WISCONSIN DEPARTMENT OF NATURAL RESOURCES

Fishery Survey Report for Big Moon Lake, Barron County, Wisconsin 2021 - 2022

WATERBODY IDENTIFICATION CODE: 2079000

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Table of Contents

Executive Summary

Big Moon Lake was surveyed during 2021-2022 to determine the abundance, harvest and population demographics (size and age structure, growth and recruitment) of walleye and muskellunge as part of the Treaty assessment protocol for lakes within the Ceded Territory. In addition, abundance and population demographics were assessed for other sport fish. Lastly, an open water creel survey was completed to assess the pressure and harvest from recreational anglers.

The adult walleye population during 2021 was estimated to be 115 fish (95% confidence interval; CI = 82 – 142 fish) or 0.6 fish/acre (95% CI = 0.4 – 0.7 fish/acre), which was low compared to other stocking-dependent walleye lakes in Barron and Polk counties. Despite a low abundance, walleye size structure, growth and condition were good, and the population remained stocking-dependent. Recreational fishing effort directed at walleye was low, but large fingerling stocking will be maintained at 10 fish/acre every other year.

Big Moon Lake provides an excellent muskellunge fishery with the highest population density in Barron and Polk counties, good overall size structure and high angler catch rates compared to similar Class B waters in northern Wisconsin. A moderate density muskellunge population was present in Big Moon Lake with an adult population density of 0.53 fish/acre. The muskellunge fishery in Big Moon Lake should continue to be managed at a moderate density (0.4 to 0.6 adults/acre), which should provide excellent angling action while maintaining a good size structure.

Big Moon Lake supports a high-density largemouth bass population, with good size structure and growth rates that offers anglers the opportunity to catch quality fish. The largemouth bass population remains healthy and supports a popular recreational fishery, so no management actions are recommended at this time.

Big Moon Lake supports a below-average bluegill fishery with low density and poor size structure. Despite this, the recreational fishery for bluegill was second most popular in directed angling efforts but was considerably lower than average for lakes in Barron and Polk counties. Bluegill harvest rates were high, comparable to other popular bluegill fisheries in the area, and could be contributing to declining relative abundances. Overall, the bass-panfish fishery in Big Moon Lake is currently more representative of a quality bass fishery as reflected by proportional stock density (PSD) index values, but both fisheries offer good angling opportunities. Future fishery surveys should continue to monitor panfish population abundance and demographics due to their importance to the overall fish community. The current panfish regulation (25 fish daily bag limit in aggregate) should continue to promote both good recreational fisheries and sustainable population dynamics. No specific management actions for largemouth bass, black crappie and bluegill are recommended at this time.

Introduction

Big Moon Lake is a 187-acre lake located in Barron County, Wisconsin. The lake has a maximum depth of 48 feet, a mean depth of 24 feet and approximately 10% less than 3 feet, and 80% greater than 20 feet of water. The lake is best characterized by relatively steep sloping shorelines in the western half of the lake and a greater littoral area in the eastern half of the lake. Big Moon Lake receives moderate recreational boating use and angling pressure and has quality and diverse fisheries. Big Moon Lake is a fertile, eutrophic system classified as a complex-cool-dark lake (Rypel et al. 2019). The July-August mean Trophic State Index (TSI) values for chlorophyll-a and total phosphorus was 55 and 52, respectively. Mean TSI has generally remained stable over the past decade. Moderate algal blooms occur in Big Moon Lake, and submerged aquatic macrophytes are abundant in the nearshore littoral areas. Approximately 47% of the shoreline is developed with 21.2 dwellings per shoreline mile, although most of the housing development is located on the eastern half of the lake. The western half of the lake is primarily undeveloped, and wetlands are abundant along the shorelines throughout the lake. Moon Creek flows into Big Moon Lake from Little Moon Lake on the western shoreline and out of Moon Lake along the northeast shoreline to Turtle Creek. Currently, recognized invasive species include Chinese mystery snail and curly-leaf pondweed. There is one public boat launch located along the eastern shoreline off 9 1/4 Street (45.342, -92.108; latitude, longitude).

The sport fish community in Big Moon Lake consists of bluegill (*Lepomis macrochirus*), pumpkinseed (*L. gibbosus*), black crappie (*Pomoxis nigromaculatus*), largemouth bass (*Micropterus salmoides*), yellow perch (*Perca flavescens*), walleye (*Sander vitreus*), northern pike (*Esox lucius*), bullheads (*Ameiurus spp.*), rockbass (*Ambloplites rupestris*), common carp (*Cyprinus carpio*) and muskellunge (*E. masquinongy*).

Big Moon Lake has had a rich history of fisheries management actions directed toward improving and enhancing the fishery. The fishery in Big Moon Lake was noted to be excellent for walleye, northern pike and panfish until the early 1950s, then became progressively poorer as the common carp population increased (Donatell 1968). Toxaphene, pro-nox and rotenone treatments occurred in Big Moon Lake, Little Moon Lake, Camelia Lake and their tributaries during 1961 and 1963 in an attempt to control a nuisance common carp population. An electric barrier was also installed at the low-head outlet dam of Big Moon Lake to prevent reentry of common carp from Moon Creek. Common carp were greatly reduced but likely not eradicated during 1963, and the lake was subsequently stocked with walleye, muskellunge, Cisco, fathead minnows, brook trout and rainbow trout (in an attempt to create a temporary pulse fishery; Donatell 1968). Follow up surveys during 1964, 1965 and 1966 indicated quality fisheries for walleye, muskellunge, and trout were developing and angling pressure increased. By the fall of 1966, the restocking program successfully established a moderate muskellunge and a quality walleye population, but the trout

fishery declined over time, and the trout stocking program was subsequently discontinued.

Schweiger (1988) noted that an abundant, self-sustaining walleye population developed soon thereafter, as indexed by high adult and age-0 walleye abundances during the 1967, 1969, 1972 and 1974 fishery surveys. Walleye stocking was discontinued in 1969 due to observations of significant natural reproduction and a desirable adult population. However, during the 1980 fishery survey, it was noted that the population abundance of walleye had significantly decreased, which coincided with an increased largemouth bass abundance (Schweiger 1988). Public input regarding stocking and the poor walleye fishery began in 1980, and conversation occurred through 1984, which spurred the initiation of small fingerling walleye stocking during 1984 and 1986. The 1987 fishery survey was conducted to evaluate the performance of stocked walleye and assess the sportfish fishery in Big Moon Lake (Schweiger 1988). The 1987 fishery survey indicated the 1984 and 1986 stocking events had successfully re-established a moderately abundant walleye fishery in Big Moon Lake, but the population remained much lower in abundance than those observed during the 1960s and 1970s when natural recruitment was high. Walleye stocking continued thereafter, and the population abundance remained similar to the 1987 survey and represented a typical stocked fishery with limited natural recruitment. The most recent fisheries survey (and first walleye population estimate) in Big Moon Lake was completed in 2008. The density of adult walleye was estimated at 0.6 fish/acre during that survey and was considered a low-density, stocking-dependent population.

Recent fish stocking in Big Moon Lake has consisted of walleye and muskellunge. Walleye stocking has occurred at variable rates into Big Moon Lake, with consistent stockings beginning in 1984 (Appendix Table 1). During 1984-2011, small fingerling walleye were stocked at a rate of 35 or 50 fish/acre. Walleye stocking in Big Moon Lake shifted to large fingerlings in 2013 as part of the Walleye Initiative with the goal of improving recruitment to the adult fishery. Since 2013, large fingerling walleye have been stocked every other year at a rate of 10 fish/acre (Appendix Table 1). Large fingerling muskellunge have been stocked into Big Moon Lake since 1979, approximately every other year. Muskellunge are currently stocked at a rate of 1 fish/acre (Appendix Table 2).

