shocking in 1977–80. Numbers per hour were lower in 1972, 1977, and 1981–83. For Monona, numbers of walleyes captured while boom shocking during the 1970s and 1980s were generally much lower. Numbers of walleyes captured in Waubesa were only slightly greater than catches in Monona for most years, although more walleyes were captured in 1970–71. Boom shocking in Kegonsa also recorded low numbers of walleyes, particularly during the early 1970s and early 1980s. However, in the 1976 and 1978 surveys, almost 25 walleyes/hour were captured. Based on regular fall boom shocker surveys, a successful walleye hatch occurred in 1978 in Lake Mendota and, to a lesser extent, in the other 3 lakes. Walleyes apparently reproduced in 1983, since a few fingerlings were found in the fall surveys in all 4 lakes.

Other surveys conducted during this same period, the 1970s and 1980s, recorded walleyes but only in low to moderate numbers. In a 1974 DNR creel survey, walleyes composed a small portion of the catch, which was dominated by panfish. Among the 4 lakes, Waubesa produced the most walleyes (2% of catch) that year. The catch of walleyes during the 1981–83 creel surveys was <1% of the total catches from all 4 lakes, with Lake Mendota yielding the largest catch (0.49% of catch).

The records of fish caught in the rough fish commercial fishing operations conducted during 1976–85 indicate different numbers of walleyes netted (and released) on each lake. Large numbers were captured in 1978–79 from Kegonsa and Waubesa. Fewer fish were recorded from Mendota and particularly Monona and from the 2 lower lakes during other years.

Spring fyke netting resulted in capture of large numbers of walleyes from Mendota in 1973 and 1977, but fishing effort was intensive. An average of 20 walleyes/fyke net lift were caught in the March–April effort in 1977. Effort data were not available for 1973. In 1972, 20 walleyes/lift were also captured during a much less-extensive survey. Smaller but still significant numbers were recorded in other fyke net surveys during the 1970s and in 1985, which was the only year a survey was conducted in the 1980s. The only fyke net survey conducted on Monona was in the spring of 1976. No effort data were recorded, but walleyes represented 3% of the total catch. In a 1974 fyke net survey, 873 walleyes were captured from Waubesa. For Kegonsa, only 3 walleyes/fyke net lift were recorded in 1975, which was less than the 8 walleyes/lift captured in 1957.

Population Trends. Walleye densities in the 4 lakes have undoubtedly been augmented by long-term stocking efforts, although the establishment of large, naturally reproducing populations has apparently not been achieved. Because of poor reproductive success and overfishing, walleye densities would probably decline without stocking. Based on the limited DNR and UW survey data, it appears that some of the stockings in the late 1960s and early 1970s increased the relative abundance of walleyes in succeeding years. In particular, the natural reproduction of walleyes that occurred in 1978 in Mendota may indicate that that lake has the potential to support a self-sustaining walleye population. However, many DNR managers and other anglers have remarked how quickly those walleyes were reduced in the early 1980s, probably by overfishing.

In general, walleyes have not been considered abundant over the years; this viewpoint is probably the main reason for the continued stocking of this prized sport fish. Whether walleyes will ever be more than a stocking-dependent fishery in the Yahara lakes is uncertain. However, the massive stocking program in Mendota during 1987–89 will provide managers and scientists with an excellent opportunity to see if a large breeding population can be established and can successfully reproduce in that lake. The 2 biggest concerns are whether the small, newly hatched walleyes can survive predation by the large panfish population and whether the large-sized walleyes can survive the increased fishing pressure from avid anglers. Reduced bag limits and higher minimum legal size restrictions will be needed to maintain larger walleye densities in Lake Mendota (Johnson and Staggs 1992).

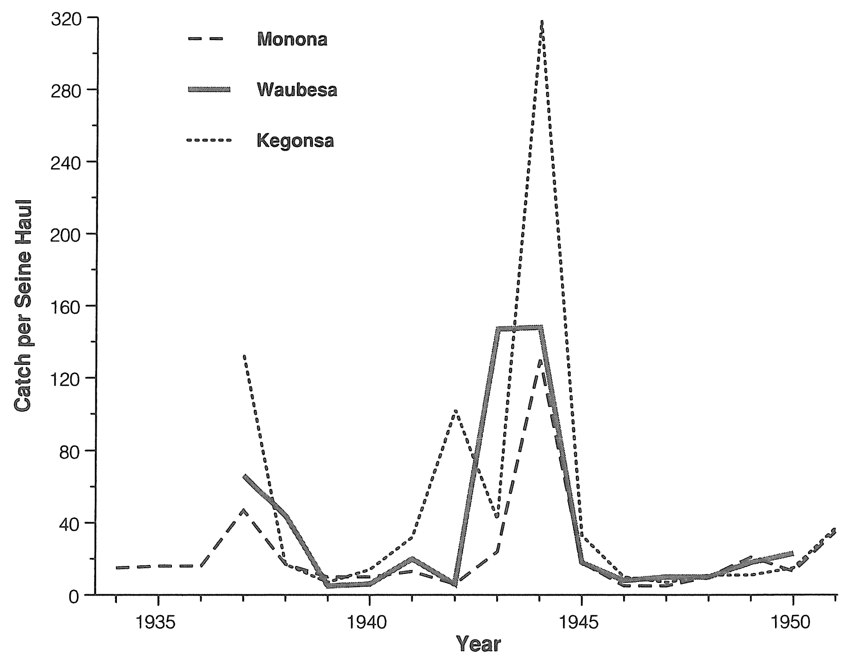
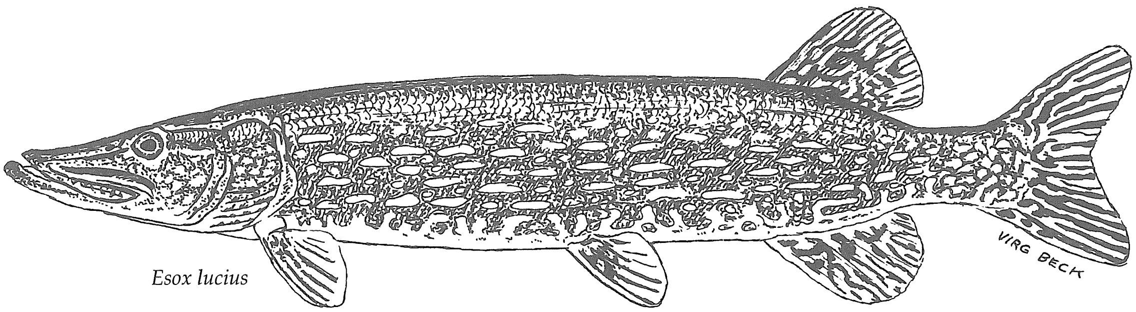


Figure 23. *Walleyes caught in the state rough fish seine hauls in Lakes Monona, Waubesa, and Kegonsa, 1934–51.*



Esox lucius

Northern Pike

Ecological Requirements

The northern pike is a cool water species (Mecozzi 1989*b*). Although northern pike generally inhabit shallow, weedy water during summer months, they may migrate to deeper water beyond the weeds in late evening (Eddy and Underhill 1976). They spawn in early spring, seeking out flooded areas with emergent vegetation. For successful reproduction, water levels in such areas need to be high and stable from the beginning of the spawning season until the young fish have hatched, grown, and moved out into the lake (Johnson 1956). Stable water levels are important because eggs are deposited on dead vegetation just below the water surface (G. Priegel, pers. comm.). In addition, the spawning areas serve as nurseries for up to 3 months (Franklin and Smith 1963).

Northern pike are tolerant of low oxygen (Cooper and Washburn 1949), although fishkills have occurred in the Yahara River when dissolved oxygen concentrations were depressed because of decomposing algae (Mackenthun et al. 1945). Northern pike are opportunistic sight feeders, consuming mainly fish (Scott and Crossman 1973, Eddy and Underhill 1976).

Relative Abundance

Survey Results. Although northern pike are native to the Yahara lakes, sporadic stocking has occurred. Of the 4 lakes, the most fish have gone into Lake Mendota. Stocking began in that lake in 1900, with 4 releases of northern pike eggs over the next 8 years. After a 2-decade lull, stocking of fry and adults occurred in separate years during the 1920s. Fingerlings were stocked annually during 1935–41. Stocking in Lake Mendota was spotty thereafter until 1981–86, when plantings were once again made each year. Since 1987, heavy stocking of northern pike has been part of the Lake Mendota biomanipulation project (Johnson et al. 1992).

Stocking of northern pike in the lower 3 lakes began in 1937. Of these 3 lakes, the most fish went into Lakes Waubesa and Kegonsa. But like the stocking in Lake Mendota, stocking in the lower lakes has varied from year to year as has the stage of development of fish that were stocked. In comparing the stocking history of all 4 lakes through 1986, nearly twice as many northern pike fingerlings have been put into Lake Mendota as into any of the 3 lower lakes. Totals for each lake were 63,103 for Mendota, 39,822 for Kegonsa, 34,338 for Waubesa, and 26,538 for Monona.[18]

Little information is available on actual densities of northern pike in the Yahara lakes during early years. Northern pike were much less frequently caught than walleyes in the rough fish seine hauls from the mid-1930s to the early 1950s on the lower 3 Yahara lakes. Monona had the lowest average number of northern pike captured per haul (3.8 fish) during those years compared with Waubesa (9.3 fish) and Kegonsa (9.4 fish). These differences in catch rates in Monona corresponded to the much-reduced area of wetlands needed for spawning (see Table 10). For Waubesa, the only lake for which data exist on annual catches of northern pike,

[18] In computing these totals, a combination of fingerlings and adults were regarded as fingerlings.

numbers per haul were greatest in 1937–38 and, to a lesser extent, in 1943–44 and 1949–50. Northern pike represented ≤1% of the creel surveys on Waubesa during 1938–39 and on Kegonsa during 1936 and 1938–39. Northern pike represented 4% on Waubesa during 1937. In general, Waubesa had higher catches than Kegonsa.

For Lake Mendota, the earliest survey information on northern pike was from a 1947 fyke net survey, in which they represented 3% of the catch. Northern pike represented 2% of the 1952 creel survey. The UW's fyke net survey from the mid-1950s through the early 1970s recorded small numbers of northern pike, representing ≤2% of the total catch, excluding white bass. Numbers per haul were generally higher in 1963–72 than in 1956–62. However, because the greatest catch per effort for northern pike is generally right around the time of ice-out, netting surveys conducted later in the spring are not good indicators of population abundance (B. Johnson, pers. comm.). The UW surveys were also conducted along rocky shorelines—areas not regularly inhabited by northern pike.

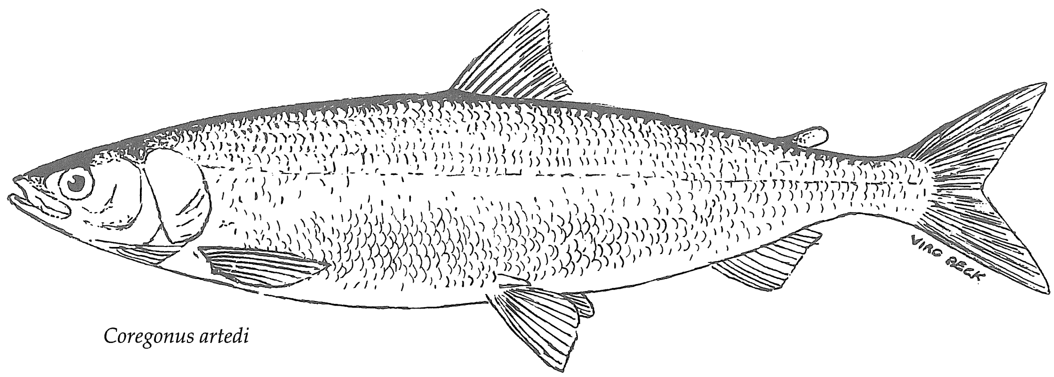
Since the early 1970s, few northern pike have been captured during the fall boom shocker surveys on the lower 3 Yahara lakes. However, because northern pike tend to avoid electroshocking, their numbers are often underestimated by this method (B. Johnson, pers. comm.). During this period, numbers of northern pike captured from Lake Mendota were largest in 1972, 1978–79, and 1982–83; numbers captured were low in other survey years. More northern pike were recorded during the 1974 and 1981–83 creel surveys on Mendota and Monona than on Waubesa and Kegonsa. The greatest percentage of the total catch was on Mendota in 1974 (2%). Reproductive success of northern pike was good in Mendota during the springs of 1971–76, when lake levels were generally high; reproductive success was generally poor from 1980–85. (More recently, efforts have been made to maintain adequate water levels during the spring spawning season.)

Population Trends. Numerous changes in the lake environment have negatively impacted northern pike abundance in the Yahara lakes. Most prominent of these changes are the loss of wetlands and the channelization of tributaries around all 4 lakes. Lake levels are probably another negative factor; for several decades, levels of the Yahara lakes have been lowered in the fall to restrict shoreline ice damage and to prevent flooding from spring runoff. During many years, these lower water levels kept adjoining marshes from reflooding in the spring, thus reducing the spawning success of northern pike and, presumably, their abundance as well. Another possible factor affecting the general decline in northern pike abundance in many southern Wisconsin lakes was macrophyte control (eradication) in the lake shallows (Brynildson 1958).

Although northern pike densities in the Yahara lakes have apparently declined since presettlement times, the evidence is circumstantial, based on documented loss of wetlands rather than on actual survey information. The lower catch rates of northern pike in the rough fish seine hauls from Monona during the 1930s and 1940s, as compared with Waubesa and Kegonsa, correspond to the greater loss of wetlands around Monona. The natural reproduction of northern pike in Mendota during the 1970s, when lake levels were high, demonstrates the need for lake level controls as well. The more extensive wetland system around Mendota may account for the greater numbers of northern pike recorded there in boom shocker surveys since the early 1970s than were recorded in the lower 3 lakes. Because catch rates in all 4 lakes have never been high, it is difficult to separate the effects of natural reproduction from those of stocking on the fishery.

PHOTO: BOB QUEEN, DNR CENTRAL OFFICE COLLECTION

DNR personnel stocking northern pike fingerlings in Lake Mendota, 1990.



Coregonus artedi

Cisco

Ecological Requirements

Ciscoes require colder temperatures than any of the other species found in the Yahara lakes. They are therefore found mainly in Lake Mendota and, to a lesser extent, in Monona.

In addition to these general temperature preferences, specific temperature-oxygen criteria are a limiting factor for ciscoes in summer. Low oxygen concentrations (<3–4 mg/L) in waters below the upper thermocline and high temperatures (>22 C) in surface waters restrict ciscoes to a narrow depth layer at the bottom of the epilimnion—the "cisco layer" (Frey 1955, Rudstam and Magnuson 1985). In Lake Mendota, this layer is usually adequate enough to allow ciscoes to occupy a broad depth range (4 m) throughout the lower epilimnion and to survive in most summers (Rudstam and Magnuson 1985). However, in some hot summers, low oxygen levels force ciscoes upward into warmer waters; the result is a cisco kill. In Lake Monona, the cisco layer is narrower, and hypolimnetic anoxia lasts as much as one month longer, making cisco habitat marginal except in cool summers. Because shallower Lakes Waubesa and Kegonsa do not permanently stratify in summer, their water temperatures are too warm for ciscoes.

Ciscoes spawn in late fall, around early December, when water temperatures drop below 4 C (Neuenschwander 1946, John 1954). Spawning occurs in shallow water over sand, gravel, or rocks in Lake Mendota, and ciscoes have occasionally been seen spawning in the Yahara River downstream from Lake Mendota's outlet. These fish may have been from Lake Monona.

Ciscoes are mainly planktivorous; their many long, fine gill rakers adapt them well to a zooplankton diet (Cahn 1927). One feeding limitation is that ciscoes do not move freely through the thermocline (Kitchell et al. 1977). Recent evidence indicates that abundant cisco populations in Lake Mendota can prevent the larger-bodied *Daphnia pulicaria* from developing during the spring (Vanni et al. 1990, Lathrop and Carpenter 1992*b*, Rudstam et al. 1993). Smaller-bodied *D. galeata mendotae* dominates as a result. Because *D. pulicaria* has higher filtering rates for algae than *D. galeata mendotae*, links have been made between cisco numbers, these 2 food organisms, and lake clarity. In years when ciscoes appear abundant and *D. galeata mendotae* dominates, water clarity is poorer (Lathrop 1992*b*). Likewise in years when ciscoes do not appear abundant and *D. pulicaria* dominates, water clarity is greater.

Relative Abundance

Because the cisco is strictly a pelagic species that feeds almost exclusively on zooplankton, and because ciscoes mainly occur in Lake Mendota and to a lesser extent in Lake Monona, WCD/DNR surveys have rarely captured them. Most information about this native species has been obtained by the UW as part of their research interest in the pelagic fish species of Lake Mendota. Almost no data exist on ciscoes that have been periodically found in Lake Monona, but the population is not thought to be large. Fish migration from Lake Mendota may be important for re-establishing the population in years following fishkills.

Early Fishery. Neuenschwander (1946) summarized the historical cisco record from newspaper clippings dating back to 1855. These accounts indicate that the cisco is native to Lake Mendota as well as other deep lakes in southern Wisconsin. John (1954) studied the cisco's ecological requirements in Lake Mendota and also commented on the historical cisco fishery. The following account of the early fishery is taken from these sources.

The spawning season in the late fall was traditionally cisco fishing time in Madison, and a seasonal commercial fishery existed from the 1860s to the early 1940s. Ciscoes were described as being "caught in great numbers from the waters of Lake Mendota . . . and extensively used upon the tables of the hotels of Madison, and by the people of that city generally" (Comm. of Fish. 1880:15). They were so abundant in Lake Mendota during this period and so prized as a commercial species that eggs were frequently collected for hatching and stocking in other Wisconsin lakes (Becker 1983).

From the 1860s to the 1880s, ciscoes were speared at night, by the light of torches, during fall spawning on Lakes Mendota and Monona, before and sometimes after freeze-up, at depths of up to about 5 m. Between 1864 and 1884, spearers and dip-netters apparently caught 100–480 ciscoes/night. The fish were sold locally, sometimes from wheelbarrows at street corners. In good years (1878 and 1892), ciscoes were shipped out of town as well. The spearing era ended in 1885, and a switch to nets took place. John (1954) tells of a veteran cisco angler who recalled a spectacular season during the cisco spawning run in 1892. He and 4 companions travelled by horse and buggy from their homes near Tenney Park to Governor's Island where they set up a fishing camp. Throughout the fishing season, wagons from a local fish market travelled to the various fishing camps to purchase fish. That season, the 5 anglers caught at least 8,500 cisco, of which 3,000 were believed to have been caught in one night.

Gill nets (introduced ca. 1870) were used commercially until 1934, when they were permanently banned. The use of gill nets peaked in 1931, when 171 people received permits for 30 m of net each. Dip-nets (introduced ca. 1880) ultimately replaced gill nets. From 1934 to 1941, dip-net permits were issued annually to about 50 people, who were often able to dip more ciscoes in a night than they had been able to catch in a 30-m gill net.

Summer Mortalities. In addition to this exploitation, Lake Mendota ciscoes regularly experienced summer mortalities, typically between mid-July and late August. In the falls of both 1858 and 1871, local newspaper articles covered these fishkills, which included other fish species but were composed mainly of whitefish (ciscoes). These mortalities were said to occur either every 3 years (*Wisconsin State Journal*, 16 Aug 1858) or nearly every season (*Wisconsin State Journal*, 16 Aug 1871). Although the estimates of recurrence were obviously rough, they indicate that the mortalities were fairly common. Severe die-offs were specifically mentioned for 11 years: 1849, 1858, 1871, 1884, 1890, 1892, 1925, 1931, 1932, 1940, and 1941, with less significant mortalities in 4 other years (1942, 1947, 1953, and 1955) during which the population of ciscoes was much lower (Neuenschwander 1946, John 1954, John and Hasler 1956).

The worst mortalities appear to have occurred in 1884, 1932, and 1940. The 1884 epidemic of yellow perch and ciscoes included what Forbes (1890:484) termed "extraordinary numbers" of whitefish; considering their relative numbers, he felt they may have died in as large or even larger proportions than the yellow perch. The 1932 mortality was cited by John and Hasler (1956) as the worst since the 1840s. On 30 July 1932, Telford (1954) saw thousands of dead 30- to 33-cm fish. Bathers were warned a few days later that hundreds of thousands of rotting fish had polluted the city beaches (K. Christensen, *The Capital Times*, 16 Dec 1981). John and Hasler (1956) reported that an estimated 100 tons were removed by the city. The 1940 mortality was also severe, for Bardach (1951) felt it was worse than the one in 1932.

In 1884 and 1940 the dead fish showed no visible signs of disease. In 1940 people retrieved dying ciscoes from the shoreline for personal consumption (Arthur Hasler, pers. comm. as cited in John 1954). In 1953, however, some fish showed extreme necrosis of the gills. Sometimes dying ciscoes showed no signs of stress. On other occasions they were clearly distressed, for example, swimming with their heads above water and gasping (John 1956).

In all of these various summer mortalities, no ciscoes <3 years old were reported (John and Hasler 1956). Older fish are thus apparently more likely to be affected by the stress produced from high water temperatures and low dissolved oxygen.

Population Decline. In some years, good fall spawning runs and/or harvests followed summers with significant mortalities (Magnuson and Lathrop 1992). This was true in 1892, when the local newspaper stated that "the fish market of Madison was never so well supplied as at present." It was true again in 1932; after heavy summer mortalities, fishing was better than it had been in 1931. However, after the early 1940s, the cisco population severely declined in Lake Mendota (John 1954). In 1940, the cisco population was probably abundant before the severe mortality that occurred that summer. Wright (1968) noted that 10,000 ciscoes were captured in a single rough fish seine haul in 1940, although it is not clear if this haul was taken before or after the mortality. (Unfortunately none of the records on ciscoes or other sport fish [game fish] were ever summarized from the rough fish removal data on Mendota.) In 1941, there was not much of a spawning run according to Telford (1954), an old-time cisco angler who had caught only 10 that year. In 1942 there was also no cisco run, and John and Hasler (1956) noted that between 1942 and 1948 there were several seasons when no ciscoes were seen or caught.

John (1954) studied the relative success of year classes during this period of apparent decline. The most successful year class was in 1944, with less successful ones in 1947 and 1950. Ciscoes apparently did not have successful year classes in the other years. Because of the decade of poor reproductive success, John (1954:113) believed the cisco population at the end of 1953 to be "at an all-time low."

Ciscoes continued to be scarce from the 1950s through the mid-1970s, causing many people to think that they were essentially extirpated from Lake Mendota. However, because occasional cisco mortalities continued to occur, ciscoes were obviously still in the lake. In August 1968, a "significant" mortality was noted, with many 38- to 46-cm ciscoes struggling or dead on the surface of Lake Mendota (C. W. Threinen, Wis. Dep. Nat. Resour., Madison Area files, unpubl. data collected in 1968). In September of the following year, 11 dead ciscoes were collected from Lake Mendota (UW Cent. Limnol. files, unpubl. data). These fish ranged from 31–48 cm in length.

The cisco decline was thought to be a result of increasing eutrophication of Lake Mendota after the 1940s (John and Hasler 1956). Although algal blooms apparently became more of a problem in the decades after the mid-1940s, summer dissolved oxygen concentrations did not decrease from concentrations in earlier years when the cisco fishery flourished. Stewart (1976) compared oxygen data that he collected during the 1960s with data collected by E. A. Birge for many years around the turn of the century. He concluded there was no substantial difference in oxygen concentrations in Mendota between the 2 periods.

Populations Return. Ciscoes began showing up in Lake Mendota again in 1977. The first records were catches of both 1- and 2-year-old ciscoes by the UW limnology class (UW Cent. Limnol., unpubl. data). A more publicized surprise occurred when ciscoes began taking yellow perch bait during the winter of 1977–78. Ciscoes

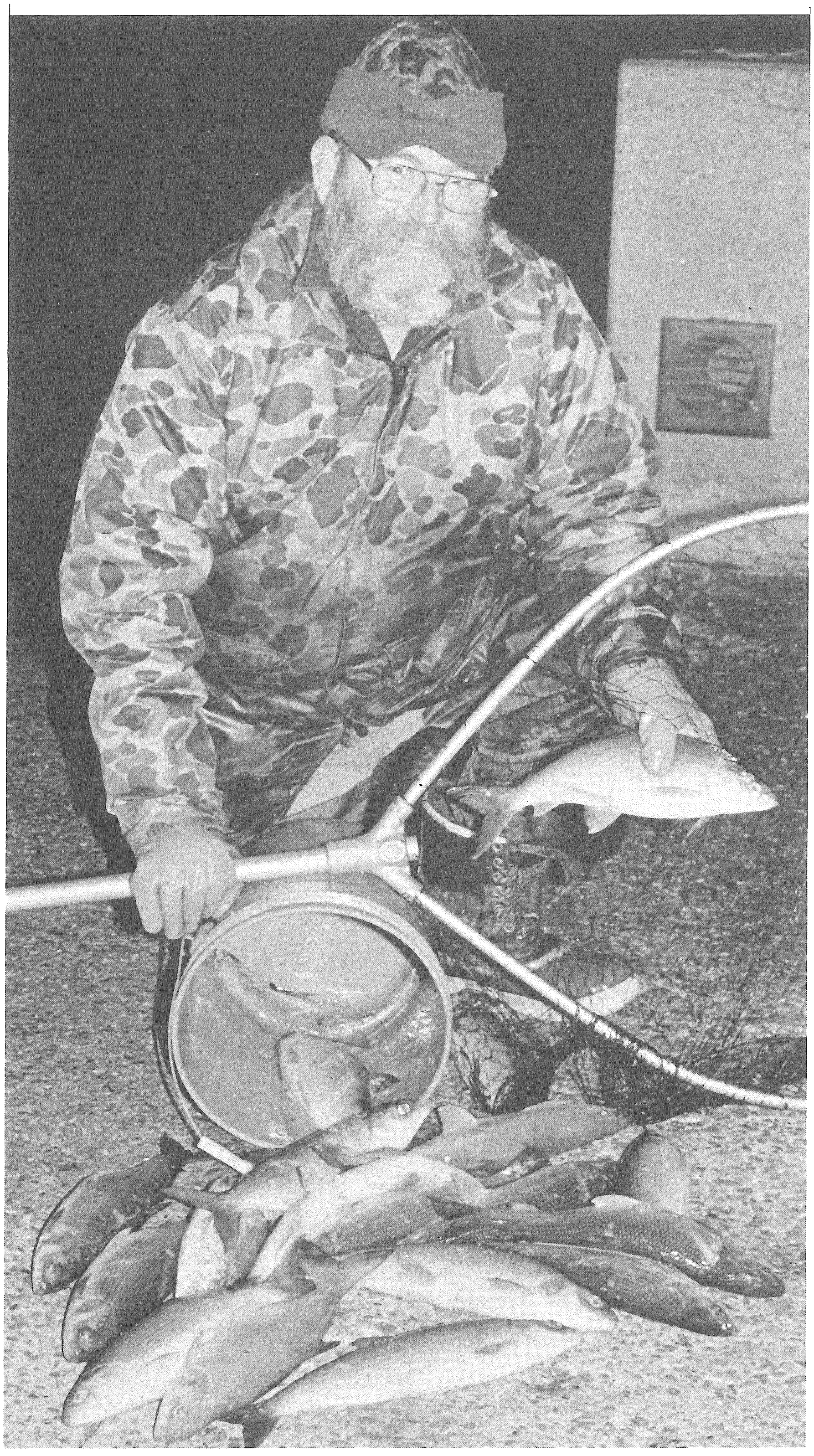


PHOTO: KEN CHRISTENSEN, THE CAPITAL TIMES

Cisco dip-netted from Lake Mendota along UW shoreline, late fall mid-1980s.

had never been numerically important in the winter fishery in Lakes Mendota and Monona (K. Christensen, pers. comm.), but they had been caught by winter anglers in other lakes in southern Wisconsin. Many of the winter anglers in Madison assumed there were no ciscoes in the lakes; when ciscoes reappeared, some anglers initially mistook them for overgrown shiners and left them to rot (K. Christensen, pers. comm.), But during the fall of 1978, a spawning run was observed in the Yahara River above Lake Monona, and people began dip-netting ciscoes again.

During the 1980s, prior to a massive mortality in August of 1987, fall spawning congregations were a regular event, and many ciscoes were taken while spawning in Lake Mendota. Summer mortalities occurred in 1980 in Mendota and to a lesser extent in Monona, where a lifeguard picked up about 200 dead ciscoes in less than a week (K. Christensen, *The Capital Times*, 20 Aug 1980). The fish caught between the winters of 1979 and 1981 were primarily from one year class, hatched in the spring of 1977 (Rudstam 1983, Rudstam et al. 1992). Scales taken from spawning ciscoes from the Yahara River above Lake Monona were of the same age and showed similar growth patterns as scales taken from Lake Mendota fish (Rudstam 1983). It is unknown if these Lake Monona fish matured in Monona, where temperature and oxygen conditions are less favorable for ciscoes, or if they came from Lake Mendota. In 1981, the cisco population in Mendota was estimated, through the use of sonar, to be 2 million fish, a remarkable comeback for a supposedly extirpated species (Rudstam et al. 1987). Smaller year classes also occurred in 1982 and 1985 (Rudstam et al. 1992).

A summer mortality of older ciscoes took place in 1983 in Lakes Mendota and Monona, but population levels in Lake Mendota only dropped about 30% (Rudstam et al. 1992). Cisco populations remained high until the large summer mortality in 1987. According to Rudstam et al. (1992), most of the fish dying that year were from the 1977 year class. The population apparently declined by over 90% as a result of the 1987 mortality. Ciscoes have not had a significant hatch since then. The effect of this cisco kill on Lake Mendota's plankton community was evaluated as part of the ongoing DNR/UW biomanipulation study (Vanni et al. 1990; Rudstam et al. 1992, 1993).

Population Trends. Early accounts suggest that ciscoes were probably abundant in Lake Mendota and, to a limited extent, in Lake Monona, from at least the mid-1800s to about 1940. In many years there were summer mortalities, with the most severe occurring in 1884, 1932, and 1940. It is not known what proportion of the cisco population died during each of those years, but the effects seemed to have been short-lived, as the commercial cisco fishery thrived. However, during the 1940s poor spawning success apparently caused cisco numbers to decline.

Between the early 1950s and about 1976, few ciscoes were caught in Lake Mendota, and the population was considered extirpated by many. Reasons for this probable decline were never conclusively demonstrated, but eutrophication of Lake Mendota was thought to be indirectly responsible. However, in 1977 a major hatch of ciscoes occurred. As a result, ciscoes remained abundant until a major mortality occurred during the summer of 1987. Water temperatures were particularly warm that summer, forcing the ciscoes (a cold water species) to be stressed by too warm temperatures and too little oxygen.

During the 1980s, ciscoes were often seen spawning in Lake Mendota and the Yahara River below the outlet of Mendota, but only 2 minor successful hatches have occurred (1982 and 1985). A much smaller population of ciscoes currently remains in Mendota after the massive 1987 die-off. The status of this species is being intensively studied by the UW and DNR, due to the cisco's key role in controlling *Daphnia* populations and concomitant water clarity in the lake.

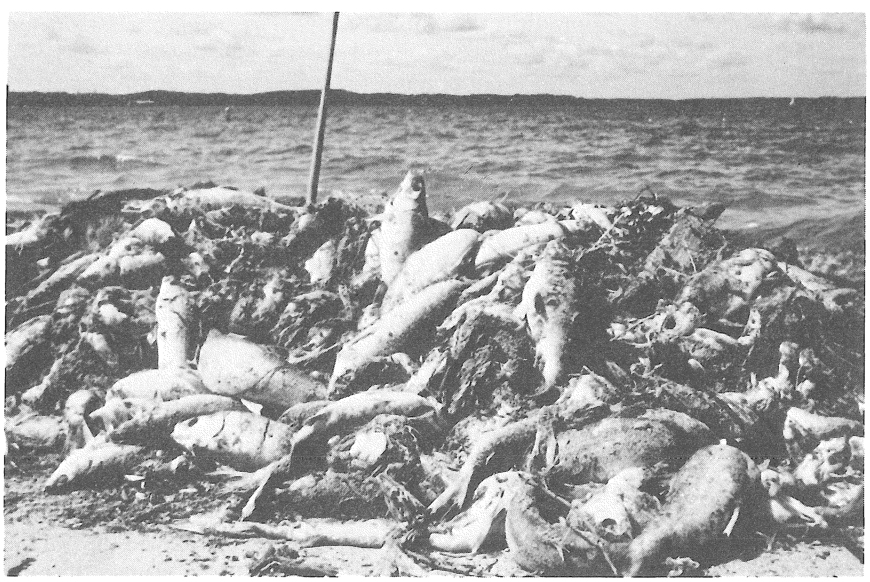
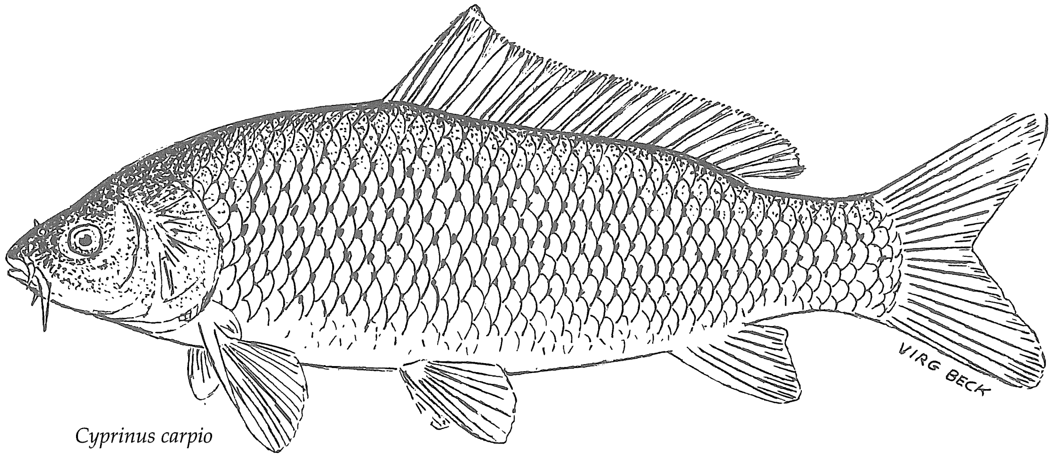


PHOTO: BRETT JOHNSON, DNR MADISON AREA OFFICE COLLECTION

Cisco kill in Lake Mendota during the late summer of 1987. Such summer mortalities of cisco have periodically occurred since they were first recorded in the mid-1800s.



Cyprinus carpio

Common Carp

Ecological Requirements

Common carp adapt to a wide variety of conditions. Their broad habitat requirements enable them to become widespread, unaffected by low oxygen content, silting, pollution, or sudden temperature changes (Lagler et al. 1962). Carp are able to use atmospheric oxygen and can thus survive in waters with very low oxygen levels (MacKay 1963), although major carp die-offs due to decomposing algae and concomitant low dissolved oxygen concentrations have occurred in the Yahara River system (Mackenthun et al. 1945). Carp prefer shallow water and seek out weedy areas for spawning.

Carp are opportunistic omnivores (Frey 1940). Their characteristic bottom-feeding behavior reduces macrophytes directly (by uprooting) and indirectly (by shading resulting from decreased water transparency) (Black 1946, Threinen and Helm 1952*b*). These activities create conditions in which carp thrive but sight-feeding fish do not. When carp densities are high, carp may compete directly with other fish species by reducing invertebrate densities as well as consuming fish eggs.

Stocking History

The common carp, not native to North America, has proliferated in astounding numbers since its first introduction to this country by private entrepreneurs and the U.S. Commission of Fish and Fisheries in the 1870s (Moyle 1984). The interest in establishing a carp fishery was primarily the result of immigrating Europeans accustomed to carp as part of their diet. In the 1880s, there was so much interest in raising carp that the stocking ponds in Washington, D.C. had to be guarded (Eddy and Underhill 1976), and congressional representatives vied with one another to distribute live carp to their respective districts (Moyle 1969).

Wisconsin's first carp arrived in Madison in 1880 to be used as breeders at the Wisconsin Fish Hatchery, Fitchburg (now known as the Nevin State Fish Hatchery) (Comm. of Fish. 1881). State waters were stocked with approximately 103,000 carp between 1881 and 1896, and Dane County received almost 4,000 carp (Frey 1940). The majority of those fish were probably stocked in the Yahara River system. Although no official records of carp being stocked in the Yahara lakes have been found, carp for stocking were reported to have been first supplied to individuals in the Madison area in 1887, an effort which continued until 1893 (McNaught 1963).

To assist in carp propagation nationwide, the Wisconsin State Fisheries Commission distributed a booklet on carp culturing (DeLoughery 1975). However, the U.S. Fish Commission ended the carp distribution in 1897, both because the species was well established in U.S. waters and because complaints about carp were already beginning (Moyle 1969).

Rough Fish Removal History. There is little quantitative documentation of carp numbers in the Yahara lakes from the end of the stocking period in the late 1800s until the early 1930s, but the rapid proliferation of carp during this period is unquestionable. By 1913, carp were observed to "abound" in Lake Wingra and were believed to contribute to that lake's poor water clarity (Cahn 1915:128). Prior to the 1930s, commercial fishing to remove carp was initiated, but records of the amounts removed were not found. Photos of commercial crews removing carp in the early 1930s indicate carp were abundant in the lower Yahara lakes at that time. As a result, in 1934 an intensive, long-term program to remove rough fish from the Yahara lakes was begun by the WCD.

The early history of carp in the Yahara lakes is rich with information on the disposition of carp caught during the state's 35-year removal program. Small carp, <2.5 lb (<1.1 kg), were either buried or processed as animal food. In 1934, a state-run cannery was built at Milton Junction, but the operation was moved to the Nevin State Fish Hatchery near Madison in 1936, which for a time was canning 800 lb carp/day (MacKenzie 1936). The cannery was later moved to Wisconsin Dells in 1938. Canned carp were used to feed mink, fox, and other furbearers at the State Experimental Game and Fur Farm at Poynette and to feed adult trout, bass, and other species kept for breeding purposes at hatcheries. Small carp were also sold fresh to mink ranchers and fox ranchers (Miller 1952).

Large carp, >2.5 lb (>1.1 kg) were kept either in pens in the lakes, in small embayments (e.g., at the outlet of Lake Waubesa), or in large, spring-fed holding ponds (e.g., Token Creek) until they were shipped live to market. According to an article in the *The Capital Times* (5 Jan 1958), the carp were held both to wait for favorable market conditions and to avoid destroying the value of the fish by dumping them all on the market at once. J. Rosenthal (*The Capital Times*, 25 Aug 1958) described carp from the lower 3 Yahara lakes being trucked to Wisconsin Dells, where they were kept in holding ponds and fed corn during the winter months until they were weighed and shipped out by railroad. Markets for human consumption were located in New York, Philadelphia, Chicago, Memphis, and Louisville (*The Capital Times*, 13 May 1963; Miller et al. 1959). In addition, carp were sold to Illinois, Missouri, and North and South Carolina, for stocking in commercial fishing ponds. Large quantities of carp once went into the making of gefilte fish, but in the 1960s that market declined when people began to use whitefish and northern pike. The price of carp, according to *The Capital Times* (18 Sep 1962), dropped from \$.10/lb (\$.22/kg) in previous years to only \$.015–.03/lb (\$.03–.07/kg) in 1962.

The state stopped its rough fish removal program in 1969 because of rising program costs, public concern over the state running a profit-making operation, and the need to use the limited work force for other important fish management activities. Commercial fishing licenses for carp and other rough fish (e.g., bigmouth buffalo and freshwater drum) were then issued in 1974 for the Yahara lakes. However, the commercial fishing effort is governed by the market price of carp and the total quantity of carp that can be sold during any one season. In the spring and late fall, when carp are most easily caught, the market is often flooded with carp. The effort on each lake for any one year is also a function of the size and condition (plumpness) of the carp;

ILLUSTRATION FROM COMMISSIONERS OF FISHERIES (1883)

Wisconsin Fish Hatchery, Fitchburg, located near Madison, showing fish rearing ponds including those used for carp propagation, circa 1882.

PHOTO: EUGENE SANBORN, DNR CENTRAL OFFICE COLLECTION

PHOTO: EUGENE SANBORN, DNR CENTRAL OFFICE COLLECTION

PHOTO: D. H. KIPP, STATE HISTORICAL SOCIETY OF WISCONSIN COLLECTION

Carp caught in rough fish seine hauls (top) were often transferred to holding pens (center) or cribs (bottom) and held until market prices became favorable. Top photos taken on Lake Kegonsa in the mid-1930s; bottom photo taken on Lake Monona in the early 1930s.

small, thin carp are less valuable. Poor condition was characteristic of Waubesa and Kegonsa carp in the mid-1980s (G. Priegel, pers. comm.), although small yields of the more commercially valuable buffalo have decreased the fishing effort for carp. Lake Mendota also receives less effort than Waubesa and Kegonsa because, with its large surface area and rough water, it is harder to fish. As a result, fewer carp have been removed annually from the Yahara lakes since the end of the state removal program in 1969.

Relative Abundance

Survey Results. In 1934, the first year of extensive rough fish removal by the state, about 660,000 lb of carp were seined from Lake Monona. In 1935, about 35,000, 580,000, 530,000, and 400,000 lb of rough fish (mostly carp) were removed from Lakes Mendota, Monona, Waubesa, and Kegonsa, respectively. A decrease occurred in the amount of carp removed the following year from the lower 3 lakes. The decrease was dramatic in Lake Waubesa, because the carp population there was dominated by fish too small to be netted in the large-mesh seines. A major effort to remove these small carp using small-mesh seines removed 9 million fry and fingerlings from the 3 lower lakes in 1936 (Frey 1940). In 1936, the amount of rough fish removed increased by one order of magnitude on Lake Mendota.

Within several years, carp catches were once again high in the 3 lower lakes. The 1938–39 rough fish removal (mostly carp) from Lake Monona averaged 900,000 lb. From Kegonsa, the amount of all rough fish removed increased to about 800,000–1,300,000 lb for 1938–42. From Waubesa, about 3,200,000 lb were removed in 1938–39, with 2,100,000 lb removed in 1938 alone (Helm 1951). This 1938 harvest from Waubesa was almost double the largest amount removed in any year from any of the 4 Yahara lakes during the 35-year history of the state rough fish removal program. In fact, during this 35-year period, only 4 other annual totals for any of the 4 lakes even approached one million lb. By comparison, the annual catch of carp from Lake Mendota during 1938–42 never exceeded 150,000 lb.

Comparing these annual totals of carp removed from each of the Yahara lakes over time shows differences in catch rates between lakes and between years for individual lakes. However, varying numbers of seine hauls each year necessitate the use of catch-per-effort data for more accurate comparisons. Unfortunately, effort information for Mendota was found only for 1963–66, whereas effort data for the lower 3 lakes were available for the mid-1930s through the early 1950s and for 1960–66.

As a result of the large 1936 hatch of carp in the lower lakes, the amount of carp removed in 1938 was 40,700 and 45,000 lb/haul for Monona and Waubesa, the highest during the years of record for those 2 lakes (Fig. 24). The Kegonsa catch was 30,200 lb/haul in 1938. For the period of 1939–45, Monona's average catch dropped to 16,700 lb/haul (Hacker 1952*a*) while Waubesa's and Kegonsa's catches stayed relatively high at 30,400 and 30,700 lb/haul, respectively (Helm 1951, Hacker 1952*b*). Carp removed from Monona and Kegonsa for 1946–51 declined to averages of 11,700, and 14,800 lb/haul, respectively; removal from Waubesa for 1946–50 declined to 17,300 lb/haul.

