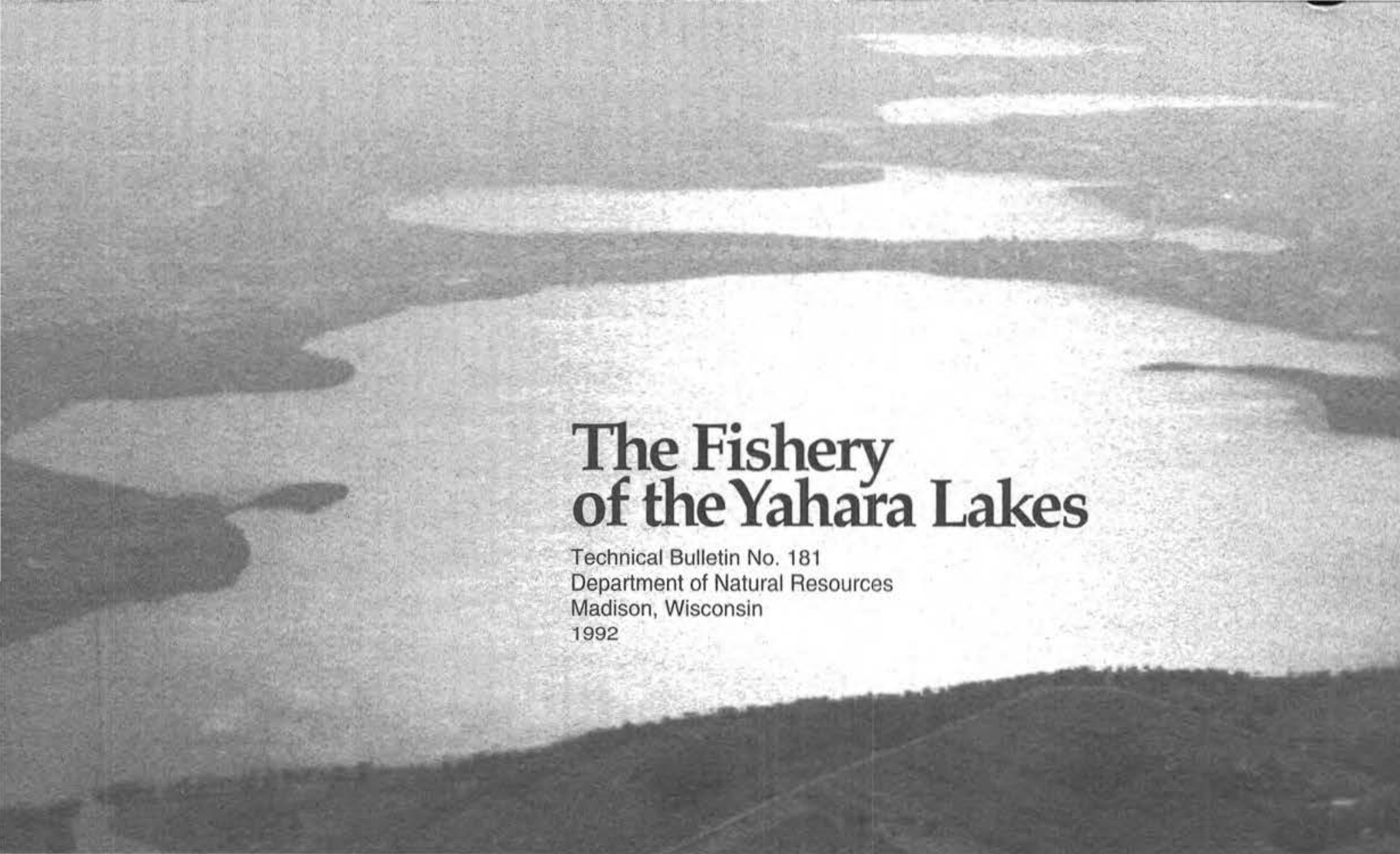

The Fishery of the Yahara Lakes

Technical Bulletin No. 181
Department of Natural Resources
Madison, Wisconsin
1992

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Monona, Waubesa, and Kegonsa—this report summarizes fishery data from the extensive amount of published and unpublished surveys and research studies that were conducted from the late 1800s through 1985 on these lakes, which are located in and around Madison, Wisconsin.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.