The Wisconsin Department of Natural Resources (DNR) surveyed Big Moon Lake to assess the status of the fishery during 2021-2022. A mark-recapture survey was performed to estimate adult densities of walleye and muskellunge. We assessed catch rates of largemouth bass, northern pike, bluegill and other panfish species to estimate relative abundance. We assessed population characteristics, size structure and growth for all species when possible. Recent management efforts have focused on walleye and muskellunge stocking, public outreach and maintaining littoral zone habitat and water quality.

Methods

FIELD SAMPLING

Big Moon Lake was sampled during 2021 with early spring fyke netting (SN1), early spring (SE1) and late spring (SE2) night electrofishing, fall night electrofishing and open water creel survey following the DNR comprehensive Treaty assessment protocol (Appendix Table 3; Cichosz 2021).

The population abundance of adult walleye was estimated using mark-recapture methodology during the SN1 and SE1 surveys. The population size of adult walleye was estimated with Chapman's modification of the Peterson model (Ricker 1975):

$$N = \frac{(M+1)(C+1)}{(R+1)}$$

where N = population estimate; M = the number of fish marked in the first (marking) sample; C = the total number of fish (marked and unmarked) captured in the second (recapture) sample; and R is the number of marked fish captured in the second sample.

Walleyes were captured with fyke nets set at ice out. Fyke nets were set April 6, 2021 and checked every 24 hours for three days. Fyke nets had 4 x 6 foot frames, 0.5 to 0.75-inch bar measure mesh, and lead lengths of 75 feet or less. All walleye were measured (total length), weighed, sexed and given a specific mark indicating capture. Adult walleye ≥ 15 inches or sexable (extrusion of eggs or milt; Cichosz 2021) were marked with a fin clip, and juvenile walleye < 15 inches were marked with a different fin clip. Aging structures were collected from five walleye of each sex per 0.5-inch length group. Scales were taken from walleye < 12 inches, and dorsal spines were taken from fish ≥ 12 inches. For the recapture period, walleye collected during the SE1 survey were measured, sexed and checked for marks.

The population abundance of adult muskellunge (≥ 30 inches) was estimated using mark-recapture methodology during the early spring netting surveys and Chapman's modification of the Peterson model (Ricker 1975). Muskellunge surveys are two-year fyke netting surveys, so 2021 served as the marking year, and 2022 was the recapture year. Nets were set shortly after ice-out and checked every 24 hours for approximately one week each year. Muskellunge were measured to the nearest 0.1 inches and weighed to the nearest 0.1 pounds. Anal fin rays were collected to determine the age. The sex of captured fish was determined by the presence of eggs or milt or by visual inspection of the urogenital pore as described by LeBeau and Pageau (1989). All adult fish were marked during 2021, and fish < 30 inches received a separate mark. During the recapture year, all fish were checked for marks, and to prevent double counting fish, all 2022 fish received a mark unique from the 2021 marks. Muskellunge were implanted with a unique passive integrated transponder

(PIT) tag in 2021 and 2022. The abundance of fish in 2021 was adjusted for recruitment over the 1-year time period. Females < 32 inches and males < 31 inches were excluded from the adult population estimate because they were assumed to have been < 30 inches during the 2021 marking event.

The SE2 survey was conducted on May 20, 2021, to assess largemouth bass and panfish populations. The SE2 survey consisted of 0.5-mile index stations where all gamefish and panfish were collected and 1.5-mile stations where only gamefish were collected. There were two index stations and two gamefish stations completed on Big Moon Lake. All fish were measured, but weights and aging structures were collected from five fish per 0.5-inch length group for age and growth analysis. Catch per unit effort (CPUE; index of relative abundance) was estimated as catch per mile.

A fall night electrofishing survey was conducted on September 9, 2021, to assess the year class strength of age-0 and age-1 walleye. The entire shoreline was sampled, and walleyes < 12 inches were collected. The CPUE (catch per mile) of age-0 and age-1 walleye was compared to previous fall evaluations.

POPULATION DEMOGRAPHICS

Population estimates and CPUE were compared to previous surveys and lake class standards when possible.

Walleye and largemouth bass were aged with dorsal spines, and muskellunge were aged with anal fin rays. Dorsal spines were cut with a Dremel saw, and ages were determined under a dissecting microscope by a single interpreter. Anal fin rays were cut with a Dremel saw and aged by two interpreters under a dissecting microscope with side illumination from a fiber optic light. When data were available, mean length at age was compared to previous surveys, county averages (Barron and Polk counties), northern region averages (18 counties in the DNR's northern region) and the median length at age for similar complex-cool-dark lakes (Rypel 2019).

The von Bertalanffy (1938) growth model was determined using mean length at age data to assess growth using the following equation:

$$Lt = L_{inf}\ (1 - e^{-k(t-t_0)})$$

where L_t is length at time t, L_{inf} is the maximum theoretical length (length infinity), e is the exponent for natural logarithms, k is the growth coefficient, t is age in years, and t_0 is the age when L_t is zero.

Growth equations for largemouth bass and muskellunge were completed by pooling sexes due to limited age data, despite sex-specific growth variation.

Size structure was assessed using proportional size distribution (PSD) indices and comparing them to previous surveys (Neumann et al. 2013). The PSD value for a species is the number of fish of a specified length and longer divided by the number of fish of stock length or longer, the result multiplied by 100. Relative weight (W_r) was

used to describe fish condition. Relative weight is the ratio of a fish's weight at capture to the weight of a "standard" fish of the same length determined by a standard weight equation (Wege and Anderson 1978). The mean W_r was determined.

The instantaneous mortality (Z) and annual mortality ($A = 1-e^{-Z}$) rates of largemouth bass were determined using a catch curve regression fitted to those ages fully recruited to the gear (Miranda and Bettoli 2007).

To assess walleye stocking survival, an age-length key was used to estimate the abundances of walleye in stocked year classes, assuming no natural reproduction and all fish were from stocked origin. Survival was estimated by dividing the population estimate for each age class by the total number of fish stocked for that year and multiplying by 100. The cost per stocking event was calculated by multiplying the number of large fingerlings stocked by the average cost per large fingerling ($1.06). The cost per recruit to age-4 and age-6 was estimated by dividing the cost of each stocking event by the estimated abundance of that year class.

RECREATIONAL CREEL AND TRIBAL HARVEST

An open water creel survey was conducted on Big Moon Lake to assess recreational fishing pressure and harvest. The creel survey began the first Saturday in May and went through October. Creel survey methods followed a stratified random design as described by Rasmussen et al. (1998). The directed effort, catch, harvest, specific harvest rate and mean length of harvested fish were evaluated for each species during the open-water creel survey. Harvest trends for each species were determined by calculating the relative harvest level each month. The angling exploitation rate for adult walleye was calculated by dividing the estimated number of marked adult walleye harvested by the total number of adult walleye marked (R/M; Ricker 1975). Tribal exploitation was calculated as the total number of adult walleyes harvested divided by the adult population estimate (C/N; Ricker 1975). Total adult walleye exploitation rates were calculated by summing angling and tribal exploitation.