Comparing these statistics with the history of Madison's sewage treatment offers a possible explanation for the changes in catch per haul. Catches were high in the shallow lower 2 lakes during the years when the lakes were heavily enriched with nutrients from the sewage effluent that was discharged to Waubesa from 1936 until 1958. The decline in catch rates for all 3 lakes suggests that the rough fish removal program was effective at controlling carp, even though Waubesa and Kegonsa were enriched by an increasing discharge of sewage effluent until this discharge was diverted in 1958. Because no carp removal was conducted prior to 1936, it cannot be conclusively demonstrated that the additional fertility caused a major increase in carp. However, Frey's (1940) description of the abundant aquatic macrophytes in Waubesa prior to 1936 suggests that the carp were not as abundant there prior to the discharge.

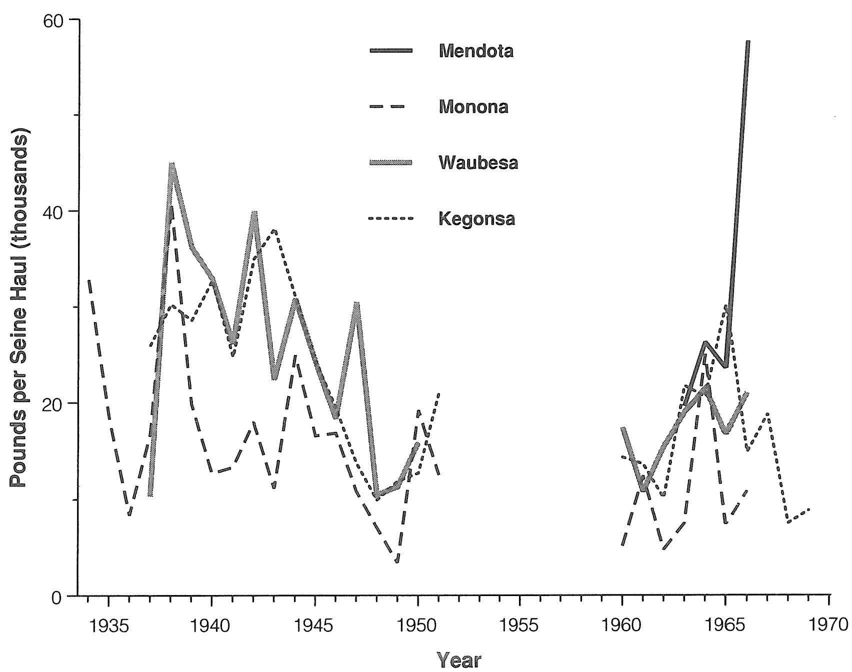
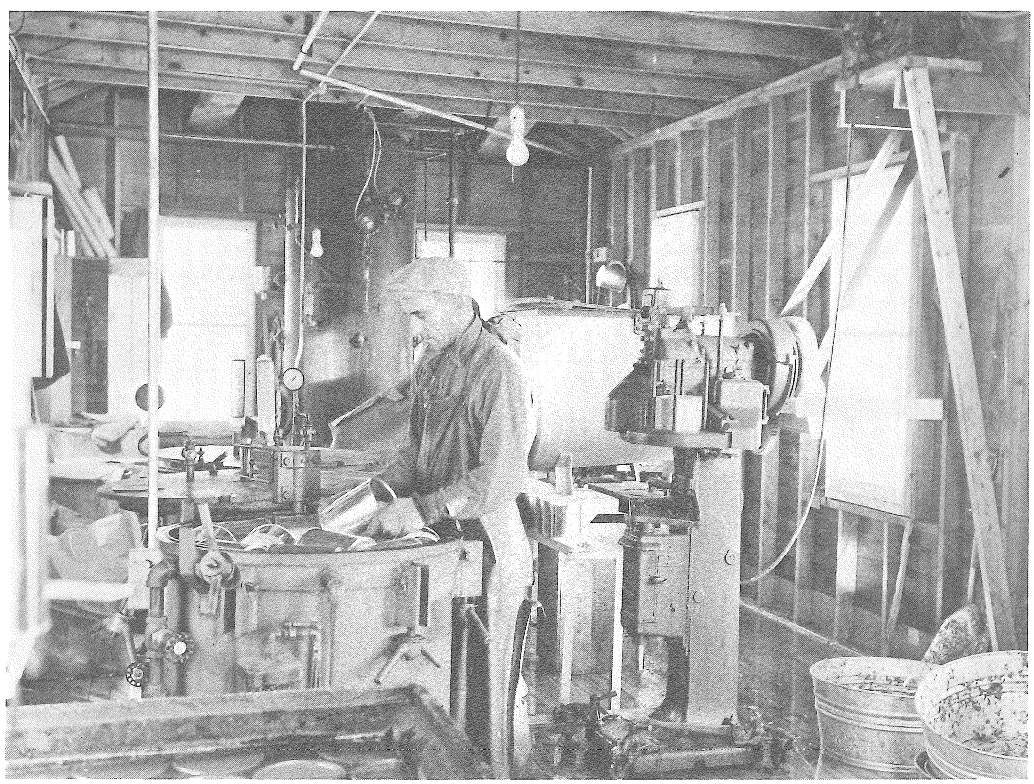


Figure 24. *Carp caught in the state rough fish seine hauls in the Yahara lakes, 1934–69.*



PHOTOS: EUGENE SANBORN, DNR CENTRAL OFFICE COLLECTION

After removal from the lakes, small carp were disposed of, such as these being spread on a farm near Lake Waubesa in 1939 (top), or processed as animal food. Processing took place at a special cannery (bottom) at the Nevin State Fish Hatchery, where cans of carp were heated in large pressurized cookers (photo dated 1936).

PHOTO: STABER REESE, DNR CENTRAL OFFICE COLLECTION

Large carp were sold to out-of-state markets. Some were hauled by fish dealers' trucks (top) or shipped by special train cars (center). Train cars (bottom) had holding tanks cooled by ice blocks.

PHOTO: STABER REESE, DNR CENTRAL OFFICE COLLECTION

PHOTO: DNR SOUTHERN DISTRICT HEADQUARTERS COLLECTION

After 1951, records of carp catches from the Yahara lakes are less extensive, because the rough fish seine haul data were never extensively summarized. In addition, no data are available on the various weight classes of carp removed in the seine hauls. The total pounds of carp removed from Lake Monona decreased after 1950, but seining effort also decreased after that time. On Lakes Waubesa and Kegonsa, which were enriched by sewage effluent until 1958, much larger amounts of carp were removed after 1950, with a slight decrease in the late 1960s. The carp removal from Lake Mendota was generally the smallest of the 4 Yahara lakes during the 1950s and 1960s, except for large quantities taken in 1963–66. One of the reasons for the low carp removal is that the lake is too large and too deep to effectively seine (G. Priegel, pers. comm.).

Catch-per-effort data for the carp removed during 1960–66 from each of the lower 3 lakes were similar to data for 1946–51. Averages for the 1960s were 10,400, 17,400, and 17,900 lb/haul for Monona, Waubesa, and Kegonsa, respectively. However, the carp removal from Mendota for 1963–66 was extensive, averaging 31,780 lb/haul (23,100 lb/haul, excluding the large harvest in 1966). These amounts suggest that carp were abundant in Mendota, particularly because in general less effort was made to remove them compared with removal effort on the lower 3 lakes.

The smaller amounts of carp taken by commercial fishing since 1976, particularly in the lower 3 lakes, probably do not reflect a decrease in carp densities in the lakes. Discussions with the DNR field crew (William Jaeger and Robert Kalhagen, former fish technicians, Wis. Dep. Nat. Resour., pers. comm.), who first began removing carp in the late 1950s, lead us to believe that the relative lack of carp removal from the lakes in recent years has allowed the carp populations to stabilize at moderate levels even though reproductive success has been poor.

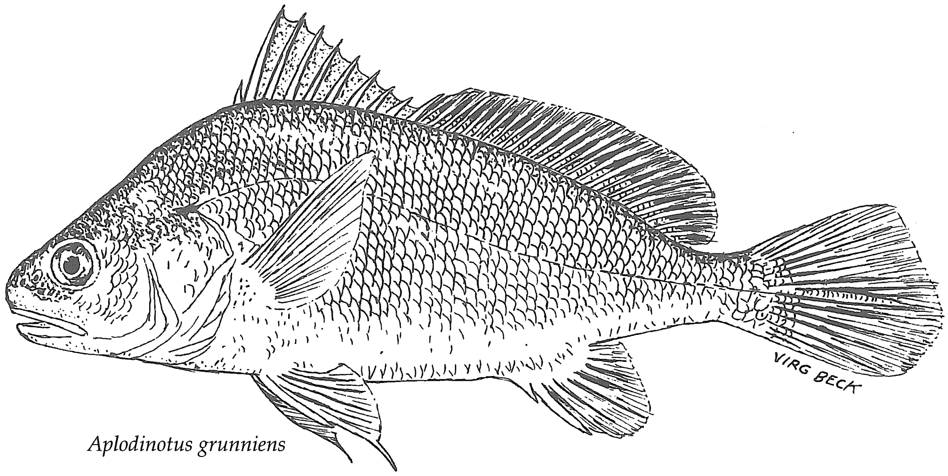
Unfortunately, no reliable assessment of true carp densities in the Yahara lakes is available. Carp were regularly taken but not recorded during the various DNR boom shocking, fyke netting, and survey seine surveys. The 2 survey seine hauls made on Lake Mendota and the single seine haul on Lake Monona in the fall of 1984 recorded 1,890, 1,645, and 2,417 lb, respectively. The average size of the carp was estimated to be about 5 lb (2.3 kg) for each of the 3 hauls. No small carp were found.

Population Trends. Beginning in the early 1900s, soon after the end of the carp stocking period, carp abundance in the Yahara lakes was undoubtedly affected by the Madison sewage effluent that went into Lake Monona in large amounts until 1936 and then in lesser amounts through the early 1950s. In central Europe, such excessive fertilization was deliberately used to increase carp production (Neess 1949). The likely response of carp to the sewage inputs was most visible when the massive carp hatch occurred, mainly in Waubesa, in 1936, the same year in which all of Madison's sewage effluent was diverted to that lake (see Fig. 7).

The large amounts of carp that were continually removed from the lower Yahara lakes from the 1940s through the 1960s, and the lack of aquatic macrophytes in these lakes prior to the Eurasian water milfoil invasion and explosion in the mid-1960s, suggest that carp were abundant. The loss of the deep-water macrophytes in Mendota after the 1950s and the large amount of carp removed for a few years in the mid-1960s suggest that carp may be more abundant in recent times than they were in early years when they were regularly removed. The decline in Mendota's deep-water benthic invertebrates, which began in the 1950s, may also have been affected by high carp densities, although changes in the sediment environment may have been the primary reason for the decline (Lathrop 1992, 1992*c*). These invertebrates would have been a major food item for carp. While little is known about present-day carp densities in the Yahara lakes, many fishery biologists and anglers believe that carp are abundant.

PHOTO: HARRINGTON, DNR CENTRAL OFFICE COLLECTION

Carp fingerlings captured by small-mesh seines on Lake Waubesa, 1936. In that year, most of Madison's sewage effluent was diverted to Lake Waubesa. A massive hatch of carp occurred in response to this increased fertility.



Aplodinotus grunniens

Freshwater Drum

Ecological Requirements

Preferred habitat for freshwater drum is open-water areas of warm, sluggish lakes and rivers with mud bottoms (Becker 1983). Freshwater drum are usually found at or near the bottom. Although they are attracted to turbid waters (Becker 1983), they become distressed when water temperatures remain high and dissolved oxygen remains low over an extended period of time (Priegel 1967). Habitat for spawning is not a limiting factor since freshwater drum spawn pelagically in open water (Wirth 1958). Adult freshwater drum are benthivorous fish, feeding mainly on invertebrates in bottom sediments. Because feeding is chiefly by touch and taste, freshwater drum are able to endure more turbid water than fish species that feed primarily by sight.

Relative Abundance

Survey Results. Freshwater drum apparently are not native to the Yahara lakes. Freshwater drum were not found in the early 1900s in the Rock River system in southern Wisconsin (Greene 1935), but they were found throughout the upper Mississippi River and in Lake Winnebago, where they were considered abundant.

Other fish species (e.g., yellow bass and white crappies) that were not found in early surveys but have since become well established in the Yahara lakes were thought to have been introduced via fish rescue stockings to Lake Wingra and the other lakes during the 1930s and 1940s. Freshwater drum may also have entered the lakes via these stockings, but Lake Wingra may not have been the major locus for the species' establishment. Freshwater drum were not found in Lake Wingra during the 1940s–1960s, after many years of stockings of other species (Baumann et al. 1974). Black (1945) summarized a period covering the late 1930s to mid-1940s and stated that freshwater drum were abundant in Lake Kegonsa, common in Waubesa, uncommon in Monona and Mendota, and absent in Wingra. Freshwater drum were already established in Monona by 1934, the first year of the state's rough fish removal program in that lake (Hacker 1952*a*). Although the greater relative abundance of freshwater drum in the 2 downstream lakes suggests a natural range expansion up the Yahara River system, drum could also have entered the system from rescue introductions to Lake Wingra and moved to Waubesa and Kegonsa where more favorable habitat (wide, warm waters) existed.

Unfortunately, very little quantitative survey data were collected since the 1930s on the relative abundance of freshwater drum. The best information is found in the rough fish removal records, although freshwater drum were not a targeted species and thus represented an incidental catch. Yearly freshwater drum catches prior to 1960 were only summarized for Lakes Monona and Kegonsa from the mid-1930s to early 1950s (Hacker 1952*a*, 1952*b*). During this period, larger amounts of freshwater drum were removed per seine haul from Kegonsa than from Monona (Fig. 25). More freshwater drum were also caught from Kegonsa during 1943–51 than in earlier years, except for 1947. Catches of freshwater drum from Lake Monona did not increase over that same period. Low amounts of freshwater drum

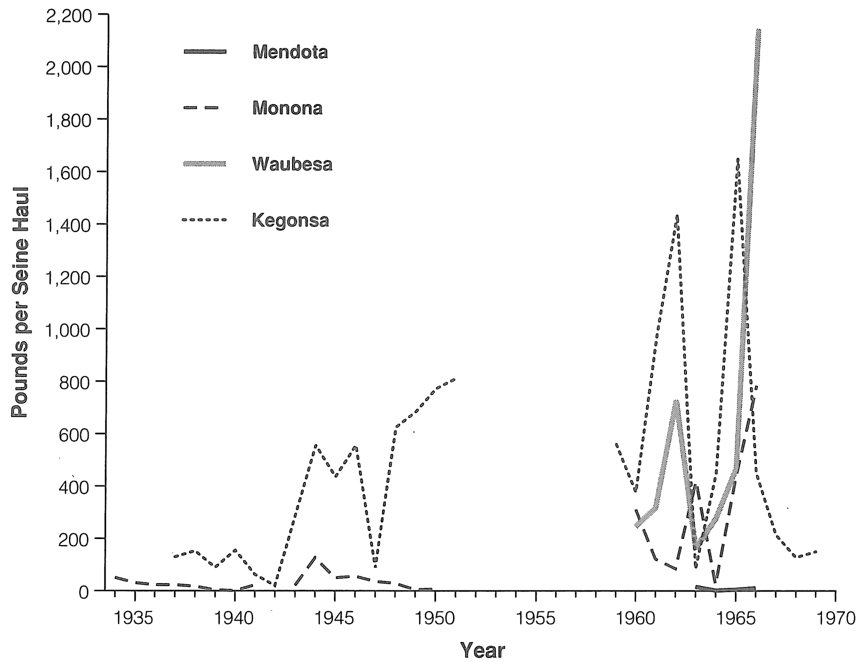


Figure 25. *Freshwater drum caught in the state rough fish seine hauls in the Yahara lakes, 1934–69.*

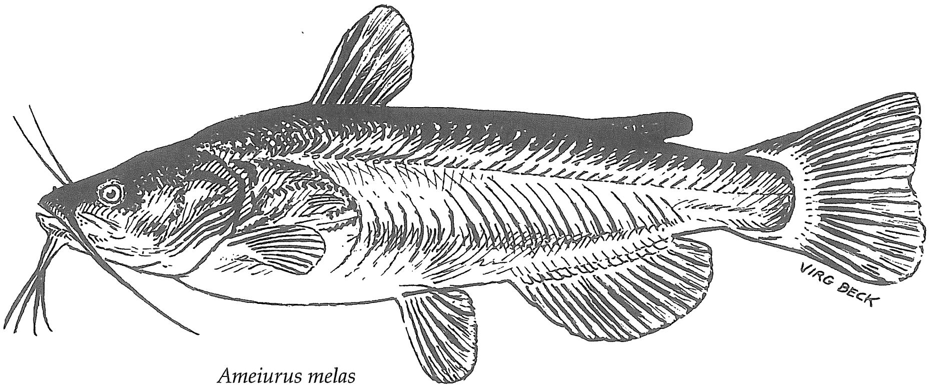
were caught per seine haul from Monona in 1939–40 and 1949–50; higher catches were taken in 1944. Data for freshwater drum from Lake Waubesa were not summarized for the corresponding years, so long-term trends cannot be assessed.

While Black (1945) stated that freshwater drum were uncommon in Lake Mendota during the mid-1940s, Mackenthun (1947) did not record any freshwater drum in his 1947 fyke net survey. McNaught (1963), in his summary of the fish species of Lake Mendota, cited Tibbles' (1956) and Horrall's (1961) Ph.D. theses as the earliest confirmable records of freshwater drum, but numbers caught in these studies were low. Freshwater drum were also not listed in the DNR fish distribution survey until after 1973, but most survey work during the 1960–73 period was by small-mesh shoreline seining.

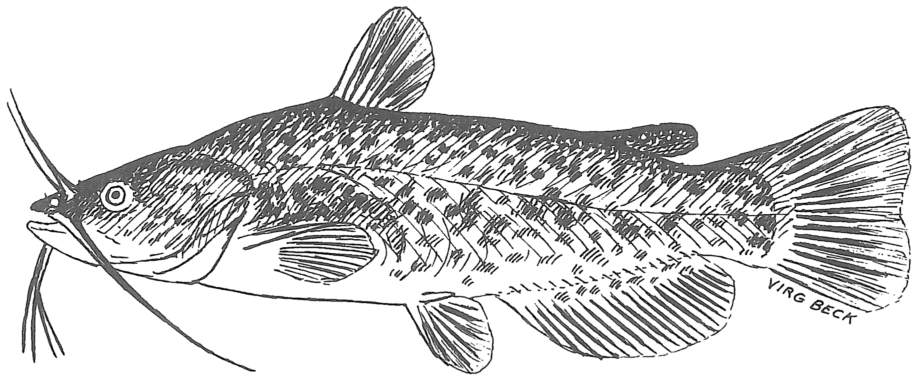
The most quantitative record of freshwater drum during this period again comes from state rough fish hauls. During 1960–69, the total removal of freshwater drum was only 360 lb from Lake Mendota, but it was approximately 16,000, 79,000, and 106,000 lb from Lakes Monona, Waubesa, and Kegonsa, respectively. These amounts were generally higher than in the 1930s and early 1940s, where data were available for comparison.

In recent decades, freshwater drum have been recorded in fyke net surveys at rates <1% of the total catch. Three types of surveys—boom shocker surveys, creel surveys, and survey seine hauls—have documented somewhat larger catch rates of freshwater drum. In fall boom shocker surveys, freshwater drum were routinely captured since the mid-1970s in all 4 lakes and were noted as abundant numerous times during the early 1980s. During the 1974 creel surveys, very few freshwater drum were caught on any of the 4 lakes. The 1981–82 creel survey on Lake Mendota indicated anglers caught over 3,000 freshwater drum, mostly during the summer. During the 1982–83 surveys on the lower 3 lakes combined, anglers caught only about 1,700 freshwater drum. During survey seine hauls in fall 1984, freshwater drum represented 14% and 6% of the total number of fish caught from Lakes Mendota and Monona, respectively.

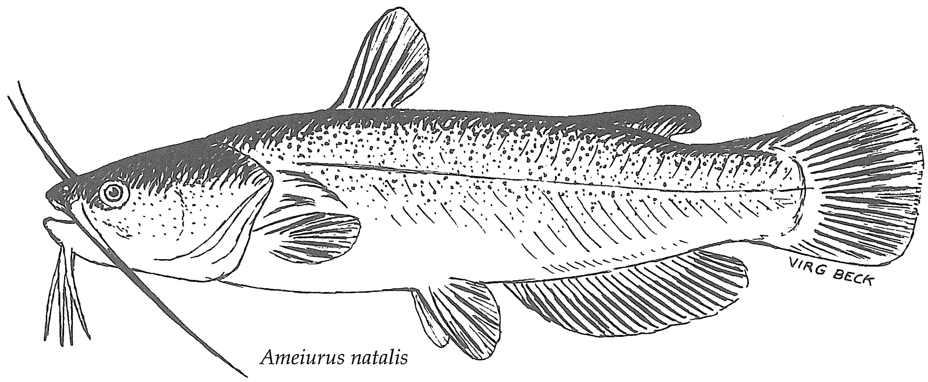
Population Trends. Freshwater drum apparently are not native to the Yahara River system. Freshwater drum were first recorded in Monona in 1934 and were noted as abundant in Kegonsa in 1937, when records were first available. Lake Wingra did not have freshwater drum through the 1960s (Baumann et al. 1974), which indicates they may not have entered the river system from fish rescue stockings to that lake or else they migrated to their preferred habitat in wide, warm waters. Freshwater drum also may have migrated up the Rock and Yahara rivers, becoming established in Kegonsa first. By the mid-1940s, freshwater drum were most abundant in Kegonsa, followed by Waubesa, then Monona and Mendota. Abundances increased greatly in Kegonsa after the mid-1940s. The abundance of freshwater drum in Waubesa and Kegonsa was undoubtedly enhanced by the excessively fertile conditions in those lakes; the algal blooms supported a benthic invertebrate community that was actively fed upon by bottom-feeding fish such as common carp and freshwater drum. In more recent years, particularly since about 1977–78, freshwater drum abundance seems to have been high in all 4 Yahara lakes. The role the increased freshwater drum populations have had in reducing the deep-water benthic invertebrates in Lake Mendota since the late 1950s is not known.



Ameiurus melas



Ameiurus nebulosus



Ameiurus natalis

Bullheads

Ecological Requirements

Bullheads are usually encountered in shallow water (Becker 1983). They are well suited to lakes that are low in oxygen, have abundant vegetation and food, and have turbid waters (Becker 1983). They are more tolerant of siltation, industrial and domestic pollutants, and warm water than most other species. For spawning habitat, black bullheads seek out mud bottoms, brown bullheads prefer rocky and sandy substrates, and yellow bullheads prefer weed banks (Mecozzi 1989*a*). Spawning occurs when water temperatures reach 21 C (Forney 1955). Bullheads are omnivorous, opportunistic bottom feeders that use a highly developed sense of taste to find food.

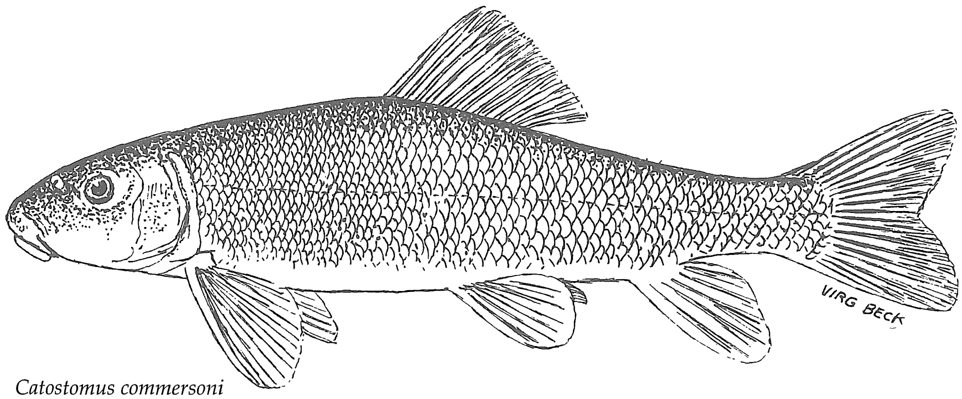
Relative Abundance

Survey Results. Because the Yahara lakes offer prime habitat for black and yellow bullheads and because all 3 bullheads are widespread, adaptable species, they are considered native to the Yahara lakes. Published reports cite 1 or 2 of the 3 species as being more abundant than the other(s) in different lakes at different times. According to McNaught (1963), brown and black bullheads were reported in Lake Mendota before plantings of unidentified bullheads in 1939–43. Baumann et al. (1974) felt that the brown bullhead was the only species originally present in nearby Lake Wingra, but that by the late 1960s black and yellow bullheads were equally abundant in the catches, while the native brown bullhead was then rare. On the lower 3 lakes, Black (1945) observed that virtually all of the bullheads in the rough fish seine hauls were browns, although a few yellow bullheads were caught. Of the 1,800 bullheads reported caught during the 1981–83 creel surveys on the Yahara lakes, 44% were blacks, 41% were browns, and the rest were yellows. However, conflicting observations describe a different picture for Lake Mendota. C. W. Threinen (pers. comm.) felt that yellow bullheads were most common in recent decades in Mendota, as they represented a major proportion of his bullhead catch. On the other hand, John Lyons (pers. comm.) has observed brown bullheads to be currently most common in Lake Mendota.

Information on individual bullhead species is difficult to evaluate because of problems with species identification. Identifications in DNR surveys and rough fish hauls are believed to have been based primarily on color, which is not a reliable characteristic with which to distinguish species (J. Lyons, pers. comm.). The only sure way to identify bullhead species is through pectoral spine and barbel characteristics and the number of anal fin rays—characteristics that are difficult for inexperienced persons to identify in the field.

Because of these identification problems, bullhead occurrence in the Yahara lakes is discussed collectively in the remainder of this section. In the rough fish seine hauls in Lakes Monona, Waubesa, and Kegonsa from the mid-1930s through 1950, bullheads were only <1% of the nonrough fish (Threinen 1951; Hacker 1952*a*, 1952*b*). The creel surveys on Waubesa and Kegonsa during the late 1930s also indicated that they were not frequently caught. Small numbers of bullheads were also stocked in all 4 lakes in the late 1930s and early 1940s—introductions that were probably the result of fish rescue operations elsewhere. However, during the 1974 creel surveys, bullheads constituted 3%, 2%, 21%, and 12% of the reported catch from Mendota, Monona, Waubesa, and Kegonsa, respectively. During the 1981–83 creel surveys, bullheads were reported caught in small numbers only. Bullheads were generally captured in large numbers during WCD/DNR spring fyke net surveys, beginning with a 1947 survey in Mendota and in later years when all 4 lakes were sampled. Other types of surveys frequently did not document many bullheads, possibly indicating gear selectivity or failure to record these species. Bullheads were regularly captured during the UW's 1956–71 spring fyke net survey on the white bass spawning grounds. Bullheads averaged more than 20% of the catch of fish other than white bass during those years. Bullheads represented a substantial part of the creel surveys and survey seine results during 1974–75 on Waubesa and Kegonsa. However, bullheads represented only 2%–3% of the 1974 creel surveys on Mendota and Monona. Bullheads composed <1% of the catch during the 1981–83 creel surveys on all 4 lakes. This apparent decline of bullheads in Waubesa and Kegonsa can be attributed to a massive die-off that occurred during the latter half of the 1970s (G. Priegel and W. Jaeger, pers. comm.). Diseased fish were emaciated and had symptoms of whirling disease.

Population Trends. Problems in species identification have complicated the historical record for bullheads in the Yahara lakes. In addition, because of differences in gear selectivity for collecting bullheads and the fact that many surveys did not record their numbers, little can be said about changes in their relative abundance. We interpret the sustained catch of large numbers of bullheads in the UW's 1956–71 spring fyke net survey on Mendota, along with other DNR fyke net data, as an indication of the relatively high abundance of bullheads over the years in that lake. Because bullheads are bottom feeders, for most years they probably have also been a major component of the fishery of the shallower lower lakes, which have been eutrophic since the early 1900s.



Catostomus commersoni

White Sucker

Ecological Requirements

White suckers are essentially bottom fish. In lakes, they are typically found at maximum depths of 5–15 m (Becker 1983), and they prefer water temperatures of 12–21 C (Ferguson 1958).

White suckers can survive a wide range of environmental conditions better than any other native Wisconsin fish (Becker 1983). They are tolerant of low levels of oxygen. White suckers eat a variety of food, primarily benthic invertebrates and detritus found in or on bottom sediments (Dobie et al. 1948). Spawning is associated with migrating runs in the tributaries of the Yahara lakes.

Relative Abundance

Survey Results. White suckers are native to the Yahara lakes. They were regularly caught in the rough fish seine hauls on the lower lakes from the mid-1930s through the early 1950s. In 1953, the legislature redefined the official status of white suckers and called them both "rough fish" and "forage fish" (Chap. 556, Laws of 1953).[19] The species has retained this dual designation ever since.

It is possible that identification of the white sucker as a valuable food source for other fish may have prompted rough fish crews to return to the lake some suckers caught in seine hauls. Black (1945) believed that white sucker abundance would have subsequently increased as a result. During the 1960s, all white suckers caught in the WCD's rough fish seines were returned to the Yahara lakes (G. Priegel., pers. comm.).

In more recent years, white suckers have regularly been recorded by various surveys in all the Yahara lakes. They were caught in most boom shocker surveys on Mendota, Waubesa, and Kegonsa, but few white suckers were recorded on Monona. White suckers represented about 1% of total fish caught in fyke net surveys during the mid-1970s on Monona and Kegonsa; on Mendota, white suckers were occasionally caught in larger percentages (2%–12%), but catches were sparse other years. The UW fyke net survey from 1956–71 generally recorded very low numbers of white suckers. On Waubesa, no white suckers were caught in DNR fyke nets and survey seines in 1974. Very few were recorded during the various creel surveys over the years on the Yahara lakes.

Population Trends. Little can be concluded about white sucker abundance in the Yahara lakes. White suckers were captured in many surveys throughout the years but generally only in small numbers. This is surprising, given the widespread frequency of occurrence of white suckers in both the Rock River basin and the entire state. We assume that the true abundance of white suckers in the Yahara lakes is higher than is suggested by their catch rates.

[19] Early published reports of white sucker catches on the Yahara lakes cite different years in which this species was designated as a rough fish (Black 1945; Hacker 1952*a*, 1952*b*). We found no explanation for these differences.

Minor Species

Rock Bass

Habitat favored by rock bass consists of clear water, gravel or rocky substrate, and some vegetation (Becker 1983). Spawning occurs in depths ranging from a few centimeters to over one meter (Becker 1983), after which adults are usually found in 2–5 m of water. The young remain in or near submersed vegetation for several months (Fish 1932). Rock bass feed primarily on a variety of invertebrates (Keast 1965).

Rock bass are native to the Yahara lakes, although they have never been very frequently caught there except possibly from Lake Mendota. Good year classes may result in higher catches of rock bass, but these good year classes are only occasional and populations of rock bass appear to remain low. As a result, rock bass are not a fish sought by anglers, and they are usually caught during fishing for other species. Creel surveys on Lakes Waubesa and Kegonsa in the late 1930s, 1974, and 1982–83 reported very few or no rock bass. Boom shocker and fyke net surveys in Lakes Mendota and Monona in the 1970s and 1980s reported more rock bass than in the lower 2 lakes. But as a percentage of the population, these numbers were still low (about 1%) and only showed one small peak (4%) in 1977.

Rock bass were, however, regularly caught in the UW's fyke net study of white bass spawning grounds off Maple Bluff and Governor's Island. The rock bass catch averaged 587 fish/50 net lifts over the study years (1956–71). In many years, they constituted the most frequently caught fish other than white bass. Apparently the rocky bottom was excellent habitat for rock bass.

Pumpkinseed

Pumpkinseeds occupy the same habitat as bluegills and have no unusual ecological requirements. They eat a variety of aquatic invertebrates (Becker 1983).

Pumpkinseeds, a species native to the Yahara lakes, are frequently caught by anglers fishing the shore areas, but in much smaller numbers than bluegills. Pumpkinseeds were reported in most of the various DNR fish population surveys and in somewhat greater numbers in recent years. However, because panfish were not quantitatively sampled during the long-term boom shocker surveys, any changes in the relative abundance of pumpkinseeds cannot be substantiated. Pumpkinseeds were not recorded during the 1952, 1973, and 1974 creel surveys on Lake Mendota, but they were found in very low numbers in all other creel surveys on the Yahara lakes. In these surveys, pumpkinseeds represented <1% of the catch in most years, except on Lake Kegonsa where their numbers reached 1% in 1936 and again in 1982–83. Pumpkinseeds were caught in relatively low numbers in the UW's fyke net study of spawning white bass. Pumpkinseeds averaged <3% of the total catch of fish other than white bass from 1956–62. Numbers of pumpkinseeds were higher in 1963–69. Stocking of pumpkinseed and the presence of pumpkinseed hybrids in the Yahara lakes are discussed in the following section on green sunfish.

Green Sunfish

Green sunfish frequently fare better in shallower, winterkill lakes than in the deeper Yahara lakes, because they are more tolerant of low oxygen conditions than some other fish. Consequently they are frequently the first panfish species to repopulate a winterkill lake in large densities. Green sunfish are also tolerant of turbidity and silt (Becker 1983). However, in the Yahara lakes, where winterkill is not a problem, green sunfish cannot out-compete bluegills and other panfish for food and thus are usually not abundant. Food eaten by green sunfish is similar to that of bluegills, but green sunfish have larger mouths and thus may exploit different food sources (Sadzikowski and Wallace 1976).

Green sunfish were found throughout southern Wisconsin (including the Rock River) prior to the 1930s (Greene 1935), but surprisingly they were not recorded in any of the early Yahara lakes surveys, particularly on Lakes Mendota and Wingra (e.g., Pearse 1918). Because of its widespread distribution, we are considering this species to be native to the Yahara lakes (J. Lyons, pers. comm.). However, green sunfish could also have entered the Yahara River system through the fish rescue stockings in Lake Wingra during the 1930s as well as through natural migration from the Rock River. "Sunfish" were stocked in Lake Monona in 1938 and 1954 and in Lake Kegonsa in 1939 and 1942. We considered these stocked fish to be *Lepomis* spp., comprising bluegills, green sunfish, and/or pumpkinseeds.

In the 1970s and early 1980s, green sunfish were caught in many DNR fall boom shocker surveys on the Yahara lakes. Numbers were low, however, which suggests that this species is not particularly abundant. The largest number of green sunfish recorded in any survey was the 86 fish (11%) caught during the June 1947 fyke net survey on Lake Mendota, although this high a number was not reported by any other surveys. Naturally occurring hybrids between green sunfish and pumpkinseeds were reported in DNR fish distribution surveys in 1974–83 for the 3 lower lakes.

Muskellunge

Muskellunge typically occur in lakes with numerous beds of submersed macrophytes (Becker 1983). They are usually found at depths <5 m but are occasionally found as deep as 12–15 m (Becker 1983). Muskellunge are more tolerant of low oxygen than many other sport fish found in the same habitat (Oehmcke et al. 1974). However, reproduction of this species is limited by several environmental conditions, such as fluctuating water temperatures and water levels during spawning and food availability for fry (Oehmcke et al. 1977). Other factors limiting reproduction include predation on eggs and fry and hybridization with northern pike. Adults feed mainly on fish and have voracious appetites (Gammon 1961).

An 1843 newspaper account of the fish species that abounded in the Yahara lakes included mention of "muscalung" (muskellunge) (Mollenhoff 1982). However, the original range of muskellunge in Wisconsin was restricted to the extreme northern part of the state (Greene 1935, Oehmcke et al. 1977). We therefore conclude that this early anecdotal account was in error and that muskellunge is not, in fact, native to the Yahara lakes. Their presence in southern Wisconsin is the result of widespread stocking of fry and fingerlings (Becker 1983). Introduction of muskellunge to the Yahara lakes began in 1906 and continued through 1941. During this period, 506,500 fry and 525 fingerlings were stocked in Lake Mendota. Since that time, the only muskellunge caught from Lake Mendota was one fish identified in 1946 (McNaught 1963). Because the average age of creeled muskellunge from other lakes is 3–6 years (Becker 1983) and since some fish live into their 20s, this 1946 record was undoubtedly a survivor from a previous stocking. That more muskellunge were not found after these early stockings is not surprising, considering the high mortality that typically takes place within 3 weeks after stocking (Snow 1968).

In recent years, muskellunge × northern pike hybrids (also called tiger muskellunge) have been introduced by the DNR. These hybrids are known to occur in the wild in northern Wisconsin lakes and have been artificially hybridized in state hatcheries since 1940. Tiger muskellunge are hardy fish and grow much faster than either parent species (Becker 1983). Approximately 18,400 hybrid musky fingerlings were stocked in Lake Mendota from 1980–86, 28,200 were stocked in Lake Monona from 1976–86, 11,200 were stocked in Lake Waubesa from 1981–86, and 4,800 were stocked in Lake Kegonsa in 1985–86. Because tiger muskellunge were stocked a few years earlier in Lake Monona than in the other Yahara lakes, they were represented by larger numbers in the 1982–83 Monona creel surveys than in other lake creel surveys conducted around the same time.

PHOTO: KEN CHRISTENSEN, THE CAPITAL TIMES

Trophy hybrid muskellunge from the Yahara lakes.

The stocking of tiger muskellunge in the Yahara lakes is a short-term management effort. Females of these hybrids are often fertile but the males are always sterile (Becker 1983); thus reproduction depends on crossbreeding with native northern pike or stocked muskellunge. However, because stocking of other predatory sport fish such as walleyes and northern pike did not result in large populations in the Yahara lakes, anglers did not expect tiger muskellunge to be numerous, either. Thus the stocking of the sterile tiger muskellunge has satisfied anglers in past years.

Longnose Gar

Longnose gar are pelagic fish, although they seek out shallow areas for spawning (Haase 1969). They prefer warm waters and feed mainly on fish (Becker 1983). Because of their slender shape and bony skeleton, they are one of the few predator fish not considered a desirable sport fish by anglers.

Greene (1935) cites several pre-1930s records of this species from the Yahara lakes. These records were based on unverified reports as well as specimens examined. Longnose gar is therefore considered native to the Yahara lakes.

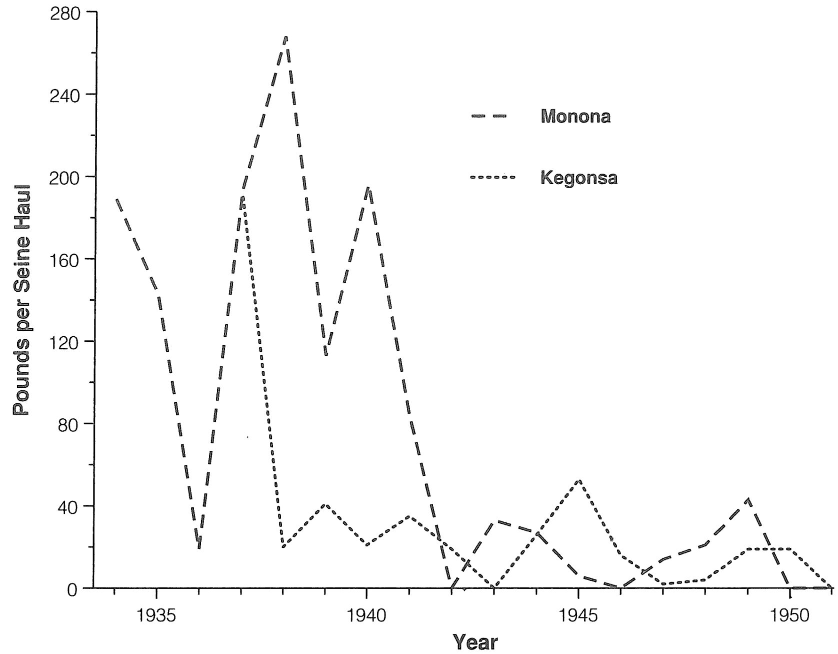


Figure 26. *Longnose gar caught in the state rough fish seine hauls in Lakes Monona and Kegonsa, 1934–51.*

PHOTO: DNR CENTRAL OFFICE COLLECTION

Discarded longnose gar, captured during rough fish seining on Lake Kegonsa, mid-1930s.

After the longnose gar was classified as a rough fish in 1935, it was removed from the Yahara lakes during the WCD/DNR rough fish seining operations. Longnose gar catches declined in the lakes after the initial years of seining, particularly in the lower lakes where the seining was more intensive (Fig. 26). The fact that this decline was dramatic suggests that longnose gar populations in the late 1930s were reduced by the removal operations. Longnose gar were vulnerable to mechanical control because they aggregate (MacKenzie 1936) and because they have a very low reproductive potential (Breder and Rosen 1966). On Lake Monona, about 32,000 lb of longnose gar were removed from 1934–51 by state rough fish removal crews, with 91% of the removal occurring in 1934–41. There was a pronounced drop in longnose gar catch rates from Lake Kegonsa after the first year of removal in 1937; almost 13,000 lb of longnose gar were removed from 1937–51. Longnose gar removal records for comparable years for Lakes Mendota and Waubesa were never summarized. It was first recommended in the late 1950s that longnose gar not be removed by fishery managers during lake surveys or by rough fish removal crews, supposedly because of their importance as a predator fish. Actual compliance with this recommendation did not occur throughout Wisconsin until a decade or more later.

Longnose gar were regularly caught during the UW's fyke net study of spawning white bass in Lake Mendota between 1956 and 1971. After 1980, longnose gar were regularly reported in the fall boom shocker surveys on Lakes Mendota and Monona. Commercial rough fish operations also occasionally caught longnose gar on Lakes Mendota and Monona in recent years but recorded no catches on Lakes Waubesa and Kegonsa, which suggests current low longnose gar abundance in those 2 lakes. Long-term records are not complete enough to document any changes in longnose gar abundance, but longnose gar are most likely not as abundant as other predator fish.

Bowfin

Based on an early-1900s report of bowfin in Lake Mendota (Greene 1935), this species is probably native to the Yahara lakes. Like longnose gar, bowfins feed extensively on other fish. The ability of bowfins to breathe air enables them to survive low dissolved oxygen and temporary strandings out of water (Becker 1983). They generally inhabit clear water with abundant vegetation.

Bowfins were considered relatively uncommon in all the Yahara lakes during the 1930s and 1940s (Black 1945, Hacker 1952*a*, 1952*b*). Their populations in the lakes may have been suppressed by intensive rough fish seining (Hacker 1952*a*; G. Priegel, pers. comm.). Bowfins were generally caught in low numbers during the UW's fyke net study of spawning white bass in Lake Mendota. More recent DNR boom shocking and fyke net surveys recorded occasional bowfins in all 4 lakes, with slightly higher catches in Lakes Mendota and Monona. On the other hand, creel surveys conducted on the 4 Yahara lakes in 1981–83 reported 34 bowfins caught from Lake Waubesa and none caught from the other lakes.

Lake Sturgeon

Lake sturgeon typically inhabit the deepest parts of lakes but seek out flowing waters of rivers for spawning (Becker 1983). They are bottom feeders, eating primarily insects. While the lake sturgeon is not an important part of the local fishery, the occasional catches that occur attract attention because of the species' rarity, distinctiveness, and often its large size.