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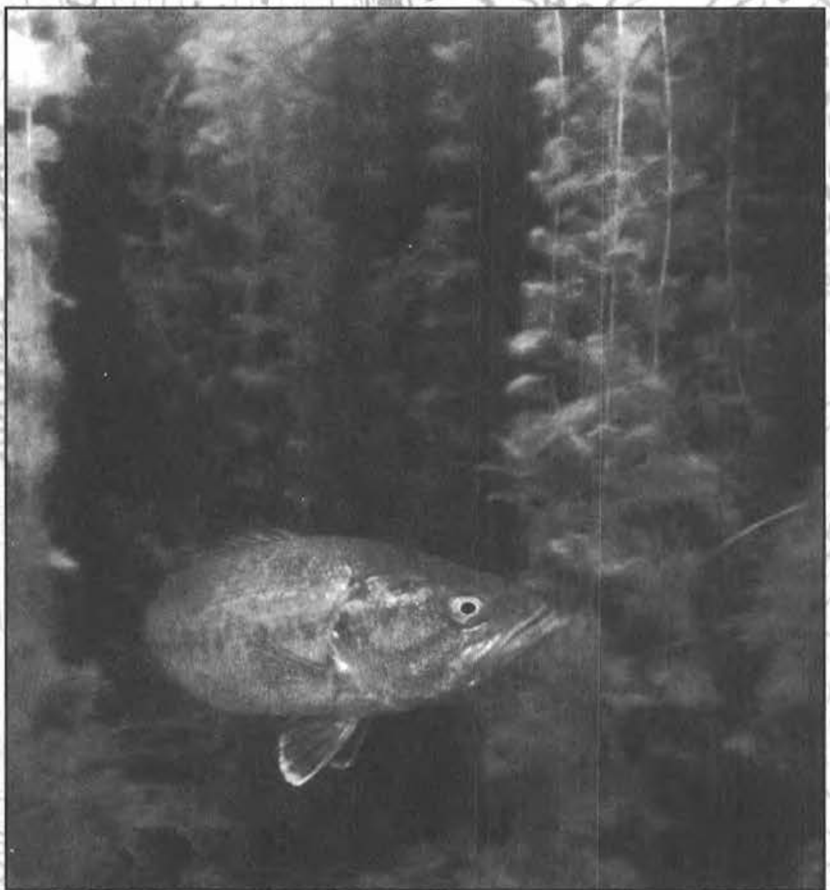

PHOTO: DNR MADISON AREA OFFICE COLLECTION

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
Richard C. Lathrop, Susan B. Nehls,
Clifford L. Brynildson, and Karen R. Plass

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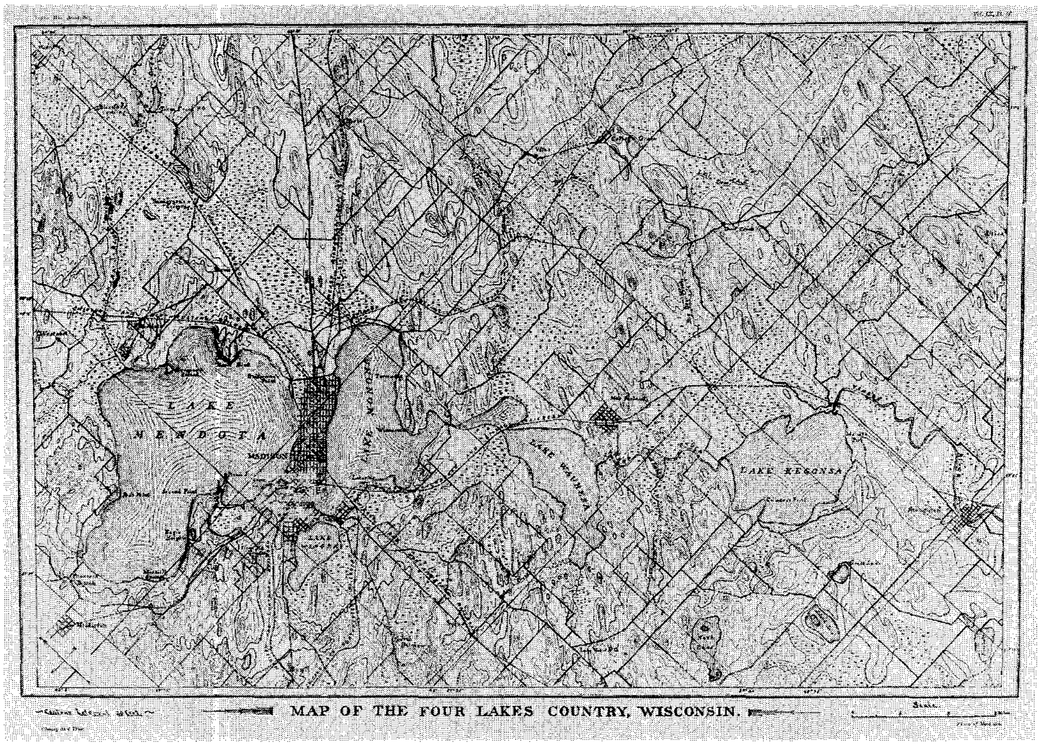

