**Brevoort Lake**

Mackinac County, Republic Township 42N / Range 05W / Section 34

**John M. Bauman, Fisheries Biologist, Escanaba**

1. **Environment**
	1. **Location**

Brevoort Lake is a large, 4001-acre, shallow lake located in central Mackinac County in Michigan’s Upper Peninsula (Figure 1). In Mackinac County, St. Ignace resides south east while Brevort Township resides just west of Brevoort Lake approximately 15 miles northwest of the Mackinac Bridge.

* 1. **Geology and Geography**

Brevoort Lake is located within the Point Aux Chenes bedrock formation consisting of sedimentary deposits such as shale, dolomite, chert and sandy shale formed during the Silurian age (Paleozoic Era) (Rosenau 1956). The surficial geology transitions from steep sand dunes near the south to a flat gently rolling mixture of glacial till and wetted sands to the north (Bassett 1987). Surrounding shoreline soils consist of a mix of various sand and silt loam types including Eastport, Carbondale, Wallace and Kalkaska. Erosion of dunes along the south shore of Brevoort Lake has produced extensive shallow, sand areas devoid of aquatic vegetation (Bassett 1987). The littoral zone of Brevoort Lake consists of unstable sand substrate with scattered beds of bulrush, while Boedne Bay (west) and Christiansen’s Bay (east) provide more productive substrates consisting of loose organic and mixed sand-organic substrates (Bassett 1987).

* 1. **Watershed Description**

Brevoort Lake is located within the Brevoort Lake watershed and was first mapped by the United States Forest Service (hereinafter referred to as “USFS”) in 1939. Brevoort Lake is positioned on a west-northwest to east-southeast axis with a total fetch length of approximately 5.5 miles and a maximum depth of 32 feet. Little Brevoort Lake is connected to and flows into Boedne Bay of Brevoort Lake via the Little Brevoort River. Silver Creek also serves as tributary to Brevoort Lake located in the northeast of Boedne Bay. The Little Cut River flows into Brevoort Lake on the northeast shore near Walker road. Brevoort River is the sole outflow of Brevoort Lake and serves as a tributary to Lake Michigan 10.8 miles downstream of Brevoort Lake. A water level control structure, built in 1935, is located near the mouth of the Brevoort River and has been operated by USFS staff annually. While the legal water level has been topic for debate, it was first established in 1936 (625.97 feet above sea level) and then was later adjusted and reaffirmed in 1994 (625.00 feet above sea level).

* 1. **Status of Lake Habitat (formerly physical and chemical parameters)**

Habitat conditions within Michigan’s inland lakes determine the rates of reproduction, mortality, and growth of fish that inhabit a waterbody. Consequently, the abundance as well as the type of fish that may inhabit a lake can also be determined by inland lake habitat. Habitat conditions influence water quality and general appearance of a lake, and as a result, can also determine the suitability of a lake for being a source for drinking water, swimming, fishing and boating. More generally, habitat indicators are used to assess the chemical, physical, and biological conditions in an inland lake.

* + 1. **Chemical Characteristics**

**Total Alkalinity -** Total alkalinity is a measure of buffering capacity and plays an important role in determining a waterbody’s pH (Wetzel 2001, Wehrly et al. 2015). Alkalinity values in Michigan inland lakes can be classified into low (< 49.5 mg/L CaCO3), medium (49.5 to 141.5) and high (>141.5) categories. On 27 August 2018, alkalinity in Brevoort Lake was 86 mg/L (medium), which is similar to alkalinity samples taken during the 1940s. Therefore, Brevoort Lake has moderate capacity to buffer against significant changes in pH which fluctuate during spring run-off or snow melt periods. The average alkalinity value for large, shallow inland lakes located within watersheds of northern Lake Michigan is 78 mg/L (Wehrly et al. 2015). Comparatively, Brevoort Lake has above average alkalinity when compared to other inland waterbodies similar in size in the Northern Lake Michigan Management Unit (NLMMU). The average alkalinity value for large, shallow inland lakes in Michigan is 95 mg/L (Wehrly et al. 2015).

**Nutrients –** Phosphorus and nitrogen are two important nutrients which influence production, biomass, and species composition of aquatic and nearby terrestrial plants in lake ecosystems. Concentrations of these two nutrients vary naturally depending on geology, watershed and the rate at which water cycles through a waterbody. Human-derived inputs of nutrients can lead to eutrophication which results in an increase in production of phytoplankton and aquatic macrophytes, which can often become noxious or a nuisance. As plants decompose, oxygen in the water is consumed by microorganisms and can be reduced to levels which compromise fish habitat and subsequently fish abundance. On the other hand, inland lakes which are characterized as having ‘too few’ nutrients tend to have lower levels of primary production and thus much lower growth rates and less biomass per acre (e.g., standing crop).