A pre-1900s record reported by McNaught (1963), documents the lake sturgeon as native to the Yahara lakes. Aside from this single record, the earliest evidence of lake sturgeon in the Yahara lakes comes from stocking records during the 1930s. Adult lake sturgeon were stocked in Lake Mendota in 1934 and 1936. Some of these fish were so large that their noses dragged in the sand when they were carried down to the water (K. Christensen, *The Capital Times*, 31 Jul 1981). Adult lake sturgeon were also stocked in Lake Monona in 1937. Because lake sturgeon are very long-lived fish, even recent catches could be survivors from the stockings in the mid-1930s.

Catches of lake sturgeon in the Yahara lakes have been documented in both rough fish removal records and DNR fish population surveys. The rough fish removal summaries for Lakes Monona and Kegonsa for the mid-1930s to the early 1950s reported irregular catches of lake sturgeon (Hacker 1952*a*, 1952*b*). Miscellaneous data for the state rough fish hauls from Lake Kegonsa recorded 11 lake sturgeon in 1968. Commercial rough fish removal operations on the Yahara lakes during the last 10 years caught only a total of 4 lake sturgeon from Lakes Mendota and Waubesa and none from Lake Kegonsa. However, relatively large numbers of small lake sturgeon were caught in Lake Monona in 1978–80, which indicates that some reproduction had occurred. Other DNR fish population surveys document a few lake sturgeon (total of 12 fish) in Lakes Mendota, Monona, and Kegonsa in the 1970s and in Lake Mendota in 1984. Records for 8 of these fish came from the fish distribution surveys summarized in the appendix tables at the end of this report.

Anecdotal accounts also report the presence of lake sturgeon in the 2 upper lakes in recent years. At least one lake sturgeon was taken in both 1971 and 1972 by anglers on Lake Monona, and a 142-cm, 33.6-kg lake sturgeon was caught there in 1976 (Wis. Dep. Nat. Resour., Madison Area files, unpubl. data). Kenneth Christensen (*The Capital Times*, 31 Jul 1981) reported the catch of a 173-cm lake sturgeon (estimated at 36.3 kg) from Lake Mendota in 1980 and a 152-cm lake sturgeon (estimated at 29.5 kg) in 1981, apparently from Lake Monona. The 1980 catch was considered a record for the Yahara lakes.

Bigmouth Buffalo

Bigmouth buffalo are mostly pelagic (Cross 1967) and are tolerant of high water temperatures and low oxygen levels (Becker 1983). Bigmouth buffalo seek out flooded marshes for spawning. They feed primarily on zooplankton.

Bigmouth buffalo from the Rock River were examined by Greene (1935). This species may therefore have been native to the Yahara lakes or else introduced during fish rescue operations.

In 1935, the legislature designated the bigmouth buffalo as a rough fish (Chap. 366, Laws of 1935). The species has been so classified ever since. As with white suckers, published reports of early bigmouth buffalo catches on the Yahara lakes cite changes in this classification (Black 1945; Helm 1951; Hacker 1952*a*, 1952*b*), but we found no official basis for these statements. To the best of our knowledge, the bigmouth buffalo has never been designated as anything other than a rough fish species.

Little can be concluded about the relative abundance of bigmouth buffalo in the Yahara lakes. The earliest local records of these fish were from the state rough fish hauls in Lake Monona. Between the mid-1930s and mid-1940s, small quantities of bigmouth buffalo were removed from the 3 lower lakes. Other data for this period corroborate that bigmouth buffalo populations were probably low (Black 1945). However, in the 1960s and from the mid-1970s to the mid-1980s, the state and commercial rough fish removal operations removed large numbers. It is quite possible that these fishing operations maintained the populations at lower levels than would be the case if fish had not been harvested.

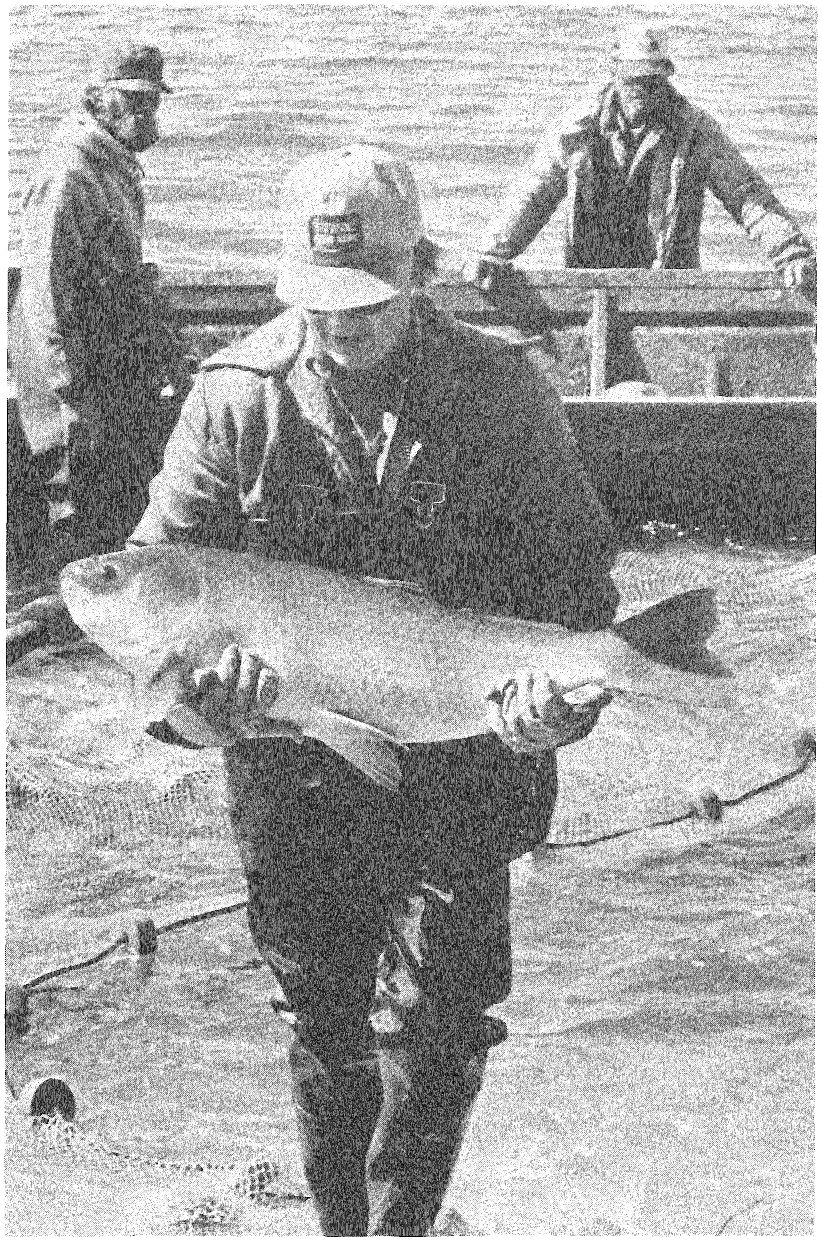


PHOTO: KEN CHRISTENSEN, THE CAPITAL TIMES

Large-sized bigmouth buffalo captured during survey seining in Lake Mendota, October 1984.

Since the early 1970s, few if any bigmouth buffalo were recorded in regular DNR surveys. For example, a survey seine haul on each of the 3 lower lakes during the mid-1970s recorded no bigmouth buffalo, even though commercial fishing removed thousands of pounds of bigmouth buffalo during the late 1970s. In one survey seine haul on Lake Mendota during 1984, more than 2,000 lb of bigmouth buffalo were captured and removed. However, the gears used in most DNR surveys do not capture bigmouth buffalo, and rough fish such as carp and bigmouth buffalo were not regularly recorded. Thus the scarcity of bigmouth buffalo in recent years may not necessarily be an indication of low abundance.

Channel Catfish

Aquatic conditions preferred by channel catfish range from clear, well-oxygenated waters to turbid waters (Becker 1983). Channel catfish require dark cavities or crevices for spawning (Becker 1983). They eat a variety of foods, which they detect on the bottom by touch and smell (Bailey and Harrison 1948).

The earliest account of channel catfish in the Yahara lakes may have been in 1837, when an English geologist recorded his purchase of a 9.1-kg catfish caught on Lake Mendota (Mollenhoff 1982). In fact, the Yahara River was called the Catfish River at the turn of the century when its habitat may have been more favorable to this species. Although we can only suspect that the river was named because catfish once lived there, the 1837 record suggests that channel catfish are native to the Yahara lakes.

Most surveys over the years in the Yahara lakes recorded few or no channel catfish. Because this species can attain large size, it has been considered an important species locally even though it is uncommon.

In the lower 3 lakes, catches of channel catfish in the large rough fish removal seines suggest that this species was not very abundant there in the 1930s–1960s. In Lake Mendota, on the other hand, channel catfish were regularly recorded in the UW's fyke netting during 1956–71. In most years, low numbers were caught, but in 1966–68, channel catfish represented 2% of the catch of fish other than white bass. Significant numbers of channel catfish were also recorded in Mendota during 1970 boom shocking and 1978 fyke netting surveys. In the last 10 years, small-to-moderate numbers of channel catfish have been recorded on all 4 lakes in the commercial rough fish catches. These catch records may mean channel catfish have higher numbers in the Yahara lakes than would be indicated by other survey techniques.

PHOTO: KEN CHRISTENSEN, THE CAPITAL TIMES

Channel catfish caught in the Yahara River above Lake Mendota, 1980s.

Brook Silverside

Brook silversides, small minnowlike fish sometimes known as skipjacks, occupy both littoral and pelagic habitats. They are found at the surface of water more often than any other Wisconsin fish (Becker 1983). Brook silversides feed primarily on zooplankton and macroinvertebrates. Spawning occurs at the surface of shallow water (Becker 1983).

Numbers of specimens examined by Greene (1935) from Lakes Mendota and Monona confirm brook silversides as a species native to the Yahara lakes. Because of their small size, brook silversides were recorded in the Yahara lakes only during shoreline seining when small-mesh nets were used. Large numbers have occasionally been taken during these DNR surveys on the 3 lower lakes but not on Lake Mendota. However, during seining on Mendota from 1981–84, large numbers of brook silversides were caught by Lyons (1989) and by UW personnel in connection with the UW-LTER Project (J. Magnuson, unpubl. data collected in 1981–85). Thousands of brook silversides were also observed in the DNR boom shocker lights during night surveys on all 4 lakes during the 1980s. However, because the silversides and other small fish are not routinely netted, records of their abundance are poor. Lyons (1989) noted that the species has been abundant throughout the 1900s, even as other littoral-zone fish species have declined. The role of the brook silverside as a forage fish in the Yahara lakes is not known, but this species may be an important food source in years when it is abundant.

Other Species

In addition to those fish species we have identified as major or minor components of the fishery, a number of other species have been reported to occur in the Yahara lakes. Table 19 lists a total of 75 species, of which 60 are likely to have been or to be present in the lakes and 15 are unlikely to have been present at any time in the lakes. Records for these latter species were unconfirmed, were the result of probable bait-bucket introductions, or were based on specimens that were misidentified or mislabelled (e.g., not in fact collected from the Yahara lakes). Of the 60 likely species, 57 are or were found in Lake Mendota, 40 in Lake Monona, 34 in Lake Waubesa, and 36 in Lake Kegonsa. Fifteen species listed as likely for Mendota are not listed as likely species for the other lakes. Only a few likely species reported in the 3 lower lakes were unreported for Mendota: the American eel (Monona only), golden redhorse (Waubesa only), quillback (Kegonsa only), and rainbow trout (Kegonsa only, but because of its preference for cold water, its presence in Kegonsa is only accidental).

The difference between the number of species reported for Mendota compared with that for the 3 lower lakes cannot be attributed solely to the characteristics of the lake itself. Although its larger and more diverse habitat would provide more niches for a greater variety of fish species, Mendota has also attracted the largest number of studies focusing on its fish. With this greater effort, it is not surprising that more species have been captured and documented there.

Another feature of past studies and surveys that biases the total species list of the Yahara lakes is that most activities have focused on the harvested species, i.e., the larger panfish and predator fish. The smaller forage species—minnows, shiners, dace, and darters—could have been present, even common, but they were generally not studied specifically. One exception was Lyons' (1989) report on changes in abundance of small littoral-zone fish in Lake Mendota.

Of all the surveys reported for the Yahara lakes, the only one which attempted to capture a representative sample of all the fish present was Fago's (1982) survey in the mid-1970s. For this survey, he selected 21, 19, 12, and 17 sampling stations for Lakes Mendota, Monona, Waubesa, and Kegonsa, respectively, at a frequency of about 1 station/72 ha of lake area. Station locations were chosen in order to reflect the habitat diversity of each lake.

In addition to the fish reported as present in the Yahara lakes in Table 19, there are some species that have been reported in nearby waters with access to the Yahara lakes. These records are summarized in Table 20. Of these records, the 4 species reported only by McNaught (1963) for Lake Wingra or ponds near Lake Wingra are extremely unlikely. The primary source for records of fish found in streams and wetlands tributary to the Yahara lakes is the Fish Distribution Study conducted during 1975–76 (Fago 1982). From these records, only fish found in tributaries close to the lakes (i.e., within 3.2 km) are included in Table 20. Seven species that were reported as present in one or more of the Yahara lakes were also listed as present in a tributary of a different lake. For these 7 species, we cannot say that their presence in tributaries makes their presence in the adjoining lake likely.

For other species that we list in Table 19 as present in the Yahara lakes, we can make some observations about possible changes in their presence over time. One measure of such change is whether or not any population decline has been reported on a statewide basis. Only one of the species reported likely for the Yahara lakes is among those identified by the Wisconsin Department of Natural Resources' Bureau of Endangered Resources as fish species either extinct, endangered, or threatened in Wisconsin (Bob Hay, Wis. Dep. Nat. Resour., Bur. Endangered Resour., pers. comm.). That species—the pugnose shiner—was recently placed on Wisconsin's list of threatened species. Only one other likely species—the lake sturgeon—is on the Bureau of Endangered Resources' list of "special concern" or "watch" species, about which an abundance or distribution problem is suspected (B. Hay, pers. comm.).

In his study of small fish species from the littoral zone of Lake Mendota, Lyons (1989) concluded that since 1900, several small fish species have been extirpated from the lake. Four—the pugnose shiner, blackchin shiner, blacknose shiner, and banded killifish—are intolerant of environmental degradation. Other species—the tadpole madtom, blackstripe topminnow, and fantail darter—are more typical of streams than lakes. Most of these species prefer habitat with extensive, diverse macrophytes. The changes in Lake Mendota's weed beds brought about by the invasion of the exotic Eurasian water milfoil may have contributed to the decline of these small fish species. Other negative impacts on the littoral zone and its fishes came from urbanization and resulting development of shorelines and loss of shore marshes.

In addition to these small fish, one other species—the shorthead redhorse—has probably been eliminated, and another—the American eel—is undoubtedly no longer present, its upstream travel limited by dams on rivers below the Yahara lakes. If one subtracts these species from the total number of species likely to have been in the Yahara lakes, these totals are reduced by 8 species for Mendota , 2 for Monona, and 1 each for Waubesa and Kegonsa. These subtractions leave 49, 38, 33, and 35 species likely to still be in Mendota, Monona, Waubesa, and Kegonsa, respectively.

The significance—discussed by Lyons (1989)—of these long-term changes in Mendota's fish community is more than just a loss of species diversity. The food supply for predator fish and large panfish has also been affected. In the past, these fish had a diverse supply of small littoral-zone fish on which to feed, particularly in the spring before the young-of-the-year panfish are available. Now a single species, the brook silverside, has become the primary littoral-zone fish, but because brook silversides can be scarce in certain years, this source of food to larger fish may be periodically reduced.

PHOTO: DON FAGO, DNR RESEARCH

PHOTO: BOB QUEEN, DNR CENTRAL OFFICE COLLECTION

Personnel (top) and reference collection (bottom) of the DNR Fish Distribution Study, the only survey designed to sample all of the fish species in the Yahara lakes. This survey, which was conducted on the Yahara lakes in 1975–76, documented the presence of many small fish species, particularly in the lower lakes.

Table 19. *Fish species reported for the Yahara lakes.*

Species	Presence Reported*				Authority**				Comments***
	ME	MO	W	K	Mendota	Monona	Waubesa	Kegonsa	
Yellow perch	◆	◆	◆	◆	1 2 3 4K	2 4K	2 4K	2 4K	
Bluegill	◆	◆	◆	◆	1 2 3 4K	2 4K	2 4K	2 4K	
Black crappie	◆	◆	◆	◆	1 2 3 4K	2 4K	2 4K	2 4K	
White crappie	◆	◆	◆	◆	1 2 3 4K	2 4K	2 4K	2 4K	
White bass	◆	◆	◆	◆	1 2 3 4K	2 4K	2 4K	2 4K	
Yellow bass	◆	◆	◆	◆	1 2 3 4K	2 4K	2 4K	2 4K	
Bass hybrid	◇	-	-	-	2				
Largemouth bass	◆	◆	◆	◆	1 2 3 4K	2 4K	2 4K	2 4K	
Smallmouth bass	◆	◆	◆	◆	1 2 3 4K	2 4K	2 4K	2 4K	
Walleye	◆	◆	◆	◆	1 2 3 4K	2 4K	2 4K	2 4K	
Northern pike	◆	◆	◆	◆	1 2 3 4K	2 4K	2 4K	2 4K	
Cisco	◆	❖	-	-	1 2 3 4K	2 4B			
Common carp	◆	◆	◆	◆	1 2 3 4K	2 4K	2 4K	2 4K	
Freshwater drum	◆	◆	◆	◆	1 2 3 4K	2 4K	2 4K	2 4K	
Black bullhead	◆	◆	◆	◆	1 2 3	2	2 4J	2	
Yellow bullhead	◆	◆	◆	◆	1 2 3	2	2	2	
Brown bullhead	◆	◆	◆	◆	1 2 3	2	2	2	
White sucker	◆	◆	◆	◆	1 2 3 4K	2 4K	2 4K	2 4K	
American brook lamprey	◇	-	-	-	1 3				a
Lake sturgeon	◆	◆	◇	❖	1 2 3 4K	2 4K	4C	2 4B	
Longnose gar	◆	◆	◆	◆	1 2 3 4K	2 4K	2 4K	2 4K	
Shortnose gar	❖	-	-	-	1 2 3				b
Bowfin	◆	◆	◆	❖	1 2 3 4K	2 4K	2 4K	2 4B	
American eel	-	◇	-	-	3	1 3			c
Mooneye	-	◇	-	-	3	4B			d
Rainbow trout	-	-	-	◇	3			4B	e
Chinook salmon	◇	-	-	-	3 4H				f
Atlantic salmon	◇	-	-	-	3 4H				g
Brown trout	❖	-	-	-	1 3				h
Brook trout	◇	-	-	-	3 4I				i
Lake trout	◇	-	-	-	3 4H				j
Central mudminnow	❖	-	-	◇	1 3			4D	k
Grass pickerel	❖	-	-	-	1 2 3				l
Muskellunge	◆	-	-	-	1 2 3 4H				
Muskellunge hybrid (tiger muskellunge)	◆	◆	◆	◆	2 3 4K	2 4K	4K	4K	
Central stoneroller	◇	-	-	-	3				m
Goldfish	◆	-	-	-	1 3 4H				n
Spotfin shiner	◆	-	-	-	1 2 3				o
Mississippi silvery minnow	◇	-	-	-	2 3				p

Table 19. *Continued.*

Species	Presence Reported* ME	MO	W	K	Authority** Mendota	Monona	Waubesa	Kegonsa	Comments***
Common shiner	❖	◆	-	-	1 2 3	2 4K			q
Hornyhead chub	◇	-	-	-	2 3				r
Golden shiner	◆	◆	◆	◆	1 2 3 4K	2 4K	2 4K	2 4K	s
Pugnose shiner	◇	-	-	-	1 2 3				t
Emerald shiner	◆	◇	◇	❖	1 2 3 4K	2	4F	2 4D	u
River shiner	◇	-	-	-	1 3				v
Bigmouth shiner	◇	-	-	-	2 3				w
Blackchin shiner	◆	-	-	-	1 2 3				x
Blacknose shiner	◆	-	-	-	1 2 3				y
Spottail shiner	◆	◇	❖	◇	1 2 3 4D	4D	2 4K	4D	z
Pugnose minnow	◇	-	-	-	2 3				aa
Bluntnose minnow	◆	◆	❖	❖	1 2 3 4K	2 4K	2 4F	2 4F	bb
Fathead minnow	◆	◇	◇	◇	1 2 3	2 4F	2	2	cc
Creek chub	◆	-	-	-	1 2 3 4D				dd
Quillback	-	-	-	❖				1 4C	ee
Lake chubsucker	◇	-	-	-	3				ff
Smallmouth buffalo	❖	◇	-	-	3 4I	3			gg
Bigmouth buffalo	◆	◆	◆	◆	1 2 3 4K	1 2 4K	4K	2 4K	
Silver redhorse	-	-	◇	-			4D		hh
Golden redhorse	-	-	◇	-			1		ii
Shorthead redhorse	◆	-	❖	◇	1 3 4I		1 4J	1	jj
Channel catfish	◆	◆	◆	◆	1 2 3 4K	2 4K	4K	4K	
Tadpole madtom	❖	-	-	-	1 3				kk
Flathead catfish	◇	-	-	-	3				ll
Burbot	◇	❖	-	-	1 2 3	2 3			mm
Banded killifish	◆	❖	-	-	1 2 3	3			nn
Blackstripe topminnow	◇	-	-	-	1 2 3				oo
Brook silverside	◆	◆	◆	◆	1 2 3 4K	2 4K	2 4K	2 4K	
Brook stickleback	◇	-	-	-	1 3				pp
Rock bass	◆	◆	◆	◆	1 2 3 4K	2 4K	2 4K	2 4K	
Green sunfish	◆	◆	◆	◆	1 2 3 4K	2 4K	2 4K	2 4K	
Pumpkinseed	◆	◆	◆	◆	1 2 3 4K	2 4K	2 4K	2 4K	
Sunfish hybrid	-	◇	◇	◇		2	2	2	
Warmouth	◇	❖	-	◇	1 3	2 3 4E		4A	qq
Iowa darter	◆	◇	◇	◇	1 2 3	2	2	2	rr
Fantail darter	◇	-	-	-	1 3				ss
Johnny darter	❖	◇	-	-	1 3	2			tt
Logperch	◆	◆	◆	◆	1 2 3 4K	2 3 4K	2 4K	2 4K	uu
Mottled sculpin	◆	◇	-	-	1 2 3 4D	2			vv
Total no. all species**	69	42	35	37					
Total no. likely species	57	40	34	36					

* Lakes are abbreviated as: ME = Mendota, MO = Monona, W = Waubesa, and K = Kegonsa. Presence is categorized as:
◆ = reported frequently (3 or more records).
❖ = reported occasionally (2 records).
◇ = reported rarely (1 record); perhaps never a breeding population.
\- = not reported.

** Excluding hybrids.

(Continued on next page)

** **Authority or sources of data** (see comments below for additional information on records for certain fish):

1 McNaught (1963).
2 Fago (1982)—per DNR fish distribution survey tables in Appendix A.
3 Lyons (1988) and/or Lyons (1989) except as noted.
4 Data compiled in Appendix A of this report from the following sources:

A Creel surveys.
B State rough fish removal records.
C Commercial rough fish removal records.
D DNR boom shocker surveys.
E DNR fyke net surveys.
F DNR shoreline seine surveys.
G DNR survey seine surveys.
H DNR stocking records.
I UW-Madison research projects.
J Anecdotal accounts.
K Two or more of the above sources—see Appendix Tables A.39–A.42.

*** **Comments.** Species presence judgments are based on information from John Lyons (Wis. Dep. Nat. Resour., Bur. Res., pers. comm.).

a **American brook lamprey.** Records: Listed by McNaught (1963) as "probably" present based on report by anglers, but no confirmed reports from the Yahara lakes or tributaries. Presence: Unlikely. Based on this species' preferred habitat (streams) and its occasional use as bait, its presence as a viable component of the lake's fishery is questionable.

b **Shortnose gar.** Records: Documented by 2 reputable museum records, both before 1950, at least one of which was a specimen examined by Greene (1935). Presence: Likely. Early records suggest the species may have been native. It may also have been introduced in operations to rescue fish from drying backwater ponds.

c **American eel.** Records: A single specimen reported 1880, "thought to be the third or fourth eel captured in the lakes since Madison was first settled" (McNaught 1963:41). Not reported from the Yahara lakes since then. Some records for the Yahara River upstream from Mendota in the 1970s (Fago 1982). Presence: Likely in the past, but undoubtedly not present now. Historical record documents species as native. If the 1970s records are legitimate, the species passes through all 4 lakes undetected. Upstream travel is undoubtedly limited by dams on the Mississippi, Rock, and Yahara rivers.

d **Mooneye.** Records: Only 1 record from the Yahara River system, reported in Hacker's (1952*a*) summary of rough fish removal activities. Presence: Extremely unlikely. Based on the source of the record, the species' preferred habitat (rivers), and its superficial similarity to cisco, the fish may have been misidentified.

e **Rainbow trout.** Records: Formerly stocked in some tributaries. Observed in Kegonsa by Hacker (1952*a*). Presence: Likely. Occurrence is only as a stray from adjoining tributaries or as an escapee from the Nevin State Fish Hatchery.

f **Chinook salmon.** Records: Stocked in Mendota in the 1870s, but no records since then. Presence: Extremely unlikely. Dead fish were observed the year after stocking of fry, but survival beyond that time is doubtful because Mendota's water temperatures are too warm.

g **Atlantic salmon.** Records: Stocked in Mendota in the 1870s, but no records since then. Presence: Extremely unlikely. Survival of fry for more than one summer after stocking is doubtful because Mendota's water temperatures are too warm.

h **Brown trout.** Records: Stocked in a tributary to Mendota and recorded several times from that lake in recent years. Presence: Likely. Occurrence is only as an escapee from the Nevin State Fish Hatchery or as a stray from adjoining tributaries in which species presence is maintained by deliberate stocking.

i **Brook trout.** Records: Formerly stocked in some tributaries. Caught rarely in Mendota during the UW's sampling for white bass in the mid-1950s–1960s. Presence: Likely. Occurrence is only as a stray from adjoining tributaries or as an escapee from the Nevin State Fish Hatchery.

j **Lake trout.** Records: Stocked as fry at the beginning of the century, but no records since then. Presence: Extremely unlikely. Survival of fry for more than one summer after stocking is doubtful because Mendota's water temperatures are too warm.

k **Central mudminnow.** Records: Several records, most recently 1981 in Mendota. Presence: Likely. Occurrence is only as an occasional stray from adjoining waters. Preferred habitat of this species is wetlands and tributaries, not large lakes with complex fish communities.

l **Grass pickerel.** Records: Only 1 confirmed museum record of a single individual in 1961. Historical records of 1 fish each in 1905 and 1906 were actually northern pike. Record of current presence on the species distribution map in Fago (1982) is a typographical error. Presence: Likely. Species is often found in other lakes similar to the Yahara lakes. It may have been native or could have been introduced from accidental inclusion with stockings of northern pike.

m **Central stoneroller.** Records: Only 1 record from 1965. Also found in tributaries to the Yahara lakes. Presence: Likely. Occurrence is as a stray which prefers riffle areas of streams.

n **Goldfish.** Records: Stocked in 1855 and found occasionally in recent years. Presence: Likely. Species is an exotic which continues to be introduced by private individuals releasing aquarium fish into the lakes.

o **Spotfin shiner.** Records: Several records within the past 50 years. Presence: Likely. Species is probably native but uncommon, occupying lake habitat which is not its primary habitat.

p **Mississippi silvery minnow.** Records: One record, from 1964, cited by several sources. Presence: Extremely unlikely. Since preferred habitat is large rivers and since only 1 record exists, specimen was probably mislabelled (i.e., not actually collected in Lake Mendota), or species was a bait bucket introduction.

q **Common shiner.** Records: Several records from Mendota and Monona, mostly recently in 1965 and 1981, respectively. Presence: Likely. Species is probably native to the lakes.

r **Hornyhead chub.** Records: One record, from 1964, cited by several sources. Presence: Unlikely. Since preferred habitat is streams and rivers and since only 1 record exists, specimen was probably mislabelled or species was a bait bucket introduction.

s **Golden shiner.** Records: Numerous records from all 4 Yahara lakes. Presence: Likely. Species is native and common.

t **Pugnose shiner.** Records: Only 1 record at the turn of the century, cited by several sources. Presence: Likely. Species was native but eliminated by degradation, to which it is very susceptible.

u **Emerald shiner.** Records: Reported frequently in Mendota and rarely or occasionally in the lower 3 lakes. Presence: Likely. Species may have been native or introduced through fish rescue operations; it is now self-sustaining, at least in Mendota.

v **River shiner.** Records: Reported only by Greene (1935). Presence: Unlikely. Since preferred habitat is large rivers and since only 1 record exists, fish was probably misidentified. If not misidentified, fish may have been brought in during fish rescue operations.

w **Bigmouth shiner.** Records: One record, from 1965, reported by several sources. Presence: Unlikely. Since preferred habitat is streams, species is not now found in any Mendota tributaries, and only 1 record exists, specimen was probably misidentified. Species is easily confused with several others.

x **Blackchin shiner.** Records: Reported several times between 1905 and 1964. Presence: Likely. Species was native and once common but has been eliminated by environmental degradation.

y **Blacknose shiner.** Records: Reported several times between 1905 and 1916 but not since then. Presence: Likely. Species was native and once common but has been eliminated by environmental degradation.

z **Spottail shiner.** Records: Reported frequently in Mendota after 1944 and rarely or occasionally in each of the 3 lower lakes after 1979. Presence: Likely. Species is common, at least in Mendota. Presence in the lower lakes may be under-reported because species is semi-pelagic and not easy to capture. It may have been native to the Yahara lakes or else introduced through fish rescue operations from the Mississippi River where it is common.

aa **Pugnose minnow.** Records: One record, from 1964, cited by several sources. Presence: Extremely unlikely. Since preferred habitat is large rivers and since only 1 record exists, specimen was probably mislabelled or species was a bait bucket introduction.

bb **Bluntnose minnow.** Records: Documented in Mendota beginning in 1914–16 and in each of the 3 lower lakes beginning in the mid-1970s. Presence: Likely. Species is native and common, at least in Mendota.

cc **Fathead minnow.** Records: Documented in Mendota beginning in 1914–16 and in each of the 3 lower lakes in the mid-1970s. Record from 1939 in Monona is disregarded since original survey notes recorded specimen as a "bighead minnow." Presence: Likely. Species prefers silty, marginal waters. Whether it would persist in the Yahara lakes without constant reintroduction by bait bucket releases is questionable. It is common in some adjoining tributaries (where it is native), so it might occasionally enter the lakes as a stray from these streams.

dd **Creek chub.** Records: Several records, most recently in 1977. Presence: Likely. Since preferred habitat is streams, species is present only as a stray from adjoining tributaries.

ee **Quillback.** Records: Reported only twice, from 1944 and 1977. Presence: Likely. Since species prefers river habitats, its presence in Kegonsa is probably as a stray or introduction through fish rescue operations.

ff **Lake chubsucker.** Records: One record, from 1904–05, cited by Marshall and Gilbert (1905). Presence: Unlikely. Since source of the single fish caught is presumed to be from Mendota but is really unknown, record is unconfirmed.

gg **Smallmouth buffalo.** Records: Two records in Mendota, from the mid-1950s–1960s in the UW's sampling for white bass and from 1966. One record for Monona from 1975; identification of this fish was confirmed by the Center for Limnology (Clifford Brynildson, Wis. Dep. Nat. Resour., Madison Area files, 16 Oct 1975 memo). Presence: Likely. Source of fish could have been use of juveniles as bait and introduction through bait bucket releases. It may also have been introduced in fish rescue operations since it is common in big rivers in which such rescue operations were conducted.

hh **Silver redhorse.** Records: One record of a single fish from 1981. Presence: Unlikely. Whether the specimen actually was a silver redhorse or was a misidentified shorthead redhorse is not known, therefore record is discounted.

ii **Golden redhorse.** Records: A single reputable museum record, from 1945. Presence: Likely. Occurrence is as an introduction through bait bucket releases or fish rescue operations. Preferred habitat is medium to large streams.

jj **Shorthead redhorse.** Records: Reported at least once from all lakes except Monona. No records within the last 20 years. Presence: Likely. Species was probably native and eliminated, or it could have been introduced in the fish rescue operations.

kk **Tadpole madtom.** Records: Several records from 1914–15, but no reports since then. Presence: Likely. Species was native but probably disappeared as a result of deterioration of Mendota's nearshore area.

ll **Flathead catfish.** Records: One newspaper record, from 1985. Presence: Unlikely. Single record was not confirmed. Since this species is a typical occupant of big rivers, its presence could only result from an introduction.

mm **Burbot.** Records: One confirmed record for Mendota from 1905, probably cited by several sources. Two records for Monona from the late 1970s. Presence: Likely. Species is probably native, at least from Mendota. It may also simply be under-reported because it is a deep-water, bottom fish which is not easily captured.

nn **Banded killifish.** Records: Numerous records for Mendota between 1905 and 1975. Several records for Monona beginning in the 1870s (Jordan 1877) and ending with only 2 individuals caught during intensive sampling in the 1960s (Neill and Magnuson 1974) and 1970s. Presence: Likely. This native species was once abundant, at least in Mendota, but eliminated by environmental degradation. It has also probably disappeared from Monona.

oo **Blackstripe topminnow.** Records: Only 1 record at the turn of the century, cited by several sources. Presence: Likely. Species was native. Although never very common, species probably disappeared as a result of the deterioration of Mendota's nearshore area.

pp **Brook stickleback.** Records: Presence suggested by distribution map in Greene (1935); also 1 record—possibly the same as that examined by Greene—from 1916. Presence: Likely. Occurrence is only as a stray from nearby tributaries in which the species is common.

qq **Warmouth.** Records: Numerous, unconfirmed records exist. Species has been reported taken infrequently by anglers in Mendota prior to the mid-1960s; several individuals were reported in Monona from 1974 and 1976 and in Kegonsa from 1982–83. Presence: Unlikely. Species is not native to the Yahara lakes. Although it could have been introduced through fish rescue operations or bait bucket releases, it is easily confused with a number of other species. Because identifications were not verified, records are suspect.

rr **Iowa darter.** Records: Although species is uncommon in Mendota, it has been reported frequently by several sources beginning in the early 1940s. Single records of multiple individuals exist for each of the 3 lower lakes in 1975–76. Presence: Likely. Species is native.

ss **Fantail darter.** Records: Documented by Pearse (1918) from 1914, but has not been reported since then. Presence: Likely. Species was an uncommon native; it may also have occurred as a stray from adjoining tributaries. Loss of this species is probably attributed to the species' preference for rocky streams rather than lakes.

tt **Johnny darter.** Records: Reported occasionally in Mendota between 1915 and 1987 and once in Monona in 1976. Presence: Likely. Species is native and uncommon.

uu **Logperch.** Records: Reported frequently from all 4 lakes. Mendota records span the 1940s–1990. Most records for the lower lakes are from the late 1970s–early 1980s, although the earliest record in Monona was from 1914 (Pearse 1918). Presence: Likely. Species is native.

vv **Mottled sculpin.** Records: Reported frequently, but in small numbers, from Mendota between 1914 and 1987. Record of a single individual from Monona in 1974. Presence: Likely. Species is native.

Table 20. *Fish species reported from streams and wetlands tributary to the Yahara lakes.*

Species	Presence Reported*								Presence in Yahara Lakes**		Comments**
	Mendota		Monona		Waubesa		Kegonsa				
	Tributary	Lake	Tributary	Lake	Tributary	Lake	Tributary	Lake	Likely	Unlikely	
American eel	X	-	-	X	-	-	-	-	X		a
Central mudminnow	-	X	-	-	X	-	-	X	X		b
Central stoneroller	-	X	-	-	X	-	-	-	X		c
Satinfin shiner	-	-	X	-	-	-	-	-		X	d
Spotfin shiner	-	X	-	-	-	-	X	-	X		e
Redfin shiner	-	-	X	-	-	-	-	-		X	f
Southern redbelly dace	X	-	-	-	-	-	-	-		X	g
Blacknose dace	X	-	-	-	-	-	-	-		X	h
Creek chub	-	X	-	-	X	-	X	-	X		i
Northern hog sucker	-	-	X	-	-	-	-	-		X	j
Spotted sucker	-	-	X	-	-	-	-	-		X	k
Brook stickleback	-	X	-	-	X	-	X	-	X		l
Johnny darter	-	X	-	X	X	-	-	-	X		m
Total	3	6	4	2	5	0	3	1	7	6	

* See comments below for details on each species. Records relating to Monona are from McNaught (1963). Records relating to Mendota, Waubesa, and Kegonsa from computer printout run by Don Fago summarizing fish occurrences recorded in a Fish Distribution Study as reported in Fago (1982). Printout was run 14 Nov 1989 (for 1974–86) and is filed with the DNR Bureau of Research. Fish Distribution Study personnel were the collectors of all fish except for American eel. These sources reported presence of species in all cases. See comments below for evaluation of presence as likely or unlikely.

** **Comments.** Species presence judgments are based on information from John Lyons (Wis. Dep. Nat. Resour., Bur. Res., pers. comm.).

a **American eel.** Records: Two records exist for the Yahara River upstream (1.3? and 2.7 km) from Lake Mendota in the late 1970s. Presence in the Yahara lakes: Likely, based on lake records only. One record from the Yahara lakes exists—from Lake Monona in 1880. Because the current tributary reports are from an unknown collector (e.g., sport angler), these records are unconfirmed.

b **Central mudminnow.** Records: Reported 2.1 km up Murphy's Creek from Lake Waubesa. Presence in the Yahara lakes: Likely. Recorded in Mendota and Kegonsa. Occurrence is as a stray from adjoining waters.

c **Central stoneroller.** Records: Reported 2.1 km up Murphy's Creek from Lake Waubesa. Presence in the Yahara lakes: Likely. One record from Mendota. Occurrence is as a stray from adjoining streams.

d **Satinfin shiner.** Records: Reported for Lake Wingra by Helm (1958). Presence in the Yahara lakes: Extremely unlikely. Based on close similarity to the spotfin shiner and on the range of the satinfin shiner (which is an Atlantic coast species that has never been found in the Midwest), record is clearly a misidentification of a spotfin shiner.

e **Spotfin shiner.** Records: Reported 2.9 km up an unnamed creek tributary to Lake Kegonsa. Presence in the Yahara lakes: Likely. Several records from Mendota where species is clearly present but uncommon.

f **Redfin shiner.** Records: Introduced into UW Arboretum ponds in 1958 (Hunter and Wisby 1961). When the ponds overflow during times of high water, the species could have had access to Lake Wingra. Presence in the Yahara lakes: Extremely unlikely. Species did not persist in Arboretum ponds, thus it is highly improbable that any individuals strayed into Lake Monona.

g **Southern redbelly dace.** Records: Reported 1.6 km up Pheasant Branch Creek from Lake Mendota. Presence in the Yahara lakes: Unlikely. Tributary record came from a high-gradient stream reach, which is the preferred habitat of this species. Lower sections of the same tributary are swampy and low-gradient; occurrence in Lake Mendota as a stray from such habitat is unlikely.

h **Blacknose dace.** Records: Reported 1.6 km up Pheasant Branch Creek from Lake Mendota. Presence in the Yahara lakes: Unlikely. Tributary record came from a high-gradient stream reach, which is the preferred habitat of this species. Lower sections of the same tributary are swampy and low-gradient; occurrence in Lake Mendota as a stray from such habitat is unlikely.

i **Creek chub.** Records: Reported 2.1 km up Murphy's Creek from Lake Waubesa and 2.9 km up an unnamed tributary creek from Lake Kegonsa. Presence in the Yahara lakes: Likely. Several records from Mendota. Occurrence only as a stray from adjoining tributaries.

j **Northern hog sucker.** Records: Collected by T. Wright (UW Cent. Limnol.) from Lake Wingra in 1963. Presence in the Yahara lakes: Extremely unlikely. Species, which had probably been introduced during fish rescue operations, did not persist in Lake Wingra. It is thus highly improbable that any individuals strayed into Lake Monona.

k **Spotted sucker.** Records: Collected by J. D. Black from Lake Wingra in 1944. Presence in the Yahara lakes: Extremely unlikely. Species, which had probably been introduced during fish rescue operations, did not persist in Lake Wingra. It is thus highly improbable that any individuals strayed into Lake Monona.

l **Brook stickleback.** Records: Reported 1.3 km up Swan Creek and 2.1 km up Murphy's Creek from Lake Waubesa and 2.9 up an unnamed tributary creek from Lake Kegonsa. Presence in the Yahara lakes: Likely. One or 2 records from Mendota. Occurrence is only as a stray from nearby tributaries in which the species is common.

m **Johnny darter.** Records: Reported 1.3 km up Swan Creek from Lake Waubesa. Presence in the Yahara lakes: Likely. Species has already been reported in Mendota and Monona.

LAKE MENDOTA
MADISON
LAKE MONONA
LAKE WINGRA
LAKE WAUBESA

PHOTO: BRETT JOHNSON, DNR MADISON AREA OFFICE COLLECTION

FISHERY PERSPECTIVES

Fishery Description

The 4 Yahara lakes—Mendota, Monona, Waubesa, and Kegonsa—all contain the same major fish species with the exception of the cisco, which is found only in deeper Lake Mendota and to some extent in Lake Monona. These major species consist of 4 predator fish species (largemouth bass, smallmouth bass, walleye, and northern pike), 6 panfish species (yellow perch, bluegill, black crappie, white crappie, white bass, and yellow bass), 6 bottom-feeding and/or rough fish species (common carp, freshwater drum, 3 bullhead species, and white sucker), and cisco. Using our definition of major species as fish having importance to management of the fishery, most of this assemblage clearly are and have been major fish species. There are a few exceptions. Rock bass might be considered a major species, at least for Mendota. Certain smaller forage fish species (e.g., brook silversides) may also be very important to the fishery, but little is known of them in the Yahara lakes. Hence we did not consider them as major species.

Because of Mendota's greater surface area, maximum depth, and bottom and shoreline diversity, the lake has more ecological niches and habitats supporting a greater fish species diversity. Monona is next in habitat diversity, followed by shallower Waubesa and Kegonsa. One important difference between the deeper lakes and the shallower ones is the development of stable temperature stratification during the summer months. Consequently, species that prefer cooler water during the warmest period of the summer are better suited for the deeper lakes, where dissolved oxygen is periodically mixed into the upper thermocline. In shallow Lakes Waubesa and Kegonsa, the thermocline is often in contact with bottom sediments that cause rapid oxygen depletion, so adequate dissolved oxygen during the summer months is usually limited to the well-mixed epilimnion. This habitat diversity and greater water depth for thermal stratification in Mendota and also in Monona apparently allow those lakes to support large populations of more species of panfish at any one time. Shallower Lakes Waubesa and Kegonsa, while having the same major species, often are dominated by fewer of these species at any one time.

Current estimates of the total number of fish species that have been found in Mendota, Monona, Waubesa, and Kegonsa are 57, 40, 34, and 36, respectively. Other species have been reported, but we consider it unlikely that these species have been established in the lakes. The larger number of species found in Mendota most likely is due to its greater size and habitat diversity, although the lake also has been the site for a greater number of surveys emphasizing small-sized fish species.