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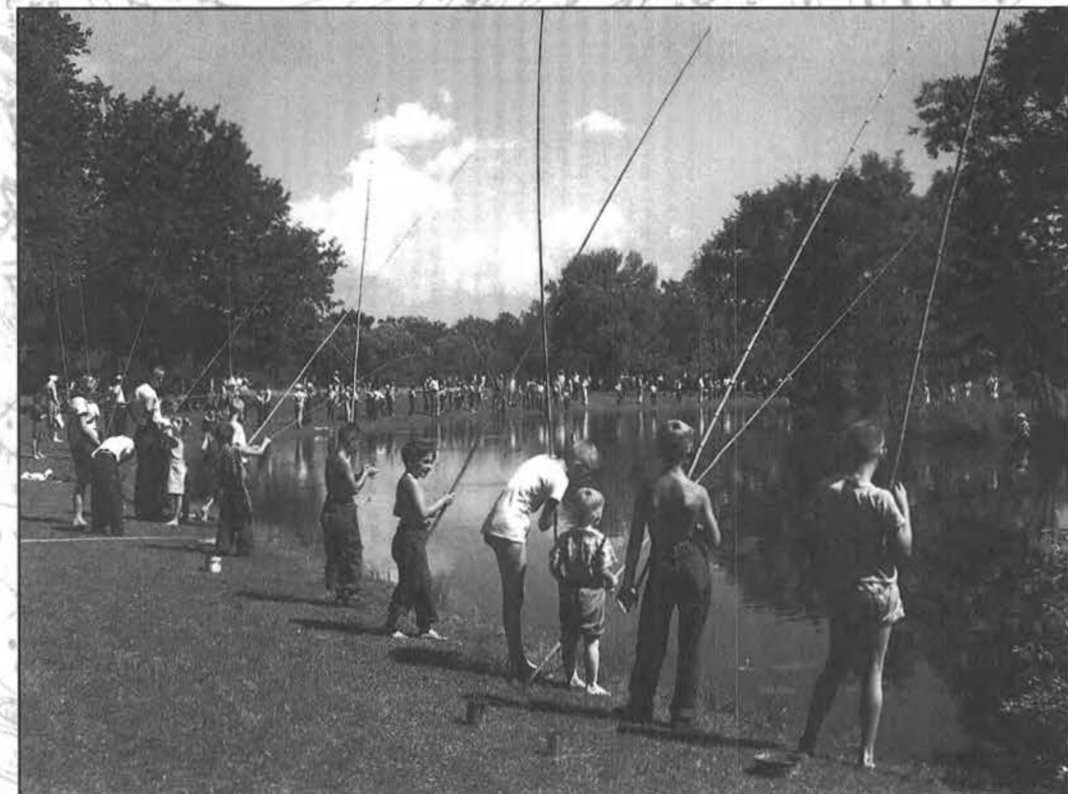


PHOTO: STATE HISTORICAL SOCIETY OF WISCONSIN COLLECTION

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).