**Total Phosphorus and Nitrogen –** Total phosphorus occurs in relatively low concentrations in the aquatic environment and as a result tends to be the limiting nutrient for primary producers (phytoplankton, periphyton, and aquatic vegetation) in an aquatic ecosystem. Phosphorus values typically vary quite widely across Michigan inland lakes having low (<0.009 mg/L), medium (0.009 to 0.020 mg/L), and high (>0.020 mg/L) concentrations. Total phosphorus values in Brevoort Lake were measured 27 August 2018 and were reported to be 0.0104 mg/L (medium).

Average total phosphorus concentrations for large shallow lakes in the NLMMU region and across the state of Michigan are 0.011 and 0.014 mg/L, respectively (Wehrly et al. 2015). Therefore, Brevoort Lake has phosphorus concentrations that are equal to below other inland lakes in the NLMMU region and across the state, respectively.

In contrast to phosphorus, total nitrogen occurs in relatively high concentrations in aquatic environments and as a result, rarely limits primary production in lakes. Nitrogen values in Michigan inland lakes range from low (<0.403 mg/L), medium (0.403 to 0.750 mg/L), and high (>0.750 mg/L) concentrations. Total nitrogen values in Brevoort Lake were measured 27 August 2018 and were reported to be 1.573 mg/L (high). Average total phosphorus concentrations for large shallow lakes in the NLMMU region and across the state of Michigan are 0.583 and 0.500 mg/L, respectively (Wehrly et al. 2015). Therefore, Brevoort Lake has total nitrogen concentrations that are well above what is to be considered normal for the region or compared to waterbodies across the state of Michigan. In 1977, Brevoort Lake was sampled at six locations for concentration of total nitrogen. The average concentration of total nitrogen across six sites was 0.468 mg/L and ranged from 0.430 to 0.550 mg/L. This suggests the 2018 results are much higher compared to previous measurements.

Based on the ratio of total nitrogen to total phosphorus (N:P), managers can classify lakes that may be limited by one nutrient versus the other. For example, plants typically require a specific ratio of N:P which tends to be 18:1, where total phosphorus is the limiting nutrient. In 2018, the N:P ratio for Brevoort Lake was 151:1 which suggests that total phosphorus is the nutrient which limits primary production in Brevoort Lake.

**Dissolved Oxygen** - Dissolved oxygen (DO) is a critical component to available habitat in aquatic ecosystems. Dissolved oxygen in lakes derives from the atmosphere as well as from aquatic plants during photosynthesis. Concentration of DO in lakes can limit the distribution and growth of fish in lakes as well as the size composition and biomass of zooplankton. Concentrations of DO begin to limit cool- and warmwater fish populations at approximately 3.0 mg/L and are often lethal below 0.5 mg/L (Schneider 2002). As DO becomes limited, two regions which characterize low levels of DO exist. The hypoxic region, which is characterized by having low levels (e.g., less than 2 to 4 mg/L) of DO and the anoxic region which contains no DO. DO was measured in Brevoort Lake on 27 August 2018 and ranged from 4.99 to 8.64 mg/L which suggests that sufficient oxygen exists throughout the water column to support aquatic organisms.

* + 1. **Physical Characteristics**

**Stratification** - Thermal stratification (which is evaluated using a temperature profile) in lakes typically occurs in deep lakes during the summer months of the year where three water column ‘layers’ form, which are called the epilimnion, metalimnion, and hypolimnion. The epilimnion consists of the upper layer of the water column which is characteristically warmer and has adequate levels of sunlight penetration to support photosynthesis. The metalimnion is the layer between the epilimnion and hypolimnion characterized by a quick transition in temperature change. The point at which temperature change is greatest within the metalimnion is referred to as the ‘thermocline’. On 27 August 2018, a summer temperature profile was recorded in Brevoort Lake which showed that no stratification had occurred. The lack of thermal stratification is normal for large shallow waterbodies in the NLMMU (Wehrly et al. 2015).