Probably no characteristic is more notable about the sport fishery of the Yahara lakes than the popularity of fishing for panfish, which has continued unabated on these lakes even as Madison's population has grown. On the other hand, fishing for walleyes and northern pike has been maintained by continual stocking. Largemouth and smallmouth bass have not required stocking in recent years, but these species have not been as significant for fishing as the millions of yellow perch, bluegills, crappies, and temperate bass (white and yellow) that have been harvested by anglers from each of the lakes over the years. Yellow perch alone have accounted for the major proportion of the fish harvested. Whether or not the large abundance of panfish has restricted the successful recruitment of large numbers of predator fish needs further study.

Among the panfish species, there has undoubtedly been competition, particularly between those with similar niches. The replacement of white bass by yellow bass in the lower 3 Yahara lakes during the 1960s may be an example of such competition. The degree of niche overlap between white crappies and black crappies in the Yahara lakes is not known but is possibly important. Of the major species that can be considered pelagic in their habitat preference, yellow perch, cisco, white bass, and crappies are all known to feed extensively on zooplankton such that interspecific competition must be a factor in their relative abundances and/or growth rates.

In general, the boom and bust panfish populations that have occurred in all the Yahara lakes, particularly in Lakes Waubesa and Kegonsa, emphasize the significance of highly variable spawning success. One species can have a very large year class that dominates the fishery for a few years until the population drastically declines by fishing or natural mortality. While the population is high, densities of other panfish are suppressed. When the population declines, other species are able to increase in abundance. The dominance of crappies in the Yahara lakes during the early 1980s is such an example. Also, species such as yellow perch exhibit frequent population cycles that indicate variable reproductive success and year class strength. Whether this is caused by unsuitable environmental conditions during spawning, by interspecific competition, or by intraspecific competition (cannibalism by older individuals) is not known. Regardless of cause, the end result is a highly variable fishery that cannot be accurately predicted much beyond the short life cycles of the currently dominating species. To predict more would require a much greater understanding of the factors that cause or enhance spawning success.

One other important characteristic of the Yahara lakes' fishery today, compared with earlier years, is the abundance of benthivorous or bottom-feeding fish, many of which are classified as rough fish. Prior to the stocking of carp in the late 1800s, white suckers and bullheads were undoubtedly abundant in the lakes, but the proportion of each lake's total benthivorous fish biomass would most likely be much smaller without the carp population explosion. In earlier years, prior to cultural eutrophication, the lake sediments were less organic. Because of agricultural and urban runoff and sewage effluent discharges, the lakes became more eutrophic, exhibiting increased algal blooms. Upon dying, these algal blooms and other sources of detritus increased the organic content of the lake sediments. This process supported an important invertebrate food resource that stimulated a massive increase in carp during the 1930s, at least for the lower 3 lakes. Mendota's enrichment was not as dramatic, although its carp population probably increased after the 1940s. Freshwater drum, a species not found in the Yahara lakes in the early 1900s, also increased in ensuing years, thus constituting additional fish biomass that is not considered desirable for angling. Because the market price of most rough fish (except for bigmouth buffalo) has been so low, the commercial fishing harvest for these species on the Yahara lakes has not been significant. The impact of large populations of carp, freshwater drum, and other rough fish species on predator and panfish populations is not known but may be significant. The tremendous loss of deep-water benthic invertebrates in Lake Mendota since the 1950s suggests that bottom-feeding rough fish may have had an impact on a food resource once heavily utilized by other fish, such as yellow perch, although a degradation of the sediment environment may have been the principal cause for the decline of invertebrates.

Major Impacts on the Fishery

Sewage and Other Nutrients

It is not possible to construct a detailed description of the fish community prior to the mid-1800s, when Euro-American settlement caused a major enrichment of the Yahara lakes. Since that time, the fish community has existed under much more eutrophic lake conditions. The drainage basin reached maximum agricultural development by 1870, causing higher nutrient and sediment loadings to the lakes, which have increased since the 1960s, when corn production and use of artificial fertilizers increased. Rural runoff has been most pronounced in Lake Mendota, which drains more rural land than any of the other 3 Yahara lakes. As Madison and the surrounding communities have grown during the 1900s, discharge from these urban lands via storm sewers has increased, thus also increasing nutrient and sediment loadings to the lakes. Lake Monona has experienced the largest impact from urban runoff, but as Madison and nearby communities continue to grow, Mendota is also increasingly affected by urban runoff. However, the greatest single source of nutrients, particularly to the lower 3 lakes, has been Madison's sewage effluent discharges, which heavily enriched the lakes for most of the early 1900s through the late 1950s. Mendota also received sewage from upstream communities until the discharges were diverted in 1971.

These higher nutrient levels may have increased the productivity of the Yahara lakes for fish species considered desirable for angling. However, much of this increased lake fertility also supported undesirable summer blue-green algal blooms which could not be directly ingested by zooplankton, thus preventing a food-chain link to desirable fish species. The decreased water clarity from the algal blooms caused a decline in aquatic macrophytes that are important as fish habitat. Much of the blue-green algae decomposed to form a detrital layer utilized by macroinvertebrates in the bottom sediments. These macroinvertebrates supported higher numbers of bottom-feeding fish, most likely at the expense of desirable sight-feeding fish.

The best illustration of fish response to this rich food source was the massive increase in numbers of common carp that occurred in the lower 2 Yahara lakes in 1936, when most of Madison's sewage effluent was diverted to Lake Waubesa. In the short-term, the hatch apparently provided large numbers of forage fish for panfish such as crappies and white bass in those lakes. In the long-term, however, the hatch led to a carp population explosion when the long-lived carp became too large to be eaten by any fish species.

This heavy enrichment of the Yahara lakes was analogous to European fish farming practices for carp, in which large amounts of fertilizer were applied to shallow ponds to maintain high carp yields (Neess 1949). In order to combat the dominance of carp in the Yahara lakes, particularly the lower 3 lakes, the WCD conducted an extensive carp removal program from the mid-1930s through 1969. The pounds-per-acre yields of carp from these lakes by the late 1940s were more than double the yields from other Wisconsin lakes that were of similar size but had not received sewage (Threinen 1949*b*). The cost effectiveness of the carp removal effort on the Yahara lakes has never been determined. Despite that, we can say that the removal program was probably needed during the years when the lower 3 lakes were receiving sewage effluents. Had no sewage enrichment occurred, we doubt carp would have become so overabundant that water clarity, aquatic macrophytes, and desirable fish species would have been negatively affected. The lack of extensive commercial fishing for carp and other rough fish on the Yahara lakes during the 1970s–1980s may have allowed those species to increase, but the impact on the fishery is not known because of the lack of good data on their population abundance.

Introductions

Humans have been responsible for introducing a surprising number of species into the Yahara lakes. The origins of species likely to be or have been present in the lakes are identified in Table 21. Of the 16 likely species believed to have been introduced by humans, deliberate stocking accounted for introduction of 2 species.

The intentional stocking of the exotic common carp in the late 1800s is a classic example of a short-sighted introduction gone amok. In the late 1870s, when the first distribution of carp within the United States began, the Wisconsin Commissioners of Fisheries proudly described this fish culture experiment: "The introduction of this new food fish will be of great interest and importance to all inland communities, for there is no ditch, pond, or mill-dam, or any boggy, muddy spot, which can be converted into a pond, in which they will not thrive. It will be strange if, within twenty years, carp do not become as common domestic animals as ducks or pigeons" (Comm. of Fish. 1880:17–18). Both of these predictions proved unfortunately true.

Within just a few years after the carp stocking ceased, lake management problems from burgeoning carp populations began to appear. Coupled with the increase in nutrient inputs to the Yahara lakes outlined in the previous section, the carp populations in the Yahara lakes exploded such that, by the mid-1930s, the WCD was engaged in a major carp removal program.

Few studies have ever attempted to document the role of the common carp in depleting a lake's food resources, which would otherwise be available to more desirable fish species (Kajak 1988), but the loss of such resources could be severe. In lakes with dense algal blooms that are exacerbated by carp recycling nutrients from the lake sediments, light conditions are poor for aquatic macrophyte growth. This not only results in loss of important habitat for fish but also places sight-feeding fish at a disadvantage. Bottom-feeding fish such as carp, bullheads, and suckers thus have an advantage. Overabundant populations of carp can also feed on or disturb the eggs of other desirable fish species, thus decreasing the reproductive success of these fish. Without good market prices for carp, commercial fishing may not maintain carp populations at levels low enough to enhance other fish species in the lakes. It should be noted, though, that the state's rough fish removal efforts have never conclusively proven that continual removal of carp can maintain good populations of desirable species.

The second species introduced through deliberate stocking is the muskellunge. This effort, in Mendota only, involved a small number of fry and a few fingerlings. In the years after stocking was discontinued (in 1941), only a single muskellunge was ever reported caught.

Stocking has been used to introduce 3 other non-native species, all members of the trout family. Atlantic and chinook salmon fry and yearlings were stocked in Mendota in the 1870s because of widespread interest in their value as a useful food for humans. Except for dead 10- to 12-inch chinook salmon observed the year after stocking (Comm. of Fish. 1879), neither species has been reported since then. Because both species require colder water than even Mendota has, it is doubtful that the fry stocked could have lived much longer than the first year.

A similar fate undoubtedly met the other non-native species introduced around this time, the lake trout. One small stocking of adults took place, along with relatively large numbers of fry, between 1885 and 1902. Like the 2 salmons, known temperature requirements of this species suggest that it could not live through a warm summer, and no survivors have been reported. (Because the presence of these 3 species is extremely unlikely, these fish were excluded from Table 21, which is limited to likely species only.)

In addition to stocking of new species, stocking has also been done in the Yahara lakes to boost populations of already existing native species. The 4 species stocked in all 4 lakes over the broadest period of years include walleye, northern pike, largemouth bass, and smallmouth bass. These stockings have apparently been conducted to try to offset a perceived lack of predator fish, from the perspective of anglers looking for good trophy fishing. Of the 4 target species, the greatest effort has gone into stocking walleyes and northern pike, but the populations of these species have shown no long-lasting increase.

Table 21. *Origin of fish species likely to be or likely to have been present in the Yahara lakes.**

Species	Native	Introduction by Humans: Deliberate Stocking	Introduction by Humans: Fish Rescue Operations	Introduction by Humans: Bait Bucket or Other Releases	Stray from Nearby Streams**
Yellow perch	X				
Bluegill	X				
Black crappie	X				
White crappie	O		O		
White bass	X				
Yellow bass			X		
Largemouth bass	X				
Smallmouth bass	X				
Walleye	X				
Northern pike	X				
Cisco	X				
Common carp		X			
Freshwater drum			X		
Black bullhead	X				
Yellow bullhead	X				
Brown bullhead	X				
White sucker	X				
Lake sturgeon	X				
Longnose gar	X				
Shortnose gar	O		O		
Bowfin	X				
American eel	X				
Rainbow trout					X
Brown trout					X
Brook trout					X
Central mudminnow					X
Grass pickerel	O			O	
Muskellunge		X			
Central stoneroller					X
Goldfish				X	
Spotfin shiner	X				
Common shiner	X				
Golden shiner	X				
Pugnose shiner	X				
Emerald shiner	O		O		
Blackchin shiner	X				
Blacknose shiner	X				
Spottail shiner	O		O		
Bluntnose minnow	X				
Fathead minnow				O	O
Creek chub					X
Quillback			O		O
Smallmouth buffalo			O	O	
Bigmouth buffalo	O		O		
Golden redhorse			O	O	
Shorthead redhorse	O		O		
Channel catfish	X				
Tadpole madtom	X				
Burbot	X				
Banded killifish	X				
Blackstripe topminnow	X				
Brook silverside	X				
Brook stickleback					X
Rock bass	X				
Green sunfish	X				
Pumpkinseed	X				
Iowa darter	X				
Fantail darter	O				O
Johnny darter	X				
Logperch	X				
Mottled sculpin	X				

* Origin is categorized as: X most likely from the single source indicated
O most likely from one of the several sources indicated.
Judgments are based on information from John Lyons (Wis. Dep. Nat. Resour., Bur. Res., pers. comm.).

** Species noted as possible strays are all native to nearby streams except for the 3 trouts (rainbow, brown, and brook); their presence was/is due solely to stocking in those streams.

Reasons for the poor reproductive success of these 2 species are not clear, but several factors are suspected. For walleyes, panfish and rough fish populations are so large that they can feed extensively on walleye eggs, fry, and fingerlings before the walleyes become too large to be eaten. For northern pike, the culprits are probably habitat loss of vital wetland spawning areas and lowered lake levels during the early spring spawning season. It is not known whether current efforts to protect the remaining wetlands and to increase lake levels in the spring can increase northern pike populations. In the future, it will be interesting to see if the massive numbers of walleye and lesser numbers of northern pike fry and fingerlings being stocked in Lake Mendota as part of the joint DNR/UW biomanipulation study will result in higher numbers of adults and increased reproduction.

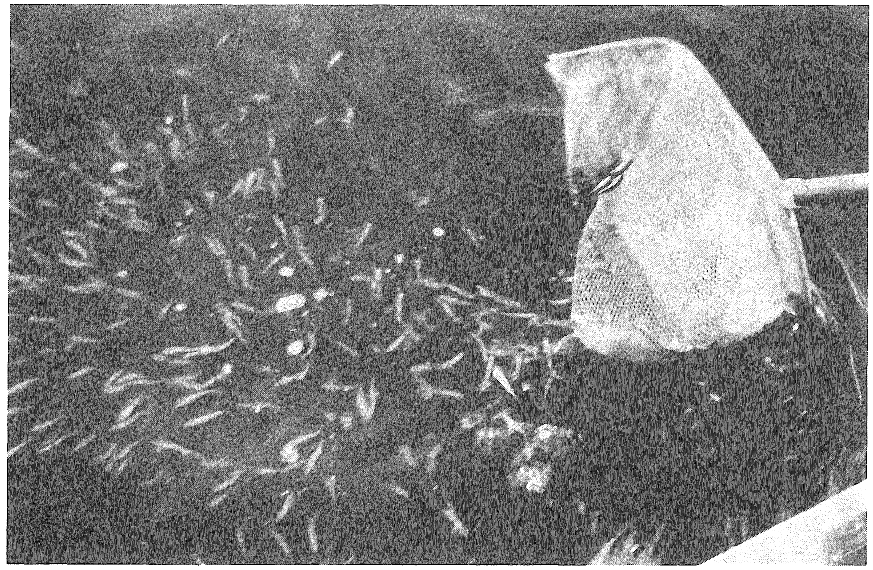


PHOTO: BRETT JOHNSON, DNR MADISON AREA OFFICE COLLECTION

Walleye fingerlings being stocked in Lake Mendota, late 1980s. This stocking was part of the DNR/UW food web research study.

One factor rarely considered in any stockings of fish in the Yahara lakes is that the genetic strains of fish cannot be considered endemic to those lakes. The source of walleyes and northern pike stocked in the past would have been mostly from other Wisconsin lakes, including walleyes raised in northern Wisconsin hatcheries. There is concern that northern Wisconsin walleye strains may not be suited to reproduce in southern Wisconsin lakes—a question that will be addressed in future research (B. Johnson, pers. comm.).

Although stocking to introduce new species and to augment existing populations is responsible for introducing the largest number of individual fish to the lakes, they have been introduced by humans in other ways as well. The most significant of these events was work done in the 1930s and 1940s to rescue fish stranded in shallow backwaters of the Mississippi River.

A species that was introduced to the Yahara lakes in such a manner and that had a major impact on the fishery of the lakes was the yellow bass. Brought into Lake Wingra, yellow bass migrated into Monona, Waubesa, and Kegonsa, where they eventually out-numbered white bass during the 1960s. Yellow bass also appeared in Mendota but never in the proportions found in the lower 3 lakes, where they constituted one of the major panfish species until a massive die-off occurred in the fall of 1976. Yellow bass have recently been observed in very small numbers in the Yahara lakes, but whether or not they will again gain such prominence as in years prior to the die-off is not certain. Because yellow bass are short-lived and never attain the size of white bass, the replacement of white bass by yellow bass probably was not considered an even trade by most anglers.

A second species introduced to the lakes through fish rescue operations was the freshwater drum, another species that was not present in the Yahara lakes in the early 1900s. By the 1940s, drum were considered abundant in Kegonsa and Waubesa but uncommon in Monona and Mendota. Drum apparently began increasing in at least the lower 3 Yahara lakes by the 1960s. Drum populations also have increased in Mendota in recent years where they are regularly caught in most survey gear. The impact of freshwater drum on other fish species in the Yahara lakes is not known.

Unfortunately, fish transferred from other waters were recorded generically and not identified to species. For those years in which actual numbers were recorded, only 5 groups of fish constituted more than 5% of the rescued fish: "catfish" (including bullheads), "sunfish," crappies, carp, and "buffalo" (Becker 1983). Stockings we document in our stocking tables for bullheads, sunfish, and crappies could be attributed to the fish rescue operations.

Although yellow bass and freshwater drum are the only 2 species whose origin is believed to be these fish rescue operations, several other Yahara lakes fish may also have come from this source. Table 21 lists 9 such species.

Finally, humans have introduced fish to the Yahara lakes in one other way: through dumping aquarium fish or bait buckets. The exotic goldfish (a native to eastern Asia) most certainly was introduced by private individuals releasing unwanted pet fish from their aquaria. Although the goldfish was also stocked in Lake Mendota in 1855 (McNaught 1963), we have no record of the number of fish introduced during this planting. Greene (1935) examined no specimens of goldfish in Wisconsin, thus it is not likely that there were survivors of this early stocking. Aquaria releases are a more likely source of the recent records of goldfish in the Yahara lakes.

Anglers emptying bait buckets at the end of their fishing trips may also account for some fish being

PHOTO: DNR CENTRAL OFFICE COLLECTION

Rescuing fish from shallow backwaters of the Mississippi River, 1930s. Fish collected during these rescues were released indiscriminately in other waters, including Lake Wingra and the Yahara lakes, which resulted in the introduction of new species to those water bodies.

introduced to the Yahara lakes. An illegal practice, such dumping nevertheless commonly occurs. One species that may have entered the Yahara lakes in this fashion is the fathead minnow, one of the most commonly used bait fish in Wisconsin. Although fathead minnows are found in some tributaries adjoining the Yahara lakes and thus could enter the lakes as strays, they prefer silty shallow waters not characteristic of the lakes themselves. Whether they would persist in the lakes without constant reintroduction by bait bucket releases is questionable. Table 21 lists 3 other species that may have been introduced by such releases. Although this source of introduction is mentioned for a few species, any minnow used as bait could be added to the Yahara lakes by these releases.

Rough Fish Removal

Common carp was the primary focus of the rough fish removal program in the Yahara lakes. In previous sections, we have discussed the stocking and subsequent population increases of carp. Another historical impact that should be considered relative to the abundant carp populations is the effect on the fishery from the intensive use of the large seines by the WCD. Because of the large mesh size of the seines, only large-sized carp and other large fish species were captured. All non-rough fish species were returned to the lakes; mortalities were supposedly minor. Two major questions asked by fishery managers during the years of the intensive seining involved what impact the removal of large numbers of carp would have on reducing their populations and what impact this removal would have on other panfish and predator fish species.

Evaluations of the carp seining written during the late 1940s and early 1950s about the 3 lower lakes indicated that each lake typically contained one carp year class that would dominate until large numbers had been removed by the seining (Helm 1951; Hacker 1952*a*, 1952*b*). Carp reproduction was generally not significant while the biomass of adult carp was high. Only when the large adult population was reduced did the carp successfully reproduce. These young fish then required about 2 years to grow large enough to be captured in the seine hauls. In Lake Wingra a similar evaluation of the effect of seining on the carp population indicated poor reproductive success when carp populations were high, with reproductive success remaining insignificant even after 2 years of intensive harvesting that reduced the population by 90% (Neess et al. 1957). The dependence of successful carp reproduction on population reduction is the generally accepted observation of other DNR personnel who had experience with the rough fish removal program in the 1960s (R. Kalhagen and W. Jaeger, pers. comm.). This population dynamic suggests that the Yahara lakes had a certain carrying capacity of carp biomass that was a function of the productivity of the lakes, particularly in relation to nutrient inputs.

The effect of the carp removal on other species in the Yahara lakes is not known. This is true in part because the large seines were selective against many of the species of panfish and predator fish of interest and also because other surveys provide only incomplete records of the 30-year period of carp removal. Hacker (1952*a*, 1952*b*) felt that populations of other fish species varied with the size of the carp population. Some species of panfish and predator fish were less abundant the year after carp reached their maximum population abundance, while others increased beginning the year after the adult carp population was reduced to a minimum by the seining.

Another impact that has not been evaluated is what happened to the carp population in each of the Yahara lakes after the intensive WCD seining ended in 1969. Commercial seining has been conducted sporadically on the lakes since the mid-1970s, but the amount of carp removed has been minimal relative to earlier years. While nutrient loadings and concentrations in the lower 3 lakes dropped significantly after the sewage discharges no longer entered the lakes, no information is available on whether the lakes experienced a decrease in their carrying capacity for carp, as would be expected.

Some anglers and biologists believe that current populations are high now that little harvesting occurs, but good scientific data are not available to substantiate this theory.

The impact of removing other rough fish species during carp seining operations is uncertain. However, Hacker (1952*a*, 1952*b*) felt that the removal of bowfins and longnose gar was responsible for maintaining small populations of those species, probably because of their low reproductive potential.

PHOTO: DEAN TVEDT, DNR CENTRAL OFFICE COLLECTION

Dead fish in the Yahara River, 1970. This fishkill occurred from effluent and sludge released when an earthen dam around a holding pond at Madison's sewage treatment plant broke.

Fishkills

Periodic die-offs are not unusual for fish populations, but when populations are abundant, the die-offs seem more spectacular. Localized fishkills in the Yahara lakes have been observed in certain bays or near storm sewer outfalls. These kills were often unexplained but may have been related to oxygen stress or spawning stress. The numbers of fish killed were not large relative to the populations in the whole lake.

However, the occasional massive fishkills have raised concerns about the health of the fishery in addition to the clean-up problems for local government agencies. Probably the greatest effect on the fishery of a massive die-off of a species is the availability of a niche for other fish species or for increased reproductive success of the same species. The fish species in the Yahara lakes that have been recorded as having the most noteworthy die-offs are yellow perch, ciscoes, white bass, and yellow bass. Dead crappies have also been recorded occasionally in significant numbers. At other times, fish species have experienced major population declines without noticeable accumulations of dead fish along lake shorelines.

In Lake Mendota, yellow perch had a massive die-off in 1884, along with significant numbers of ciscoes (Forbes 1890). Ciscoes also had been reported as having periodic fishkills in earlier years but in smaller numbers. Based on Forbes' observations that yellow perch were by far the most abundant fish species in Mendota even after the fishkill, and that yellow perch were very abundant during the early 1900s, no major species shift apparently occurred. The continued success of the commercial cisco fishery during those years also suggests that the cisco population was not significantly reduced for very long. Because no fish disease organisms were found and because both the yellow perch and ciscoes appeared healthy, the fishkill in 1884 may have been caused by dissolved oxygen stress coupled with temperature stress for the cisco. The fact that no mention was made of a yellow perch die-off in Lake Monona during that year suggests that a broad-scale environmental problem did not occur.

Ciscoes also experienced major die-offs in Lake Mendota during the summers of 1932 and 1940, which along with poor reproductive success during the 1940s caused this species to decline (John 1954). Ciscoes were apparently not abundant again until a successful hatch occurred in 1977. Minor fishkills happened in 1980 and 1983, but no massive die-off occurred again until the summer of 1987. Temperature/dissolved oxygen stress was the cause of these die-offs, as has been postulated for the earlier die-offs. However, most of the dying fish were older individuals; this indicates that the age structure of the population is also important (L. Rudstam, UW Cent. Limnol., pers. comm.). Finally, as long as ciscoes were successfully reproducing, periodic large die-offs did not adversely affect population abundances. Except for 1977, no large hatch of cisco has occurred since the 1940s.

Because ciscoes are planktivorous, one important species with which they compete in Lake Mendota is yellow perch. A change could thus be expected in abundance or growth rate of yellow perch or other planktivorous fish following a major cisco die-off. No such response has been recorded, but a change in food supply does occur. The larger-sized *Daphnia pulicaria* dominates when the cisco population is low (Rudstam et al. 1992, 1993). The smaller *Daphnia galeata mendotae* dominates when ciscoes are abundant. Because water clarity is greater in years when *D. pulicaria* dominates (Lathrop 1992*b*), maintaining a low abundance of cisco is a management objective for Lake Mendota.

While the 1884 yellow perch die-off in Lake Mendota could not be attributed to disease, the massive die-offs of yellow perch that occurred in 1939, 1946, and to a lesser extent in other years during the 1940s were attributed to a parasite (*Myxobolus*) (Bardach 1949, 1951). An important impact of these die-offs was an apparent decrease in abundance of the yellow perch population, an increase in yellow perch growth rates, and an increase in average size of yellow perch in the lake. Since the 1940s, the yellow perch population in Lake Mendota has not reverted to the extremely large numbers of small-sized yellow perch that were found in earlier years. The effects of these population changes on food organisms and other fish species is unknown.

For the lower 3 Yahara lakes, no records were found for earlier massive die-offs. The only major fishkill that was recorded for all the lakes was the population crash of white bass and yellow bass in the fall of 1976. Of these 2 species, white bass dominated catches in Mendota, whereas yellow bass dominated catches in the lower lakes prior to the die-off. After the die-off, neither of these species was recorded in DNR surveys until the white bass began to slowly reappear beginning in the mid-1980s. White bass are now frequently found in both Mendota and Kegonsa, but yellow bass are only occasionally found.

One can only speculate about the effects on the fishery of the die-off of these 2 species. Soon thereafter, white and black crappies experienced a major increase. Together they constituted the largest percentage of fish caught in the creel surveys of 1981–83 in Mendota, Waubesa, and Kegonsa, and they were second only to yellow perch in Monona. Based on available data, at no other time have crappies so dominated the fishery of all 4 lakes simultaneously. Following their apparent population explosion, their numbers in various surveys have declined substantially. The crappies may have exploited a niche left vacant by the die-off of the white bass and yellow bass. Another factor that may have been important was the significant loss of aquatic macrophyte habitat around 1976 because of the decline in Eurasian water milfoil. Bluegill catches declined, which may have allowed the crappies to reproduce successfully. The Mendota fish die-off in 1976 was also followed by strong year classes of perch and cisco in 1977. Whether there was any link between these 2 events is not known.

Macrophyte Changes

Aquatic macrophytes in the Yahara lakes have undergone major changes since the late 1800s. Historically, Lakes Mendota, Monona, and Waubesa had extensive stands of diverse species of macrophytes, while macrophytes in Kegonsa were less extensive. In the early 1900s, Lake Monona received Madison's sewage effluent, which increased lake fertility and caused dense algal blooms. The resultant loss of water clarity restricted the macrophytes to shallower water. Algal blooms became very severe in Waubesa and Kegonsa after 1936, when all of Madison's sewage effluent was discharged immediately upstream from Waubesa. Because these lakes were shallower and the amount of sewage had increased since earlier years, the large increase in fertility resulted in such poor water clarity that macrophytes were almost entirely eliminated from those lakes. Sago pondweed, a shade-tolerant species, was the main macrophyte found; it occurred in sporadic patches in nearshore areas.

In Lake Monona, the summer algal blooms were reduced during the late 1920s and throughout the 1930s by heavy applications of copper sulfate, which increased the water clarity. As water clarity improved, aquatic macrophytes began growing in deeper water, but shallow-water macrophytes were chemically eradicated; thus an unusual habitat was created. Algal blooms in Lakes Waubesa and Kegonsa were also treated with copper sulfate, but the macrophytes in these lakes did not become dense because the water clarity was still relatively poor. Mendota's extensive macrophyte community remained essentially unchanged during these years. When the large-scale copper sulfate treatments ended after 1946, water clarity decreased in Lake Monona, causing the deep-water macrophytes to disappear.

The next major change in macrophytes occurred after Madison's sewage was diverted downstream from the lower lakes in 1958. The macrophyte community in all 4 Yahara lakes changed drastically around the mid-1960s with the invasion of the exotic Eurasian water milfoil. Mendota lost its deep-water macrophytes, while the shallow-water milfoil stands became very dense. Shallow-water milfoil in Monona and Waubesa also became very dense, and milfoil densities were significant in Kegonsa as well. These densities in the 4 lakes continued until about 1976, when a major population decline in milfoil occurred in the lakes. Densities were severely reduced in Mendota and Monona, and plants were almost eliminated in Waubesa and Kegonsa. The reason for this decline may have been poor water clarity caused by increased algal blooms. However, from the early 1980s through 1987, milfoil densities began increasing substantially again in Monona and Waubesa. During those years, macrophyte densities were sporadic in Mendota but remained low in Kegonsa.

The fishery responses in the lower 3 Yahara lakes to the early macrophyte changes are difficult to document. The creel surveys on Lakes Waubesa and Kegonsa during 1936–37 indicated that bluegills were a major component of the fishery. In the creel surveys of both lakes for 1938–39, crappies increased substantially, especially in Waubesa. The rough fish removal records were less conclusive for bluegills, although a small decline in catch did occur in Kegonsa. The apparent crappie explosion was evident beginning in 1938 in Waubesa as well as in 1937 in Monona. These crappies would have hatched a few year earlier. Crappies did not increase significantly in the rough fish catches in Kegonsa during those years.

As discussed in an earlier section, a similar decrease in catches of bluegills with a subsequent major increase in catches of crappies occurred soon after the decline in macrophytes in all 4 lakes around 1976. Since bluegills usually predominate the shallow-water fishery in the lakes when macrophyte growth is extensive, it is possible that this sudden loss of macrophyte habitat triggered poor bluegill reproductive success, allowing crappies to have a large successful hatch in succeeding years. However, crappie dominance of the fishery has always been short-lived; large populations have not extended beyond the cycle of the one major year class. With the return of aquatic macrophytes in the Yahara lakes during the 1980s (particularly in Monona and Waubesa), catches of bluegills increased again. This increase was especially great in Waubesa, where bluegills dominated the fishery during the latter half of the 1980s.

Because largemouth bass are also associated with extensive macrophytes, their relative abundance may have been affected by the varying plant densities over the years. Slightly larger catches were recorded in the 1936–37 Kegonsa and Waubesa creel surveys than in the 1938–39 surveys, but catch rates were generally too low to be precise. The numbers of largemouth bass captured in fall boom shocker surveys on all 4 Yahara lakes during the early 1970s and the 1980s also were much higher than in similar surveys during the late 1970s, when macrophyte densities in the lakes were lower.

Another possible effect of the loss of macrophytes in the Yahara lakes is a decline in small shore-area fishes. Lyons (1989) documented that such a decline has occurred in Lake Mendota during this century. He suggests that one major reason for the decline was the change in macrophytes. Magnuson and Lathrop (1992) also suggest that an increase in piscivory resulting from more intensive stocking in recent decades may have been a factor.

One other factor about the aquatic macrophyte changes that may have been important to the fishery involves the association of invertebrate food organisms with macrophyte types. Andrews and Hasler (1943) found that plants with highly dissected leaf structures had much larger densities of invertebrates than did plants with undissected (broad or ribbonlike) leaves. However, densely entangled dissected leaves would hamper the ability of fish to feed on invertebrates, while insects on plants with undissected leaf structure would be more accessible to foraging by fish. Possible impacts of a change from macrophytes with undissected leaves to dissected leaves on fish populations have not yet been studied, but such a change occurred during the early 1960s in Lake Mendota when the native macrophytes (many of which had undissected leaves) were replaced by milfoil, a plant with highly dissected leaves. Whether the same high invertebrate densities that were found on native milfoil during the 1940s in Lake Mendota also were characteristic of the Eurasian milfoil-dominated community after the 1960s is not known. The new UW/DNR research project on Lake Mendota's littoral zone should help answer this question.

In many small lakes dominated by dense aquatic macrophytes, stunting of bluegills is common, as reproduction is excessive and fish predation on the smaller bluegills is low. In the Yahara lakes, which have relatively large pelagic areas, stunting of bluegills has not occurred. The macrophytes in the lakes often decline in abundance later in the summer, thus offering less cover for overabundant small fish.

Loss of Benthic Invertebrates

Although macroinvertebrates have not been extensively studied in the Yahara lakes, one change was recorded for Lake Mendota. This occurred in waters >9 m, an area representing about 65% of the total lake area. During the early 1900s and the late 1930s to mid-1940s, sediments in these deep waters were populated with large numbers of *Chaoborus* and *Chironomus* midge larvae. These midge larvae were identified as major food items for yellow perch (Pearse and Achtenberg 1920). By the early 1950s, surveys suggested *Chaoborus* larval densities had declined, while *Chironomus* densities increased. However, populations of both midges had declined drastically by the early 1960s and continued to be low in the late 1980s. The effect of this decline in a major food source for yellow perch and other desirable fish species has not been determined.

The reasons for this decline in Lake Mendota are not certain, but the most likely cause may be related to a degradation in the sediment environment due to lake eutrophication. However, an increase in the abundance of bottom-feeding fish such as common carp and freshwater drum may also have been a factor. Benthic invertebrate surveys that were conducted on the lower 3 Yahara lakes in 1939 and 1944, and on Monona in 1951, recorded low midge larval densities. This was during a period of large carp abundance linked to nutrient loadings from sewage effluents.

Loss of Spawning Areas

Loss of spawning areas has resulted from the filling-in of the Yahara lakes' shorelines in urban areas, the draining and/or filling of wetlands adjacent to the lakes and their drainage system, and the lowering of spring water levels, which makes remaining wetlands unusable by northern pike. Most of the filling around Lake Monona and its tributaries occurred during the early development of Madison. In more recent years, urbanization has caused the decline of other wetlands along parts of Lake Mendota's northeast and west shorelines. Significant losses of wetlands occurred as a result of drainage programs in the agricultural watersheds of the Yahara lakes during the first half of this century. As of the mid-1970s, only 50%, 8%, 27%, and 30% of the original wetland areas remain in the watersheds of Lakes Mendota, Monona, Waubesa, and Kegonsa, respectively.

In-lake spawning areas are important for many fish species in the Yahara lakes, while wetlands are used primarily by northern pike for spawning. The loss of wetlands has caused poor northern pike reproduction in the lakes and has resulted in low population numbers that must be maintained by stocking. Walleyes, which spawn on gravel substrate in the lake shallows as well as in marshes, also reproduce poorly in the Yahara lakes. However, this poor reproductive success may be more related to excessive fish predation on the eggs, fry, and fingerlings than to the lack of suitable habitat. Panfish still spawn adequately in spite of filling-in along lake shorelines.

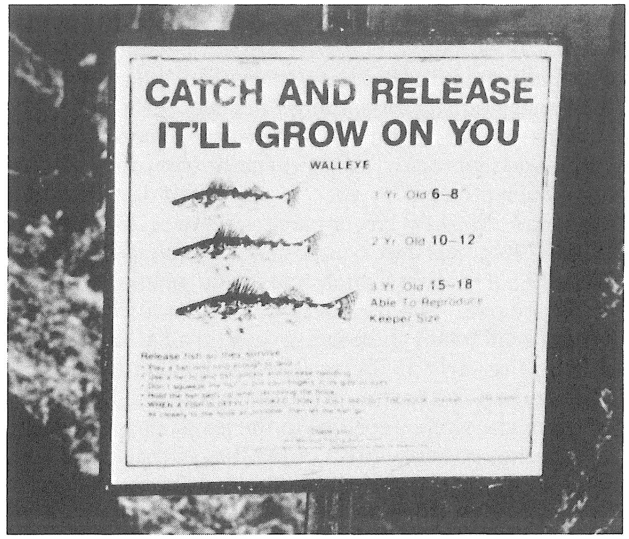
Today the remaining wetlands in the Yahara lakes drainage system are recognized as important for providing fish and wildlife habitat as well as for improving water quality. Efforts have been made for their preservation and in some cases their restoration, but urban expansion continually creates new concerns about preventing loss of additional wetland and shoreline habitat. In addition, efforts have only recently been made to maintain adequate water levels in the wetlands during northern pike spawning in the early spring. Just a few years ago, the wetlands were often not flooded during this period because of lake level management programs.

Angling

Angling is another major impact on the fishery of the Yahara lakes. Harvests of the numerous dominant panfish have been extensive throughout this past century as Madison's population has grown. Ice fishing and open-water fishing have both been popular. The annual sport fishing harvest from Lake Mendota in the 1960s was estimated at as much as 110 kg/ha of fish. This harvest rate was at least twice as great as similar estimates for northern Wisconsin lakes (Corey et al. 1967). At times, concerns about overfishing have resulted in bag limit restrictions for fish such as yellow perch. Currently a bag limit of 50 panfish of any species is in effect for the Yahara lakes.

Intensive harvesting has reduced the abundance of desirable-sized panfish when populations have been high, but harvesting has not restricted the successful reproduction and growth of any panfish species in the 4 lakes. This exploitation may have altered the competitive ability of one species over another during the short-term. However, because of the high fertility and productivity of the Yahara lakes, niches made available by the rapid decline of one species have been rapidly refilled by the successful spawning of that same species or other species.

While intensive angling for panfish has not decreased their abundance for prolonged periods, concerns have been raised about overexploitation of predator fish species (walleyes, northern pike, largemouth bass, and smallmouth bass). In recent years, catch and release of predator fish has been encouraged, and increased minimum size limits and reduced bag limits for these species have been instituted. Past experience has indicated that whenever predator fish populations become relatively large, fishing pressure increases tremendously. An example of this pattern is the rapid removal of abundant walleyes from Lake Mendota during the early 1980s. That was a period when walleye populations had apparently increased because of successful reproduction a few years earlier. Another recent example was the major increase in fishing pressure in response to the large walleye populations built up from the massive stockings in Lake Mendota during the 1980s. As fishing pressure intensifies because of the increased numbers of people and the use of more sophisticated fishing gear, preventing the overexploitation of predator fish populations will be of even more concern for fishery managers and others interested in the fishery of the Yahara lakes.



Catch and release sign for the Yahara lakes.

PHOTOS: BRETT JOHNSON, DNR MADISON AREA OFFICE COLLECTION

Increased minimum size limits and reduced bag limits on walleyes caught in Lake Mendota. Such regulations are aimed at reducing overfishing of this species.

RECOMMENDATIONS

UW/DNR Research Recommendations

In past years, distinctions have been made between the type of research that is best suited for the UW and for the DNR. University research has been considered basic, whereas DNR research has been applied. In the context of research recommendations for the Yahara lakes' fishery, basic research would focus on furthering our understanding about the ecology of important fish species, their food organisms, and important habitat requirements for sustaining abundant harvestable populations. The research would elucidate important community interactions that need to be understood for sound fishery management. Applied research would be geared more to solving problems that affect the day-to-day management of the Yahara lakes' fishery. Obviously, the 2 types of research are not mutually exclusive. The UW/DNR collaborative research projects currently being conducted on Lake Mendota's pelagic and littoral zone food webs indicate that the distinction between applied and basic research is less clear. The presence of the UW Center for Limnology on the shores of Lake Mendota and the long-term involvement and experience of the UW in fishery research on that lake add weight to using Lake Mendota as a study site for additional research on its fishery. Continued collaboration is recommended.

1. While a significant amount of research has been conducted on a few major fish species in Lake Mendota (i.e., yellow perch, cisco, and white bass), relatively little is known about the other major fish species in the lake. We recommend that research on the other major predator fish, panfish, rough fish, and forage fish species in Lake Mendota be conducted. This research would focus on the ecological role of these species and would include bioenergetics modeling as a major component of the project. Of particular importance would be research on reasons for the variable year class strength of all the major fish species, particularly yellow perch and cisco. Because of the complexity of the fish community in Lake Mendota, this research should be a long-term effort of at least 10 years. Further refinement of techniques to assess fish population abundance also should be conducted as part of this long-term study. This standardized sampling could then be used on the 3 lower lakes as well.
2. Stocking of fish in the Yahara lakes has been done in the past without a clear understanding of how it affects the fishery. If stocking is continued as a management tool, research is needed to assess the effectiveness of stocking predator fish; techniques for improving the survivorship of stocked fish also should be researched and developed.
3. Research is also needed on the effects of weed harvesting and weed spraying on fish populations in the Yahara lakes. Appropriate management guidelines should be developed, and optimum plant densities for fish should be recommended.
4. Research should be conducted on the reasons for the dramatic loss of benthic macroinvertebrates in Mendota's profundal sediments. If the main reason is that the sediment environment has been degraded because of lake eutrophication, then reversing conditions may not be possible. If, on the other hand, an increase in benthivorous fish populations contributed to the decline, then future action may be possible.

Management Recommendations

DNR Fisheries Management

1. Develop and implement standardized index sampling to provide information on relative densities and size structure of fish species. This would include expanding boom shocking to sample all encountered fish species for a period of time along certain shorelines in each of the 4 lakes. Index sampling for pelagic species is also needed. This increase in sampling effort should provide quantitative data about the more abundant panfish and rough fish species as well as predator fish species.
2. Continue evaluating the importance of lake level changes on spawning fish populations, including but not limited to northern pike.
3. Regularly conduct a creel survey, winter and summer, on all 4 lakes. Such surveys should include the recording of length-weight data on a random subsample of fish. Ongoing creel surveys would require the long-term funding of a part-time LTE or seasonal employee.
4. Because of the importance of the fishery of the Yahara lakes, we recommend focusing more management attention on these resources. Establishing a Yahara lakes fishery management coordinator could serve as a catalyst for developing new initiatives and would ensure that work among various bureaus, groups, and agencies would be optimized.
5. Develop a management strategy for removing ciscoes when they are abundant and monitor the cisco population. Abundant ciscoes play a key

role in preventing the larger-bodied *Daphnia pulicaria* from dominating in Lake Mendota as opposed to the smaller-bodied *D. galeata mendotae*. High numbers of *D. pulicaria* have been linked to enhanced water clarity.

6. Take a closer look at largemouth and smallmouth bass populations and habitat in all 4 lakes. If their populations are considered too low for available habitat, techniques for increasing their populations may be important.
7. Support the collection of routine, long-term water quality data on the Yahara lakes and the completion of regular macrophyte surveys. Shared funding could be sought from other DNR programs and local governmental agencies.
8. Periodically summarize results of routine surveys. During our search of files containing unpublished materials, we found numerous memoranda describing individual surveys. The value of these records would be enhanced if the results of similar surveys could be summarized—and distributed—every few years.
9. Continue to collaborate with UW on long-term fisheries research on the Yahara lakes. As results of the Lake Mendota study are obtained, reconsider regulations governing the harvest of predator fish. Reduced bag limits and increase legal minimum size restrictions may be needed to maintain desired densities of larger fish. Overharvesting of panfish such as yellow perch may require reduced bag limits.
10. Archive the remaining original daily records of rough fish removal for all affected lakes. The State Historical Society would be an excellent repository for such records.
11. Collect all future fisheries data in metric units. This would allow easier comparisons with studies at UW and elsewhere. In popular summaries for the general public, measurements could be converted to English units.

Dane County

1. The Dane County Public Works Department should continue to maintain complete records on its weed harvesting program and should begin recording information on harvesting hours so that harvesting effort data can be obtained (e.g., tons of weeds removed per hour of harvesting). In addition, this agency should work closely with the DNR Bureau of Fisheries Management on maintaining adequate spring lake levels to enhance spawning of northern pike.
2. The newly formed Dane County Lakes and Watershed Commission has as one of its missions to improve the water quality and recreational value of all county water bodies. For the Yahara watershed, the commission should work to decrease the nutrient inputs to the lakes and to preserve wetland habitat around the lakes.