Results

EARLY SPRING FYKE NETTING AND ELECTROFISHING

WALLEYE

There were six fyke nets fished for eight nights, which totaled 48 net nights. The adult walleye population during 2021 was estimated to be 115 fish (95% confidence interval; CI = 82 – 142 fish) or 0.6 fish/acre (95% CI = 0.4 – 0.7 fish/acre; CV = 0.15). Adult density was low compared to other stocking-dependent walleye lakes in Barron and Polk counties (1.4 ± 1.1 fish/acre; mean PE ± mean error; estimated using data from 55 PE surveys across 26 lakes ranging from 1995 to 2021) but has remained similar to the

previous adult density estimate in 2008 (0.6 fish/acre; 95% CI = 0.4 – 0.7 fish/acre; CV = 0.10). Walleye CPUE was 2.4 fish/net night and was well below the 50th percentile (4.3 fish/net night) for similar complex-cool-dark Wisconsin lakes. In total, there were 117 walleyes collected fyke netting (Figure 1), all of which were adults.

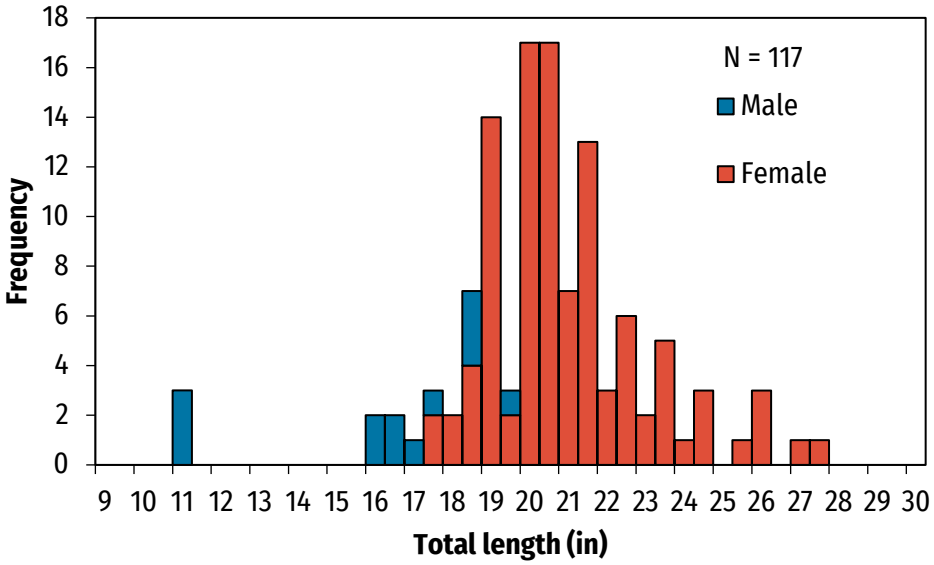

Figure 1. Length frequency histogram for walleye collected during the SN1 survey in Big Moon Lake, Barron County, WI, 2021.

There were 40 walleyes collected during the SE1 survey (recapture period) with a CPUE of 12.5 fish/mi.

Walleyes ranged in length from 11.1 – 27.6 inches, and the mean lengths of females and males were 21.5 inches and 15.9 inches, respectively (Figure 1). Walleye size structure was good in Big Moon Lake. PSD-15 was 97, PSD-20 was 68, and PSD-25 was 25. These PSD index values indicate quality size structure and are above the generally accepted range (PSD-15 = 30 - 60; Anderson and Weithman 1978) for a balanced walleye population. During the 2008 survey, PSD-15 was 13, PSD-20 was 10, and PSD-25 was 0. Despite population abundance remaining similar between the 2008 and 2021 surveys, size structure greatly improved in this survey. The sex ratio was skewed toward females, with a male-to-female ratio of approximately 1:8.

Walleye condition was slightly below average. The mean W_r for all walleye was 92, and for males, females and unknown sex fish was 79, 106 and 87, respectively. Walleye condition was variable between and among sexes and near the suggested range of 95 – 105 by Anderson (1980) for balanced fish populations. Differences in body condition between sexes could be due to sexual size-dimorphism and sample timing (spawning time frame, females tend to have a greater body proportion of gametes compared to males).

Walleye in Big Moon Lake had good growth rates. Walleye ages ranged from 2 to 10, with female ages ranging from 4 to 10 years old and males 2 to 8 years old (Table 1). Mean lengths at age of walleye during the 2021 survey were greater than those observed during the 1987 survey (average difference in mean length at age: 1.9 inches; ages 2 - 8; Schweiger 1988) but were similar to those observed during the 2008 survey (average difference in mean length at age: 0.4 inches; ages 4 – 7; Table 1). Similarly, the mean length at age of walleye were greater than the median from complex-cool-dark Wisconsin lakes (average difference in mean length at age: 3.9 inches; ages 2 - 9) and the Barron/Polk counties average (average difference in mean lengths at age: 2.2 inches; ages 2 - 9; Table 1 & Figure 2).

Table 1. Mean length (inches) at age for walleye (sexes pooled) in Big Moon Lake, Barron County from the 1987, 2008 and 2021 comprehensive surveys.

AGE	1987	2008	2021
1	10.1	-	-
2	12.3	-	10.6
3	14.3	13.0	-
4	16.1	14.0	17.4
5	-	22.4	19.7
6	-	-	20.5
7	19.7	24.7	25.2
8	21.3	-	23.9
9	-	-	26.7
10	-	-	27.6
11	26.0	-	-
12	26.6	-	-

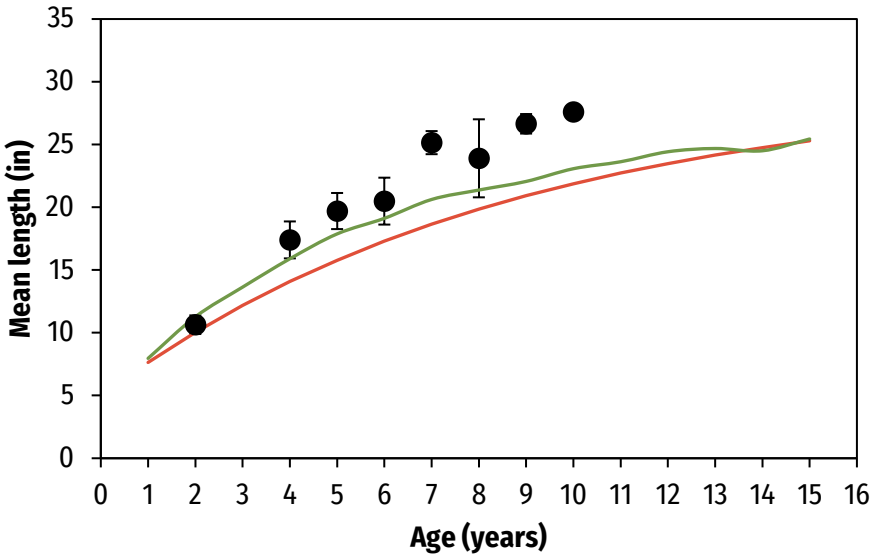

Figure 2. Mean length at age ± standard deviation of walleye (black circles) in Big Moon Lake. The median length at age for similar complex-cool-dark Wisconsin lakes is represented by the red line. Mean length at age estimates for Barron/Polk counties is represented by the green line.