**Transparency** - Water transparency, which is measured using a Secchi Disk, provides an index of phytoplankton production and overall lake productivity. For example, lakes with greater transparency (i.e., greater Secchi depth) are often classified as Oligotrophic, meaning there are low levels of lake productivity (e.g., standing crop). Summer Secchi depths vary considerably across Michigan with lakes having low (<7.5 feet), medium (7.5 to 13.5 feet), and high (>13.5 feet) transparency. On 27 August 2018, the Brevoort Lake Secchi Disk reading was 8 feet (high). The average Secchi depths for large shallow inland lakes in the NLMMU region and across the state of Michigan are 8.2 and 9.8 feet, respectively. Therefore, Brevoort Lake has a transparency depth equal to or slightly less than similar-sized waterbodies in the NLMMU region and across the state, respectively.

**Residential Development** – Residential development provides an index of the potential influence human activities have in areas adjacent to shoreline resources. Building structures (dwellings) in riparian areas, removing vegetation or woody debris, armoring shorelines, and building docks all have the potential to impact lake ecosystems and negatively affect fish populations and water quality.

Dwelling density values along Michigan inland lake shorelines can be classified as low (<4.8 dwellings per mile), medium (4.8 to 30.4 dwellings per mile) and high (>30.4 dwellings per mile). The number of dwellings per mile along the shoreline of Brevoort Lake was measured 18 July 2018 and is reported to have 11.7 dwellings per mile (medium). Average dwellings per mile for large shallow inland lakes in the NLMMU region and across the state of Michigan is 14.3 and 18.5 dwellings per mile, respectively. Therefore, Brevoort Lake has a residential development level that is below average compared to other waterbodies in the NLMMU region and across the state of Michigan.

The density of boat docks, measured as the number of docks per mile of shoreline, provides an index of the nearshore disturbance level as well as the potential boat activity level. Construction of docks is often accompanied by the removal of large woody debris and aquatic vegetation which disrupts nearshore sediment and reduces available refugia habitat for aquatic organisms. Dock density values along Michigan’s inland lake shorelines can be classified as low (<1.9 docks per mile), medium (1.9 to 21.9 dock per mile) and high (>19.1 docks per mile). The number of docks in Brevoort Lake was measured 17 July 2018 and is reported to have 9.6 docks per mile (medium). The number of docks per mile for large shallow inland lakes in the NLMMU region and across the state of Michigan is 8.5 and 14.3 boat docks per mile, respectively. Therefore, Brevoort Lake has more docks per mile compared to large shallow waterbodies in the NLMMU region, yet less compared to similar sized waterbodies across the state of Michigan.

The degree to which lake shorelines have been armored, to reduce impacts of wave action, provides an index of the extent to which shorelines may have been modified from their natural state. Shoreline armoring is measured as the percent of shoreline armored across all transects. The amount of shoreline armoring in Michigan’s inland lakes can be classified as low (<0.6 percent), medium (0.6 to 30.1 percent) and high (>30.1 percent). The amount of shoreline armoring was measured in Brevoort Lake 17 July 2018 and was reported to be 44.3 percent (high). Average percent of shoreline armored in other large shallow inland lakes in the NLMMU region and across the state of Michigan is 26.5 and 28.4 percent armored, respectively. Therefore, Brevoort Lake has highly modified shoreline compared to similar sized waterbodies in the NLMMU region and across the state of Michigan.

Large woody debris is an important habitat component providing structure for aquatic organisms (e.g., fish, aquatic insects) during various life periods and providing stability of the lake bottom (e.g., sediments, vegetation). Trees growing adjacent to shoreland fall into the water and become a primary source for large woody debris habitat, however humans have greatly impacted the degree to which large woody debris exists in many lakes. Humans often remove woody debris from shoreline areas reducing critical habitat. Furthermore, humans reduce recruitment of new large woody debris by removing trees from shoreland areas during landscaping. The amount of large woody debris in Michigan’s inland lakes can be classified as low (<1.1 trees per mile), medium (1.1 to 22.7 trees per mile) and high (>22.7 trees per mile). The amount of large woody debris in Brevoort Lake was measured 17 July 2018 and is reported to be 44.3 trees per mile (high). Average densities of large woody debris in other large shallow inland lakes in the NLMMU region and across the state of Michigan are 15.3 and 27.8 trees per mile, respectively. Therefore, Brevoort Lake has a greater density of large woody debris compared to similar sized waterbodies in the NLMMU region and across the state of Michigan.