Local Fishing Clubs

Last but not least of the managers of the Yahara lakes are the many local fishing organizations. Some, such as the Lake Mendota Fishing Association and the Yahara Fisherman's Club, are unique to the Madison vicinity. Others, such as the Capital City Chapter of Muskies Inc. and the 4 Lakes Bassmasters, are local chapters of statewide or national organizations.

Together these local groups can improve the fishery of the Yahara lakes in many ways. They can promote education on proper fish release techniques and promote catch-and-release fishing. They can express their support for implementing the research and management recommendations outlined in this report. They can continue their assistance and cooperation with the DNR Bureau of Fisheries Management in stocking predator fish, preserving or restoring habitat, and instituting stricter bag limits and minimum size restrictions. As state dollars and available labor are stretched thinner, contributions by local groups become more important. Well-kept and accurate personal fishing diaries and other records of fish caught would enhance the long-term assessment of changing fish populations and abundance. If fishing contests are held, good records can help document changes in fish populations. The long-running Percharee, for example, could record the average aggregate weights of all fish submitted from each lake and the length/weight data of selected fish.

APPENDIXES

Appendix A. Data on relative abundance of fish species.

How to use Appendix A

The tables in Appendix A have been systematically arranged and indexed to guide readers in finding certain records for certain lakes.

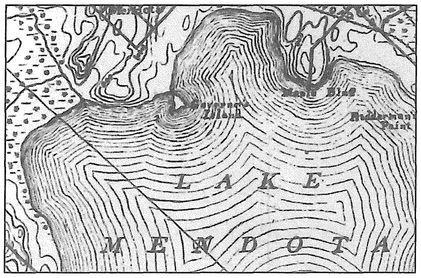
First, all records are grouped together for each lake and presented in this sequence: Mendota, Monona, Waubesa, and Kegonsa. For each lake, records from related survey types are summarized in separate tables for each survey type. The sequence in which these tables are presented follows the same sequence in which these data sources were discussed in the Methods Section. The index below provides a quick guide to these sequences.

Secondly, records listed in the tables of data from various fishery surveys (Appendix Tables A.1–A.38) follow a systematic species sequence. Records are given first for all fish species that are major components of the fishery of the Yahara lakes, in the same sequence as in the text. Records for other species are then presented in phylogenetic order (see footnote on p. 20).

Lastly, indexes at the end of Appendix A (Appendix Tables A.39–A.42) summarize all fish presence records that are included in the Appendix A tables. Again, separate summaries are provided for each lake. For easy comparison, the sequence in which species are listed in these index tables is the same as that in the survey tables.

Index to surveys summarized in Appendix A.

	Appendix Table Number by Subject			
Survey Type	**Mendota**	**Monona**	**Waubesa**	**Kegonsa**
Creel surveys	A.1	A.11	A.20	A.30
Rough fish removal records				
State	A.2	A.12	A.21	A.31
Commercial	A.3	A.13	A.22	A.32
DNR fish population surveys				
Boom shockers	A.4	A.14	A.23	A.33
Fyke nets	A.5	A.15	A.24	A.34
Shoreline seines	A.6	A.16	A.25	A.35
Survey seines	A.7	A.17	A.26	A.36
Stocking records	A.8	A.18	A.27	A.37
DNR fish distribution surveys	A.9	A.19	A.28	A.38
UW research projects	A.10	-	-	-
Anecdotal accounts	-	-	A.29	-



Appendix Table A.1. *Lake Mendota creel surveys, 1952, 1973–74, and 1981–82.**

	1952		1973		1974		1981–82	
Species	No. Caught	% of Catch	No. Caught	% of Catch	No. Caught	% of Catch	No. Caught**	% of Catch
Yellow perch	4,057	78	18,524	74	25,454	75	125,912	37
Bluegill	98	2	1,942	8	3,213	9	1,856	1
Black crappie	-	-	192	1	-	-	94,371	28
White crappie	-	-	76	0	-	-	108,562	32
Crappie spp.	52	1	268	1	133	0	202,933	59
White bass	455	9	1,819	7	2,694	8	942	0
Yellow bass	-	-	549	2	295	1	-	-
Largemouth bass	-	-	69	0	35	0	427	0
Smallmouth bass	79	2	92	0	38	0	1,010	0
Walleye	-	-	96	0	335	1	1,664	0
Northern pike	84	2	187	1	637	2	428	0
Cisco	-	-	-	-	-	-	14	0
Common carp	-	-	-	-	-	-	561	0
Freshwater drum	-	-	81	0	21	0	3,110	1
Bullhead spp.	42	1	929	4	981	3	1,111	0
White sucker	-	-	-	-	-	-	9	0
Longnose gar	-	-	1	0	-	-	-	-
Muskellunge hybrid	-	-	-	-	-	-	19	0
Channel catfish	-	-	12	0	14	0	170	0
Rock bass	355	7	471	2	202	1	2,366	1
Pumpkinseed	-	-	-	-	-	-	66	0
Total	5,222	100	25,040	100	34,052	100	342,598	100
Survey description								
Period	17 May–31 Aug		12 May–26 Oct		19 Jan–30 Nov		1 Jul 81–30 Jun 82	
Method	voluntary		personal interview		personal interview		personal interview	
No. anglers	415		-		5,132		70,498	
No. hours	1,630		-		-		289,042	

* Sources of data:
1952 - Kuntzelman (1952)
1973 - Phelan (1973)
1974 - Wis. Dep. Nat. Resour., Madison Area files (unpubl. data).
1981–82 - Wis. Dep. Nat. Resour., Madison Area files (unpubl. data).

** Numbers represent **projected** fish catch for the year.

Appendix Table A.2. *Lake Mendota state rough fish removal records, 1935–69.**

Year	No. Hauls	Rough Fish (lb)**							No. Game Fish [a]	
		Total	CC	FD	WS	BB	LG	BF	WB	YB
1935	-	35,349	-	-	-	-	-	-	-	-
1936	-	351,025	-	-	-	-	-	-	-	-
1937	-	49,000	-	-	-	-	-	-	-	-
1938	-	135,780	-	-	-	-	-	-	-	-
1939	-	-	-	-	-	-	-	-	-	-
1940	-	141,077	-	-	-	-	-	-	-	-
1941	-	106,211	-	-	-	-	-	-	-	-
1942	-	86,783	-	-	-	-	-	-	-	-
1943	-	-	-	-	-	-	-	-	-	-
1944	-	-	-	-	-	-	-	-	-	-
1945	-	-	-	-	-	-	-	-	-	-
1946	-	76,300	-	-	-	-	-	-	-	-
1947	-	27,000	-	-	-	-	-	-	-	-
1948	-	20,310	-	-	-	-	-	-	-	-
1949	-	68,800	-	-	-	-	-	-	-	-
1950	-	18,000	-	-	-	-	-	-	-	-
1951	-	66,780	-	-	-	-	-	-	-	-
1952	-	21,417	-	-	-	-	-	-	-	-
1953	-	1,958	-	-	-	-	-	-	-	-
1954	-	-	-	-	-	-	-	-	-	-
1955	-	78,703	-	-	-	-	-	-	-	-
1956	-	22,574	-	-	-	-	-	-	-	-
1957	-	92,469	-	-	-	-	-	-	-	-
1958	-	158,832	-	-	-	-	-	-	-	-
1959	-	117,862	-	-	-	-	-	-	-	-
1960	-	100	100	-	-	-	-	-	-	-
1961	-	6,005	5,100	5	-	900	-	-	-	-
1962	-	13,000	13,000	-	-	-	-	-	-	-
1963	9	180,740	176,500	140	100	3,500	300	200	918	5
1964	10	265,220	262,500	20	100	2,600	-	-	270	0
1965	8	190,365	188,650	40	-	1,675	-	-	280	3
1966	7	417,600	415,550	75	100	1,775	100	-	2,532	191
1967	-	2,270	2,000	70	-	200	-	-	-[b]	-[b]
1968	-	5,510	5,400	10	-	100	-	-	-	-
1969	-	2,100	2,000	-	100	-	-	-	-	-

* Sources of data: White and yellow bass data from 1963–66 are from Wright (1968). Rough fish data from 1960–69 are from rough fish records in DNR's central library in Madison (unpubl. data). All other data are from Wis. Dep. Nat Resour., Madison Area files (unpubl. data). Description of gear: The state rough fish seine varied in length from 1,370–1,830 m, in mesh size from 90–110 mm, and in depth from 3–4 m.

** Species codes: CC = Common carp FD = Freshwater drum
WS = White sucker BB = Bigmouth buffalo
LG = Longnose gar BF = Bowfin

[a] Species codes: WB = White bass YB = Yellow bass

[b] Data for 1967 are from only one haul, in which 1,071 white bass and 229 yellow bass were taken (Wright 1968).

Appendix Table A.3. *Lake Mendota commercial rough fish removal records, 1976–84.**

		Rough Fish (lb)**				No. Game Fish[a]										
Year	Days	Total	CC	FD	BB	BG	CS	WB	LB	WE	NP	BH	CF	LS	LG	MH
1976	14	82,230	5,410	4	6,816	-	-	-	-	-	-	-	-	-	-	-
1977	-	132,460	129,050	60	3,350	-	-	-	-	-	-	-	-	-	-	-
1978	-	74,690	73,425	-	1,265	-	-	-	-	5	5	-	-	-	-	-
1979	-	54,140	51,450	50	2,640	-	-	-	1	27	22	-	220	-	-	1
1980	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1981	15	29,626	16,440	190	12,996	-	-	2	-	11	13	2	27	-	-	1
1982	6	6,451	5,617	207	627	1	100	20	-	12	2	3	76	1	40	-
1983	4	860	415	-	445	-	-	-	-	-	-	-	-	-	-	-
1984[b]	35	23,255	14,080	-	9,175	-	-	-	-	-	-	-	-	-	-	-

* Source of data: Wis. Dep. Nat. Resour., Madison Area files (unpubl. data). Description of gear: The commercial rough fish removal contracts allowed for use of seines not less than 760 m with a maximum mesh size of 150 mm, or entanglement nets 910 m long with a minimum mesh size of 150 mm.

** Species codes: CC = Common carp; FD = Freshwater drum; BB = Bigmouth buffalo

[a] Species codes: BG = Bluegill; CS = Crappie spp.; WB = White bass; LB = Largemouth bass; WE = Walleye; NP = Northern pike; BH = Bullhead spp.; CF = Channel catfish; LS = Lake sturgeon; LG = Longnose gar; MH = Muskellunge hybrid

[b] In addition to the 23,255 lb of rough fish removed commercially, 5,670 lb of rough fish were removed by the state in 1984.

Appendix Table A.4. *Lake Mendota fish population surveys using boom shockers, 1970, 1972, 1977–83, and 1985.**

	No. Fish Caught**											
Species	**1970**	**1972**	**— 1977 —**		**1978**	**1979**	**1980**	**— 1981 —**		**1982**	**1983**	**1985**
Yellow perch	1	-	18 A	12	32	44	44	35	38	102	149	9
Bluegill	2	21	5	11	57	20	31	-	36	122	104	84
Black crappie	-	15	-	46	107	23 A	41 A	-	99	83	56	9
White crappie	-	-	3	1	20	- A	16 A	-	145	23	1	1
Crappie spp.	-	15	3	47	127	23 A	57 A	20	244	106	57	10
White bass	8	-	-	-	1	-	3	-	10	39	89	19
Yellow bass	8	-	-	-	2	-	-	-	-	-	1	10
Largemouth bass	1	5	43	10	5	5	11	5	62	112	76	28
Smallmouth bass	-	-	-	-	3	1	1	-	6	21	40	13
Walleye	200	57	47	96	329	118	137	1	25	29	47	65
Northern pike	2	53	10	4	33	21	10	-	2	66	16	9
Cisco	-	-	-	-	-	-	1	-	-	1	2	-
Common carp	-	- P	50	3	-	-	-	19	- A	- A	5 A	-
Freshwater drum	-	-	13	29	14	-	17 A	18	48	69	55	36
Bullhead spp.	1	11	24	30	15	40 A	27	-	10	29	14	3
White sucker	-	17	18	12	7	7	-	1	6 A	7	9	6
Longnose gar	-	-	-	1	-	-	10	3	4	2	2	1
Bowfin	1	-	-	-	3	-	2	-	3	-	-	-
Muskellunge hybrid	-	-	-	-	-	-	-	-	-	3	1	-
Golden shiner	-	-	-	-	1	-	-	-	-	-	1	-
Emerald shiner	-	-	-	-	-	-	-	-	-	- A	-	-
Spottail shiner	-	-	-	-	-	-	-	-	-	- A	1	-
Bluntnose minnow	-	-	-	-	-	-	-	-	-	- P	-	-
Creek chub[a]	-	-	1	-	-	-	-	-	-	-	-	-
Bigmouth buffalo	-	-	-	-	-	-	2	3	6 A	1 A	2	-
Channel catfish	35	-	-	-	-	1	-	-	-	-	1	-
Brook silverside	-	2	-	-	-	-	-	-	2	1 A	9 A	- A
Rock bass	5	3	3	1	75	106	31	2	24	6	21	1
Green sunfish	-	-	-	1	3	1	2	-	2	3	-	2
Pumpkinseed	9	-	2	3	2	2	1	1	6	31	18	4
Logperch	-	1	-	1	3	-	-	-	-	-	3	6
Mottled sculpin[b]	1	-	-	-	-	-	-	-	-	-	-	-
Survey description[c]												
Month	Oct	Nov	Sep	Oct	Nov	Oct	Sep	Aug	Sep	Sep	Sep	Oct
Time of day	day/night	night	day	night	night	night	night	-	night	night	night	night
Hours	-	-	5	4.2	14	3.0	5.0	-	3.4	5.2	4.7	5.9

* Sources of data: August 1981 - UW-LTER Project (John Magnuson, Univ. Wis.-Madison, Cent. Limnol., unpubl. data). All other years - Wis. Dep. Nat. Resour., Madison Area files (unpubl. data). Most calculations of effort and some corrections to the numbers of fish recorded were provided by Steve Gilbert (former Madison Lakes fish biologist, Wis. Dep. Nat. Resour., pers. comm., 1990).

** In general, only a few of the more abundant panfish, minnows, and rough fish were sampled. Fish recorded as abundant and present in the field notes are marked with A and P, respectively.

[a] Data were recorded as chub, and were interpreted to mean creek chub.

[b] Data recorded as sculpin, and were interpreted to mean mottled sculpin.

[c] DC current of 230 v was used from an 18-ft boat.

Appendix Table A.5. *Lake Mendota fish population surveys using fyke nets, 1947, 1957, 1970–73, 1977–78, and 1985.**

	1947		1957**	1970				1971		1972		1973		1977				1978	1985	
Species	No. Caught	% of Catch	No. Caught	No. Caught	% of Catch	No. Caught	% of Catch	No. Caught	% of Catch	No. Caught	% of Catch	No. Caught	% of Catch	No. Caught	% of Catch	No. Caught	% of Catch	No. Caught	No. Caught	% of Catch
Yellow perch	23	3	-	138	4	1	0	843	20	-	-	34	1	5,318	38	119	33	194	-	-
Bluegill	127	16	-	2,398	62	3	1	645	15	60	23	33	1	774	6	15	4	540	8	10
Black crappie	142	18	-	-	-	24	10	-	-	-	-	-	-	917	7	27	7	-	-	26
White crappie	17	2	-	-	-	-	-	-	-	-	-	-	-	586	4	-	-	-	-	-
Crappie spp.	159	20	-	912	23	24	10	1,462	34	15	6	155	7	1,503	11	27	7	5,646	20	26
White bass	107	13	-	30	1	206	85	471	11	-	-	52	2	-	-	-	-	10	-	-
Yellow bass	-	-	-	-	-	-	-	6	0	-	-	-	-	-	-	-	-	-	-	-
Largemouth bass	26	3	-	14	0	-	-	17	0	-	-	18	1	43	0	-	-	16	-	-
Smallmouth bass	2	0	-	-	-	-	-	-	-	-	-	-	-	4	0	-	-	-	-	-
Walleye	5	1	-	175	4	-	-	134	3	80	31	1,768	75	1,663	12	169	47	246	45	58
Northern pike	26	3	93	222	6	2	1	261	6	73	28	300	13	679	5	26	7	221	5	6
Common carp	-	-	-	-	-	-	-	-	-	-	-	-	-	146	1	-	-	15 A[a]	-	-
Freshwater drum	-	-	-	-	-	-	-	-	-	-	-	-	-	10	0	-	-	606	-	-
Bullhead spp.	222	27	-	-	-	3	1	368	9	1	0	7	0	2,651	19	-	-	3,803	-	-
White sucker	-	-	-	-	-	-	-	104	2	31	12	-	-	657	5	-	-	408 A[a]	-	-
Bowfin	-	-	-	-	-	-	-	-	-	-	-	-	-	18	0	-	-	29	-	-
Muskellunge hybrid	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-
Golden shiner	-	-	-	-	-	-	-	-	-	-	-	-	-	12	0	-	-	55	-	-
Bigmouth buffalo	-	-	-	-	-	-	-	-	-	-	-	-	-	17	0	-	-	3	-	-
Channel catfish	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	45	-	-
Rock bass	16	2	-	-	-	2	1	1	0	-	-	-	-	539	4	5	1	-	-	-
Green sunfish	86	11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumpkinseed	-	-	-	-	-	3	1	-	-	-	-	-	-	27	0	-	-	38	-	-
Unidentified	10	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	809	100	93	3,889	100	242	100	4,312	100	260	100	2,367	100	14,065	101	361	99	11,878+	78	100
Survey description[b]																				
Month	Jun		Mar/Apr	Apr		Oct		Apr		Mar		Mar/Apr		Mar/Apr		Apr		Apr	Apr	
No. fyke net lifts	-		-	19		-		26		4		-		84		4		89	4	

* Sources of data:
1947 - Mackenthun (1947)
All other years - Wis. Dep. Nat. Resour., Madison Area files (unpubl. data).

** No summary was found for the sampling done in 1957, only a later correspondence referring to the number of northern pike caught.

[a] Fish recorded as abundant in the field notes are marked with A.

[b] Fyke nets varied in hoop size from 1–1.5 m and in mesh size from 19–50 mm.

Appendix Table A.6. *Lake Mendota fish population surveys using shoreline seines, 1966 and 1977–80.**

Species	No. Fish Caught				
	1966	1977	1978	1979	1980
Yellow perch	41	4	1	3	1
Bluegill	780	173	350	394	629
Black crappie	-	-	28	72	182
White crappie	-	-	3	1	26
Crappie spp.	105	-	31	73	208
White bass	4	-	-	-	-
Largemouth bass	127	5	4	-	3
Walleye	-	1	-	-	-
Cisco	-	-	-	-	2
Bullhead spp.	-	-	1	-	-
Golden shiner	-	-	5	17	6
Emerald shiner	-	-	-	20	-
Bluntnose minnow	-	37	15	-	-
Brook silverside	-	5	25	-	40
Rock bass	-	-	5	-	1
Green sunfish	-	-	1	-	-
Pumpkinseed	-	1	-	-	-
Logperch	-	1	1	1	-
Survey description**					
Month	Jul	Sep	Sep	Aug	Sep
No. hauls	7	18	22	22	29

*Source of data: Wis. Dep. Nat. Resour., Madison Area files (unpubl. data).

**Shoreline seines varied in length from 6–8 m, in mesh size from 3–9 mm, and had a depth of 1 m.

Appendix Table A.7. *Lake Mendota fish population surveys using survey seines, 1984.**

Species	1984	
	No. Caught	% of Catch
Yellow perch	947	28
Bluegill	1,076	32
Black crappie	484	14
White crappie	5	0
White bass	220	7
Yellow bass	4	0
Largemouth bass	33	1
Smallmouth bass	11	0
Walleye	2	0
Northern pike	9	0
Common carp	- **	-
Freshwater drum	470	14
Bullhead spp.	1	0
White sucker	29	1
Lake sturgeon	1	0
Longnose gar	3	0
Muskellunge hybrid	1	0
Golden shiner	8	0
Bigmouth buffalo	- **	-
Pumpkinseed	42	1
Total	3,346	98
Survey description[a]		
Month	Sep	
Seine length (ft)	1,800	
Hauls	2	

* Source of data: Wis. Dep. Nat. Resour., Madison Area files (unpubl. data).

** 1,890 lb of carp and 2,075 lb of buffalo were caught off Warner Park, and 1,645 lb of carp and 60 lb of buffalo were caught off the west side of Picnic Point.

[a] Survey seines varied in mesh size from 32–50 mm and in depth from 3–4 m.

Appendix Table A.8. *Lake Mendota stocking records, 1852–1986.**

	No. Stocked**											
Year(s)[b]	Yellow Perch	Bluegill	Crappie spp.	White Bass	Largemouth Bass	Smallmouth Bass	Bass spp.[a]	Walleye	Northern Pike	Cisco	Bullhead spp.	Others[a]
1852–55	-	-	-	-	-	-	-	-	-	unk. no.[c]	-	unk. no.[c], G
1875	-	-	-	-	-	-	-	-	-	-	-	10,000 R, AS
1877	-	-	-	-	-	-	-	-	-	-	-	15,800 R, CS
	-	-	-	-	-	-	-	-	-	-	-	6,000 Y, CS
1880	-	-	-	-	-	-	-	-	-	75,000 R	-	-
1885	-	-	-	-	-	-	-	200,000 R	-	-	-	400 A[d], LT
1886	-	-	-	-	-	-	-	-	-	15,000,000 E	-	-
	-	-	-	-	-	-	-	-	-	180,000 R	-	-
1887	-	-	-	-	-	-	-	1,000,000 R	-	-	-	-
1889	-	-	-	-	-	-	-	100,000 R	-	-	-	-
1890	-	-	-	-	-	-	-	160,000 R	-	-	-	-
1891	-	-	-	-	-	-	-	-	-	-	-	-
1895	-	-	-	-	-	-	-	3,400,000 R	-	-	-	-
1899	-	-	-	500 A	-	-	-	-	-	-	-	132,000 R, LT
1900	-	-	-	-	-	-	-	5,250,000 R	7,000,000 E	-	-	600,000 R, LT
1901	-	-	-	-	-	-	-	-	-	-	-	1,200,000 R, LT
1902	-	-	-	-	-	-	-	600,000 R	-	-	-	480,000 R, LT
1903	-	-	-	-	-	-	-	300,000 R	2,080,000 E	-	-	-
1904	-	-	-	-	-	-	6,000 I	-	-	-	-	-
1905	-	-	-	-	-	-	12,000 I	1,250,000 R	-	-	-	-
1906	-	-	-	-	-	-	22,500 R	1,500,000 R	5,180,000 E	-	-	50,000 R, M
	-	-	-	-	-	-	5,000 I	-	-	-	-	-
1907	-	-	-	-	-	-	-	650,000 R	-	-	-	-
1908	-	-	-	-	-	-	9,000 R	500,000 R	5,530,090 E	-	-	-
	-	-	-	-	-	-	15,200 I	-	-	-	-	-
1910–19	-	-	-	-	-	-	68,500 I	26,445,000 R	-	-	-	-
1920–29	-	-	-	-	-	-	-	8,025,000 R	-	-	-	-
1922	-	-	-	-	-	-	-	-	340,000 R	-	-	-
1929	-	-	-	-	-	-	-	-	300 A	-	-	-
1930–34	-	-	-	-	28,102 I	-	-	-	-	-	-	-
1933	-	-	-	-	-	-	-	-	-	-	-	80 I, M
1934	-	-	-	-	-	-	-	-	-	-	-	20 A, LS
1935	-	-	-	-	-	-	-	2,738,000 R	3,750 I	-	-	40,000 R, M
1936	352,000 I	-	-	-	-	-	-	2,738,000 R	2,500 I	-	-	51 A, LS
	-	-	-	-	-	-	-	-	-	-	-	52,250 R, M
1937	-	10,000 I	5,000 I	-	7,200 I	-	-	1,845,750 R	3,750 I	-	-	181,750 R, M
	-	3,000 Y	-	-	500 Y	-	-	-	-	-	-	-
1938	-	-	-	-	2,000 I	-	-	5,092,556 R	12,000 I	-	-	62,500 R, M
	-	-	-	-	-	-	-	-	-	-	-	95 I, M
1939	-	-	-	-	18,007 I	-	-	4,000,000 R	3,500 I	-	25,000 Y	60,000 R, M
	-	-	-	-	192 A	-	-	-	-	-	-	50 I, M
	-	-	-	-	-	-	-	-	-	-	-	-

Appendix Table A.8. *Continued.*

Year(s)[b]	No. Stocked**											
	Yellow Perch	Bluegill	Crappie spp.	White Bass	Largemouth Bass	Smallmouth Bass	Bass spp.[a]	Walleye	Northern Pike	Cisco	Bullhead spp.	Others[a]
1940	15,000 I	-	-	15,000 I	30,000 I	25,000 I	-	11,000,000 R	15,000 R	-	-	60,000 R, M
	-	-	-	-	-	-	-	-	695 I	-	-	-
1941	-	8,000 I	150 A	-	15,000 I	20,000 I	-	4,995,071 R	5,247 I	-	-	300 I, M
	-	400 A	-	-	-	-	-	-	-	-	-	
	-	-	-	-	-	-	-	-	-	-	-	-
1942	-	12,000 Y	-	-	20,000 I	20,000 I	-	10,735 I	-	-	25,000 I	-
	-	800 A	-	-	725 Y	-	-	-	-	-	500 A	-
	-	-	-	-	20 A	-	-	-	-	-	-	-
1943	12,902,400 E	6,000 I	-	12,500 I	15,000 I	10,000 I	-	9,000,000 R	-	-	1,800 Y	-
	-	-	-	-	-	-	-	-	-	-	200 A	-
1944	-	4,500 I	-	-	5,000 I	5,000 I	-	2,000,000 R	50,000 R	-	-	-
1945	-	-	-	-	-	10,000 I	-	380,000 R	-	-	-	-
	-	-	-	-	-	-	-	13,310 I	-	-	-	-
1946	-	-	-	-	-	-	-	-	-	6,282,086 R	-	-
	-	-	-	-	-	-	-	-	-	-	-	-
1947	-	-	-	-	-	-	-	-	-	-	-	-
1948	-	-	-	-	12,692 I	10,000 I	-	1,000 I	35 Y	-	-	-
1949	-	-	-	-	10,000 I	-	-	5,000 I	30,000 R	-	-	-
1950	-	-	-	-	500 I	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-
1951	-	-	-	-	5,000 I	-	-	-	-	-	-	-
1952	-	-	-	-	-	-	-	-	-	-	-	-
1953	-	-	-	-	-	-	-	-	-	-	-	-
1954	-	-	-	-	-	-	-	-	-	-	-	-
1955	-	-	-	-	-	-	-	-	-	-	-	-
1956	-	-	-	-	-	-	-	-	-	-	-	-
1957	-	-	-	-	-	-	-	-	-	-	-	-
1958	-	-	-	-	5,052 I	-	-	1,500 I	32 A	-	-	-
1959	-	-	-	-	-	-	-	-	-	-	-	-
1960	-	-	-	-	-	-	-	-	-	-	-	-
1961	-	-	-	-	-	-	-	-	334 A	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-
1962	-	-	-	-	-	-	-	-	36 A	-	-	-
1963	-	-	-	-	-	-	-	-	21 A	-	-	-
1964	-	-	-	-	-	-	-	-	5,000 I	-	-	-
1965	-	-	-	-	-	-	-	-	-	-	-	-
1966	-	-	-	-	-	-	-	-	-	-	-	-
1967	-	-	-	-	-	-	-	360,355 I	-	-	-	-
1968	-	-	-	-	-	-	-	-	-	-	-	-
1969	-	-	-	-	-	-	-	299,000 I	-	-	-	-

(*Continued on next page*)

Appendix Table A.8. *Continued.*

Year(s)[b]	No. Stocked** Yellow Perch	Bluegill	Crappie spp.	White Bass	Largemouth Bass	Smallmouth Bass	Bass spp.[a]	Walleye	Northern Pike	Cisco	Bullhead spp.	Others[a]
1970	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-
1971	-	-	-	-	-	-	-	80,500 I	-	-	-	-
1972	-	-	-	-	-	-	-	-	-	-	-	-
1973	-	-	-	-	-	-	-	246,000 I	-	-	-	-
1974	-	-	-	-	-	-	-	-	-	-	-	-
1975	-	-	-	-	-	-	-	-	-	-	-	-
1976	-	-	-	-	-	-	-	-	-	-	-	-
1977	-	-	-	-	-	-	-	98,445 I	-	-	-	-
1978	-	-	-	-	-	-	-	-	-	-	-	-
1979	-	-	-	-	-	-	-	-	-	-	-	-
1980	-	-	-	-	-	-	-	-	-	-	-	3,610 I, MH
1981	-	-	-	-	1,000 I	-	-	-	3,600 I	-	-	10,000 I, MH
	-	-	-	-	-	-	-	-	500 A	-	-	-
1982	-	-	-	-	-	-	-	-	2,005,000 R	-	-	-
	-	-	-	-	-	-	-	-	10,260 I	-	-	-
1983	-	-	-	-	-	-	-	-	5,357 I	-	-	-
1984	-	-	-	-	-	-	-	-	2,910 I	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-
1985	-	-	-	-	-	-	-	106,200 I	2,500 I	-	-	3,312 I, MH
1986	-	-	-	-	-	-	-	20,000 R	56,000 R	-	-	1,500 I, MH
	-	-	-	-	-	-	-	57,662 I	2,274 I	-	-	-
Totals												
E	12,902,400	-	-	-	-	-	-	-	19,790,090	15,000,000	-	e
R	-	-	-	-	-	-	31,500	93,189,377	2,496,000	6,537,086	-	e
I	367,000	28,500	5,000	27,500	174,553	100,000	106,700	1,279,707	63,103	-	25,000	e
Y	-	15,000	-	-	1,225	-	-	-	35	-	26,800	e
A	-	1,200	150	500	212	-	-	-	1,223	-	700	e
C	-	-	-	-	-	-	-	-	-	-	-	e

* Sources of data: Early records came from annual reports of the Wisconsin Commissioners of Fisheries (1876–79, in the State Historical Society), WCD memoranda in the State Historical Society archives, ledgers in the DNR's central library, and Mackenthun (1947). Data from 1959 to 1986 came from stocking receipts in Wis. Dep. Nat. Resour., Madison Area and South. Dist. files. Sources of fish: all fish were raised at DNR fish hatcheries with the exception of fish taken from the Mississippi River during rescue operations in the late 1930s and early 1940s, and walleye fingerlings raised by the Lake Mendota Fishing Association for stocking in Lake Mendota in 1986. Corrections to selected stocking totals since 1970 for walleyes, northern pike, and muskellunge hybrids were made by Steve Gilbert (former Madison Lakes fish biologist, Wis. Dep. Nat. Resour., pers. comm., 1990).

** Numbers stocked are coded as: E = eggs, R = fry, I = fingerlings, Y = yearlings, A = adults, and C = combination of fingerlings and adults.

[a] Of major species, bass spp. are *Micropterus* spp. Other species are coded as: G = goldfish, AS = Atlantic salmon, CS = chinook salmon, LT = lake trout, M = muskellunge, LS = lake sturgeon, and MH = muskellunge hybrid.

[b] Between 1852 and the mid-1930s, years listed are only those for which stocking records on any one of the Yahara lakes were found. After 1935, stocking took place more regularly, so all years are listed including 1955 and 1966, for which no records were located.

[c] Gov. Farwell stocked unknown numbers of ciscoes in 1852–55 and unknown numbers of goldfish in 1855.

[d] Year is estimated from a reference to a stocking "about four years ago" in a report covering 1889–90 (Comm. of Fish. 1891).

[e] Totals for other species are: Goldfish (unknown no. and life stage); Atlantic salmon 10,000 fry; chinook salmon 15,800 fry and 6,000 yearlings; lake trout 2,412,000 fry; muskellunge 506,500 fry and 525 fingerlings; lake sturgeon 71 adults; muskellunge hybrid 18,422 fingerlings.

Appendix Table A.9. *Lake Mendota fish distribution survey, 1900–83.**

	1900–59			1960–73				1974–83			
Species	No. Stn.	Gear Type**	Collector[a]	No. Stn.	% of Total	Gear Type**	Collector[a]	No. Stn.	% of Total	Gear Type**	Collector[a]
Yellow perch	5	2,4	A	5	83	3	F	8	38	1,3,5	B,D
Bluegill	4	2,3,-	A	6	100	3	F	12	57	1,3,5	B,D
Black crappie	3	2,-	A	3	50	3	F	10	48	1,3,5	B,D
White crappie	-	-	-	1	17	3	F	3	14	1,3	B,D
White bass	1	2	A	1	17	3	F	3	14	1,3	B,D
Yellow bass[b]	-	-	-	-	-	-	-	6	29	1,3	B,D
Bass hybrid[c]	-	-	-	-	-	-	-	1	5	3	B
Largemouth bass	3	2,3	A	2	33	3	F	3	14	1,3	B,D
Smallmouth bass	1	2	A	1	17	3	F	1	5	1	D
Walleye	-	-	-	-	-	-	-	6	29	1,3,4,5	B,D,G
Northern pike	2	2,4	A	1	17	3	F	5	24	1,3,4,5	B,D,G
Cisco	3	4,6	A,H	-	-	-	-	2	10	7,-	C,E
Common carp	-	-	-	1	17	3	F	6	29	1,3,4	B,D,G
Freshwater drum	-	-	-	-	-	-	-	3	14	1,3	B,D
Black bullhead	-	-	-	1	17	3	F	8	38	1,3	B,D
Yellow bullhead	-	-	-	-	-	-	-	3	14	1,3	B,D
Brown bullhead	-	-	-	-	-	-	-	5	24	1,3	B,D
White sucker	2	2	A	-	-	-	-	4	19	1,3	B,D
American brook lamprey	-	-	-	-	-	-	-	-	-	-	-
Lake sturgeon	-	-	-	1	17	5	E	4	19	4,7	G,H
Longnose gar	2	2,3	A	-	-	-	-	2	10	1	D
Shortnose gar	1	7	E	-	-	-	-	-	-	-	-
Bowfin	-	-	-	-	-	-	-	1	5	1	D
American eel	-	-	-	-	-	-	-	-	-	-	-
Mooneye	-	-	-	-	-	-	-	-	-	-	-
Rainbow trout	-	-	-	-	-	-	-	-	-	-	-
Brown trout	-	-	-	-	-	-	-	-	-	-	-
Brook trout	-	-	-	-	-	-	-	-	-	-	-
Lake trout	-	-	-	-	-	-	-	-	-	-	-
Central mudminnow	-	-	-	-	-	-	-	-	-	-	-
Grass pickerel[b]	-	-	-	-	-	-	-	-	-	-	-
Muskellunge	1	7	E	-	-	-	-	-	-	-	-
Muskellunge hybrid[c]	-	-	-	-	-	-	-	2	10	4	G
Central stoneroller	-	-	-	-	-	-	-	-	-	-	-
Goldfish	-	-	-	-	-	-	-	-	-	-	-
Spotfin shiner	-	-	-	1	17	3	F	2	10	3	B
Mississippi silvery minnow	-	-	-	1	17	3	F	-	-	-	-
Common shiner	-	-	-	1	17	3	F	-	-	-	-
Hornyhead chub	-	-	-	1	17	3	F	-	-	-	-
Golden shiner	1	-	A	2	33	3	F	3	14	3	B,D
Pugnose shiner	2	-	A	-	-	-	-	-	-	-	-
Emerald shiner	1	-	A	-	-	-	-	4	19	3	B,D
River shiner	-	-	-	-	-	-	-	-	-	-	-
Bigmouth shiner	-	-	-	1	17	3	F	-	-	-	-
Blackchin shiner	4	2,3,-	A	2	33	3	F	-	-	-	-
Blacknose shiner	4	2,3,-	A	-	-	-	-	-	-	-	-
Spottail shiner	-	-	-	-	-	-	-	3	14	1,3	B,C
Pugnose minnow	-	-	-	1	17	3	F	-	-	-	-
Bluntnose minnow	4	2,3,-	A	4	67	3	F	5	24	3	B,D
Fathead minnow	-	-	-	2	33	3	F	2	10	3	B
Creek chub	-	-	-	1	17	3	F	-	-	-	-
Quillback	-	-	-	-	-	-	-	-	-	-	-
Lake chubsucker	-	-	-	-	-	-	-	-	-	-	-
Smallmouth buffalo	-	-	-	-	-	-	-	-	-	-	-
Bigmouth buffalo	-	-	-	-	-	-	-	2	10	1,3	B,D

(Continued on next page)

Appendix Table A.9. *Continued.*

Species	1900–59 No. Stn.	Gear Type**	Collector[a]	1960–73 No. Stn.	% of Total	Gear Type**	Collector[a]	1974–83 No. Stn.	% of Total	Gear Type**	Collector[a]
Silver redhorse	-	-	-	-	-	-	-	-	-	-	-
Golden redhorse	-	-	-	-	-	-	-	-	-	-	-
Shorthead redhorse	-	-	-	-	-	-	-	-	-	-	-
Channel catfish	-	-	-	-	-	-	-	4	19	2,3,4	B,G
Tadpole madtom	-	-	-	-	-	-	-	-	-	-	-
Flathead catfish	-	-	-	-	-	-	-	-	-	-	-
Burbot	1	2	A	-	-	-	-	-	-	-	-
Banded killifish	5	2,3,-	A	4	67	3	F	1	5	3	B
Blackstripe topminnow	1	-	A	-	-	-	-	-	-	-	-
Brook silverside	4	2,3,-	A	4	67	3	F	7	33	3	B,D
Brook stickleback	-	-	-	-	-	-	-	-	-	-	-
Rock bass	3	2,3	A	2	33	3	F	3	14	1,5	D
Green sunfish	-	-	-	1	17	3	F	2	10	1	D
Pumpkinseed	4	2,3,-	A	5	83	3	F	3	14	1,3	B,D
Sunfish hybrid[c]	-	-	-	-	-	-	-	-	-	-	-
Warmouth	-	-	-	-	-	-	-	-	-	-	-
Iowa darter	-	-	-	2	33	3	F	-	-	-	-
Fantail darter	-	-	-	-	-	-	-	-	-	-	-
Johnny darter	-	-	-	-	-	-	-	-	-	-	-
Logperch	-	-	-	2	33	3	F	2	10	1,3	D
Mottled sculpin	2	-	A	-	-	-	-	-	-	-	-
Totals											
No. species[d]	25			29				37			
No. occurrences[e]	64			60				138			
No. stations[f]	15			6				21			

* Source of data: Data were compiled from computer printouts run by Don Fago summarizing fish occurrences recorded in an ongoing DNR Fish Distribution Study, as reported in Fago (1982). All printouts were run so that occurrence was recorded only once per station. Printouts were run on 28 May 1987 (for 1900–59 and 1960–73) and 14 May 1987 (for 1974–83); all 3 are filed with the DNR Bureau of Research.

** Gear types are identified by the following codes:
1 DC boom shocker
2 survey seine
3 small-mesh seine
4 gill, trammel, or entanglement net
5 fyke, hoop, trap, or drop net
6 hook and line, spear, or arrow
7 miscellaneous (e.g., found dead, winterkilled, etc.).

[a] Collectors of fish are grouped into related categories and identified by the following codes:

Historic
A Early Wisconsin fish collectors (1900–31) reported by Greene (1935).

DNR Research
B Fish Distribution Study personnel.

DNR Fisheries Management
C Fisheries Management personnel.
D Fisheries Management survey (based on reports only).

University of Wisconsin System
E UW-Madison students.
F Prof. Marlin Johnson and UW-Waukesha students.

Miscellaneous
G Commercial fishing.
H Unknown collector (e.g., sport angler).

[b] We discovered 2 incorrect historical records in the computerized database from which this table was compiled: 2 specimens of northern pike incorrectly identified as grass pickerels and 1 specimen of a smallmouth bass incorrectly identified as a yellow bass. This table reflects the correct information.

[c] Hybrids were white bass × yellow bass, northern pike × muskellunge, and green sunfish × pumpkinseed.

[d] Excludes hybrids and unspecified species.

[e] Sum of number of species taken at each station.

[f] Total number of stations. Several species may have been taken from the same station.

Appendix Table A.10. *Spring fyke net sampling for white bass in Lake Mendota conducted by R. Horrall and C. Voigtlander, UW-Madison Center for Limnology, 1956–69 and 1971.**

	1956		1957				1958		1959		1960		1961		1962	
Species	No./50 Lifts**	% of Catch[a]	No./50 Lifts**	% of Catch[a]	No./50 Lifts**	% of Catch[a]	No./50 Lifts**	% of Catch[a]	No./50 Lifts**	% of Catch[a]	No./50 Lifts**	% of Catch[a]	No./50 Lifts**	% of Catch[a]	No./50 Lifts**	% of Catch[a]
White bass	3,562		4,165		3,274		2,070		1,834		10,503		7,695		1,714	
Yellow perch	408	8	206	7	387	11	158	8	232	8	557	16	645	24	12	1
Bluegill	339	7	907	33	1,037	29	302	15	170	6	168	5	56	2	759	41
Black crappie	1,086	22	389	14	1,028	29	193	9	597	22	416	12	300	11	512	28
White crappie	45	1	3	0	56	2	37	2	26	1	84	2	134	5	11	0
Yellow bass	-	-	1	0	-	-	-	-	-	-	-	62	2	9	0	40
Largemouth bass	7	0	-	-	7	0	2	0	3	0	6	0	1	0	5	0
Smallmouth bass	27	1	26	0	13	0	23	1	51	2	48	1	21	1	-	-
Walleye	-	-	2	0	4	0	2	0	1	0	5	0	8	0	11	0
Northern pike	7	0	3	0	10	0	13	0	13	0	14	0	5	0	7	0
Common carp	30	1	57	2	29	0	112	5	68	2	63	2	28	1	7	0
Freshwater drum	-	-	-	-	-	-	-	-	-	-	2	0	-	-	-	-
Bullhead spp.	1,232	25	688	25	356	10	500	24	694	25	757	22	714	26	107	6
White sucker	7	0	4	0	7	0	39	2	10	0	21	0	5	0	1	0
Longnose gar	101	2	61	2	25	0	7	0	56	2	432	13	101	4	112	6
Bowfin	-	-	1	0	39	1	4	0	2	0	4	0	33	1	8	0
Bigmouth buffalo	1	0	-	-	1	0	-	-	2	0	11	0	-	-	-	-
Channel catfish	-	-	-	-	5	0	<1	0	2	0	14	0	3	0	4	0
Rock bass	1,591	32	477	17	591	16	625	31	783	29	704	21	625	23	267	15
Green sunfish	-	-	1	0	5	0	-	-	<1	0	-	-	1	0	-	-
Pumpkinseed	64	1	23	0	-	-	17	1	9	0	9	0	21	1	9	0
Other[b]	-	-	-	-	1	0	-	-	-	-	-	-	-	-	-	-
Total[c]	4,945	100	2,748	100	3,601	98	2,033	98	2,717	97	3,377	98	2,710	99	1,835	97
Survey description																
Gear type	Std.[d]		Std.		D-end.[e]		Std.		Std.		Std.		Std.		Std.	
Stations sampled	2		2		5		3		3		2		2		2	
Fyke net lifts	37		52		57		133		117		94		75		38	

(Continued on next page)

Appendix Table A.10. *Continued.*

Species	1963		1964		1965		1966		1967		1968		1969		1971	
	No./50 Lifts**	% of Catch[a]	No./50 Lifts**	% of Catch[a]	No./50 Lifts**	% of Catch[a]	No./50 Lifts**	% of Catch[a]	No./50 Lifts**	% of Catch[a]	No./50 Lifts**	% of Catch[a]	No./50 Lifts**	% of Catch[a]	No./50 Lifts**	% of Catch[a]
White bass	4,063		7,675		3,935		10,927		1,968		2,415		3,297		895	
Yellow perch	243	4	10	0	43	2	178	7	36	2	35	2	235	15	352	24
Bluegill	1,506	26	310	13	246	9	527	21	86	5	490	26	353	22	77	5
Black crappie	2,799	49	983	42	260	10	337	13	78	5	205	11	33	2	4	0
White crappie	50	1	30	1	68	3	119	5	137	8	60	3	13	1	-	-
Yellow bass	16	0	4	0	12	0	35	1	8	0	22	1	12	1	-	-
Largemouth bass	5	0	3	0	2	0	2	0	-	-	-	-	2	0	4	0
Smallmouth bass	9	0	9	0	108	4	40	2	34	2	50	3	52	3	41	3
Walleye	4	0	-	-	5	0	1	0	2	0	2	0	33	2	15	1
Northern pike	31	1	26	1	6	0	41	2	10	1	20	1	3	0	26	2
Common carp	58	1	59	3	20	1	104	4	17	1	16	1	13	1	10	1
Freshwater drum	1	0	-	-	-	-	6	0	-	-	1	0	-	-	4	0
Bullhead spp.	336	6	435	18	1,143	43	608	24	583	35	383	20	265	17	87	6
White sucker	4	0	6	0	3	0	-	-	1	0	2	0	2	0	-	-
Longnose gar	13	0	133	6	25	1	81	3	74	4	57	3	3	0	5	0
Bowfin	11	0	5	0	10	0	1	0	5	0	5	0	8	1	-	-
Bigmouth buffalo	-	-	-	-	2	0	7	0	-	-	-	-	-	-	-	-
Channel catfish	1	0	-	-	8	0	39	2	26	2	29	2	2	0	-	-
Rock bass	496	9	273	12	542	20	353	14	500	30	359	19	422	26	777	53
Green sunfish	1	0	-	-	13	0	1	0	2	0	5	0	33	2	-	-
Pumpkinseed	133	2	70	3	147	6	61	2	56	3	128	7	113	17	1	0
Other[b]	-	-	-	-	1	0	4	0	-	-	-	-	-	-	-	-
Total[c]	5,716	99	2,354	99	2,664	99	2,545	100	1,654	98	1,869	99	1,598	100	1,455	99
Survey description																
Gear type	Std.[d]		Std.[d]		Std.[d]		Std.[d]		Std.[d]		Std.[d]		Std.[d]		D-end.[e]	
Stations sampled	2		2		2		2		2		2		1		1	
Fyke net lifts	71		40		61		55		53		41		30		55	

* Sources of data: Data were collected by Ross Horrall from 1956–62 and in 1969 and 1971, and by Clyde Voigtlander from 1963–68. Information on species other than white bass caught was compiled from original field records provided by John Magnuson (UW-Madison Cent. Limnol., unpubl. data).