Large fingerling walleye have been stocked into Big Moon Lake every other year since 2013 at a rate of approximately 9-10 fish/acre. Survival to age-4 was < 1%, and the cost per age-4 walleye was estimated at $520.00; however, the age-4 year class was stocked at a smaller size (4 inches) than the typical large fingerling (6-8 inches). Walleye become susceptible to the recreational fishery at age-4. Survival to age-6 was 4.5%, and the cost per age-6 walleye was estimated at $23.00. Age-6 walleye composed the majority (> 75%) of the adult population and had an average length of 20.5 inches. Recruitment of stocked walleye appears variable, with poor survival of the 2017 stocked year class.

NORTHERN PIKE

Northern pike abundance in Big Moon Lake was low, but the size structure was respectable. There were 47 northern pike collected during the SN1 survey. The CPUE was 0.9 fish/net night, which resembled the 25th percentile (0.9 fish/net night) for similar complex-cool-dark Wisconsin lakes. The northern pike population has declined in abundance since 2008 (three fish/net night). Northern pike ranged in length from 12.5 to 36.0 inches and had an average length of 24.9 inches. The mean length of northern pike was above the 99th percentile (23.8 inches) for similar complex-cool-dark Wisconsin lakes. Too few individuals were measured (n = 20) to accurately index population size structure.

MUSKELLUNGE

There were six fyke nets set for ten nights in 2021, which totaled 60 net nights of effort and six fyke nets set for six nights in 2022, which totaled 36 net nights of effort. There were 52 adult muskellunge (≥ 30 inches) (26 males, 22 females and four

unknown sex) marked in 2021 and 41 adult muskellunge (18 males, 23 females, and zero unknown sex) collected in 2022 (Figure 3). There were five sub-adult (< 30 inches) muskellunge collected during 2021 and 2022. Of the muskellunge captured in 2022, there were 19 (12 males and seven females) recaptures from 2021. The adult population (sexes combined ≥ 30 inches) was estimated to be 101 fish (95% CI: 70-132), or 0.53 adult fish/acre (CV = 0.16). Population estimates by sex (≥ 30 inches) for 2021 were 38 males (CV = 0.17) and 66 females (CV = 0.27). The CPUE was 1.0 fish/net night in 2021 and 1.6 fish/net night in 2022. Muskellunge CPUE was above the 75th percentile for similar complex-cool-dark Wisconsin lakes.

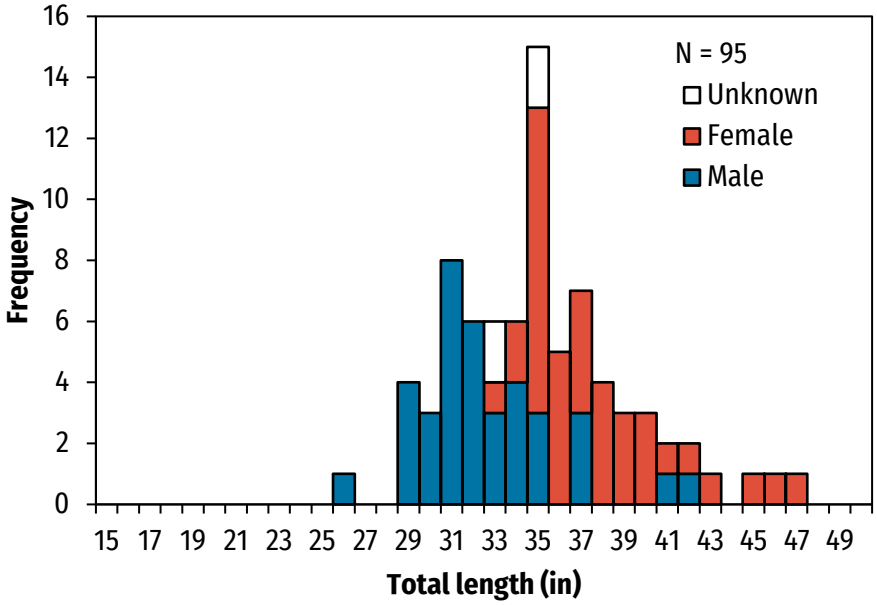

Figure 3. Length frequency histogram for muskellunge captured with fyke nets in Big Moon Lake, Polk County, WI 2021-2022. Recaptures were excluded.

Muskellunge ranged in length from 26.5 to 47.5 inches, and the mean length of muskellunge (sexes combined) was 35.4 inches, which was above the 90th percentile (33.3 inches) for similar complex-cool-dark Wisconsin lakes. The mean length by sex was 33.1 in for males and 38.1 in for females. Muskellunge PSD-30 was 56, PSD-38 was 22, PSD-42 was 6 and PSD-46 was 2. The mean W_r was 98, which indicated muskellunge were in above-average condition. The sex ratio was nearly 1:1.

Big Moon Lake muskellunge had good growth rates. The mean length at age of Big Moon Lake muskellunge closely followed the Barron and Polk counties average (average difference in mean length at age: 0.5 inches; ages 4 - 11; Figure 4). Big Moon Lake averaged 2.8 inches greater than the northern region mean length at age and 2.9 inches greater than the mean length at age for similar complex-cool-dark Wisconsin lakes (ages 4 to 8 and 11 for both comparisons; Figure 4). Age-9 and age-10 each had only one fish and were not included in mean length at age comparisons. Ages of

muskellunge ranged from 4 to 13. No age and growth comparisons were made with previous surveys because this was the first Big Moon Lake muskellunge survey with an extensive aging dataset using anal fin rays. The predicted length infinity (L_{inf}) from the von Bertalanffy growth model was 47.8 inches for both sexes combined (Figure 4). The catch curve regression model (fitted to age-4 to age-13) estimated annual mortality to be 32.2% (Z= -0.39, R^2 = 0.66).

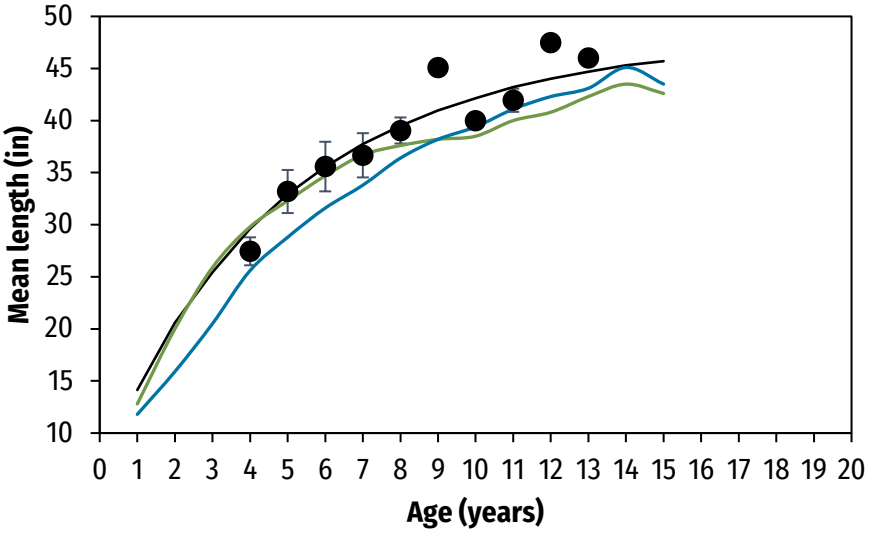

Figure 4. Mean length at age ± standard deviation for muskellunge (sexes pooled) from Big Moon Lake during 2021. The predicted theoretical maximum length from the von Bertalanffy growth model (black line) was 47.8 in with k (growth coefficient) and t_0 (time at which length equals zero) estimated to be 0.2 and -0.96, respectively. The mean length at age estimate for the northern region is represented by the blue line. Mean length at age estimates for Barron/Polk counties is represented by the green line.