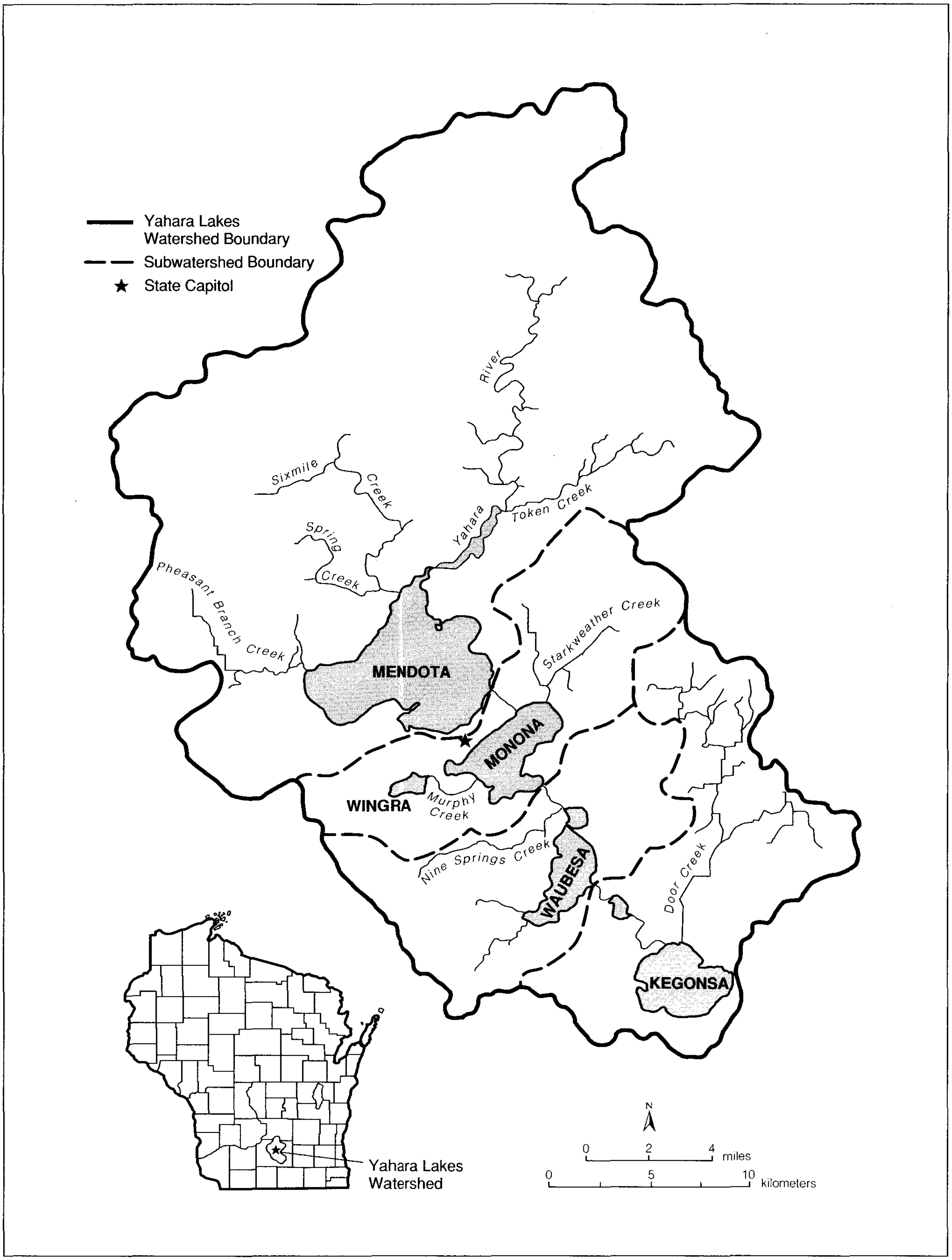


Figure 1. *The Yahara River watershed showing subbasins and adjoining tributaries and wetlands.*

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.

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.