** Number of fish was standardized to 50 fyke net lifts.

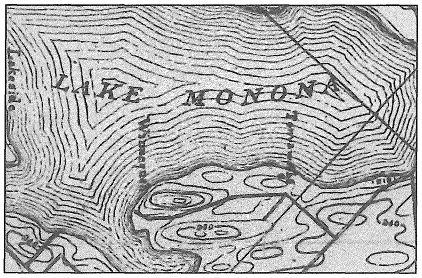
[a] Percent of species present excludes white bass since the purpose of this sampling was to collect white bass, possibly resulting in an overrepresentation of this species in the total catch.

[b] Fish caught only rarely. Species in order of abundance were: lake sturgeon, smallmouth buffalo, shorthead redhorse, and brook trout.

[c] Excludes white bass.

[d] Standard fyke net set with lead perpendicular to shore.

[e] Double-ended fyke net set parallel to shore, with a fyke net on both ends.



Appendix Table A.11. *Lake Monona creel surveys, 1974 and 1982–83.**

	1974		1982–83	
Species	**No. Caught**	**% of Catch**	**No. Caught****	**% of Catch**
Yellow perch	19,592	58	201,246	52
Bluegill	10,911	32	40,554	10
Black crappie	-	-	103,579	27
White crappie	-	-	33,977	9
Crappie spp.	332	1	137,556	35
White bass	700	2	90	0
Yellow bass	762	2	-	-
Largemouth bass	312	1	3,562	1
Smallmouth bass	33	0	143	0
Walleye	122	0	308	0
Northern pike	180	1	826	0
Common carp	3	0	-	-
Freshwater drum	3	0	771	0
Bullhead spp.	799	2	196	0
White sucker	-	-	21	0
Lake sturgeon	1	0	-	-
Bowfin	2	0	-	-
Muskellunge hybrid	3	0	943	0
Bigmouth buffalo	-	-	206	0
Channel catfish	1	-	-	-
Rock bass	8	0	609	0
Green sunfish[a]	9	0	-	-
Pumpkinseed	115	0	892	0
Total	33,888	100	387,923	100
Survey description				
Period	10 Jan–30 Nov		1 Jul 82–30 Jun 83	
Method	personal interview		personal interview	
No. anglers	3,036		93,836	
No. hours	-		282,867	

* Source of data: Wis. Dep. Nat. Resour., Madison Area files (unpubl. data).

** Numbers represent **projected** fish catch for the year.

[a] Data were recorded as common sunfish and were interpreted to mean green sunfish.

Appendix Table A.12. *Lake Monona state rough fish removal records, 1934–69.**

Year	No. Hauls	Rough Fish (lb)**							No. Game Fish[a]					
		Total	CC	FD	WS	BB	LG	BF	CS	WB	YB	LB[b]	WE	SF
1934	20	658,160	656,380	1,020	760	300	3,780	280	1,760	8,500	-	240	300	10,380
1935	31	580,196	576,507	961	2,728	1,209	4,433	124	589	6,944	-	93	496	3,503
1936	22	184,668	183,788	506	374	616	418	220	440	2,750	-	418	352	6,556
1937	15	252,045	251,700	345	-	-	2,910	-	107,160	360	-	1,050	705	17,835
1938	20	816,220	813,900	360	1,960	60	5,360	100	11,020	2,800	-	160	340	4,700
1939	49	975,345	973,287	196	1,862	-	5,537	245	21,462	3,969	-	49	490	1,862
1940	22	279,840	279,422	22	396	-	4,312	11	2,068	1,386	-	22	220	638
1941	34	453,968	453,186	782	-	68	2,822	-	4,454	3,808	-	68	442	2,992
1942	4	72,000	72,000	-	-	-	-	-	632	852	-	36	24	576
1943	13	145,054	144,716	273	65	-	429	-	1,794	1,547	-	312	234	10,699
1944	6	150,408	149,646	762	-	-	162	12	834	744	-	108	780	4,200
1945	9	149,886	149,436	450	-	-	54	-	117	567	-	81	162	1,296
1946	16	270,896	270,000	896	-	-	-	-	432	960	-	16	80	816
1947	24	260,784	259,920	864	-	-	336	24	1,800	2,424	-	48	120	3,624
1948	30	212,400	211,530	870	-	-	630	30	4,500	5,460	-	90	300	12,690
1949	27	91,746	91,611	135	-	-	1,161	135	1,458	4,968	-	216	567	9,045
1950	5	96,035	96,000	35	-	-	-	-	275	260	-	235	65	2,310
1951	5	62,590	62,590	-	-	-	-	170	55	195	-	70	175	260
1952	-	145,300	-	-	-	-	-	-	-	-	-	-	-	-
1953	-	78,400	-	-	-	-	-	-	-	-	-	-	-	-
1954	-	161,582	-	-	-	-	-	-	-	-	-	-	-	-
1955	-	67,480	-	-	-	-	-	-	-	-	-	-	-	-
1956	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1957	-	117,340	-	-	-	-	-	-	-	-	-	-	-	-
1958	6	20,312	-	-	-	-	-	-	-	627	33	-	-	-
1959	6	42,450	-	-	-	-	-	-	-	1,422	330	-	-	-
1960	9	67,500	46,150	2,800	-	18,550	-	-	-	2,133	315	-	-	-
1961	7	91,055	87,000	855	-	2,600	600	-	-	511	903	-	-	-
1962	13	65,767	61,767	1,100	-	2,900	-	-	-	377	182	-	-	-
1963	4	31,675	30,000	1,675	-	-	-	-	-	644	48	-	-	-
1964	1	25,025	25,000	25	-	-	-	-	-	45	0	-	-	-
1965	8	64,720	59,200	3,520	-	2,000	-	-	-	276	2,484	-	-	-
1966	7	84,485	76,000	5,485	-	3,000	-	-	-	623	11,900	-	-	-
1967	-	36,235	33,500	535	-	2,000	-	-	-	-	-	-	-	-
1968	-	3,975	3,200	25	-	750	-	-	-	-	-	-	-	-
1969	-	20,050	20,000	50	-	-	-	-	-	-	-	-	-	-

* Sources of data: Rough and game fish data from 1934–51 are from Hacker (1952*a*). Other species noted by Hacker were *Esox* sp., bullhead spp., cisco, perch, sturgeon, and mooneye. White and yellow bass data from 1958–66 are from Wright (1968). Rough fish data from 1960–69 are from rough fish records in DNR's central library in Madison (unpubl. data). All other data are from Wis. Dep. Nat. Resour., Madison Area files (unpubl. data). Description of gear: The state rough fish seine varied in length from 1,370–1,830 m, in mesh size from 90–110 mm, and in depth from 3–4 m.

** Species codes: CC = Common carp; FD = Freshwater drum; WS = White sucker; BB = Bigmouth buffalo; LG = Longnose gar; BF = Bowfin

[a] Species codes: CS = Crappie spp.; WB = White bass; YB = Yellow bass; LB = Largemouth bass; WE = Walleye; SF = Sunfish spp.

[b] Early records (for mid-1930s to early 1950s) are listed as largemouth bass but were recorded in original field notes as black bass.

Appendix Table A.13. *Lake Monona commercial rough fish removal records, 1977–85.**

Year	Days	Rough Fish (lb)**					No. Game Fish[a]						
		Total	CC	FD	BB	LG	BG	LB	WE	NP	CF	LS	MH
1977	-	95,120	9,505	25	15,040	550	-	-	-	-	-	-	-
1978	2+	37,330	34,640	-	2,690	-	-	-	4+	-	8+	22+	-
1979	5+	3,250	2,050	-	1,200	-	10	2	-	-	2	7	1
1980	11	1,220	1,050	-	170	-	-	-	4	2	2	11	4
1981–83	-	-	-	-	-	-	-	-	-	-	-	-	-
1984[b]	-	2,417	2,417	-	-	-	-	-	-	-	-	-	-
1985	1	2,205	2,143	12	50	-	-	-	-	1	10	-	-

* Source of data: Wis. Dep. Nat. Resour., Madison Area files (unpubl. data). Description of gear: The commercial rough fish removal contracts allowed for use of seines not less than 760 m with a maximum mesh size of 150 mm, or entanglement nets 910 m long with a minimum mesh size of 150 mm.

** Species codes: CC = Common carp; FD = Freshwater drum; BB = Bigmouth buffalo; LG = Longnose gar

[a] Species codes: BG = Bluegill; LB = Largemouth bass; WE = Walleye; NP = Northern pike; CF = Channel catfish; LS = Lake sturgeon; MH = Muskellunge hybrid

[b] These fish were removed by the state.

Appendix Table A.14. *Lake Monona fish population surveys using boom shockers, 1970 and 1978–83.**

Species	No. Fish Caught** 1970	1978	1979	1980	1981	1982	1983
Yellow perch	17	55	56	41	26 A	23	49
Bluegill	16	140	160	42	10	90	73
Black crappie	-	70	48	41	31 A	21	47 A
White crappie	-	1	3	9	26 A	21	13
Crappie spp.	2	71	51	50	57	42	60 A
White bass	3	2	3	13	2	-	-
Yellow bass	16	-	-	-	-	-	-
Largemouth bass	20	13	2	22	53 A	93	76
Smallmouth bass	2	-	-	1	2	-	-
Walleye	15	31	15	34	10	5	8
Northern pike	1	2	1	3	2	6	4
Common carp	5	- P	-	-	- A	- P	- A
Freshwater drum	5	20	55	56	12 A	40A	19
Bullhead spp.	-	21	3	-	2	2	6
White sucker	-	-	-	4	4	-	4
Longnose gar	-	-	-	7	8	7	2
Bowfin	-	4	-	3	1	-	-
Muskellunge hybrid	-	-	-	1	6	8	4
Common shiner	-	-	-	-	- A	-	-
Golden shiner	-	-	-	4	3	-	- A
Spottail shiner	-	-	-	-	- A	-	-
Bluntnose minnow	-	-	-	-	- A	-	-
Bigmouth buffalo	-	-	-	-	-	-	1
Channel catfish	-	-	-	1	-	-	-
Brook silverside	-	-	-	-	- A	- A	- A
Rock bass	15	-	3	25	4	47	8
Green sunfish	-	-	-	3	1	15	1
Pumpkinseed	14	-	1	19	24	80	29
Logperch	-	-	1	-	-	- P	-
Survey description[a]							
Month	Jul	Nov	Oct	Sep	Sep	Sep	Sep
Time of day	day	night	night	night	night	night	night
Hours	-	3.5	2.4	3.8	4.0	3.8	2.6

* Source of data: Wis. Dep. Nat. Resour., Madison Area files (unpubl. data). Most calculations of effort and some corrections to the numbers of fish recorded were provided by Steve Gilbert (former Madison Lakes fish biologist, Wis. Dep. Nat. Resour., pers. comm., 1990).

** In general, only a few of the more abundant panfish, minnows, and rough fish were sampled. Fish recorded as abundant and present in the field notes are marked with A and P, respectively.

[a] DC current of 230 v was used from an 18-ft boat.

Appendix Table A.15. *Lake Monona fish population surveys using fyke nets, 1976.**

Species	1976 No. Caught	1976 % of Catch
Yellow perch	1,017	24
Bluegill	1,668	39
Black crappie	684	16
White crappie	8	0
White bass	28	1
Yellow bass	36	1
Largemouth bass	17	0
Walleye	131	3
Northern pike	83	2
Common carp	30	1
Freshwater drum	3	0
Bullhead spp.	443	10
White sucker	39	1
Longnose gar	1	0
Bowfin	68	2
Golden shiner	5	0
Rock bass	44	1
Green sunfish	8	0
Pumpkinseed	4	0
Warmouth	3	0
Total	4,320	101
Survey description**		
Month	Mar/Apr	
No. fyke net lifts	-	

* Source of data: Wis. Dep. Nat. Resour., Madison Area files (unpubl. data).

** Fyke nets varied in hoop size from 1–1.5 m and in mesh size from 19–50 mm.

Appendix Table A.16. *Lake Monona fish population surveys using shoreline seines, 1939, 1966, and 1976–80.**

	No. Fish Caught**							
Species	**1939**		**1966**	**1976**	**1977**	**1978**	**1979**	**1980**
Yellow perch	1	602	-	34	4	6 A	13	-
Bluegill	529	1,904	-	21	1,146	12	109	20
Black crappie	-	-	-	-	57	-	67	66
White crappie	-	-	-	-	1	0	3	-
Crappie spp	11	1	20	307	58	1 A	70	66
White bass	-	-	10	-	-	-	-	-
Largemouth bass	9	34	1	33	51	7	21	8
Smallmouth bass	-	1	-	-	-	-	-	-
Walleye	2	37	-	-	-	-	-	1
Common carp	22	2	1	1	16	-	-	-
Bullhead spp.	-	-	1,000	-	-	-	-	-
White sucker	-	3	-	-	-	-	-	-
Lake sturgeon	-	-	-	-	2	-	-	-
Muskellunge hybrid	-	-	-	-	-	-	-	4
Common shiner	-	-	-	-	-	61	-	-
Golden shiner	-	-	-	4	-	-	12	1
Shiner spp.	57	142	30	4	-	61	12	1
Bluntnose minnow	-	-	-	-	578	126	152	54
Fathead minnow[a]	-	1	-	-	-	-	-	-
Minnow spp.	-	1	-	-	578	180 A	152	54
Brook silverside	-	-	-	-	5,726	-	65	359
Rock bass	1	1	-	-	-	-	-	3
Pumpkinseed	-	1	-	-	39	4	3	20
Darter spp.	1	9	-	-	-	-	-	-
Logperch	-	-	-	-	2	-	3	-
Survey description[b]								
Month	Jul	Jul	Jul	Jul	Sep	Sep	Aug	Sep
No. Hauls	11	5	2	16	18	14	16	23

* Source of data: Wis. Dep. Nat. Resour., Madison Area files (unpubl. data).
** Fish recorded as abundant in the field notes are marked with A.
[a] Data were recorded as bighead minnow, and were interpreted to mean fathead minnow.
[b] Shoreline seines varied in length from 6–8 m, in mesh size from 3–9 mm, and had a depth of 1 m.

Appendix Table A.17. *Lake Monona fish population surveys using survey seines, 1976 and 1984.**

Species	1976 No. Caught	1976 % of Catch	1984** No. Caught	1984** % of Catch
Yellow perch	63	1	74	22
Bluegill	578	16	147	43
Black crappie	290	8	29	8
White crappie	-	-	20	6
White bass	10	0	-	-
Yellow bass	2,505	71	-	-
Largemouth bass	22	1	21	6
Walleye	5	0	1	0
Northern pike	13	0	15	4
Common carp	-	-	-[a]	-
Freshwater drum	32	1	20	6
Bullhead spp.	3	0	-	-
White sucker	-	-	3	1
Longnose gar	3	0	-	-
Bowfin	5	0	-	-
Muskellunge hybrid	-	-	6	2
Golden shiner	6	0	1	0
Bluntnose minnow	1	0	-	-
Rock bass	6	0	-	-
Green sunfish	-	-	1	0
Pumpkinseed	19	1	4	1
Darter spp.	1	0	-	-
Total	3,537	99	342	99
Survey description[b]				
Month	Sep		Sep	
Seine length (ft)	3,000		1,800	
No. Hauls	1		1	

* Source of data: Wis. Dep. Nat. Resour., Madison Area files (unpubl. data).
** Many fish escaped because heavy weeds caused the net to roll up.
[a] 2,417 lb of carp were caught and removed in 1984.
[b] Survey seines varied in mesh size from 32–50 mm and in depth from 3–4 m.

Appendix Table A.18. *Lake Monona stocking records, 1852–1986.**

Year(s)[b]	No. Stocked** Yellow Perch	Bluegill	Crappie spp.	White Bass	Largemouth Bass	Smallmouth Bass	Bass spp.[a]	Walleye	Northern Pike	Cisco	Bullhead spp.	Others[a]
1852–55	-	-	-	-	-	-	-	-	-	-	-	-
1875	-	-	-	-	-	-	-	-	-	-	-	-
1877	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-
1880	-	-	-	-	-	-	-	-	-	-	-	-
1885	-	-	-	-	-	-	-	-	-	-	-	-
1886	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-
1887	-	-	-	-	-	-	-	-	-	-	-	-
1889	-	-	-	-	-	-	-	-	-	-	-	-
1890	-	-	-	-	-	-	-	-	-	-	-	-
1891	-	-	-	2,000,000 R	-	-	-	-	-	-	-	-
1895	-	-	-	-	-	-	-	-	-	-	-	-
1899	-	-	-	-	-	-	-	-	-	-	-	-
1900	-	-	-	-	-	-	-	-	-	-	-	-
1901	-	-	-	-	-	-	700 I	-	-	-	-	-
1902	-	-	-	-	-	-	-	500,000 R	-	-	-	-
1903	-	-	-	-	-	-	6,000 I	300,000 R	-	-	-	-
1904	-	-	-	-	-	-	6,000 I	-	-	-	-	-
1905	-	-	-	-	-	-	-	750,000 R	-	-	-	-
1906	-	-	-	-	-	-	-	1,460,000 R	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-
1907	-	-	-	-	-	-	-	1,250,000 R	-	-	-	-
1908	-	-	-	-	-	-	7,000 R	500,000 R	-	-	-	-
	-	-	-	-	-	-	8,000 I	-	-	-	-	-
1910–19	-	-	-	-	-	-	-	-	-	-	-	-
1920–29	-	-	-	-	-	-	-	-	-	-	-	-
1922	-	-	-	-	-	-	-	-	-	-	-	-
1929	-	-	-	-	-	-	-	-	-	-	-	-
1930–34	-	-	-	-	-	-	-	-	-	-	-	-
1933	-	-	-	-	-	-	-	-	-	-	-	-
1934	-	-	-	-	-	-	-	-	-	-	-	-
1935	-	-	-	-	-	-	-	-	-	-	-	-
1936	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-
1937	10,000 I	26,000 I	12,000 I	-	-	55 A	-	1,845,750 R	3,750 I	-	-	120 A, LS
	8,000 A	-	-	-	-	-	-	-	-	-	-	-
1938	2,903,040 R	-	4,000 A	-	-	-	-	5,092,556 R	-	-	5,000 I	5,000 I, SF
	12,000 I	-	-	-	-	-	-	-	-	-	-	-
1939	23,000 I	1,000 I	350 A	-	2,380 I	-	-	8,000,000 R	-	-	-	-
	-	800 A	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-

(Continued on next page)

Appendix Table A.18. *Continued.*

Year(s)[b]	Yellow Perch	Bluegill	Crappie spp.	White Bass	Largemouth Bass	Smallmouth Bass	Bass spp.[a]	Walleye	Northern Pike	Cisco	Bullhead spp.	Others[a]
	No. Stocked**											
1940	-	-	-	-	-	-	-	6,000,000 R	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-
1941	-	7,700 Y	650 Y	-	5,000 I	-	-	3,000,000 R	-	-	-	-
	-	450 A	200 A	-	1,000 Y	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-
1942	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-
1943	-	15,000 I	-	-	2,000 I	-	-	-	-	-	10,000 I	-
	-	-	-	-	-	-	-	-	-	-	-	-
1944	-	-	-	-	-	-	-	-	-	-	-	-
1945	-	-	-	-	-	-	-	12,615 I	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-
1946	-	-	-	-	400 R	-	-	5,000,000 R	-	-	-	-
	-	-	-	-	2,100 I	-	-	10,000 I	-	-	-	-
1947	-	-	-	-	5,000 I	-	-	3,200 I	-	-	-	-
1948	-	-	-	-	6,250 I	-	-	-	-	-	-	-
1949	-	-	-	-	-	3,000 I	-	2,500 I	-	-	-	-
1950	-	-	-	-	-	-	-	6,563 I	6,241 I	-	-	-
	-	-	-	-	-	-	-	1,632 Y	60 A	-	-	-
1951	-	-	-	-	-	9,126 I	-	-	-	-	-	-
1952	-	-	-	-	-	6,966 I	-	59,930 I	-	-	-	-
1953	-	-	-	-	-	6,564 I	-	74 Y	-	-	-	-
1954	1,150 A	2,740 A	-	-	3,440 I	-	-	-	-	-	-	4,150 A, SF
1955	-	-	-	-	-	-	-	-	-	-	-	-
1956	-	-	-	-	-	-	-	10,800 I	-	-	-	-
1957	-	-	-	-	-	-	-	18,024 I	-	-	-	-
1958	-	-	-	-	-	-	-	15,392 I	-	-	-	-
1959	-	-	-	-	-	-	-	46,481 I	-	-	-	-
1960	-	-	-	-	-	-	-	-	6,301 C	-	-	-
1961	-	-	-	-	-	-	-	-	994 C	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-
1962	-	-	-	-	-	-	-	-	20 A	-	-	-
1963	-	-	-	-	-	-	-	-	-	-	-	-
1964	-	-	-	-	-	-	-	-	-	-	-	-
1965	-	-	-	-	-	-	-	10,050 I	-	-	-	-
1966	-	-	-	-	-	-	-	-	-	-	-	-
1967	-	-	-	-	-	-	-	335,440 I	-	-	-	-
1968	-	-	-	-	-	-	-	-	-	-	-	-
1969	-	-	-	-	-	-	-	-	-	-	-	-

Appendix Table A.18. *Continued.*

Year(s)[b]	Yellow Perch	Bluegill	Crappie spp.	White Bass	Largemouth Bass	Smallmouth Bass	Bass spp.[a]	Walleye	Northern Pike	Cisco	Bullhead spp.	Others[a]
	No. Stocked**											
1970	-	-	-	-	-	-	-	1,500,000 R	900,000 R	-	-	-
	-	-	-	-	-	-	-	6,730 Y	-	-	-	-
1971	-	-	-	-	-	-	-	-	-	-	-	-
1972	-	-	-	-	-	-	-	-	-	-	-	-
1973	-	-	-	-	-	-	-	-	-	-	-	-
1974	-	-	-	-	-	-	-	171,000 I	-	-	-	-
1975	-	-	-	-	-	-	-	-	-	-	-	-
1976	-	-	-	-	-	-	-	-	-	-	-	2,100 I, MH
1977	-	-	-	-	-	-	-	-	-	-	-	2,000 I, MH
1978	-	-	-	-	-	-	-	170,400 I	-	-	-	-
1979	-	-	-	-	-	-	-	-	-	-	-	2,000 I, MH
1980	-	-	-	-	-	-	-	-	-	-	-	5,110 I, MH
1981	-	-	-	-	1,200 I	-	-	-	-	-	-	7,000 I, MH
	-	-	-	-	200 A	-	-	-	-	-	-	-
1982	-	-	-	-	-	-	-	-	-	-	-	2,500 I, MH
	-	-	-	-	-	-	-	-	-	-	-	-
1983	-	-	-	-	-	-	-	-	3,857 I	-	-	-
1984	-	-	-	-	-	-	-	-	2,895 I	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-
1985	-	-	-	-	-	-	-	-	2,500 I	-	-	3,313 I, MH
1986	-	-	-	-	-	-	-	109,059 I	-	-	-	4,150 I, MH
	-	-	-	-	-	-	-	-	-	-	-	-
Totals												
E	-	-	-	-	-	-	-	-	-	-	-	[c]
R	2,903,040	-	-	2,000,000	400	-	7,000	35,198,306	900,000	-	-	[c]
I	45,000	42,000	12,000	-	27,370	25,656	20,700	981,454	19,243	-	15,000	[c]
Y	-	7,700	650	-	1,000	-	-	8,436	-	-	-	[c]
A	9,150	3,990	4,550	-	200	55	-	-	80	-	-	[c]
C	-	-	-	-	-	-	-	-	7,295	-	-	[c]

* Sources of data: Early records came from WCD memoranda in the State Historical Society archives, and ledgers in the DNR's central library. Data from 1959 to 1986 came from stocking receipts in Wis. Dep. Nat. Resour., Madison Area and South. Dist. files. Source of stocked fish: all fish were raised at DNR fish hatcheries with the exception of fish taken from the Mississippi River during rescue operations in the late 1930s and early 1940s. Corrections to selected stocking totals since 1970 for walleyes, northern pike, and muskellunge hybrids were made by Steve Gilbert (former Madison Lakes fish biologist, Wis. Dep. Nat. Resour., pers. comm., 1990).

** Numbers stocked are coded as: E = eggs, R = fry, I = fingerlings, Y = yearlings, A = adults, and C = combination of fingerlings and adults.

[a] Of major species, bass spp. is *Micropterus* spp. Other species are coded as: LS = lake sturgeon, SF = sunfish (which were *Lepomis* spp.), and MH = muskellunge hybrid.

[b] Between 1852 and the mid-1930s, years listed are only those for which stocking records on any one of the Yahara lakes were found. After 1935, stocking took place more regularly, so all years are listed including 1955 and 1966, for which no records were located.

[c] Totals for other species are: lake sturgeon 120 adults; sunfish 5,000 fingerlings and 4,150 adults; muskellunge hybrid 28,173 fingerlings.

Appendix Table A.19. *Lake Monona fish distribution survey, 1900–83.**

Species	1900–59			1960–73				1974–83			
	No. Stn.	Gear Type**	Collector[a]	No. Stn.	% of Total	Gear Type**	Collector[a]	No. Stn.	% of Total	Gear Type**	Collector[a]
Yellow perch	-	-	-	4	67	3,5	E,F	10	53	1,3,5	B,D,E
Bluegill	-	-	-	5	83	3,5	E,F	10	53	1,3,5	B,D,E
Black crappie	-	-	-	1	17	3	F	11	58	1,2,3	B,D
White crappie	-	-	-	-	-	-	-	2	11	1,3	B,D
White bass	-	-	-	3	50	5	E	4	21	1,5	D,E
Yellow bass	-	-	-	2	33	3,5	E,F	12	63	3,5	B,D,E
Bass hybrid[b]	-	-	-	-	-	-	-	-	-	-	-
Largemouth bass	-	-	-	3	50	5	E	14	74	1,2,3,5	B,D,E,G
Smallmouth bass	-	-	-	-	-	-	-	1	5	1	D
Walleye	-	-	-	4	67	3,5	E,F	6	32	1,2,4,5	D,E,G
Northern pike	-	-	-	-	-	-	-	6	32	1,2,4,5	D,E,G
Cisco	1	6	H	-	-	-	-	2	11	2,4	G
Common carp	-	-	-	4	67	3,5	E,F	8	42	1,2,3,4,5	B,D,E,G
Freshwater drum	-	-	-	3	50	3,5	E,F	4	21	1,5	D,E
Black bullhead	-	-	-	4	67	3,5	E,F	4	21	1,5	D,E
Yellow bullhead	-	-	-	3	50	5	E	4	21	1,5	D,E
Brown bullhead	-	-	-	3	50	5	E	4	21	1,5	D,E
White sucker	-	-	-	3	50	5	E	4	21	1,5	D,E
American brook lamprey	-	-	-	-	-	-	-	-	-	-	-
Lake sturgeon	1	7	H	1	17	7	H	2	11	4	G
Longnose gar	-	-	-	2	33	5	E	4	21	1,5	D,E
Shortnose gar	-	-	-	-	-	-	-	-	-	-	-
Bowfin	-	-	-	3	50	5	E	4	21	1,5	D,E
American eel	-	-	-	-	-	-	-	-	-	-	-
Mooneye	-	-	-	-	-	-	-	-	-	-	-
Rainbow trout	-	-	-	-	-	-	-	-	-	-	-
Brown trout	-	-	-	-	-	-	-	-	-	-	-
Brook trout	-	-	-	-	-	-	-	-	-	-	-
Lake trout	-	-	-	-	-	-	-	-	-	-	-
Central mudminnow	-	-	-	-	-	-	-	-	-	-	-
Grass pickerel	-	-	-	-	-	-	-	-	-	-	-
Muskellunge	-	-	-	-	-	-	-	-	-	-	-
Muskellunge hybrid[b]	-	-	-	-	-	-	-	2	11	1,2	D,G
Central stoneroller	-	-	-	-	-	-	-	-	-	-	-
Goldfish	-	-	-	-	-	-	-	-	-	-	-
Spotfin shiner	-	-	-	-	-	-	-	-	-	-	-
Mississippi silvery minnow	-	-	-	-	-	-	-	-	-	-	-
Common shiner	-	-	-	-	-	-	-	1	5	3	D
Hornyhead chub	-	-	-	-	-	-	-	-	-	-	-
Golden shiner	-	-	-	-	-	-	-	6	32	1,3	B,D
Pugnose shiner	-	-	-	-	-	-	-	-	-	-	-
Emerald shiner	-	-	-	-	-	-	-	1	5	3	B
River shiner	-	-	-	-	-	-	-	-	-	-	-
Bigmouth shiner	-	-	-	-	-	-	-	-	-	-	-
Blackchin shiner	-	-	-	-	-	-	-	-	-	-	-
Blacknose shiner	-	-	-	-	-	-	-	-	-	-	-
Spottail shiner	-	-	-	-	-	-	-	-	-	-	-
Pugnose minnow	-	-	-	-	-	-	-	-	-	-	-
Bluntnose minnow	-	-	-	-	-	-	-	8	42	2,3	B,D
Fathead minnow	-	-	-	-	-	-	-	1	5	3	B
Creek chub	-	-	-	-	-	-	-	-	-	-	-
Quillback	-	-	-	-	-	-	-	-	-	-	-
Lake chubsucker	-	-	-	-	-	-	-	-	-	-	-
Smallmouth buffalo	-	-	-	-	-	-	-	-	-	-	-
Bigmouth buffalo	-	-	-	1	17	5	E	-	-	-	-

Appendix Table A.19. *Continued.*

Species	1900–59 No. Stn.	1900–59 Gear Type**	1900–59 Collector[a]	1960–73 No. Stn.	1960–73 % of Total	1960–73 Gear Type**	1960–73 Collector[a]	1974–83 No. Stn.	1974–83 % of Total	1974–83 Gear Type**	1974–83 Collector[a]
Golden redhorse	-	-	-	-	-	-	-	-	-	-	-
Shorthead redhorse	-	-	-	-	-	-	-	-	-	-	-
Channel catfish	-	-	-	1	17	5	E	4	21	1,4,5	D,E,G
Tadpole madtom	-	-	-	-	-	-	-	-	-	-	-
Flathead catfish	-	-	-	-	-	-	-	-	-	-	-
Burbot	-	-	-	-	-	-	-	2	11	5,6	E,H
Banded killifish	-	-	-	-	-	-	-	-	-	-	-
Blackstripe topminnow	-	-	-	-	-	-	-	-	-	-	-
Brook silverside	-	-	-	2	33	3	F	11	58	3	B,D
Brook stickleback	-	-	-	-	-	-	-	-	-	-	-
Rock bass	-	-	-	3	50	5	E	4	21	1,5	D,E
Green sunfish	-	-	-	3	50	5	E	5	26	1,3,5	B,D,E
Pumpkinseed	-	-	-	4	67	3,5	E,F	7	37	1,3,5	B,D,E
Sunfish hybrid[b]	-	-	-	-	-	-	-	3	16	3	B
Warmouth	-	-	-	-	-	-	-	1	5	5	D
Iowa darter	-	-	-	-	-	-	-	1	5	3	B
Fantail darter	-	-	-	-	-	-	-	-	-	-	-
Johnny darter	-	-	-	-	-	-	-	1	5	3	B
Logperch	-	-	-	1	17	3	F	5	26	1,3	B,D
Mottled sculpin	-	-	-	-	-	-	-	1	5	5	E
Totals											
No. species[c]	2			23				36			
No. occurrences[d]	2			63				175			
No. stations[e]	1			6				19			

* Source of data: Data were compiled from computer printouts run by Don Fago summarizing fish occurrences recorded in an ongoing DNR Fish Distribution Study, as reported in Fago (1982). All printouts were run so that occurrence was recorded only once per station. Printouts were run on 28 May 1987 (for 1900–59 and 1960–73) and 14 May 1987 (for 1974–83); all 3 are filed with the DNR Bureau of Research.

** Gear types are identified by the following codes:
- 1 DC boom shocker
- 2 survey seine
- 3 small-mesh seine
- 4 gill, trammel, or entanglement net
- 5 fyke, hoop, trap, or drop net
- 6 hook and line, spear, or arrow
- 7 miscellaneous (e.g., found dead, winterkilled, etc.).

[a] Collectors of fish are grouped into related categories and identified by the following codes:

Historic
- A Early Wisconsin fish collectors (1900–31) reported by Greene (1935).

DNR Research
- B Fish Distribution Study personnel.

DNR Fisheries Management
- C Fisheries Management personnel.
- D Fisheries Management survey (based on reports only).

University of Wisconsin System
- E UW-Madison students.
- F Prof. Marlin Johnson and UW-Waukesha students.

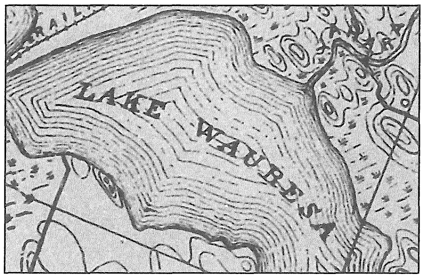
Miscellaneous
- G Commercial fishing.
- H Unknown collector (e.g., sport angler).

[b] Hybrids were white bass × yellow bass, northern pike × muskellunge, and green sunfish × pumpkinseed.

[c] Excludes hybrids and unspecified species.

[d] Sum of number of species taken at each station.

[e] Total number of stations. Several species may have been taken from the same station.



Appendix Table A.20. *Lake Waubesa creel surveys, 1937–39, 1974, and 1982–83.**

	1937		1938		1939		1974		1982–83	
Species	**No. Caught**	**% of Catch**	**No. Caught**	**% of Catch**	**No. Caught**	**% of Catch**	**No. Caught**	**% of Catch**	**No. Caught****	**% of Catch**
Yellow perch	17,970	28	452	2	60	0	2,124	10	17,215	7
Bluegill	20,249	31	1,902	7	505	4	12,132	56	27,386	11
Black crappie	-	-	-	-	-	-	-	-	96,266	38
White crappie	-	-	-	-	-	-	-	-	109,833	43
Crappie spp.	7,067	11	20,576	81	13,531	93	1,003	5	206,099	81
White bass	11,367	18	1,228	5	256	2	3	0	-	-
Yellow bass	-	-	-	-	-	-	1,118	5	-	-
Largemouth bass	980	2	62	0	19	0	131	1	710	0
Smallmouth bass	172	0	48	0	7	0	1	0	16	0
Walleye	2,308	4	554	2	43	0	330	2	368	0
Northern pike	2,430	4	222	1	32	0	25	0	84	0
Common carp	-	-	103	0	5	0	3	0	49	0
Freshwater drum	-	-	-	-	-	-	90	0	498	0
Bullhead spp.	1,624	3	252	1	56	0	4,515	21	95	0
White sucker	-	-	-	-	-	-	-	-	14	0
Bowfin	-	-	-	-	-	-	-	-	34	0
Muskellunge hybrid	-	-	-	-	-	-	1	0	89	0
Channel catfish	-	-	-	-	-	-	-	-	37	0
Rock bass	111	0	40	0	4	0	-	-	-	-
Pumpkinseed	56	0	76	0	18	0	86	0	846	0
Total	64,334	100	25,515	100	14,536	100	21,562	100	253,506	100
Survey description										
Period	15 May–5 Nov		15 May–15 Oct		15 May–25 Sep		19 Jan–30 Nov		1 Jul 82–30 Jun 83	
Method	voluntary		voluntary		personal interview		personal interview		personal interview	
No. anglers	-		8,490		4,590		2,261		45,261	
No. hours	-		40,320		18,030		-		174,854	

* Sources of data:
1937 - Juday et al. (1938)
1938 - Frey et al. (1939)
1939 - Frey and Vike (1941)
1974 - Wis. Dep. Nat. Resour., Madison Area files (unpubl. data).
1982–83 - Wis. Dep. Nat. Resour., Madison Area files (unpubl. data).

** Numbers represent **projected** fish catch for the year.

Appendix Table A.21. *Lake Waubesa state rough fish removal records, 1935–69.**

Year	No. Hauls	Rough Fish (lb)**					No. Game Fish[a]									
		Total	CC	FD	WS	BB	YP	BG	CS	WB	YB	LB[b]	WE	NP	BH	BB[c]
1935	-	534,419	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1936	-	44,246	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1937	26	333,293	268,196	-	-	-	-	1,820	10,998	1,976	-	520	1,716	520	806	-
1938	33	2,101,448	1,488,788	-	-	-	17	14,916	115,962	37,323	-	561	1,452	990	5,610	-
1939	36	1,090,793	1,300,793	-	-	-	-	3,672	49,680	5,472	-	18	180	216	72	-
1940	14	245,915	460,915	-	-	-	7	7,728	14,406	12,950	-	7	84	84	56	-
1941	31	795,108	810,188	-	-	-	806	8,680	11,377	6,696	-	31	620	93	93	-
1942	26	1,018,682	1,038,602	-	-	-	52	2,990	5,044	2,704	-	26	156	26	78	-
1943	20	424,018	446,853	-	-	-	200	5,980	4,460	1,420	-	40	2,940	280	180	-
1944	8	202,655	246,793	-	-	-	16	1,088	176	328	-	40	1,184	80	16	24
1945	13	315,233	315,233	-	-	-	442	2,379	2,249	26,312	-	7	234	104	13	104
1946	32	586,795	587,345	-	-	-	128	4,416	5,408	135,872	-	6	256	128	96	128
1947	31	945,635	945,665	-	-	-	217	12,369	4,929	31,155	-	9	310	124	124	806
1948	28	-	292,857	-	-	-	196	2,184	532	36,736	-	11	280	84	56	140
1949	21	-	237,855	-	-	-	546	6,111	378	38,514	-	42	378	231	189	63
1950	18	-	287,172	-	-	-	162	4,608	198	38,376	-	18	414	162	1,188	36
1951	-	506,602	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1952	-	530,529	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1953	-	431,503	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1954	-	526,980	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1955	-	195,335	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1956	-	298,810	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1957	-	569,719	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1958	26	507,160	-	-	-	-	-	-	-	936	26	-	-	-	-	-
1959	33	531,350	-	-	-	-	-	-	-	3,498	297	-	-	-	-	-
1960	21	377,040	366,800	5,140	-	5,100	-	-	-	2,100	378	-	-	-	-	-
1961	22	244,820	237,000	7,020	-	800	-	-	-	2,134	1,430	-	-	-	-	-
1962	18	291,730	278,100	13,130	-	500	-	-	-	10,440	3,474	-	-	-	-	-
1963	12	229,450	227,500	1,950	-	-	-	-	-	396	384	-	-	-	-	-
1964	17	370,110	364,000	4,710	-	1,400	-	-	-	1,088	4,386	-	-	-	-	-
1965	17	294,150	285,500	7,950	400	300	-	-	-	901	17,017	-	-	-	-	-
1966	14	324,480	294,000	30,030	-	450	-	-	-	1,932	17,346	-	-	-	-	-
1967	-	247,350	243,030	4,120	200	-	-	-	-	-	-	-	-	-	-	-
1968	-	162,970	159,000	3,670	-	300	-	-	-	-	-	-	-	-	-	-
1969	-	103,900	102,000	1,300	200	400	-	-	-	-	-	-	-	-	-	-

* Sources of data: Rough and game fish data from 1937–50 are from Helm (1951). White and yellow bass data from 1958–66 are from Wright (1968). Rough fish data from 1960–69 are from rough fish records in DNR's central library in Madison (unpubl. data). All other data are from Wis. Dep. Nat. Resour., Madison Area files (unpubl. data). For the years 1939–47, totals cited in unpublished records differ from pounds of carp reported for the same period in Helm (1951). Description of gear: The state rough fish seine varied in length from 1,370–1,830 m, in mesh size from 90–110 mm, and in depth from 3–4 m.

** Species codes: CC = Common carp FD = Freshwater drum WS = White sucker BB = Bigmouth buffalo

[a] Species codes: YP = Yellow perch BG = Bluegill CS = Crappie spp. WB = White bass LB = Largemouth bass YB = Yellow bass WE = Walleye NP = Northern pike BH = Bullhead spp. BB = Bigmouth buffalo

[b] Early records (for mid-1930s to early 1950s) are listed as largemouth bass but were recorded in original field notes as black bass.

[c] Bigmouth buffalo were listed by Helm (1951) as "game fish" even though their official designation at the time was "rough fish."