LATE SPRING ELECTROFISHING

LARGEMOUTH BASS

There were 92 largemouth bass collected during the 2021 SE2 survey with a CPUE of 27.9 fish/mi. The CPUE was above the 90th percentile (25.7 fish/mile) for similar complex-cool-dark Wisconsin lakes and indicated a high-density population. The CPUE of largemouth bass ≥ 14 inches was similarly high with 9.4 fish/mile and represented 33.7% of the catch. Largemouth bass CPUE has declined since 2008 (67.6 fish/mile and 10.5 fish ≥ 14 inches/mile).

Largemouth bass ranged in length from 4.0-18.5 inches, and the mean length was 12.6 inches (Figure 5), which was above the 90th percentile (12.2 inches) for similar complex-cool-dark Wisconsin lakes. PSD-12 was 74, which indicates good size structure that has improved since the 1987 (PSD-12 = 44; Schweiger 1988) and the 2008 (PSD-12 = 36) fisheries surveys and was well above the generally accepted range

of values for a balanced largemouth bass population (PSD-12 = 40–70; Gabelhouse 1984). The PSD-14 was 37 and has also improved since the 2008 survey (PSD-14 = 17).

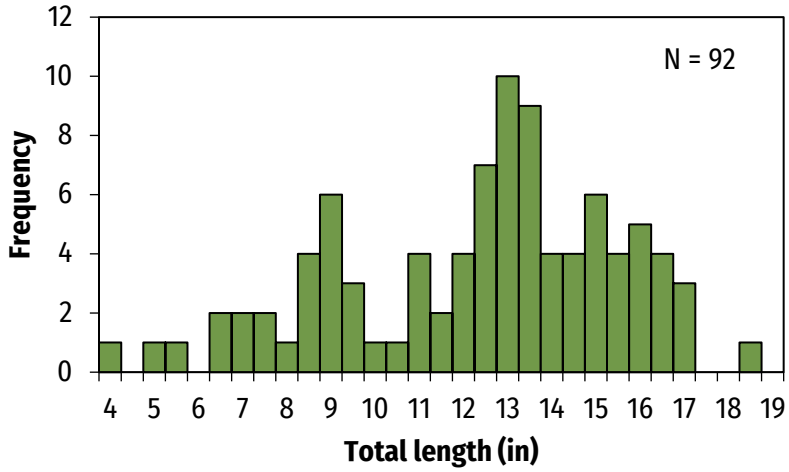

Figure 5. Length frequency of largemouth bass captured in Big Moon Lake during the 2021 SE2 survey.

The mean W_r of largemouth bass was 90 and suggested fish were in average overall condition (Bennett 1970). Largemouth bass growth was above average. The mean length at age was consistently greater than both the northern region averages and the median length at age for similar complex-cool-dark Wisconsin lakes (average difference in mean length at age: 0.9 inches for both comparisons; ages 1 – 10; Figure 6).

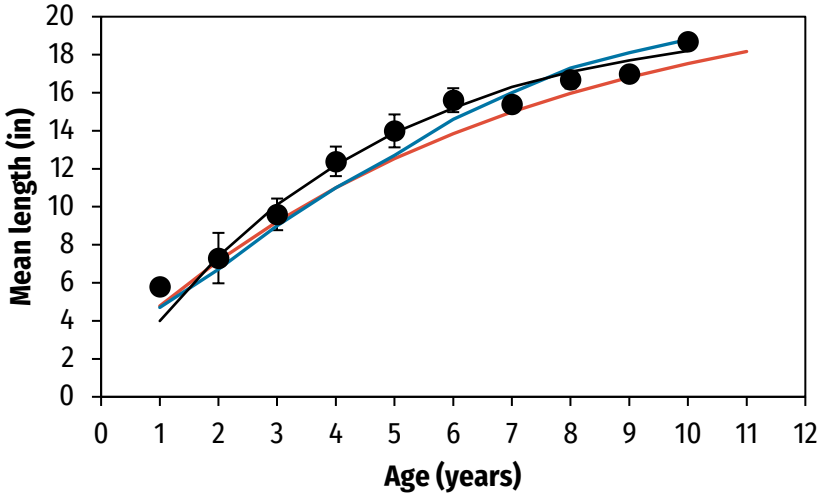

Figure 6. Mean length at age ± standard deviation for largemouth bass during the 2021 SE2 survey on Big Moon Lake. Red line represents the median length at age estimates for complex-cool-dark Wisconsin lakes, and the blue line represents the northern region mean length at age. The predicted theoretical maximum length from the von Bertalanffy growth model (black line) was 20.1 in with k

(growth coefficient) and t_0 (time at which length equals zero) estimated to be 0.17 and -0.33, respectively.

Total annual mortality estimated from a catch curve regression model was 46.0% (ages 4 – 10; R^2 = 0.73; Figure 7).

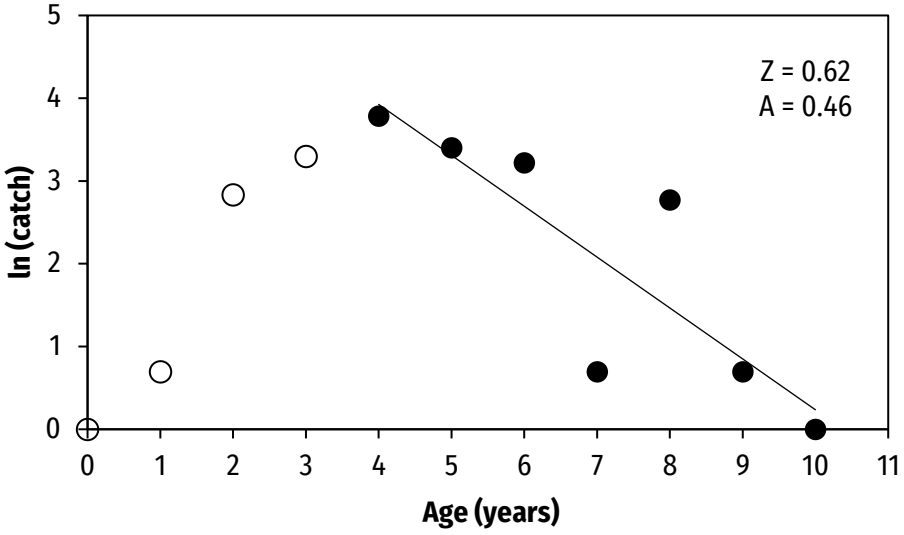

Figure 7. Catch curve analysis plot representing the natural logarithm of the catch for each largemouth bass age class used in the analysis (black circles) and not (white circles). Z = instantaneous total mortality, A = annual total mortality rate.

BLUEGILL

Big Moon Lake supports a below average bluegill fishery with low density and poor size structure. A total of 138 bluegills were collected during the SE2 survey. Bluegill CPUE was 41.8 fish/mile, which was near the 25th percentile (42.1 fish/mile) for similar complex-cool-dark Wisconsin lakes and has declined since 2008 (67.6 fish/mile). The CPUE of quality-size (≥ 6 inches) and preferred-size (≥ 8 inches) fish was 14.6 fish/mile and 0 fish/mile, respectively (Gabelhouse 1984).