PHOTO: STATE HISTORICAL SOCIETY OF WISCONSIN COLLECTION

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

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

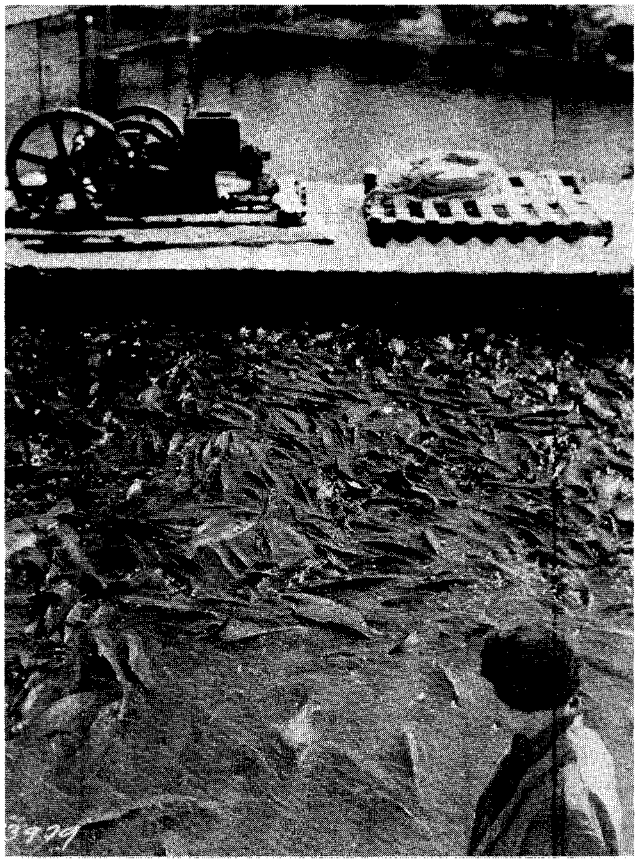


PHOTO: EUGENE SANBORN, DNR CENTRAL OFFICE COLLECTION

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-

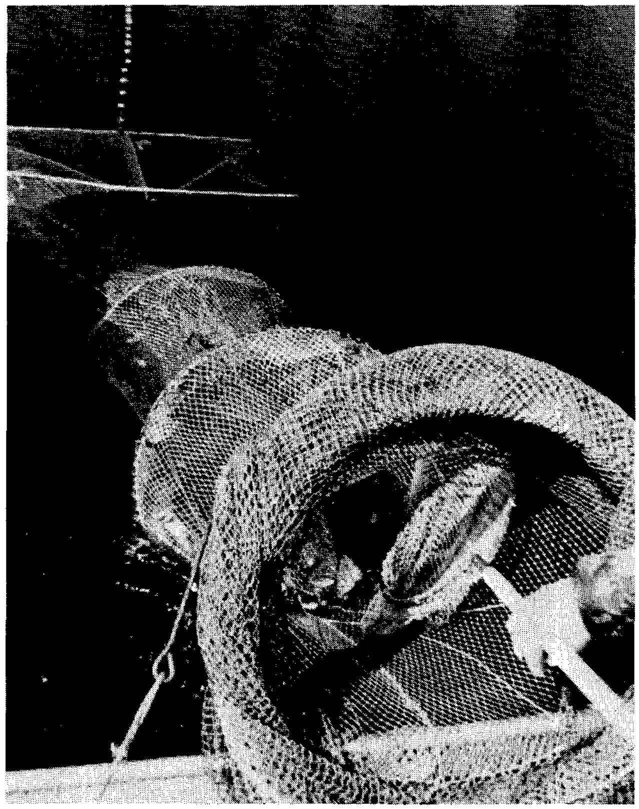
Fall night boom shocking by DNR personnel, Lake Mendota, late 1980s.

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.

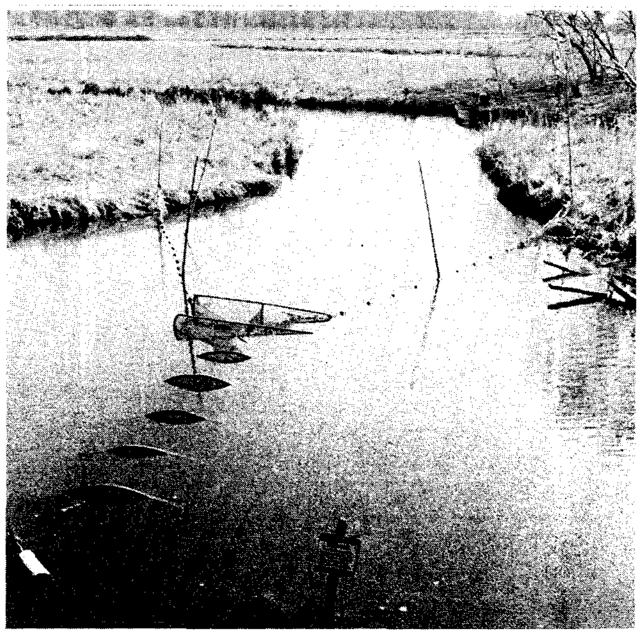
Fyke Nets. Records of fyke net surveys were found primarily for Lake Mendota; data for at least one year were located for each of the other 3 lakes (Appendix Tables A.5, A.15, A.24, and A.34). One historical survey is summarized (Mackenthun 1947); all others came from unpublished data in DNR Madison 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.