* + 1. **Biological Characteristics**

Additional biological parameters provide a picture of lakes level of productivity. The more productive a lake is, the more aquatic organisms (e.g., fish, insects) the lake can ‘grow’ and support. Biological parameters often used to gauge a lake’s level of productivity include; chlorophyll-a, trophic status and zooplankton size. Zooplankton size was not measured due to time and staff constraints and is not discussed further in this report.

**Chlorophyll-a** - Chlorophyll-a is a pigment used by plants for photosynthesis. Summer chlorophyll-a concentrations in the epilimnion provide a measure of lake primary production (e.g., algal biomass) by phytoplankton. Chlorophyll-a is also used to estimate trophic state which provides an index of overall lake productivity. Lakes which have ‘low’ levels of chlorophyll-a tend to be limited by low nutrient availability. Concentrations of chlorophyll-a in Michigan inland lakes can be classified as low (<1.9 ug/L), medium (1.9 to 4.8 ug/L) and high (>4.8 ug/L). The concentration of chlorophyll-a in Brevoort Lake was measured 17 July 2018 and is reported to be 0.22 ug/L (low). Average chlorophyll-a concentrations for large shallow inland lakes in the NLMMU region and across the state of Michigan are 2.9 and 2.8 ug/L, respectively. Therefore, chlorophyll-a is limiting primary production in Brevoort Lake given the low values compared to similar sized waterbodies in the NLMMU region and across the state of Michigan.

**Trophic status** - Trophic status provides an index of the amount of phytoplankton production can occur in a lake. This is determined by using a Carlson’s Trophic Index (TSI) which uses phosphorus, Secchi depth, and chlorophyll-a values to provide a value which fits between a scale of 0 to 100 (Fuller and Jodoin 2016). Lakes with low TSI values tend to represent waterbodies with low phytoplankton production, while lakes with higher TSI values tend to represent lakes with high phytoplankton production. Values for TSI can be classified as oligotrophic (TSI<38), mesotrophic (TSI from 38 to 48), eutrophic (49 to 61), and hypereutrophic (TSI>61). On 27 August 2018, the total phosphorus, Secchi depth, and chlorophyll-a values were reported to be 0.22 ug/L, 8.0 ft, and 10.4 ug/L, respectively (Average TSI = 33.4, oligotrophic).

* 1. **Development, Public Ownership, and Access**
		1. **Development**

The Brevoort Lake area is a recreational destination located in the eastern region of the Hiawatha National Forest offering diverse opportunities for outdoor activities (e.g., camping, hunting fishing, hunting, ORVing, hiking, ice fishing, snowshoeing). Nearly the entire south shore of Brevoort Lake is public land (USFS ownership). Two public boat launches exist in Brevoort Lake: 1) located in Boedne Bay (GPS: 46.009612 -84.972115) as part of a USFS campground and 2) located in Christiansen’s Bay (GPS: 45.991098 -84.878275) in the south east corner of the lake off Dukes Road.

1. **Fishery Resource**
	1. **Describe the fish stocks and the fishery in earlier years along with problems and management history.**

Historical records indicate that Fisheries Management in Brevoort Lake began in the late 1800s when Walleye and Lake Trout were stocked. The intent of stocking during that period is unknown, however it may have been to develop a commercial fishery. Survival of Lake Trout would have been severely limited by the shallow and warm water characteristics of Brevoort Lake. Following initial stocking in the late 1800s, Brevoort Lake was stocked with a variety of species at varying rates over the period of 120 years (Table 1). From 1900 through the 1920s Brevoort Lake was stocked with Largemouth Bass, Smallmouth Bass, and Walleye. However, there are no records as to how these fish survived or whether a fishery developed for these species. Following the 1920s, Brevoort Lake was stocked with Brook Trout, Walleye, Yellow Perch, Bluegill, Largemouth Bass, and Smallmouth Bass through the 1930s.

During the 1930s documentation and records for Brevoort Lake fisheries management began to improve. In 1935 a water-level control structure was designed to be built in Brevoort Lake and a court-ordered water level was established soon after in 1936 (625.97 feet above sea level). The dam was constructed in summer of 1936. The United States Forest Service (USFS) mapped Brevoort Lake in 1938 and a popular sport fishery was noted to exist. By the late 1930s Brevoort Lake provided an attractive fishery for Muskellunge, Northern Pike, and Smallmouth Bass. However, there were concerns at this time over the management of Muskellunge populations and the potential impacts of spearing during the winter months. During the late 1930s, Brevoort Lake was being managed under a “Pike” lake regulation. However, there were petitions submitted to the Department of Conservation (hereinafter referred to as MI DNR) requesting Brevoort Lake be changed to “all other lakes” regulation. This change was made in 1938 in hopes of providing additional protection to early spring spawners (presumable, Northern Pike and Muskellunge). For example, “Pike” lakes were open to fishing March 15, while “all other lakes” were open to fishing on June 25th.