Appendix Table A.22. *Lake Waubesa commercial rough fish removal records, 1976–83.**

		Rough Fish (lb)**				No. Game Fish[a]											
Year	Days	Total	CC	FD	BB	YP	BG	CS	WB	LB	SB	WE	NP	BH	CF	LS	MH
1976	1	1,280	1,280	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1977	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1978	-	15,161	14,950	-	211	-	350	300	6	21	-	94	15	50	35	1	8
1979	2	226,260	220,500	2,600	3,160	-	150	100	-	18	-	125	35	56	20	-	5
1980	2	29,090	29,000	-	90	-	50	175	-	26	-	10	27	6	21	1	-
1981	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1982	2	20,625	20,500	-	125	5	1,000	700	-	60	1	10	28	3	-	-	-
1983	4	48,940	46,256	-	2,684	-	-	-	-	1	-	3	1	-	40	1	3

* Source of data: Wis. Dep. Nat. Resour., Madison Area files (unpubl. data). Description of gear: The commercial rough fish removal contracts allowed for use of seines not less than 760 m with a maximum mesh size of 150 mm, or entanglement nets 910 m long with a minimum mesh size of 150 mm.

** Species codes: CC = Common carp; FD = Freshwater drum; BB = Bigmouth buffalo

[a] Species codes: YP = Yellow perch; BG = Bluegill; CS = Crappie spp.; WB = White bass; LB = Largemouth bass; SB = Smallmouth bass; WE = Walleye; NP = Northern pike; BH = Bullhead spp.; CF = Channel catfish; LS = Lake sturgeon; MH = Muskellunge hybrid

Appendix Table A.23. *Lake Waubesa fish population surveys using boom shockers, 1968, 1970–71, 1973, and 1978–84.**

	No. Fish Caught**										
Species	**1968**	**1970**	**1971**	**1973**	**1978**	**1979**	**1980**	**1981**	**1982**	**1983**	**1984**
Yellow perch	-	18	1	9	42	13	3	14	26 A	25	20
Bluegill	5	25	11	59	103	77 A	99	32	122 A	44 A	134 A
Black crappie	3	-	-	-	32	1	75 A	35	76 A	30	32
White crappie	-	-	-	-	55	114 A	74 A	19	40	10	2
Crappie spp.	3	-	2	11	87	115 A	149 A	54	116 A	40	34
White bass	-	7	50	2	-	-	3	3	1	-	-
Yellow bass	31	29	2,000	-	1	-	-	-	-	-	-
Largemouth bass	10	88	(27)[a]	33	11	12	32	45 A	46 A	95 A	150 A
Smallmouth bass	-	2	-	-	-	-	-	-	-	-	-
Walleye	-	63	9+(51)[a]	14	39	8	25	14	17	8	8
Northern pike	-	6	(3)[a]	3	-	-	4	7	1	4	3
Common carp	21	-	1	-	-	-	-	- A	-	2 A	1 A
Freshwater drum	3	-	1	-	5	14	28	14	52	25	20
Bullhead spp.	1	23	1	-	4	4	4	7	2	1	3
White sucker	1	-	-	6	14	-	6	4	1	5	9
Longnose gar	-	-	-	-	-	-	2	-	-	-	-
Bowfin	-	-	-	-	1	-	1	1	-	-	1
Muskellunge hybrid	-	-	-	-	-	-	-	1	1	2	1
Golden shiner	-	-	-	-	-	-	7	5	-	7	1
Spottail shiner	-	-	-	-	-	-	-	- A	-	-	-
Bigmouth buffalo	-	-	1	-	-	-	-	-	-	-	-
Silver redhorse	-	-	-	-	-	-	-	1	-	-	-
Brook silverside	-	-	-	-	-	-	-	-	- A	15 A	- A
Rock bass	-	-	-	-	-	-	1	1	-	-	-
Green sunfish	3	-	-	-	1	-	3	10	6	-	2
Pumpkinseed	25	28	-	-	3	3	9	25	45	24	28
Logperch	-	-	-	-	-	-	-	-	-	1	-
Survey description[b]											
Month	Sep	Nov	Oct	Oct	Nov	Oct	Sep	Sep	Sep	Sep	Oct
Time of day	day	night	night	day/night	night	night	night	night	night	night	night
Hours	6	-	0.5	1.5+3.5	4	4	4.5	3.5	2.6	3.9	3.6

* Source of data: Wis. Dep. Nat. Resour., Madison Area files (unpubl. data). Most calculations of effort and some corrections to the numbers of fish recorded were provided by Steve Gilbert (former Madison Lakes fish biologist, Wis. Dep. Nat. Resour., pers. comm., 1990).

** In general, only a few of the more abundant panfish, minnows, and rough fish were sampled. Fish recorded as abundant in the field notes are marked with A.

[a] ( )=Indicates more extensive sampling for predator fish.

[b] DC current of 230 v was used from an 18-ft boat.

Appendix Table A.24. *Lake Waubesa fish population surveys using fyke nets, 1974.**

Species	1974 No. Caught**
Yellow perch	414
Bluegill	47 A
Crappie spp.	32 A
Largemouth bass	82
Walleye	873
Northern pike	287
Total	1,735+
Survey description[a]	
Month	Apr
No. fyke net lifts	-

* Source of data: Wis. Dep. Nat. Resour., Madison Area files (unpubl. data).
** Fish recorded as abundant in the field notes are marked with A.
[a] Fyke nets varied in hoop size from 1–1.5 m and in mesh size from 19–50 mm.

Appendix Table A.26. *Lake Waubesa fish population surveys using survey seines, 1974.**

	1974	
Species	No. Caught**	% of Catch
Yellow perch	698	1
Bluegill	33,055	71
Black crappie	5,480	12
White crappie	6	0
White bass	1,600	3
Yellow bass	536	1
Largemouth bass	160	0
Walleye	68	0
Northern pike	105	0
Common carp	50	0
Freshwater drum	50	0
Bullhead spp.	4,656	10
Longnose gar	1	0
Bowfin	1	0
Channel catfish	1	0
Pumpkinseed	105	0
Total	46,572	98
Survey description**		
Month	Oct	
Seine length (ft)	2,200	
No. hauls	2	

* Source of data: Wis. Dep. Nat. Resour., Madison Area files (unpubl. data).
** Survey seines varied in mesh size from 32–50 mm and in depth from 3–4 m.

Appendix Table A.25. *Lake Waubesa fish population surveys using shoreline seines, 1966 and 1976–80.**

	No. Fish Caught**						
Species	1966	1976	1977	1978	1979	1979	1980
Yellow perch	-	15	5	1 A	1	6	1
Bluegill	85	-	1,044	160 A	14	318	48
Black crappie	-	-	20	24	3	21	159
White crappie	-	-	-	16	171	-	11
Crappie spp.	1,200	8,650	20	40	174	21	170
White bass	125	-	-	-	-	-	-
Yellow bass	-	63	-	-	-	-	-
Largemouth bass	12	251	19	21 A	9	17	3
Northern pike	1	-	-	-	-	-	-
Common carp	60	1	-	1	-	-	1
Freshwater drum	10	-	1	3	-	-	-
Bullhead spp.	6	-	-	2	-	-	-
Golden shiner	-	1	-	5	-	12	7
Emerald shiner	-	-	-	-	-	-	9
Spottail shiner	-	-	-	-	5	-	-
Bluntnose minnow	-	-	186	7	-	23	49
Bigmouth buffalo	-	-	-	-	-	-	5
Brook silverside	-	85	2,665	10	3	1,946	227
Green sunfish	-	-	-	1	-	-	-
Pumpkinseed	-	-	31	4	1	11	7
Logperch	-	-	3	-	-	4	-
Survey description[a]							
Month	Jul	Jul	Sep	Sep	Aug	-	Sep
No. hauls	2	13	8	23	17	22	24

* Source of data: Wis. Dep. Nat. Resour., Madison Area files (unpubl. data).
** Fish recorded as abundant in the field notes are marked with A.
[a] Shoreline seines varied in length from 6–8 m, in mesh size from 3–9 mm, and had a depth of 1 m.

Appendix Table A.27. *Lake Waubesa stocking records, 1852–1986.**

	No. Stocked**											
Year(s)[b]	Yellow Perch	Bluegill	Crappie spp.	White Bass	Largemouth Bass	Smallmouth Bass	Bass spp.[a]	Walleye	Northern Pike	Cisco	Bullhead spp.	Others[a]
1852–55	-	-	-	-	-	-	-	-	-	-	-	-
1875	-	-	-	-	-	-	-	-	-	-	-	-
1877	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-
1880	-	-	-	-	-	-	-	-	-	-	-	-
1885	-	-	-	-	-	-	-	-	-	-	-	-
1886	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-
1887	-	-	-	-	-	-	-	-	-	-	-	-
1889	-	-	-	-	-	-	-	-	-	-	-	-
1890	-	-	-	-	-	-	-	-	-	-	-	-
1891	-	-	-	-	-	-	-	-	-	-	-	-
1895	-	-	-	-	-	-	-	-	-	-	-	-
1899	-	-	-	-	-	-	-	-	-	-	-	-
1900	-	-	-	-	-	-	-	420,000 R	-	-	-	-
1901	-	-	-	-	-	-	-	-	-	-	-	-
1902	-	-	-	-	-	-	-	525,000 R	-	-	-	-
1903	-	-	-	-	-	-	-	-	-	-	-	-
1904	-	-	-	-	-	-	-	-	-	-	-	-
1905	-	-	-	-	-	-	-	-	-	-	-	-
1906	-	-	-	-	-	-	6,000 I	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-
1907	-	-	-	-	-	-	-	600,000 R	-	-	-	-
1908	-	-	-	-	-	-	11,000 R	1,000,000 R	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-
1910–19	-	-	-	-	-	-	-	-	-	-	-	-
1920–29	-	-	-	-	-	-	-	-	-	-	-	-
1922	-	-	-	-	-	-	-	-	-	-	-	-
1929	-	-	-	-	-	-	-	-	-	-	-	-
1930–34	-	-	-	-	-	-	-	-	-	-	-	-
1933	-	-	-	-	-	-	-	-	-	-	-	-
1934	-	-	-	-	-	-	-	-	-	-	-	-
1935	-	-	-	-	-	-	-	-	-	-	-	-
1936	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-
1937	43,700 I	-	16,000 I	-	-	-	-	5,902,000 R	3,750 I	-	-	-
	-	-	4,000 A	-	-	-	-	-	-	-	-	-
1938	-	8,000 I	3,000 A	-	-	214 I	-	5,419,704 R	-	-	-	-
	-	-	-	-	-	30 A	-	-	-	-	-	-

(Continued on next page)

Appendix Table A.27. *Continued.*

Year(s)[b]	No. Stocked** Yellow Perch	Bluegill	Crappie spp.	White Bass	Largemouth Bass	Smallmouth Bass	Bass spp.[a]	Walleye	Northern Pike	Cisco	Bullhead spp.	Others[a]
1939	6,773,760 E	30,000 I	25,800 I	-	7,400 I	5,000 I	-	6,250,000 R	-	-	3,000 I	-
	15,000 I	-	-	-	21 A	-	-	-	-	-	-	-
	54 A	-	-	-	-	-	-	-	-	-	-	-
1940	3,548,160 E	15,000 I	-	-	12,000 I	-	-	6,250,000 R	15,000 R	-	5,000 I	-
	-	-	-	-	-	-	-	-	1,190 I	-	-	-
1941	1,720,320 E	-	-	-	10,000 I	-	-	2,500,000 R	5,000 I	-	-	-
	4,000 I	-	-	-	-	-	-	-	-	-	-	-
	244 A	-	-	-	-	-	-	-	-	-	-	-
1942	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-
1943	-	15,000 I	-	-	13,500 I	-	-	-	-	-	10,000 I	-
	-	-	-	-	-	-	-	-	-	-	-	-
1944	7,071,515 R	-	-	-	500 I	-	-	2,000,000 R	60,000 R	-	-	-
1945	-	-	-	-	-	-	-	380,000 R	-	-	15,000 I	-
	-	-	-	-	-	-	-	16,125 I	-	-	-	-
1946	-	-	-	-	2,000 I	-	-	5,000,000 R	-	-	8,000 I	-
	-	-	-	-	-	-	-	8,000 I	-	-	-	-
1947	-	5,000 I	-	-	5,000 I	-	-	3,200 I	60,000 R	-	-	-
1948	-	5,000 I	-	-	-	-	-	-	5,040 I	-	-	-
1949	-	-	-	-	-	5,000 I	-	-	30,000 R	-	-	-
1950	-	-	-	-	5,000 I	-	-	2,500 I	4,239 I	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-
1951	-	-	-	-	6,960 I	5,000 I	-	-	-	-	-	-
1952	-	-	-	-	4,200 I	-	-	51,030 I	-	-	-	-
1953	-	-	-	-	-	-	-	35,750 I	-	-	-	-
1954	-	-	-	-	-	-	-	-	-	-	-	-
1955	-	-	-	-	-	-	-	-	-	-	-	-
1956	-	-	-	-	-	-	-	-	-	-	-	-
1957	-	-	-	-	-	-	-	15,180 I	-	-	-	-
1958	-	-	-	-	-	-	-	14,102 I	-	-	-	-
1959	-	-	-	-	-	-	-	42,613 I	-	-	-	-
1960	-	-	-	-	-	-	-	-	4,239 I	-	-	-
1961	-	-	-	-	-	-	-	-	363 C	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-
1962	-	-	-	-	-	-	-	-	20 A	-	-	-
1963	-	-	-	-	-	-	-	-	1,450 Y	-	-	-
1964	-	-	-	-	-	-	-	-	5,000 I	-	-	-
1965	-	-	-	-	-	-	-	-	-	-	-	-

Appendix Table A.27. *Continued.*

Year(s)[b]	No. Stocked** Yellow Perch	Bluegill	Crappie spp.	White Bass	Largemouth Bass	Smallmouth Bass	Bass spp.[a]	Walleye	Northern Pike	Cisco	Bullhead spp.	Others[a]
1966	-	-	-	-	-	-	-	-	-	-	-	-
1967	-	-	-	-	-	-	-	58,300 I	17 C	-	-	-
1968	-	-	-	-	-	-	-	-	-	-	-	-
1969	-	-	-	-	-	-	-	-	-	-	-	-
1970	-	-	-	-	-	-	-	9,556,306 R	706,306 R	-	-	-
		-	-	-	-	-	-	-	-	-	-	-
1971	-	-	-	-	-	-	-	-	-	-	-	-
1972	-	-	-	-	-	-	-	43,390 I	1,000,000 R	-	-	-
1973	-	-	-	-	-	-	-	-	2,490,000 R	-	-	-
1974	-	-	-	-	31 A	-	-	92,400 R	-	-	-	-
1975	-	-	-	-	-	-	-	3,300 R	-	-	-	-
1976	-	-	-	-	-	-	-	-	-	-	-	-
1977	-	-	-	-	-	-	-	-	-	-	-	-
1978	-	-	-	-	-	-	-	-	-	-	-	-
1979	-	-	-	-	-	-	-	-	-	-	-	-
1980	-	-	-	-	-	-	-	-	-	-	-	3,610 I, MH
1981	-	-	-	-	2,200 I	-	-	-	-	-	-	2,100 I, MH
		-	-	-	-	300 A	-	-	-	-	-	-
1982	-	-	-	-	-	-	-	3,000,000 R	-	-	-	713 I, MH
		-	-	-	-	-	-	-	-	-	-	-
1983	-	-	-	-	-	-	-	-	-	-	-	-
1984	-	-	-	-	-	-	-	36,240 R	1,500 I	-	-	-
		-	-	-	-	-	-	-	-	20 A	-	-
1985	-	-	-	-	-	-	-	-	2,500 I	-	-	3,312 I, MH
1986	-	-	-	-	-	-	-	5,450 I	1,500 I	-	-	1,500 I, MH
		-	-	-	-	-	-	-	-	-	-	-
Totals												
E	12,042,240	-	-	-	-	-	-	-	-	-	-	-
R	7,071,515	-	-	-	-	-	11,000	48,934,950	4,361,306	-	-	-
I	62,700	24,000	41,800	-	68,760	15,214	6,000	295,640	33,958	-	41,000	11,235
Y	-	-	-	-	-	-	-	-	1,450	-	-	-
A	298	-	7,000	-	352	30	-	-	40	-	-	-
C	-	-	-	-	-	-	-	-	380	-	-	-

* Sources of data: Early records came from WCD memoranda in the State Historical Society archives and ledgers in the DNR's central library. Data from 1959 to 1986 came from stocking receipts in Wis. Dep. Nat. Resour., Madison Area and South. Dist. files. Source of stocked fish: all fish were raised at DNR fish hatcheries with the exception of fish taken from the Mississippi River during rescue operations in the late 1930s and early 1940s. Corrections to selected stocking totals since 1970 for walleyes, northern pike, and muskellunge hybrids were made by Steve Gilbert (former Madison Lakes fish biologist, Wis. Dep. Nat. Resour., pers. comm., 1990).

** Numbers stocked are coded as: E = eggs, R = fry, I = fingerlings, Y = yearlings, A = adults, and C = combination of fingerlings and adults.

[a] Of major species, bass spp. are *Micropterus* spp. Other species are coded as: MH = muskellunge hybrid.

[b] Between 1852 and the mid-1930s, years listed are only those for which stocking records on any one of the Yahara lakes were found. After 1935, stocking took place more regularly, so all years are listed including 1955 and 1966, for which no records were located.

Appendix Table A.28. *Lake Waubesa fish distribution survey, 1900–83.**

Species	1900–59 No. Stn.	1900–59 Gear Type**	1900–59 Collector[a]	1960–73 No. Stn.	1960–73 Gear Type**	1960–73 Collector[a]	1974–83 No. Stn.	1974–83 % of Total	1974–83 Gear Type**	1974–83 Collector[a]
Yellow perch	-	-	-	-	-	-	7	58	1,3	B,D
Bluegill	-	-	-	-	-	-	8	67	1,3	B,D
Black crappie	-	-	-	-	-	-	3	25	1,3	B,D
White crappie	-	-	-	-	-	-	2	17	1,3	B,D
White bass	-	-	-	-	-	-	1	8	1	D
Yellow bass	-	-	-	-	-	-	4	33	1,3	B,D
Bass hybrid[b]	-	-	-	-	-	-	-	-	-	-
Largemouth bass	-	-	-	-	-	-	3	25	1,3	B,D
Smallmouth bass	-	-	-	-	-	-	-	-	-	-
Walleye	-	-	-	-	-	-	1	8	1	D
Northern pike	-	-	-	-	-	-	1	8	1	D
Cisco	-	-	-	-	-	-	-	-	-	-
Common carp	-	-	-	-	-	-	1	8	3	D
Freshwater drum	-	-	-	-	-	-	9	75	1,3	B,D
Black bullhead	-	-	-	-	-	-	7	58	1,3	B,D
Yellow bullhead	-	-	-	-	-	-	2	17	1,3	B,D
Brown bullhead	-	-	-	-	-	-	1	8	1	D
White sucker	-	-	-	-	-	-	1	8	1	D
American brook lamprey	-	-	-	-	-	-	-	-	-	-
Lake sturgeon	-	-	-	-	-	-	-	-	-	-
Longnose gar	-	-	-	-	-	-	1	8	1	D
Shortnose gar	-	-	-	-	-	-	-	-	-	-
Bowfin	-	-	-	-	-	-	1	8	1	D
American eel	-	-	-	-	-	-	-	-	-	-
Mooneye	-	-	-	-	-	-	-	-	-	-
Rainbow trout	-	-	-	-	-	-	-	-	-	-
Brown trout	-	-	-	-	-	-	-	-	-	-
Brook trout	-	-	-	-	-	-	-	-	-	-
Lake trout	-	-	-	-	-	-	-	-	-	-
Central mudminnow	-	-	-	-	-	-	-	-	-	-
Grass pickerel	-	-	-	-	-	-	-	-	-	-
Muskellunge	-	-	-	-	-	-	-	-	-	-
Muskellunge hybrid[b]	-	-	-	-	-	-	-	-	-	-
Central stoneroller	-	-	-	-	-	-	-	-	-	-
Goldfish	-	-	-	-	-	-	-	-	-	-
Spotfin shiner	-	-	-	-	-	-	-	-	-	-
Mississippi silvery minnow	-	-	-	-	-	-	-	-	-	-
Common shiner	-	-	-	-	-	-	-	-	-	-
Hornyhead chub	-	-	-	-	-	-	-	-	-	-
Golden shiner	-	-	-	-	-	-	4	33	1,3	B,D
Pugnose shiner	-	-	-	-	-	-	-	-	-	-
Emerald shiner	-	-	-	-	-	-	-	-	-	-
River shiner	-	-	-	-	-	-	-	-	-	-
Bigmouth shiner	-	-	-	-	-	-	-	-	-	-
Blackchin shiner	-	-	-	-	-	-	-	-	-	-
Blacknose shiner	-	-	-	-	-	-	-	-	-	-
Spottail shiner	-	-	-	-	-	-	1	8	3	D
Pugnose minnow	-	-	-	-	-	-	-	-	-	-
Bluntnose minnow	-	-	-	-	-	-	6	50	3	B,D
Fathead minnow	-	-	-	-	-	-	2	17	3	B
Creek chub	-	-	-	-	-	-	-	-	-	-
Quillback	-	-	-	-	-	-	-	-	-	-
Lake chubsucker	-	-	-	-	-	-	-	-	-	-
Smallmouth buffalo	-	-	-	-	-	-	-	-	-	-
Bigmouth buffalo	-	-	-	-	-	-	-	-	-	-

Appendix Table A.28. *Continued.*

Species	1900–59 No. Stn.	Gear Type**	Collector[a]	1960–73 No. Stn.	Gear Type**	Collector[a]	1974–83 No. Stn.	% of Total	Gear Type**	Collector[a]
Silver redhorse	-	-	-	-	-	-	-	-	-	-
Golden redhorse	-	-	-	-	-	-	-	-	-	-
Shorthead redhorse	-	-	-	-	-	-	-	-	-	-
Channel catfish	-	-	-	-	-	-	-	-	-	-
Tadpole madtom	-	-	-	-	-	-	-	-	-	-
Flathead catfish	-	-	-	-	-	-	-	-	-	-
Burbot	-	-	-	-	-	-	-	-	-	-
Banded killifish	-	-	-	-	-	-	-	-	-	-
Blackstripe topminnow	-	-	-	-	-	-	-	-	-	-
Brook silverside	-	-	-	-	-	-	1	8	3	D
Brook stickleback	-	-	-	-	-	-	-	-	-	-
Rock bass	-	-	-	-	-	-	1	8	1	D
Green sunfish	-	-	-	-	-	-	5	42	1,3	B,D
Pumpkinseed	-	-	-	-	-	-	9	75	1,3	B,D
Sunfish hybrid[b]	-	-	-	-	-	-	5	42	3	B
Warmouth	-	-	-	-	-	-	-	-	-	-
Iowa darter	-	-	-	-	-	-	2	17	3	B
Fantail darter	-	-	-	-	-	-	-	-	-	-
Johnny darter	-	-	-	-	-	-	-	-	-	-
Logperch	-	-	-	-	-	-	1	8	3	B
Mottled sculpin	-	-	-	-	-	-	-	-	-	-
Totals										
No. species[c]	-			-			27			
No. occurrences[d]	-			-			85			
No. stations[e]	-			-			12			

* Source of data: Data were compiled from computer printouts run by Don Fago summarizing fish occurrences recorded in an ongoing DNR Fish Distribution Study, as reported in Fago (1982). All printouts were run so that occurrence was recorded only once per station. Printouts were run on 28 May 1987 (for 1900–59 and 1960–73) and 14 May 1987 (for 1974–83); all 3 are filed with the DNR Bureau of Research.

** Gear types are identified by the following codes:
1 DC boom shocker
2 survey seine
3 small-mesh seine
4 gill, trammel, or entanglement net
5 fyke, hoop, trap, or drop net
6 hook and line, spear, or arrow
7 miscellaneous (e.g., found dead, winterkilled, etc.).

[a] Collectors of fish are grouped into related categories and identified by the following codes:

Historic
A Early Wisconsin fish collectors (1900–31) reported by Greene (1935).

DNR Research
B Fish Distribution Study personnel.

DNR Fisheries Management
C Fisheries Management personnel.
D Fisheries Management survey (based on reports only).

University of Wisconsin System
E UW-Madison students.
F Prof. Marlin Johnson and UW-Waukesha students.

Miscellaneous
G Commercial fishing.
H Unknown collector (e.g., sport angler).

[b] Hybrids were white bass × yellow bass, northern pike × muskellunge, and green sunfish × pumpkinseed.

[c] Excludes hybrids and unspecified species.

[d] Sum of number of species taken at each station.

[e] Total number of stations. Several species may have been taken from the same station.

Appendix Table A.29. *Data from personal fishing diaries of Robert "Buck" Kalhagen for Lake Waubesa, 1976–82.**

Diary Entry	1976		1977		1978		1979		1980**		1981		1982	
	No./50 Trips	% of Catch	No./50 Trips	% of Catch	No./50 Trips	% of Catch	No./50 Trips	% of Catch	No./50 Trips	% of Catch	No./50 Trips	% of Catch	No./50 Trips	% of Catch
Ice fishing														
Species														
Yellow perch	36	74	158	86	184	82	1,157	80	252	35	78	4	665	76
Bluegill	-	-	10	6	26	12	-	-	-	-	-	-	167	19
Black crappie[a]	-	-	2	1	2	1	151	10	236	33	458	24	4	0
White crappie[a]	-	-	1	1	1	1	119	8	233	32	1,355	72	37	4
Largemouth bass	-	-	2	1	-	-	-	-	-	-	-	-	-	-
Walleye	13	26	8	5	10	4	14	1	2	0	3	0	4	0
Northern pike	-	-	1	1	-	-	-	-	-	-	-	-	-	-
Total	49	100	184	100	224	100	1,441	100	724	100	1,893	100	878	100
No. trips	28		72		70		81		21		20		23	
Open-water fishing														
Species														
Yellow perch	745	39	330	32	106	13	14	1	8	1	-	-	-	-
Bluegill	608	32	430	42	140	17	43	2	14	1	1	0	13	1
Black crappie[a]	63	3	168	16	362	43	853	47	766	51	877	83	1,197	67
White crappie[a]	-	-	53	5	171	20	881	49	716	47	120	11	577	32
White bass	1	0	-	-	1	0	-	-	-	-	-	-	-	-
Yellow bass	442	23	-	-	-	-	-	-	-	-	-	-	-	-
Largemouth bass	8	0	5	0	2	0	<1	0	<1	0	4	0	-	-
Walleye	30	2	14	1	44	5	10	1	8	1	35	3	-	-
Northern pike	1	0	1	0	<1	0	-	-	-	-	1	0	-	-
Common carp	1	0	-	-	1	0	-	-	-	-	1	0	-	-
Freshwater drum	7	0	9	1	6	1	11	1	<1	0	-	-	-	-
Bullhead spp.	16	1	9	1	5	1	-	-	<1	0	-	-	-	-
White sucker	1	0	-	-	-	-	-	-	-	-	-	-	-	-
Bowfin	1	0	-	-	-	-	-	-	-	-	-	-	-	-
Muskellunge hybrid	-	-	<1	0	-	-	<1	0	-	-	-	-	-	-
Shorthead redhorse	-	-	<1	0	-	-	-	-	-	-	-	-	-	-
Channel catfish	-	-	1	0	1	0	<1	0	-	-	13	1	3	0
Green sunfish	5	0	4	0	1	0	1	0	-	-	-	-	2	0
Total	1,927	100	1,025	100	840	100	1,815	100	1,513	100	1,051	100	1,792	100
No. trips	95		138		160		108		125		71		30	

* Source of data: Robert Kalhagen, former Wis. Dep. Nat. Resour. South. Dist. fish technician, pers. comm. Journal data were recorded in fish caught per day; for comparison, these data were standardized to number caught per 50 trips.

** Less ice fishing took place on Lake Waubesa in 1980 than in other years. Most ice fishing that winter was done on Lake Mendota, where 1,105 yellow perch were caught in 24 trips.

[a] Black and white crappies were separated by counting dorsal fin spines.

Appendix Table A.30. *Lake Kegonsa creel surveys, 1936, 1938–39, 1974, and 1982–83.**

	1936		1938		1939		1974		1982–83	
Species	**No. Caught**	**% of Catch**	**No. Caught**	**% of Catch**	**No. Caught**	**% of Catch**	**No. Caught**	**% of Catch**	**No. Caught****	**% of Catch**
Yellow perch	731	9	4,085	22	165	5	9,422	45	3,712	2
Bluegill	2,672	34	1,193	6	72	2	1,494	7	15,916	9
Black crappie	-	-	-	-	-	-	-	-	82,701	44
White crappie	-	-	-	-	-	-	-	-	80,245	43
Crappie spp.	106	1	2,591	14	1,048	31	380	2	162,946	87
White bass	2,115	27	8,955	48	1,932	57	731	3	-	-
Yellow bass	-	-	-	-	-	-	6,085	29	-	-
Largemouth bass	161	2	57	0	3	0	49	0	373	0
Smallmouth bass	35	0	46	0	11	0	10	0	126	0
Walleye	1,094	14	893	5	54	2	113	1	421	0
Northern pike	67	1	176	1	27	1	22	0	174	0
Common carp	-	-	128	1	27	1	1	0	95	0
Freshwater drum	-	-	-	-	-	-	37	0	446	0
Bullhead spp.	-[a]	-	355	2	59	2	2,584	12	416	0
White sucker	-	-	-	-	-	-	-	-	17	0
Muskellunge hybrid	-	-	-	-	-	-	-	-	9	0
Sucker spp.	-	-	-	-	-	-	-	-	86	0
Channel catfish	-	-	-	-	-	-	11	0	-	-
Rock bass	19	0	24	0	6	0	-	-	63	0
Pumpkinseed	47	1	55	0	4	0	15	0	1,568	1
Warmouth	-	-	-	-	-	-	-	-	18	0
Unidentified	699[a]	0	-	-	-	-	-	-	-	-
Total	7,746	100	18,558	100	3,408	100	20,939	100	186,386	100
Survey description										
Period	14 Jun–31 Oct		15 May–15 Oct		15 May–25 Sep		1 Jun–30 Nov		1 Jul 82–30 Jun 83	
Method	voluntary		voluntary		personal interview		personal interview		personal interview	
No. anglers	-		6,900		2,340		698		37,242	
No. hours	-		36,500		10,960		-		131,787	

* Sources of data:
1936 - Juday and Vike (1938)
1938 - Frey et al. (1939)
1939 - Frey and Vike (1941)
1974 - Wis. Dep. Nat. Resour., Madison Area files (unpubl. data)
1982–83 - Wis. Dep. Nat. Resour., Madison Area files (unpubl. data).

** Numbers represent **projected** fish catch for the year.

[a] Mostly bullheads.

Appendix Table A.31. *Lake Kegonsa state rough fish removal records, 1935–69.**

Year	No. Hauls	Rough Fish (lb)**							No. Game Fish[a]												
		Total	CC	FD	WS	BB	LG	BF	YP	CS	WB	YB	LB	SB	WE	NP	BH	WS[b]	CF	LS	SF
1935	-	403,396	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1936	-	281,020	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1937	22	578,665	571,571	2,849	-	-	4,180	65	1,201	8,818	2,910	-	-	-	2,911	-	-	-	-	-	4,677
1938	29	881,675	876,650	4,440	-	-	580	-	-	7,076	25,929	-	-	-	507	-	-	-	-	-	3,454
1939	45	1,291,948	1,286,055	4,041	-	-	1,845	16	1,526	14,261	57,371	-	-	-	297	-	-	-	-	-	6,350
1940	26	855,560	850,970	4,035	-	-	543	11	1,131	2,870	21,247	-	-	-	367	-	-	2,057	-	-	1,050
1941	45	1,118,880	1,114,443	2,844	-	-	1,593	-	1,769	5,684	22,514	-	-	-	1,422	-	-	2,192	-	-	2,003
1942	23	806,037	804,871	465	-	-	446	255	283	1,856	7,176	-	-	-	2,351	-	-	350	-	-	1,134
1943	10	384,195	381,300	2,895	-	-	-	-	331	561	2,500	-	-	-	422	-	-	325	-	-	430
1944	7	221,170	217,100	3,890	-	-	180	-	153	302	3,632	-	-	-	2,227	-	-	388	-	-	729
1945	24	595,236	583,500	10,462	-	-	1,274	-	283	2,501	175,918	-	-	-	780	-	-	1,447	-	-	3,708
1946	34	681,839	662,402	18,904	-	-	534	-	891	3,536	114,339	-	-	-	347	-	-	4,944	-	-	6,729
1947	19	263,635	261,900	1,693	-	-	42	-	137	3,939	10,038	-	-	-	125	-	-	2,440	-	-	5,092
1948	41	432,181	406,400	25,625	-	-	156	-	1,812	283	36,334	-	-	-	463	-	-	1,681	-	-	1,718
1949	33	414,813	391,581	22,602	-	-	630	-	409	1,030	38,669	-	-	-	353	-	-	1,614	-	-	4,821
1950	28	378,543	356,370	21,633	-	-	540	-	384	493	36,862	-	-	-	414	-	-	1,579	-	-	4,066
1951	15	327,609	315,435	12,174	-	-	-	-	68	395	20,355	-	-	-	560	-	-	965	-	-	657
1952	-	734,107	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1953	-	741,900	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1954	-	787,786	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1955	-	441,456	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1956	-	156,890	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1957	-	741,591	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1958	-	963,735	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1959	38	581,482	545,800	21,262	-	14,420	-	-	-	-	10,070	304	-	-	-	-	-	-	-	-	-
1960	24	340,660	327,755	9,070	-	3,785	50	-	-	-	7,224	144	-	-	-	-	-	-	-	-	-
1961	23	475,282	447,340	22,210	-	5,730	-	-	-	-	18,400	1,173	-	-	-	-	-	-	-	-	-
1962	20	237,120	202,540	28,710	-	5,870	-	-	-	-	19,820	1,500	-	-	-	-	-	-	-	-	-
1963	15	328,480	326,000	1,280	-	1,200	-	-	-	-	465	60	-	-	-	-	-	-	-	-	-
1964	12	253,170	247,200	5,370	200	400	-	-	-	-	120	-	-	-	-	-	-	-	-	-	-
1965	17	541,540	511,600	28,040	-	1,900	-	-	-	-	442	646	-	-	-	-	-	-	-	-	-
1966	16	250,115	238,600	7,215	-	4,300	-	-	-	-	1,376	18,320	-	-	-	-	-	-	-	-	-
1967	12	228,200	225,600	2,550	-	50	-	-	19	85	468	31,548	9	3	132	79	4,164	-	204	-	2,772
1968	8	62,025	60,100	1,025	-	900	-	-	15	168	68	13,224	11	-	35	26	472	-	50	11	932
1969	3	27,950	26,500	450	-	1,000	-	-	1	5	10	60	5	-	7	5	36	-	7	-	105

* Sources of data: Rough and game fish data from 1937–51 are from Hacker (1952*b*). Other species noted by Hacker were *Esox* spp., buffalo, catfish, black bass, bullhead spp., sturgeon, and rainbow trout. White and yellow bass data from 1959–66 are from Wright (1968). Rough fish data from 1960–69 are from rough fish records in DNR's central library in Madison (unpubl. data). All other data are from Wis. Dep. Nat. Resour., Madison Area files (unpubl. data). Description of gear: The state rough fish seine varied in length from 1,370–1,830 m, in mesh size from 90–110 mm, and in depth from 3–4 m.

**Species codes: CC = Common carp FD = Freshwater drum WS = White sucker BB = Bigmouth buffalo LG = Longnose gar BF = Bowfin

[a] Species codes: YP = Yellow perch CS = Crappie spp. WB = White bass YB = Yellow bass LB = Largemouth bass SB = Smallmouth bass WE = Walleye NP = Northern pike BH = Bullhead spp. WS = White sucker CF = Channel catfish LS = Lake sturgeon SF = Sunfish spp.

[b] White suckers were listed by Hacker (1952*b*) as "game fish" even though their official designation at the time was "rough fish."

Appendix Table A.32. *Lake Kegonsa commercial rough fish removal records, 1976–85.**

		Rough Fish (lb)**					No. Game Fish[a]										
Year	Days	Total	CC	FD	BB	QB	YP	BG	CS	WB	LB	SB	WE	NP	BH	CF	MH
1976	5	19,608	15,651	-	3,957	-	-	-	-	-	-	-	-	-	-	-	-
1977	-	7,626	7,318	-	200	108	-	-	-	-	-	-	-	-	-	-	-
1978	7+	26,430	16,450	-	9,980	-	-	-	-	-	-	-	116	3	-	22	-
1979	-	343,105	331,525	600	10,980	-	2	137	1,015	1	5	4	298	16	215	148	-
1980	5	103,775	100,050	-	3,725	-	-	-	150	-	-	-	30	3	-	20	-
1981	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1982	3	58,281	57,581	700	-	-	3	-	50	3	-	-	13	18	24	52	-
1983–84	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1985	3	7,465	7,205	-	260	-	-	10	30	-	20	-	11	2	10	2	1

* Source of data: Wis. Dep. Nat. Resour., Madison Area files (unpubl. data). Description of gear: The commercial rough fish removal contracts allowed for use of seines not less than 760 m with a maximum mesh size of 150 mm, or entanglement nets 910 m long with a minimum mesh size of 150 mm.

** Species codes: CC = Common carp; FD = Freshwater drum; BB = Bigmouth buffalo; QB = Quillback

[a] Species codes: YP = Yellow perch; BG = Bluegill; CS = Crappie spp.; WB = White bass; LB = Largemouth bass; SB = Smallmouth bass; WE = Walleye; NP = Northern pike; BH = Bullhead spp.; CF = Channel catfish; MH = Muskellunge hybrid

Appendix Table A.34. *Lake Kegonsa fish population surveys using fyke nets, 1957 and 1975.**

	1957		1975	
Species	No. Caught	% of Catch	No. Caught	% of Catch
Yellow perch	414	17	5,657	83
Bluegill	79	3	13	0
Black crappie	-	-	412	6
White crappie	-	-	2	0
Crappie spp.	94	4	414	6
White bass	986	39	15	0
Yellow bass	-	-	6	0
Largemouth bass	2	0	4	0
Smallmouth bass	1	0	-	-
Walleye	258	10	112	2
Northern pike	12	0	27	0
Common carp	9	0	56	1
Freshwater drum	-	-	10	0
Bullhead spp.	590	24	397	6
White sucker	37	1	85	1
Golden shiner	4	0	-	-
Bigmouth buffalo	8	0	4	0
Channel catfish	2	0	-	-
Rock bass	4	0	2	0
Green sunfish	-	-	2	0
Pumpkinseed	1	0	1	0
Total	2,501	98	6,805	99
Survey description**				
Month	Apr		Apr	
No. fyke net lifts	32		36	

* Source of data: Wis. Dep. Nat. Resour., Madison Area files (unpubl. data).

** Fyke nets varied in hoop size from 1–1.5 m and in mesh size from 19–50 mm.

Appendix Table A.33. *Lake Kegonsa fish population surveys using boom shockers, 1968, 1970, 1973, 1976, 1978–84.**

Species	No. Fish Caught**										
	1968	1970	1973	1976	1978	1979	1980	1981	1982	1983	1984
Yellow perch	1	9	12	19	7	-	11	3	43 A	13	4
Bluegill	19	24	26	100	101	153	165	111	150 A	127	185
Black crappie	7	-	-	15	-	52	-	15	31	57	45
White crappie	2	-	-	-	14 A	64	29	59	34	38	2
Crappie spp.	9	1	-	15	46 A	116	109 A	74	65	95	47
White bass	7	5	-	-	-	-	-	1	1	3	-
Yellow bass	165 A	22	-	66 A	-	-	-	-	-	-	2
Largemouth bass	19	13	15	9	25	19	7	58	119 A	143	82
Smallmouth bass	-	-	-	-	-	1	3	3	-	-	-
Walleye	10	3	11	57	69	23	15	10	2	4	22
Northern pike	3	1	1	-	4	3	3	3	1	7	7
Common carp	-	-	-	- A	- P	-	250	-	- A	2 A	- A
Freshwater drum	24	-	-	27	102	39	9 A	23	7 A	59	11
Bullhead spp.	12	-	-	33	26	7	1	3	8 A	8	16
White sucker	-	-	-	1	- P	-	10	2	- A	1	3 A
Longnose gar	-	-	-	-	1	-	-	2	-	-	-
Bowfin	-	-	-	1	-	1	-	-	-	-	-
Central mudminnow[a]	-	-	-	-	-	-		-	1	-	-
Muskellunge hybrid	-	-	-	-	-	-	-	-	1	-	-
Golden shiner	-	-	-	2	-	-	2	-	12	9	3 A
Emerald shiner	-	-	-	-	-	-	1	-	-	-	-
Spottail shiner	-	-	-	-	-	-	-	-	1	-	-
Channel catfish	-	-	-	-	-	-	-	3	1	-	-
Brook silverside	-	-	-	- A	-	-	2	- A	2	- A	- A
Green sunfish	-	-	-	1	2	2	1	9	16	6	6
Pumpkinseed	31	14	-	7	10	4	4	2	52	18	46
Logperch	-	-	-	4	-	-	-	-	1	1	-
Survey description[b]											
Month	Sep	Jul	Oct	Sep	Oct	Oct	Sep	Sep	Sep	Sep	Oct
Time of day	day/night	day	day/night	night	night	night	night	night	night	night	night
Hours	2+4	-	4+2	3.6	4	1.8	4.0	5.8	3.5	2.7	4.1

* Source of data: Wis. Dep. Nat. Resour., Madison Area files (unpubl. data). Most calculations of effort and some corrections to the numbers of fish recorded were provided by Steve Gilbert (former Madison Lakes fish biologist, Wis. Dep. Nat. Resour., pers. comm., 1990).

** In general, only a few of the more abundant panfish, minnows, and rough fish were sampled. Fish recorded as abundant and present in the field notes are marked with A and P, respectively.

[a] Data were recorded as mudminnow and were interpreted to mean central mudminnow.

[b] DC current of 230 v was used from an 18-ft boat.

Appendix Table A.35. *Lake Kegonsa fish population surveys using shoreline seines, 1966, 1971, and 1976–80.**

	No. Fish Caught						
Species	**1966**	**1971**	**1976**	**1977**	**1978**	**1979**	**1980**
Yellow perch	-	-	7	1	2	-	-
Bluegill	220	5	3	1,129	26	46	79
Black crappie	-	-	-	40	-	21	5
White crappie	-	-	-	2	6	3	-
Crappie spp.	335	-	98	42	6	24	5
White bass	2	-	-	-	-	-	-
Yellow bass	-	-	55	-	-	-	-
Largemouth bass	90	-	8	16	-	-	-
Walleye	1	-	3	1	1	-	-
Northern pike	-	45	-	1	-	-	-
Common carp	177	-	-	-	1	1	-
Bullhead spp.	17	1	2	15	-	-	-
White sucker	-	2	-	-	-	-	-
Golden shiner	-	-	-	-	-	-	1
Bluntnose minnow	-	-	-	26	2	-	1
Brook silverside	-	-	-	1,008	12	-	-
Green sunfish	20	-	-	4	2	-	-
Pumpkinseed	-	-	-	15	-	-	-
Logperch	-	-	-	6	-	-	-
Survey description**							
Month	Jul	Apr	Jul	Sep	Sep	Aug	Sep
No. hauls	3	1	13	17	22	17	20

* Source of data: Wis. Dep. Nat. Resour., Madison Area files (unpubl. data).
** Shoreline seines varied in length from 6–8 m, in mesh size from 3–9 mm, and had a depth of 1 m.