Bluegill lengths ranged from 3.0 – 7.6 inches, with an average length of 5.4 inches (Figure 8). The mean length of bluegill was above the 95th percentile (5.5 inches) for similar complex-cool-dark Wisconsin lakes. Bluegill had a low size structure and few large individuals. PSD-6 was 35, and the PSD-8 was 0. The PSD-6 index value was low but within the generally accepted range for a balanced bluegill population (PSD-6 = 20-60); however, PSD-8 was well below the recommendation (PSD-8 = 5-20) by Anderson (1985). PSD index values have remained similar to 2008 (PSD-6 was 41 and PSD-8 was 0).

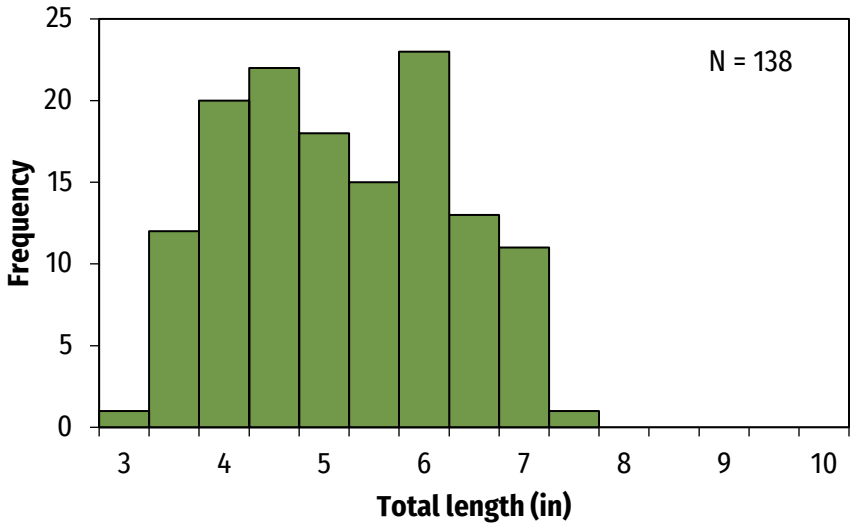

Figure 8. Length frequency of bluegill captured from Big Moon Lake during the SE2 survey.

OTHER PANFISH

There were 10 black crappies collected during the SE2 survey. Black crappie CPUE was 10 fish/mile and CPUE of quality-size fish (≥ 8 inches) was eight fish/mile (80.0% of catch; Gabelhouse 1984). Lengths ranged from 6.6 – 10.1 inches, with an average length of 8.4 inches, which was above the 90th percentile for similar complex-cool-dark Wisconsin lakes.

There were 16 yellow perch collected during the SE2 survey. Yellow perch CPUE was 16 fish/mile and CPUE of quality-size fish (≥ 8 inches) was two fish/mile (12.5% of catch; Gabelhouse 1984). Lengths ranged from 3.0 – 10.0 inches with an average length of 5.8 inches, which was above the 75th percentile for similar complex-cool-dark Wisconsin lakes.

FALL ELECTROFISHING

AGE-0 WALLEYE

There were no age-0 or age-1 walleye collected during the fall electrofishing survey. There were six age-2 walleye collected during the fall electrofishing survey and lengths ranged from 11.2 - 13.1 inches. Age-2 walleye would have corresponded with the 2019 fall stocking event.

RECREATIONAL CREEL AND TRIBAL SPEARING

Open water angling effort amounted to 3,201 hours (16.8 hours/acre) on Big Moon Lake. Angling effort was highest during May (4.3 hours/acre) and July (4.5 hours/acre),

with the early summer months (May – July) comprising > 75% of the total open water angling effort (12.8 hours/acre). Fishing effort during the open water season was directed mostly toward muskellunge (7.0 hours/acre), bluegill (3.8 hours/acre) and largemouth bass (3.6 hours/acre).

WALLEYE

Walleye were the least targeted species by anglers, with 280 hours of directed effort (8.4% of angling effort). There were 76 walleyes estimated to be caught (specific catch rate of 0.27 fish/hour), and eight were estimated to be harvested (specific harvest rate of 0.03 fish/hour). Fishing efforts targeting walleye occurred only during May.

Walleye harvest from the recreational fishery was low. Since no marked walleyes were documented in the open water creel survey, an exploitation rate was not determined. There were no additional walleyes harvested by off-reservation tribal spearers.

LARGEMOUTH BASS

Largemouth bass were the third most targeted species by anglers, with 694 hours of directed effort (20.9% of angling effort). Largemouth bass catch was 876 fish (specific catch rate of 1.2 fish/hour) and harvest was zero fish, indicative of a catch and release fishery. Directed effort occurred mostly during May (53.2%), followed by July (11.5%) and August (27.1%).

NORTHERN PIKE

Anglers did not target northern pike during the open water creel survey; however, northern pike were caught by recreational anglers during May (69 fish; 66.3%) and June (35 fish; 33.7%).

MUSKELLUNGE

Muskellunge were the most targeted species by anglers, with 1,341 hours of directed effort (40.3% of angling effort). The estimated catch of muskellunge was 129 fish (specific catch rate of 0.1 fish/hour), and no harvest occurred. Angler effort was greatest during July (571 hours; 42.6%), followed by June (436 hours; 32.5%), August (237 hours; 17.7%), September (57 hours; 4.3%) and October (40 hours; 3.0%). Specific catch rates did not correspond with the directed effort spent. Catch rates were greatest in September (0.12 fish/hour) and July (0.12 fish/hour) followed by August (0.09 fish/hour) and June (0.08 fish/hour).

BLUEGILL

Bluegill were the second most targeted species by anglers with 717 hours of directed effort (3.8 hours/acre; 21.6% of angling effort). It was estimated that 2,380 bluegills were caught (specific catch rate of 3.3 fish/hour), and 1,194 were harvested (specific harvest rate of 1.7 fish/hour; Figure 9). Angler effort, catch and harvest of bluegills

peaked during July, followed by a decline through the remainder of the summer months. The mean length of harvested bluegills was 7.4 inches, and fish ≥ 7 inches composed 69% and fish ≥ 8 inches composed 26% of harvested fish (Figure 9). This suggests bluegills ≥ 7 inches are most susceptible to harvest from the recreational fishery.

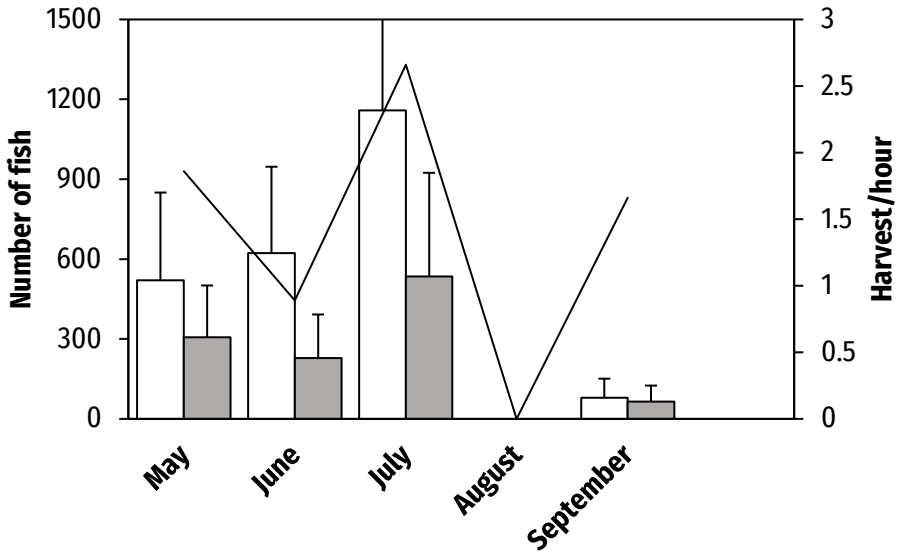

Figure 9. Total number of bluegills caught (white bars ± standard deviation) and harvested (grey bars ± standard deviation) by the recreational fishery during May - September. The specific rate of harvest (fish/hour) is represented by the solid line.