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

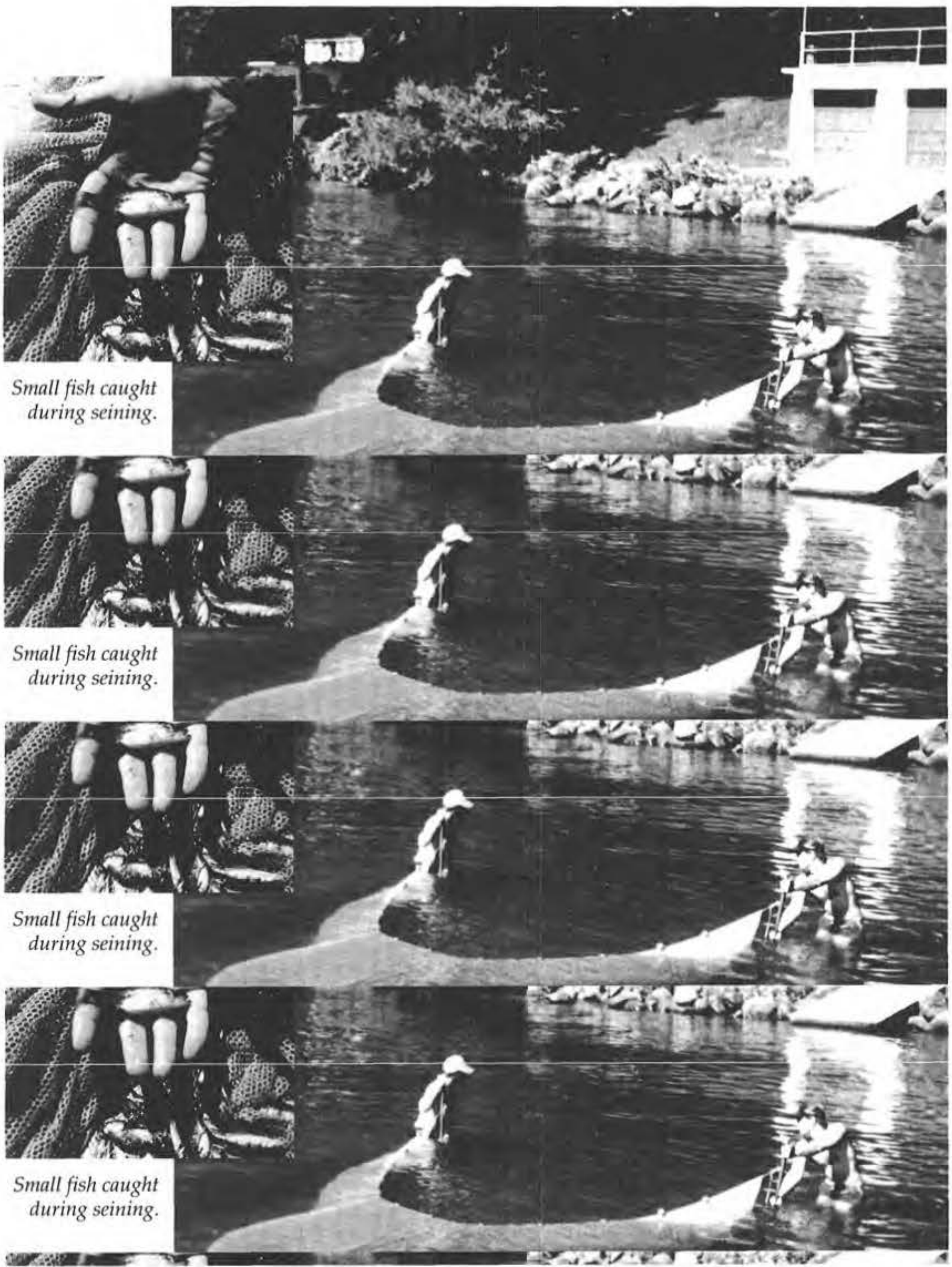


Fyke net set for spawning northern pike in Sixmile Creek, March 1958.

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.

Small fish caught during seining.

Small fish caught during seining.

Small fish caught during seining.

JOHNSON, DNR MADISON AREA OFFICE COLLECTION