Appendix Table A.36. *Lake Kegonsa fish population surveys using survey seines, 1975.**

	1975	
Species	**No. Caught**	**% of Catch**
Yellow perch	296	7
Bluegill	286	6
Black crappie	486	11
White crappie	3	0
White bass	6	0
Yellow bass	165	4
Largemouth bass	3	0
Walleye	7	0
Northern pike	14	0
Freshwater drum	5	0
Bullhead spp.	3,110	71
White sucker	4	0
Longnose gar	3	0
Golden shiner	15	0
Pumpkinseed	3	0
Total	4,406	99
Survey description**		
Month	Oct	
Seine length (ft)	2,400	
No. hauls	1	

* Source of data: Wis. Dep. Nat. Resour., Madison Area files (unpubl. data).
** Survey seines varied in mesh size from 32–50 mm and in depth from 3–4 m.

Appendix Table A.37. *Lake Kegonsa stocking records, 1852–1986.**

Year(s)[b]	No. Stocked** Yellow Perch	Bluegill	Crappie spp.	White Bass	Largemouth Bass	Smallmouth Bass	Bass spp.[a]	Walleye	Northern Pike	Cisco	Bullhead spp.	Others[a]
1852–55	-	-	-	-	-	-	-	-	-	-	-	-
1875	-	-	-	-	-	-	-	-	-	-	-	-
1877	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-
1880	-	-	-	-	-	-	-	200,000 R	-	-	-	-
1885	-	-	-	-	-	-	-	-	-	-	-	-
1886	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-
1887	-	-	-	-	-	-	-	-	-	-	-	-
1889	-	-	-	-	-	-	-	300,000 R	-	-	-	-
1890	-	-	-	-	-	-	-	-	-	-	-	-
1891	-	-	-	-	-	-	-	160,000 R	-	-	-	-
1895	-	-	-	-	-	-	-	-	-	-	-	-
1899	-	-	-	-	-	-	-	-	-	-	-	-
1900	-	-	-	-	-	-	-	420,000 R	-	-	-	-
1901	-	-	-	-	-	-	-	-	-	-	-	-
1902	-	-	-	-	-	-	-	600,000 R	-	-	-	-
1903	-	-	-	-	-	-	-	300,000 R	-	-	-	-
1904	-	-	-	-	-	-	-	200,000 R	-	-	-	-
1905	-	-	-	-	-	-	-	1,000,000 I	-	-	-	-
1906	-	-	-	-	-	-	6,000 R	1,200,000 R	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-
1907	-	-	-	-	-	-	4,000 R	-	-	-	-	-
1908	-	-	-	-	-	-	8,000 R	1,000,000 R	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-
1910–19	-	-	-	-	-	-	-	-	-	-	-	-
1920–29	-	-	-	-	-	-	-	-	-	-	-	-
1922	-	-	-	-	-	-	-	-	-	-	-	-
1929	-	-	-	-	-	-	-	-	-	-	-	-
1930–34	-	-	-	-	-	-	-	-	-	-	-	-
1933	-	-	-	-	-	-	-	-	-	-	-	-
1934	-	-	-	-	-	-	-	-	-	-	-	-
1935	-	-	-	-	-	-	-	-	-	-	-	-
1936	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-
1937	7,200 I	-	10,000 I	-	2,000 I	-	-	-	11,409 I	-	22,000 I	-
	-	-	-	-	-	-	-	-	-	-	-	-
1938	22,600 I	2,000 A	2,000 A	-	-	300 I	-	5,975,380 R	-	-	-	-
	-	-	-	-	-	65 A	-	-	-	-	-	-

(Continued on next page)

Appendix Table A.37. *Continued.*

Year(s)[b]	No. Stocked** Yellow Perch	Bluegill	Crappie spp.	White Bass	Largemouth Bass	Smallmouth Bass	Bass spp.[a]	Walleye	Northern Pike	Cisco	Bullhead spp.	Others[a]
1939	2,903,040 E	27,000 I	-	-	10,500 I	-	-	11,669,704 R	-	-	2,000 R	12,000 I, SF
	32,000 I	-	-	-	-	-	-	-	-	-	-	-
	200 A	-	-	-	-	-	-	-	-	-	-	-
1940	25,000 I	15,000 I	-	-	18,000 I	-	-	6,250,000 R	15,000 R	-	100,000 I	-
	-	-	-	-	-	-	-	-	785 I	-	-	-
1941	1,827,840 E	-	-	-	10,000 I	2,000 I	-	-	5,000 I	-	6,000 I	-
	4,000 I	-	-	-	-	-	-	-	-	-	1,000 A	-
	1,300 A	-	-	-	-	-	-	-	-	-	-	-
1942	-	-	-	-	-	-	-	7,500,000 R	-	-	-	2,000 A, SF
	-	-	-	-	-	-	-	8,000 I	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-
1943	-	13,000 I	-	-	25,500 I	10,000 I	-	-	-	-	10,000 I	-
	-	-	-	-	-	-	-	-	-	-	-	-
1944	7,076,515 E	5,000 I	-	-	5,000 I	-	-	-	6,000 R	-	-	-
1945	-	-	-	-	-	10,000 I	-	2,009,615 I	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-
1946	-	-	-	-	-	-	-	5,380,000 R	-	-	-	-
	-	-	-	-	-	-	-	10,000 I	-	-	-	-
1947	-	5,000 I	-	-	5,000 I	-	-	3,200 I	60,000 R	-	-	-
1948	-	5,000 I	3,450 I	-	5,040 I	5,000 I	-	-	-	-	-	-
1949	-	-	-	-	-	5,000 I	-	-	30,000 R	-	-	-
1950	-	-	-	-	-	5,000 I	-	14,992 I	4,054 I	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-
1951	-	-	-	-	9,280 I	5,000 I	-	5,360 I	-	-	-	-
1952	-	-	-	-	-	5,000 I	-	42,705 I	-	-	-	-
1953	-	-	-	-	-	-	-	-	-	-	-	-
1954	-	-	-	-	-	-	-	7,698 I	-	-	-	-
1955	-	-	-	-	-	-	-	-	-	-	-	-
1956	-	-	-	-	-	-	-	-	-	-	-	-
1957	-	-	-	-	-	-	-	17,325 I	1,000 I	-	-	-
1958	-	-	-	-	-	-	-	15,363 I	33 A	-	-	-
1959	-	-	-	-	-	-	-	46,057 I	-	-	-	-
1960	-	-	-	-	-	-	-	9,632 I	4,054 I	-	-	-
1961	-	-	-	-	-	-	-	16,500 I	4,159 I	-	-	-
	-	-	-	-	-	-	-	-	521 C	-	-	-
1962	-	-	-	-	10,000 I	-	-	-	22 A	-	-	-
1963	-	-	-	-	-	-	-	11,442 I	700 Y	-	-	-
1964	-	-	-	-	-	-	-	15,685 I	3,340 I	-	-	-

Appendix Table A.37. *Continued.*

Year(s)[b]	No. Stocked** Yellow Perch	Bluegill	Crappie spp.	White Bass	Largemouth Bass	Smallmouth Bass	Bass spp.[a]	Walleye	Northern Pike	Cisco	Bullhead spp.	Others[a]
1965	-	-	-	-	-	-	-	10,000 I	-	-	-	-
1966	-	-	-	-	-	-	-	-	-	-	-	-
1967	-	-	-	-	-	-	-	96,400 I	6 A	-	-	-
1968	-	-	-	-	-	-	-	20,300 I	-	-	-	-
1969	-	-	-	-	-	-	-	10,500 I	-	-	-	-
1970	-	-	-	-	-	-	-	9,010 I	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-
1971	-	-	-	-	-	-	-	4,995 I	-	-	-	-
1972	-	-	-	-	-	-	-	28,800 I	-	-	-	-
1973	-	-	-	-	-	-	-	-	-	-	-	-
1974	-	-	-	-	-	-	-	125,500 I	-	-	-	-
1975	-	-	-	-	-	-	-	-	-	-	-	-
1976	-	-	-	-	-	-	-	292,276 I	-	-	-	-
1977	-	-	-	-	-	-	-	-	-	-	-	-
1978	-	-	-	-	-	-	-	-	-	-	-	-
1979	-	-	-	-	-	-	-	-	-	-	-	-
1980	-	-	-	-	-	-	-	-	-	-	-	-
1981	-	-	-	-	2,200 I	-	-	12,780 I	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-
1982	-	-	-	-	-	-	-	3,000,000 R	351,000 R	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-
1983	-	-	-	-	-	-	-	-	-	-	-	-
1984	-	-	-	-	-	-	-	8,400,000 R	1,500 I	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-
1985	-	-	-	-	-	-	-	-	2,500 I	-	-	3,313 I, MH
1986	-	-	-	-	-	-	-	5,100 I	1,500 I	-	-	1,500 I, MH
	-	-	-	-	-	-	-	-	-	-	-	-
Totals												
E	11,807,395	-	-	-	-	-	-	-	-	-	-	c
R	-	-	-	-	-	-	18,000	52,555,084	462,000	-	2,000	c
I	90,800	70,000	13,450	-	102,520	47,300	-	3,849,235	39,301	-	138,000	c
Y	-	-	-	-	-	-	-	-	700	-	-	c
A	1,500	2,000	2,000	-	-	65	-	-	61	-	1,000	c
C	-	-	-	-	-	-	-	-	521	-	-	c

* Sources of data: Early records came from WCD memoranda in the State Historical Society archives and ledgers in the DNR's central library. Data from 1959 to 1986 came from stocking receipts in Wis. Dep. Nat. Resour., Madison Area and South. Dist. files. Source of stocked fish: all fish were raised at DNR fish hatcheries with the exception of fish taken from the Mississippi River during rescue operations in the late 1930s and early 1940s. Corrections to selected stocking totals since 1970 for walleyes, northern pike, and muskellunge hybrids were made by Steve Gilbert (former Madison Lakes fish biologist, Wis. Dep. Nat. Resour., pers. comm., 1990).

** Numbers stocked are coded as: E = eggs, R = fry, I = fingerlings, Y = yearlings, A = adults, and C = combination of fingerlings and adults.

[a] Of major species, bass spp. are *Micropterus* spp. Other species are coded as: SF = sunfish (which were *Lepomis* spp.) and MH = muskellunge hybrid.

[b] Between 1852 and the mid-1930s, years listed are only those for which stocking records on any one of the Yahara lakes were found. After 1935, stocking took place more regularly, so all years are listed including 1955 and 1966, for which no records were located.

[c] Totals for other species are: sunfish 12,000 fingerlings and 2,000 adults; muskellunge hybrid 4,813 fingerlings.

Appendix Table A.38. *Lake Kegonsa fish distribution survey, 1900–83.**

Species	1900–59 No. Stn.	1900–59 Gear Type**	1900–59 Collector[a]	1960–73 No. Stn.	1960–73 Gear Type**	1960–73 Collector[a]	1974–83 No. Stn.	1974–83 % of Total	1974–83 Gear Type**	1974–83 Collector[a]
Yellow perch	-	-	-	-	-	-	5	29	1,3	B,D
Bluegill	-	-	-	-	-	-	10	59	1,3	B,D
Black crappie	-	-	-	-	-	-	9	53	1,3	B,D
White crappie	-	-	-	-	-	-	1	6	1	D
White bass	-	-	-	-	-	-	5	29	3,5	B,D
Yellow bass	-	-	-	-	-	-	9	53	1,3	B,D
Bass hybrid[b]	-	-	-	-	-	-	-	-	-	-
Largemouth bass	-	-	-	-	-	-	7	41	1,3	B,D
Smallmouth bass	-	-	-	-	-	-	2	12	1,3	B,D
Walleye	-	-	-	-	-	-	3	18	1,3	B,D
Northern pike	-	-	-	-	-	-	1	6	1	D
Cisco	-	-	-	-	-	-	-	-	-	-
Common carp	-	-	-	-	-	-	8	47	1,3	B,D
Freshwater drum	-	-	-	-	-	-	3	18	1,3	B,D
Black bullhead	-	-	-	-	-	-	5	29	1,3	B,D
Yellow bullhead	-	-	-	-	-	-	1	6	1	D
Brown bullhead	-	-	-	-	-	-	1	6	1	D
White sucker	-	-	-	-	-	-	2	12	1,3	B,D
American brook lamprey	-	-	-	-	-	-	-	-	-	-
Lake sturgeon	-	-	-	-	-	-	1	6	4	G
Longnose gar	-	-	-	-	-	-	3	18	1,3	B,D
Shortnose gar	-	-	-	-	-	-	-	-	-	-
Bowfin	-	-	-	-	-	-	1	6	1	D
American eel	-	-	-	-	-	-	-	-	-	-
Mooneye	-	-	-	-	-	-	-	-	-	-
Rainbow trout	-	-	-	-	-	-	-	-	-	-
Brown trout	-	-	-	-	-	-	-	-	-	-
Brook trout	-	-	-	-	-	-	-	-	-	-
Lake trout	-	-	-	-	-	-	-	-	-	-
Central mudminnow	-	-	-	-	-	-	-	-	-	-
Grass pickerel	-	-	-	-	-	-	-	-	-	-
Muskellunge	-	-	-	-	-	-	-	-	-	-
Muskellunge hybrid[b]	-	-	-	-	-	-	-	-	-	-
Central stoneroller	-	-	-	-	-	-	-	-	-	-
Goldfish	-	-	-	-	-	-	-	-	-	-
Spotfin shiner	-	-	-	-	-	-	-	-	-	-
Mississippi silvery minnow	-	-	-	-	-	-	-	-	-	-
Common shiner	-	-	-	-	-	-	-	-	-	-
Hornyhead chub	-	-	-	-	-	-	-	-	-	-
Golden shiner	-	-	-	-	-	-	1	6	1	D
Pugnose shiner	-	-	-	-	-	-	-	-	-	-
Emerald shiner	-	-	-	-	-	-	3	18	1,3	B,D
River shiner	-	-	-	-	-	-	-	-	-	-
Bigmouth shiner	-	-	-	-	-	-	-	-	-	-
Blackchin shiner	-	-	-	-	-	-	-	-	-	-
Blacknose shiner	-	-	-	-	-	-	-	-	-	-
Spottail shiner	-	-	-	-	-	-	-	-	-	-
Pugnose minnow	-	-	-	-	-	-	-	-	-	-
Bluntnose minnow	-	-	-	-	-	-	1	6	3	D
Fathead minnow	-	-	-	-	-	-	1	6	3	B
Creek chub	-	-	-	-	-	-	-	-	-	-
Quillback	-	-	-	-	-	-	-	-	-	-
Lake chubsucker	-	-	-	-	-	-	-	-	-	-
Smallmouth buffalo	-	-	-	-	-	-	-	-	-	-

Appendix Table A.38. *Continued.*

Species	1900–59 No. Stn.	1900–59 Gear Type**	1900–59 Collector[a]	1960–73 No. Stn.	1960–73 Gear Type**	1960–73 Collector[a]	1974–83 No. Stn.	1974–83 % of Total	1974–83 Gear Type**	1974–83 Collector[a]
Bigmouth buffalo	-	-	-	-	-	-	2	12	3,5	B,D
Silver redhorse	-	-	-	-	-	-	-	-	-	-
Golden redhorse	-	-	-	-	-	-	-	-	-	-
Shorthead redhorse	-	-	-	-	-	-	-	-	-	-
Channel catfish	-	-	-	-	-	-	-	-	-	-
Tadpole madtom	-	-	-	-	-	-	-	-	-	-
Flathead catfish	-	-	-	-	-	-	-	-	-	-
Burbot	-	-	-	-	-	-	-	-	-	-
Banded killifish	-	-	-	-	-	-	-	-	-	-
Blackstripe topminnow	-	-	-	-	-	-	-	-	-	-
Brook silverside	-	-	-	-	-	-	9	53	1,3	B,D
Brook stickleback	-	-	-	-	-	-	-	-	-	-
Rock bass	-	-	-	-	-	-	1	6	5	D
Green sunfish	-	-	-	-	-	-	2	12	1,3	B,D
Pumpkinseed	-	-	-	-	-	-	3	18	1,3	B,D
Sunfish hybrid[b]	-	-	-	-	-	-	2	12	3	B
Warmouth	-	-	-	-	-	-	-	-	-	-
Iowa darter	-	-	-	-	-	-	1	6	3	B
Fantail darter	-	-	-	-	-	-	-	-	-	-
Johnny darter	-	-	-	-	-	-	-	-	-	-
Logperch	-	-	-	-	-	-	2	12	1,3	B,D
Mottled sculpin	-	-	-	-	-	-	-	-	-	-
Totals										
No. species[c]	-			-			30			
No. occurrences[d]	-			-			103			
No. stations[e]	-			-			17			

* Source of data: Data were compiled from computer printouts run by Don Fago summarizing fish occurrences recorded in an ongoing DNR Fish Distribution Study, as reported in Fago (1982). All printouts were run so that occurrence was recorded only once per station. Printouts were run on 28 May 1987 (for 1900–59 and 1960–73) and 14 May 1987 (for 1974–83); all 3 are filed with the DNR Bureau of Research.

** Gear types are identified by the following codes:
1 DC boom shocker
2 survey seine
3 small-mesh seine
4 gill, trammel, or entanglement net
5 fyke, hoop, trap, or drop net
6 hook and line, spear, or arrow
7 miscellaneous (e.g., found dead, winterkilled, etc.).

[a] Collectors of fish are grouped into related categories and identified by the following codes:

Historic
A Early Wisconsin fish collectors (1900–31) reported by Greene (1935).

DNR Research
B Fish Distribution Study personnel.

DNR Fisheries Management
C Fisheries Management personnel.
D Fisheries Management survey (based on reports only).

University of Wisconsin System
E UW-Madison students.
F Prof. Marlin Johnson and UW-Waukesha students.

Miscellaneous
G Commercial fishermen.
H Unknown collector (e.g., sport angler).

[b] Hybrids were white bass × yellow bass, northern pike × muskellunge, and green sunfish × pumpkinseed.

[c] Excludes hybrids and unspecified species.

[d] Sum of number of species taken at each station.

[e] Total number of stations. Several species may have been taken from the same station.

Appendix Table A.39. *Index to fish presence records summarized in Appendix A tables for Lake Mendota.*

	Table Number and Subject									
Species	A.1 Creel Survey	A.2 State Rough Fish Removal	A.3 Comm. Rough Fish Removal	A.4 Boom Shocker	A.5 Fyke Net	A.6 Shoreline Seine	A.7 Survey Seine	A.8 Stocking	A.9 Distribution Survey	A.10 UW Research
Yellow perch	X			X	X	X	X	X	X	X
Bluegill	X		X	X	X	X	X	X	X	X
Black crappie	X			X	X	X	X		X	X
White crappie	X			X	X	X	X		X	X
Crappie spp.	X		X	X	X	X		X		
White bass	X	X	X	X	X	X	X	X	X	X
Yellow bass	X	X		X	X		X		X	X
Bass hybrid									X	
Largemouth bass	X		X	X	X	X	X	X	X	X
Smallmouth bass	X			X	X		X	X	X	X
Bass spp.								X		
Walleye	X		X	X	X	X	X	X	X	X
Northern pike	X		X	X	X		X	X	X	X
Cisco	X			X		X		X	X	
Common carp	X	X	X	X	X		X		X	X
Freshwater drum	X	X	X	X	X		X		X	X
Black bullhead									X	
Yellow bullhead									X	
Brown bullhead									X	
Bullhead spp.	X		X	X	X	X	X	X		X
White sucker	X	X		X	X		X		X	X
American brook lamprey										
Lake sturgeon			X				X	X	X	X
Longnose gar	X	X	X	X			X		X	X
Shortnose gar									X	
Bowfin		X		X	X				X	X
American eel										
Mooneye										
Rainbow trout										
Chinook salmon								X		
Atlantic salmon								X		
Brown trout										
Brook trout										X
Lake trout								X		
Central mudminnow										
Grass pickerel										
Muskellunge								X	X	
Muskellunge hybrid	X		X	X	X		X	X	X	
Central stoneroller										
Goldfish								X		
Spotfin shiner									X	

Appendix Table A.39. *Continued.*

Species	A.1 Creel Survey	A.2 State Rough Fish Removal	A.3 Comm. Rough Fish Removal	A.4 Boom Shocker	A.5 Fyke Net	A.6 Shoreline Seine	A.7 Survey Seine	A.8 Stocking	A.9 Distribution Survey	A.10 UW Research
	Table Number and Subject									
Mississippi silvery minnow									X	
Common shiner									X	
Hornyhead chub									X	
Golden shiner				X	X	X	X		X	
Pugnose shiner									X	
Emerald shiner				X		X			X	
River shiner										
Bigmouth shiner									X	
Blackchin shiner									X	
Blacknose shiner									X	
Spottail shiner				X					X	
Pugnose minnow									X	
Bluntnose minnow				X		X			X	
Fathead minnow									X	
Creek chub				X					X	
Quillback										
Lake chubsucker										
Smallmouth buffalo										X
Bigmouth buffalo		X	X	X	X		X		X	X
Silver redhorse										
Golden redhorse										
Shorthead redhorse										X
Channel catfish	X		X	X	X				X	X
Tadpole madtom										
Flathead catfish										
Burbot									X	
Banded killifish									X	
Blackstripe topminnow									X	
Brook silverside				X		X			X	
Brook stickleback										
Rock bass	X			X	X	X			X	X
Green sunfish				X	X	X		X	X	
Pumpkinseed	X			X	X	X	X		X	X
Sunfish spp.										
Sunfish hybrid										
Warmouth										
Iowa darter									X	
Fantail darter										
Johnny darter										
Logperch				X		X			X	
Mottled sculpin				X		X				

Appendix Table A.40. *Index to fish presence records summarized in Appendix A tables for Lake Monona.*

Species	Table Number and Subject								
	A.11	A.12	A.13	A.14	A.15	A.16	A.17	A.18	A.19
	Creel Survey	State Rough Fish Removal*	Comm. Rough Fish Removal	Boom Shocker	Fyke Net	Shoreline Seine*	Survey Seine*	Stocking	Distribution Survey
Yellow perch	X			X	X	X	X	X	X
Bluegill	X		X	X	X	X	X	X	X
Black crappie	X			X	X	X	X		X
White crappie	X			X	X	X	X		X
Crappie spp.	X	X		X		X		X	
White bass	X	X		X	X	X			X
Yellow bass	X	X		X	X		X		X
Bass hybrid									
Largemouth bass	X	X	X	X	X	X	X	X	X
Smallmouth bass	X			X		X		X	X
Bass spp.								X	
Walleye	X	X	X	X	X	X	X	X	X
Northern pike	X		X	X	X		X	X	X
Cisco		X							X
Common carp	X	X	X	X	X	X			X
Freshwater drum	X	X	X	X	X		X		X
Black bullhead									X
Yellow bullhead									X
Brown bullhead									X
Bullhead spp.	X			X	X	X	X	X	
White sucker	X	X		X	X	X	X		X
American brook lamprey									
Lake sturgeon	X		X			X		X	X
Longnose gar		X	X	X	X		X		X
Shortnose gar									
Bowfin	X	X		X	X		X		X
American eel									
Mooneye		X							
Rainbow trout									
Chinook salmon									
Atlantic salmon									
Brown trout									
Brook trout									
Lake trout									
Central mudminnow									
Grass pickerel									
Muskellunge									
Muskellunge hybrid	X		X	X		X	X	X	X
Central stoneroller									
Goldfish									
Spotfin shiner									

Appendix Table A.40. *Continued.*

Species	A.11 Creel Survey	A.12 State Rough Fish Removal*	A.13 Comm. Rough Fish Removal	A.14 Boom Shocker	A.15 Fyke Net	A.16 Shoreline Seine*	A.17 Survey Seine*	A.18 Stocking	A.19 Distribution Survey
	Table Number and Subject								
Mississippi silvery minnow									
Common shiner				X		X			X
Hornyhead chub									
Golden shiner				X	X	X	X		X
Pugnose shiner									
Emerald shiner									X
River shiner									
Bigmouth shiner									
Blackchin shiner									
Blacknose shiner									
Spottail shiner				X					
Pugnose minnow									
Bluntnose minnow				X		X	X		X
Fathead minnow						X			X
Creek chub									
Quillback									
Lake chubsucker									
Smallmouth buffalo									
Bigmouth buffalo	X	X	X	X					X
Silver redhorse									
Golden redhorse									
Shorthead redhorse									
Channel catfish	X		X	X					X
Tadpole madtom									
Flathead catfish									
Burbot									X
Banded killifish									
Blackstripe topminnow									
Brook silverside				X		X			X
Brook stickleback									
Rock bass	X			X	X	X	X		X
Green sunfish	X			X	X		X		X
Pumpkinseed	X		X	X	X	X			X
Sunfish spp.								X	
Sunfish hybrid									X
Warmouth					X				X
Iowa darter									X
Fantail darter									
Johnny darter									X
Logperch				X		X			X
Mottled sculpin									X

*Excluded from this summary are certain groups of unspecified fishes cited in the tables, i.e., shiner, minnow, sunfish, and darter spp.

Appendix Table A.41. *Index to fish presence records summarized in Appendix A tables for Lake Waubesa.*

	Table Number and Subject									
Species	A.20 Creel Survey	A.21 State Rough Fish Removal	A.22 Comm. Rough Fish Removal	A.23 Boom Shocker	A.24 Fyke Net	A.25 Shoreline Seine	A.26 Survey Seine	A.27 Stocking	A.28 Distribution Survey	A.29 Anecdote
Yellow perch	X	X	X	X	X	X	X	X	X	X
Bluegill	X	X	X	X	X	X	X	X	X	X
Black crappie	X			X		X	X		X	X
White crappie	X		X		X	X			X	X
Crappie spp.	X	X	X	X	X	X		X		
White bass	X	X	X	X		X	X		X	X
Yellow bass	X	X		X		X	X		X	X
Bass hybrid										
Largemouth bass	X	X	X	X	X	X	X	X	X	X
Smallmouth bass	X		X	X				X		
Bass spp.								X		
Walleye	X	X	X	X	X		X	X	X	X
Northern pike	X	X	X	X	X	X	X	X	X	X
Cisco										
Common carp	X	X	X	X		X	X		X	X
Freshwater drum	X	X	X	X		X	X		X	X
Black bullhead									X	X
Yellow bullhead									X	
Brown bullhead									X	
Bullhead spp.	X	X	X	X		X	X	X	X	
White sucker	X	X		X				X	X	
American brook lamprey										
Lake sturgeon			X							
Longnose gar				X			X		X	
Shortnose gar										
Bowfin	X			X			X		X	X
American eel										
Mooneye										
Rainbow trout										
Chinook salmon										
Atlantic salmon										
Brown trout										
Brook trout										
Lake trout										
Central mudminnow										
Grass pickerel										
Muskellunge										
Muskellunge hybrid	X		X	X				X		X
Central stoneroller										
Goldfish										
Spotfin shiner										

Appendix Table A.41. *Continued.*

Species	A.20 Creel Survey	A.21 State Rough Fish Removal	A.22 Comm. Rough Fish Removal	A.23 Boom Shocker	A.24 Fyke Net	A.25 Shoreline Seine	A.26 Survey Seine	A.27 Stocking	A.28 Distribution Survey	A.29 Anecdote
	Table Number and Subject									
Mississippi silvery minnow										
Common shiner										
Hornyhead chub										
Golden shiner				X		X			X	
Pugnose shiner										
Emerald shiner						X				
River shiner										
Bigmouth shiner										
Blackchin shiner										
Blacknose shiner										
Spottail shiner				X		X			X	
Pugnose minnow										
Bluntnose minnow						X			X	
Fathead minnow									X	
Creek chub										
Quillback										
Lake chubsucker										
Smallmouth buffalo										
Bigmouth buffalo		X	X	X		X				
Silver redhorse				X						
Golden redhorse										
Shorthead redhorse				X						X
Channel catfish	X		X				X			X
Tadpole madtom										
Flathead catfish										
Burbot										
Banded killifish										
Blackstripe topminnow										
Brook silverside				X		X			X	
Brook stickleback										
Rock bass	X			X					X	
Green sunfish				X		X			X	X
Pumpkinseed	X			X		X	X		X	
Sunfish spp.										
Sunfish hybrid									X	
Warmouth										
Iowa darter									X	
Fantail darter										
Johnny darter										
Logperch				X		X			X	
Mottled sculpin										

Appendix Table A.42. *Index to fish presence records summarized in Appendix A tables for Lake Kegonsa.*

	Table Number and Subject								
	A.30	A.31	A.32	A.33	A.34	A.35	A.36	A.37	A.38
Species	Creel Survey	State Rough Fish Removal*	Comm. Rough Fish Removal*	Boom Shocker	Fyke Net	Shoreline Seine	Survey Seine	Stocking	Distribution Survey
Yellow perch	X	X	X	X	X	X	X	X	X
Bluegill	X		X	X	X	X	X	X	X
Black crappie	X			X	X	X	X		X
White crappie	X			X	X	X	X		X
Crappie spp.	X	X	X	X	X	X		X	
White bass	X	X	X	X	X	X	X		X
Yellow bass	X	X		X	X	X	X		X
Bass hybrid									
Largemouth bass	X	X	X	X	X	X	X	X	X
Smallmouth bass	X	X	X	X	X			X	X
Bass spp.		X						X	
Walleye	X	X	X	X	X	X	X	X	X
Northern pike	X	X	X	X	X	X	X	X	X
Cisco									
Common carp	X	X	X	X	X	X			X
Freshwater drum	X	X	X	X	X		X		X
Black bullhead									X
Yellow bullhead									X
Brown bullhead									X
Bullhead spp.	X	X	X	X	X	X	X	X	
White sucker	X	X		X	X	X	X		X
American brook lamprey									
Lake sturgeon		X							X
Longnose gar		X		X			X		X
Shortnose gar									
Bowfin		X							X
American eel									
Mooneye									
Rainbow trout		X							
Chinook salmon									
Atlantic salmon									
Brown trout									
Brook trout									
Lake trout									
Central mudminnow				X					
Grass pickerel									
Muskellunge									
Muskellunge hybrid	X		X	X			X		
Central stoneroller									
Goldfish									
Spotfin shiner									

Appendix Table A.42. *Continued.*

Species	A.30 Creel Survey	A.31 State Rough Fish Removal*	A.32 Comm. Rough Fish Removal*	A.33 Boom Shocker	A.34 Fyke Net	A.35 Shoreline Seine	A.36 Survey Seine	A.37 Stocking	A.38 Distribution Survey
	Table Number and Subject								
Mississippi silvery minnow									
Common shiner									
Hornyhead chub									
Golden shiner				X	X	X	X		X
Pugnose shiner									
Emerald shiner				X					X
River shiner									
Bigmouth shiner									
Blackchin shiner									
Blacknose shiner									
Spottail shiner				X					
Pugnose minnow									
Bluntnose minnow						X			X
Fathead minnow									X
Creek chub									
Quillback		X							
Lake chubsucker									
Smallmouth buffalo									
Bigmouth buffalo	X	X		X					X
Silver redhorse									
Golden redhorse									
Shorthead redhorse									
Channel catfish	X	X	X	X	X				
Tadpole madtom									
Flathead catfish									
Burbot									
Banded killifish									
Blackstripe topminnow									
Brook silverside				X		X			X
Brook stickleback									
Rock bass	X				X				X
Green sunfish				X	X	X			X
Pumpkinseed	X			X	X	X	X		X
Sunfish spp.								X	
Sunfish hybrid									X
Warmouth	X								
Iowa darter									X
Fantail darter									
Johnny darter									
Logperch				X		X			X
Mottled sculpin									

* Excluded from this summary are certain groups of unspecified fishes cited in the table, i.e., *Esox* and sunfish spp., buffalo, and catfish.

Appendix B. *Taxonomy of fish species cited.**

Scientific Name	Common Name
Petromyzontidae - lampreys	
Lampetra appendix (DeKay, 1842)	American brook lamprey
Acipenseridae - sturgeons	
Acipenser fulvescens Rafinesque, 1817	lake sturgeon
Lepisosteidae - gars	
Lepisosteus osseus (Linnaeus, 1758)	longnose gar
Lepisosteus platostomus Rafinesque, 1820	shortnose gar
Amiidae - bowfins	
Amia calva Linnaeus, 1766	bowfin
Anguillidae - freshwater eels	
Anguilla rostrata (Lesueur, 1817)	American eel
Hiodontidae - mooneyes	
Hiodon tergisus Lesueur, 1818	mooneye
Salmonidae - trouts	
Coregonus artedi Lesueur, 1818	cisco
Oncorhynchus mykiss (Walbaum, 1792)	rainbow trout
Oncorhynchus tshawytscha (Walbaum, 1792)	chinook salmon
Salmo salar Linnaeus, 1752	Atlantic salmon
Salmo trutta Linnaeus, 1758	brown trout
Salvelinus fontinalis (Mitchill, 1814)	brook trout
Salvelinus namaycush (Walbaum, 1792)	lake trout
Umbridae - mudminnows	
Umbra limi (Kirtland, 1840)	central mudminnow
Esocidae - pikes	
Esox americanus vermiculatus Lesueur, 1846	grass pickerel
Esox lucius Linnaeus, 1758	northern pike
Esox masquinongy Mitchill, 1824	muskellunge
Esox lucius × *masquinongy*	muskellunge hybrid (tiger muskellunge)
Cyprinidae - carps and minnows	
Campostoma anomalum (Rafinesque, 1820)	central stoneroller
Carassius auratus (Linnaeus, 1758)	goldfish
Cyprinella analostana Girard, 1859	satinfin shiner
Cyprinella spiloptera (Cope, 1868)	spotfin shiner
Cyprinus carpio Linnaeus, 1758	common carp
Hybognathus nuchalis Agassiz, 1855	Mississippi silvery minnow
Luxilus cornutus (Mitchill, 1817)	common shiner
Lythrurus umbratilis (Girard, 1856)	redfin shiner
Nocomis biguttatus (Kirtland, 1840)	hornyhead chub
Notemigonus crysoleucas (Mitchill, 1814)	golden shiner
Notropis anogenus Forbes, 1855	pugnose shiner
Notropis atherinoides Rafinesque, 1818	emerald shiner
Notropis blennius (Girard, 1856)	river shiner
Notropis dorsalis (Agassiz, 1854)	bigmouth shiner
Notropis heterodon (Cope, 1865)	blackchin shiner
Notropis heterolepis Eigenmann and Eigenmann, 1893	blacknose shiner
Notropis hudsonius (Clinton, 1824)	spottail shiner
Opsopoeodus emiliae Hay, 1881	pugnose minnow
Phoxinus erythrogaster (Rafinesque, 1820)	southern redbelly dace
Pimephales notatus (Rafinesque, 1820)	bluntnose minnow
Pimephales promelas Rafinesque, 1820	fathead minnow
Rhinichthys atratulus (Hermann, 1804)	blacknose dace
Semotilus atromaculatus (Mitchill, 1818)	creek chub

Appendix B. *Continued.*

Scientific Name	Common Name
Catostomidae - suckers	
Carpiodes cyprinus (Lesueur, 1817)	quillback
Catostomus commersoni (Lacepède, 1803)	white sucker
Erimyzon sucetta (Lacepède, 1803)	lake chubsucker
Hypentelium nigricans (Lesueur, 1817)	northern hog sucker
Ictiobus bubalus (Rafinesque, 1818)	smallmouth buffalo
Ictiobus cyprinellus (Valenciennes, 1844)	bigmouth buffalo
Minytrema melanops (Rafinesque, 1820)	spotted sucker
Moxostoma anisurum (Rafinesque, 1820)	silver redhorse
Moxostoma erythrurum (Rafinesque, 1818)	golden redhorse
Moxostoma macrolepidotum (Lesueur, 1817)	shorthead redhorse
Ictaluridae - bullhead catfishes	
Ameiurus melas (Rafinesque, 1820)	black bullhead
Ameiurus natalis (Lesueur, 1819)	yellow bullhead
Ameiurus nebulosus (Lesueur, 1819)	brown bullhead
Ictalurus punctatus (Rafinesque, 1818)	channel catfish
Noturus gyrinus (Mitchill, 1817)	tadpole madtom
Pylodictis olivaris (Rafinesque, 1818)	flathead catfish
Gadidae - cods	
Lota lota (Linnaeus, 1758)	burbot
Cyprinodontidae - killifish	
Fundulus diaphanus (Lesueur, 1817)	banded killifish
Fundulus notatus (Rafinesque, 1820)	blackstripe topminnow
Atherinidae - silversides	
Labidesthes sicculus (Cope, 1865)	brook silverside
Gasterosteidae - sticklebacks	
Culaea inconstans (Kirtland, 1841)	brook stickleback
Percichthyidae - temperate basses	
Morone chrysops (Rafinesque, 1820)	white bass
Morone mississippiensis Jordan and Eigenmann, 1887	yellow bass
Morone chrysops × *mississippiensis*	bass hybrid
Centrarchidae - sunfishes	
Ambloplites rupestris (Rafinesque, 1817)	rock bass
Lepomis cyanellus Rafinesque, 1819	green sunfish
Lepomis gibbosus (Linnaeus, 1758)	pumpkinseed
Lepomis cyanellus × *gibbosus*	sunfish hybrid
Lepomis gulosus (Cuvier, 1829)	warmouth
Lepomis macrochirus Rafinesque, 1819	bluegill
Micropterus dolomieu Lacepède, 1802	smallmouth bass
Micropterus salmoides (Lacepède, 1802)	largemouth bass
Pomoxis annularis Rafinesque, 1818	white crappie
Pomoxis nigromaculatus (Lesueur, 1829)	black crappie
Percidae - perches	
Etheostoma exile (Girard, 1859)	Iowa darter
Etheostoma flabellare Rafinesque, 1819	fantail darter
Etheostoma nigrum Rafinesque, 1820	johnny darter
Perca flavescens (Mitchill, 1814)	yellow perch
Percina caprodes (Rafinesque, 1818)	logperch
Stizostedion vitreum (Mitchill, 1818)	walleye
Sciaenidae - drums	
Aplodinotus grunniens Rafinesque, 1819	freshwater drum
Cottidae - sculpins	
Cottus bairdi Girard, 1850	mottled sculpin

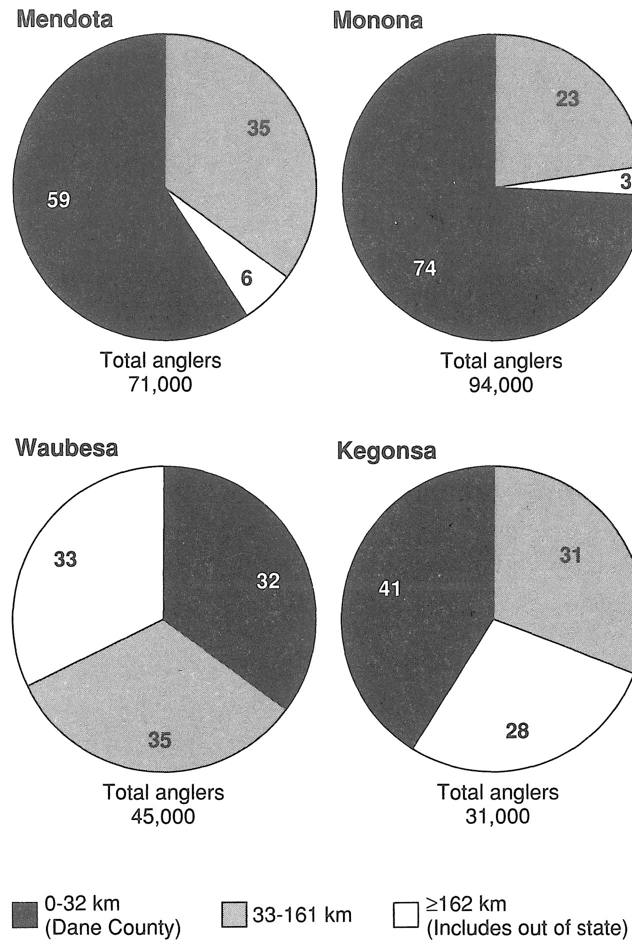
* Source of taxonomy: For all fish species except hybrids, Robins et al. (1991).

Appendix C. *Sources of unpublished information cited.*

Name*	Affiliation
Kenneth Christensen	Outdoor writer, *The Capital Times*
Sandy Engel	Aquatic ecologist, Wisconsin Department of Natural Resources, Bureau of Research
Don Fago	Fish distribution and data base specialist, Wisconsin Department of Natural Resources, Bureau of Research
David Frey	Indiana University, Department of Biology
Steve Gilbert	Former Madison lakes fish biologist, Wisconsin Department of Natural Resources, Madison Area
Howard Hartwig	Former harvesting crew chief, Dane County Public Works Department
Arthur Hasler	Former director, University of Wisconsin-Madison Center for Limnology
Robert Hay	Cold-blooded species program manager, Wisconsin Department of Natural Resources, Bureau of Endangered Resources
Ross Horrall	Senior scientist, University of Wisconsin-Madison, Institute for Environmental Studies
William Jaeger	Former fish technician, Wisconsin Department of Natural Resources, Southern District
Brett Johnson	Lake Mendota Study project leader, Wisconsin Department of Natural Resources, Madison Area
Robert Kalhagen	Former fish technician, Wisconsin Department of Natural Resources, Southern District
John Klingbiel	Former warm water lakes and regulation specialist, Wisconsin Department of Natural Resources, Bureau of Fisheries Management
Pam Naber Knox	State climatologist, University of Wisconsin-Madison
Ken Koscik	Director, Dane County Public Works Department
John Lyons	Rivers and streams fisheries research group leader, Wisconsin Department of Natural Resources, Bureau of Research, and curator of fishes, University of Wisconsin-Madison Zoology Museum
John Magnuson	Director, University of Wisconsin-Madison Center for Limnology
John Mason	Former limnologist, Wisconsin Department of Natural Resources, Bureau of Research
Mike Michaels	Former president, Yahara Fisherman's Club
Richard Narf	Aquatic entomologist, Wisconsin Department of Natural Resources, Bureau of Research
Gordon Priegel	Fisheries management supervisor, Wisconsin Department of Natural Resources, Southern District
Lars Rudstam	Research associate, Cornell University Biological Field Station
Bernard Saley	Former water quality specialist, City of Madison Public Health Department
Jonce Šapkarev	University of Skopje, Yugoslavia
Mike Staggs	Chief, fisheries research, Wisconsin Department of Natural Resources, Bureau of Research
Scot Stewart	Fish manager, Wisconsin Department of Natural Resources, Madison Area
C. William Threinen	Former staff specialist, Wisconsin Department of Natural Resources, Bureau of Fisheries Management
William Yaeger	Fish operations specialist, Wisconsin Department of Natural Resources, Southern District

* Authors of this report are excluded; also excluded are sources for which the name of the person gathering the data was unknown. For these latter sources, the location of the files from which the data were obtained is given in the appropriate text reference (e.g., Madison Area files, Bureau of Research files, and Center for Limnology files).

Appendix D. *Distance travelled to fish the Yahara lakes. (Data obtained during 1981–82 creel surveys.)*



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	To convert metric...	into English...	multiply by...
Length	millimeters	inches	0.0394
	centimeters	inches	0.3937
	meters	feet	3.281
	kilometers	miles	0.6214
Area	square meters	square yards	1.196
	square kilometers	square miles	0.3861
	hectares	acres	2.471
Volume	cubic meters	cubic feet	35.31
Weight	milligrams/liter	parts/million	1.0
	grams	ounces	0.0354
	kilograms	pounds	2.205
Temperature	degrees Centigrade	degrees Fahrenheit	(°C × 9/5) + 32

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