BLACK CRAPPIE

Black crappie were the fourth most targeted species by anglers with 293 hours of directed effort (1.5 hours/acre; 8.8% of angling effort). An estimated 45 black crappies were caught (specific catch rate of 0.15 fish/hour), and 23 were harvested (specific harvest rate of 0.1 fish/hour). Black crappie directed effort occurred during May (55%) and June (45%). The mean length of harvested black crappies was 10.6 inches.

Discussion

Big Moon Lake has desirable sportfish populations that are utilized by anglers. Although, the angling effort is low overall compared to other popular fishing lakes in the area.

The adult walleye population was low, with poor survival of stocked fish and a nearly non-existent recreational fishery. Adult walleye density in 2021 remained similar to 2008, and despite similar adult densities, size structure greatly improved. Walleye were in good condition and growth was above average. The mean lengths of fish sampled during the 2008 and 2021 netting surveys increased by 5 inches, and PSD-15

improved from 2008 to 2021 from 30 to 97, respectively. This change was likely the result of variable recruitment of stocked year classes from 2013 – 2019, which created an adult walleye age structure that consisted primarily of age-6 fish. The female-biased population also likely contributed to a higher size structure.

The sex ratio was skewed toward females in 2021 (1:8), and this varied greatly from the male-biased sex ratio observed during the 2008 survey (4:1). This could be driven by a shift in stocking practices to large fingerlings during 2013. A survey of extended growth hatchery walleye produced by Wisconsin hatcheries showed that 60-100% of hatchery products were female (Sass et al. 2022). Naturally-reproducing walleye fisheries typically have male bias but stocking-dependent fisheries that received extended growth walleye have been observed to be female-biased.

Despite many years of stocking, the adult walleye density in 2021 remains low compared to other stocking-dependent lakes in Barron and Polk counties. A shift in stocking practices from small to large fingerlings in 2013 has not resulted in measurable changes to adult density. Large fingerlings (6-8 inches in length in the fall) are generally preferred over small fingerlings (~2 inches) due to higher survival. Although, year class recruitment of stocked large fingerlings since 2013 (Appendix Table 1) has been low (survival < 1%) except for 2015 (survival 4.5%; age-6 fish). The low survival of the age-4 year class may be attributed to an early stock out during 2017 (summer stocking with a mean length of 4 inches; Appendix Table 1). Perhaps survival would have been greater if they were stocked in the fall at the typical large fingerling size (6-8 inches).

Additionally, no age-0 or age-1 walleye were observed during the 2021 fall electrofishing survey, which indicates natural recruitment is still limited and the current fishery remains stocking dependent. Although the exact reason is unknown why the survival of large fingerling walleye in Big Moon Lake is poor, other researchers have found the recruitment of stocked large fingerling walleye to be dependent on fall water temperatures leading to ice up and predation pressure (Grausgruber and Weber 2021; Santucci and Wahl 1993). Other potential factors may include lake productivity and age-0 walleye forage availability and foraging success. Populations exhibiting poor recruitment and skewed age structures may be less resilient to harvest and other perturbations.

Stocking is a common rehabilitation tool to mitigate declining adult walleye abundance and natural reproduction and has occurred every other year in Big Moon Lake since at least 1985, but rehabilitation programs largely dependent on stocking are not as effective as they were 30 years ago (Lawson et al. 2022). Big Moon Lake is a stocking-dependent system with marginal walleye habitat, low recruitment of stocked fish and a low probability of reestablishing natural recruitment. Thus, stocking efficacy and recruitment of stocked year classes to the fishery should be

closely monitored in the future. If warranted, changes in stocking practices may be recommended.

The Big Moon Lake walleye population does not appear to be limited by harvest, as exploitation could not even be determined. Also, the walleye fishery had the least amount of directed effort of any species on the lake, with directed angler effort (280 hour; 1.5 hours/acre) well below the 10-year average of walleye directed effort (3.9 hours/acre) on other stocked fisheries in Barron and Polk counties (indexed using open water creel survey data during 2009-2020 from 11 lakes).

There is currently a low-density northern pike population in Big Moon Lake with respectable size structure. Catch rates declined by over half since 2008. Northern pike were not targeted by the recreational fishery during the 2021 open water season. However, given their respectable size structure, northern pike likely provide a bonus opportunity for Big Moon Lake muskellunge anglers. It is also likely that greater directed effort for northern pike occurs during the ice fishing season.

A moderate density muskellunge population with good size structure was present in Big Moon Lake. The 2021 adult population density (0.53 fish/acre) was greater than recent density estimates (average density = 0.31 fish/acre; range = 0.29 – 0.42 fish/acre) for other popular muskellunge fisheries in Barron and Polk counties (Bear Trap Lake, Wapogasset Lake, Sand Lake, Deer Lake, Rice Lake and Bone Lake). Population size structure (PSD-30 = 56) in Big Moon Lake was lower than recent PSD estimates (average PSD-30 = 81; range = 72-93) for these same lakes. Muskellunge fisheries often display strong inverse relationships between density and size structure, where higher density populations typically have lower size structure and poor fish condition, and vice-versa, which is typically the result of intra-specific competition. The Big Moon Lake muskellunge population was 'middle of the road' in terms of adult density, and although size structure was lower compared to other popular Barron and Polk county fisheries, fish were in above average condition, and the average length (35.4 inches) was above the 90th percentile for similar complex-cool-dark Wisconsin lakes.

Big Moon Lake is currently designated as a Class B muskellunge lake, and the muskellunge fishery plays a large role in the Big Moon Lake fishery. Muskellunge were the most targeted fish species in Big Moon Lake during the 2021 open water creel survey. Directed fishing effort during May - October (7.0 hours/acre) was similar to the average directed effort noted by Simonson and Hewett (1999) for Class B (5.2 hours/acre) waters in northern Wisconsin. Although, catch rates were ≥ 2x Class B (0.04 fish/hour) waters in northern Wisconsin (Simonson and Hewett 1999). Big Moon Lake provides an excellent muskellunge fishery with the highest population density in Barron and Polk counties, good overall size structure and high angler catch rates.

The muskellunge fishery in Big Moon Lake should continue to be managed at a moderate density (0.4 to 0.6 adults/acre), which should provide a good size structure that offers excellent angling action. Big Moon Lake muskellunge will continue to be managed with the 40-inch minimum length limit and one fish daily bag limit. All muskellunge were implanted with PIT tags, and recaptures of those fish by both anglers and future fishery surveys will greatly benefit future analysis of population metrics.

Big Moon Lake supports a high-density largemouth bass population with good size structure that offers anglers the opportunity to catch quality fish. Fish growth was good and exceeded average estimates for both the northern region and similar complex-cool-dark Wisconsin lakes. Fish condition was lower than the target range of 95 – 105 for balanced fish populations but within the recommended target range (85 – 95) proposed by Gabelhouse (1984) for quality bluegill populations. High-density largemouth bass populations generally have lower condition due to intraspecific competition but are effective regulators of bluegill recruitment and population size through predation, which promotes greater size structure of bluegill populations. Largemouth bass PSD index values were well above recommendations (PSD-12 = 20-40 and PSD-15 = 0-10) for quality bluegill management (Willis et al. 1993), and similarly, the PSD index values for bluegill were well below. However, it appears bluegill size structure may have been underrepresented during the SE2 survey, as larger bluegills (>8 inches) were observed during the open water creel survey but were not observed during the SE2 survey. The bass-panfish fishery in Big Moon Lake is currently more representative of a quality bass fishery, as reflected by PSD index values. Overall, both fisheries offer good angling opportunities.

The recreational fishery for bluegill was second most popular in directed angling effort (3.8 hours/acre) but was considerably lower than average for lakes in Barron and Polk counties (29.7 hours/acre) over the previous decade. Despite this, harvest rates were high, comparable to other popular bluegill fisheries in the area and could be contributing to declining relative abundances. Bluegill recreational fisheries are size selective and consumptive orientated, and size selectivity by the recreational fishery was evidenced by a mismatch in size frequencies estimated by the SE2 survey and the open water creel survey. The bluegill catch-to-harvest ratio by anglers was 50%, which is indicative of ‘fish sorting’ or self-imposed size limitations to harvest. Bluegills greater than 7 inches were most susceptible to harvest by the recreational fishery. Future fishery surveys should closely monitor population abundance and size structure of bluegill due to the local popularity of the recreational fishery and their importance to the overall fish community.

Few black crappies were observed during the 2021 SE2 survey. The SE2 surveys are often not the most reliable method to index black crappie relative abundance and size structure. A fishable population exists in Big Moon Lake, and > 90% of the

directed effort occurred during May. It is likely black crappies are also targeted during the ice fishing season.

Management Recommendations

1. Maintain walleye density near two fish/acre by continuing to stock large fingerling walleyes (6-8 inches) in alternate years at a rate of 10 fish/acre. Walleye stocking efforts should focus solely on large fingerling stockings. The relative contribution of large fingerlings to the adult population should be reassessed during the next comprehensive survey in 2033. The survey timing is subject to change depending on local and statewide sampling plans. Additionally, the survival of age-1 stocked walleye will be assessed every other year during off-stocking years. If the large fingerling walleye stockings continue to have low efficacy in Big Moon Lake, walleye stocking should be reconsidered altogether.
2. The adult muskellunge population (≥ 30 inches) should be maintained between 0.4 – 0.6 adult fish/acre. This density should continue to provide a high-action recreational fishery with a good size structure. The stocking regime should be maintained at one large fingerling/acre every other year. All muskellunge will continue to be PIT tagged during future fishery surveys.
3. No specific management actions regarding northern pike, largemouth bass, bluegill and black crappie are recommended at this time. Otoliths should be collected from largemouth bass, bluegill and black crappie during the next survey to improve age and growth estimation.
4. The next comprehensive fisheries survey is scheduled for 2033. Special attention should be directed at reassessing the stocking efficiency and survival of large fingerling walleye. The abundance, size structure, age structure and growth of largemouth bass and panfish should be monitored, as these species support popular recreational fisheries.
5. Efforts to increase habitat complexity in Big Moon Lake should also be encouraged where applicable. Inputs of coarse woody habitat, protection/promotion of aquatic vegetation and maintenance/restoration of vegetative buffers would be beneficial. Inputs of coarse woody habitat, protection/promotion of aquatic vegetation and maintenance/restoration of vegetative buffers would be beneficial. The Healthy Lakes and Rivers website (healthylakeswi.com) is a great resource to learn about this recommendation.
6. Invasive species monitoring and control programs should continue.

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Appendices

Appendix Table 1. Walleye stocking records for Big Moon Lake, 1984 – 2021.

YEAR	SPECIES	AGE CLASS	NUMBER STOCKED	AVG. LENGTH (IN.)
1984	Walleye	Small Fingerling	10,385	3.0
1986	Walleye	Small Fingerling	9,660	3.0
1988	Walleye	Small Fingerling	9,500	3.0
1990	Walleye	Small Fingerling	9,600	3.0
1992	Walleye	Small Fingerling	9,583	2.0
1994	Walleye	Small Fingerling	9,500	1.9
1997	Walleye	Small Fingerling	9,500	1.7
1999	Walleye	Small Fingerling	9,550	1.6
2001	Walleye	Small Fingerling	9,550	1.6
2003	Walleye	Small Fingerling	9,537	1.8
2005	Walleye	Small Fingerling	9,910	1.7
2007	Walleye	Small Fingerling	6,747	2.8
2009	Walleye	Small Fingerling	6,685	1.7
2011	Walleye	Small Fingerling	6,685	2.0
2013	Walleye	Large Fingerling	1,910	6.3
2015	Walleye	Large Fingerling	1,869	7.4
2017	Walleye	Large Fingerling	1,965	4.0
2019	Walleye	Large Fingerling	1,929	6.3
2021	Walleye	Large Fingerling	2,097	6.3

Appendix Table 2. Muskellunge stocking records for Big Moon Lake, 1979 – 2021.

YEAR	SPECIES	AGE CLASS	NUMBER STOCKED	AVG. LENGTH (IN.)
1979	Muskellunge	Large Fingerling	190	11.0
1980	Muskellunge	Large Fingerling	190	7.0
1983	Muskellunge	Large Fingerling	190	9.0
1985	Muskellunge	Large Fingerling	190	7.0
1987	Muskellunge	Large Fingerling	285	9.0
1988	Muskellunge	Large Fingerling	190	11.0
1990	Muskellunge	Large Fingerling	382	11.0
1992	Muskellunge	Large Fingerling	190	9.0
1993	Muskellunge	Large Fingerling	190	12.0
1996	Muskellunge	Large Fingerling	190	11.6
1998	Muskellunge	Large Fingerling	190	11.7
2000	Muskellunge	Large Fingerling	95	11.0
2002	Muskellunge	Large Fingerling	191	11.4
2004	Muskellunge	Large Fingerling	141	10.7
2006	Muskellunge	Large Fingerling	105	11.6
2008	Muskellunge	Large Fingerling	96	10.8
2010	Muskellunge	Large Fingerling	84	12.4
2012	Muskellunge	Large Fingerling	191	12.6
2014	Muskellunge	Large Fingerling	191	11.1
2016	Muskellunge	Large Fingerling	174	12.0
2018	Muskellunge	Large Fingerling	194	11.8

Appendix Table 3. Survey types, gear used, target water temperature and target species.

SURVEY TYPE	GEAR USED	TARGET WATER TEMPERATURE (°F)	TARGET SPECIES
Spring Netting 1 (SN1)	Fyke Net	~45	Walleye, northern pike
Spring Electrofishing 1 (SE1)	Boat Electrofishing	45-50	Walleye
Spring Netting 2 (SN2)	Fyke Net	50-55	Muskellunge, black crappie, yellow perch
Spring Electrofishing 2 (SE2)	Boat Electrofishing	55-70	Largemouth bass, smallmouth bass, bluegill and other panfish, non-game species
Spring Netting 3 (SN3)	Fyke Net	65-80	Bluegill, black crappie
Fall Electrofishing (FE)	Boat Electrofishing	50-60	Juvenile walleye and muskellunge