During the 1940s, additional petitions were received regarding the interest of closing Brevoort Lake to spearing. In addition to a request of closing the spearing season, anglers expressed interest in transferring adult Northern Pike into Brevoort Lake from the Seney National Wildlife Refuge to provide additional angling opportunity. Although there are no stocking records of this plant, Northern Pike were noted to have been transferred into Brevoort Lake from the Seney National Wildlife Refuge in 1941. Following that stocking event, the MI DNR stated that no additional adult transfers would be completed due to the high cost of transferring individuals with only minimal returns to creel. In 1941, Brevoort Lake was closed to spearing.

Given the recent stocking that had taken place in Brevoort Lake as well as the management topics which were being discussed, the Institute of Fisheries Research conducted a comprehensive survey of Brevoort Lake. The survey was conducted in July and August of 1942 with an effort to provide quantitative information that could be used to help guide management decision for the Brevoort Lake fishery. During the period that this survey was conducted, Brevoort Lake was reported to be providing good fishing opportunities with the exception of the last few years. Muskellunge in particular provided a big attraction, however other gamefish species existed and offered additional angling opportunities. Data collected during this assessment included a netting survey, documentation of aquatic vegetation, dissolved oxygen, water transparency, alkalinity, and a temperature profile. At this time, Brevoort Lake was noted as being an unproductive shallow large lake with significant wave action resulting in low transparency. Also, based on temperature and chemical characteristics, Brevoort Lake was noted to only be suitable for growth of warmwater fish. Although there were concerns among anglers that Northern Pike were scarce, survey results from the 1942 survey showed a large population present and it was noted that “there is no need for planting” Northern Pike in Brevoort Lake. Finally, managers noted that spawning habitat was adequate for all gamefish with the exception of Walleye which had been stocked previously but failed to produce a fishery and hence stocking was discontinued at that time.

During the 1940s Brevoort Lake was stocked with Bluegill, Northern Pike, Largemouth Bass, Smallmouth Bass and Walleye. Walleye stocking had ceased in 1941 due to poor returns. In 1947 and 1948 a total of 153 brush shelters were constructed and added to Brevoort Lake to improve angling opportunities. By 1949 there were mixed reports of poor or good fishing in Brevoort Lake. Individuals concerned about the presence or abundance of Common Carp stated that fishing was poor, possibly due to the Common Carp. While those that were interested in maintaining the closed spearing season were stating that fishing had improved which justified a continuation or renewal in that regulation. There were growing concerns that spearing may be legalized in 1950 which resort owners opposed by providing letters to MI DNR. MI DNR staff at this time stated that Michigan was liberalizing regulations to promote use and enjoyment of sport and recreation. Also, very little data supported the claim that spearing through the ice resulted in a decline in the fishery. Therefore, there was little reason at this time to renew the current closed spearing regulation on Brevoort Lake. The closed spearing regulation on Brevoort Lake was renewed but discussion continued through to the next decade. By 1946 the “all other lakes” and “Pike” classification of lakes was abandoned and the Northern Pike regulations reverted back to the May 15th date while bass regulations remained at June 25th.

During the 1950s, anglers and MI DNR staff worked though Muskellunge spearing regulations, water level concerns, fish (sucker) die-offs, complaints of stunted Yellow Perch, concerns of poor fishing and a request to stock Muskellunge into Brevoort Lake. There are no records of fish stocking in Brevoort Lake during the 1950s. In preparation for review of the closed spearing regulation MI DNR staff prepared a report listing the existing fishery conditions in Brevoort Lake. Reports from resort owners, conservation officers, and anglers led staff to recommend the that Brevoort Lake be opened to spearing (which may have been enacted by sunset regulation in 1955). Generally fishing reports from the 1950s were fair to good and at times contradictory. Northern Pike fishing was reported as good until summer while Yellow Perch was good with abundant smaller fish present. Alternatively, there were also reports of “exceptional Northern Pike” and “excellent Yellow Perch” during the early 1950s with reports of ‘undersized Yellow Perch’ during the later part of the decade. Discussion during the mid-1950s regarding spearing continued and some expressed interest in closing the winter spearing fishery to only Muskellunge due to their low abundance. The matter of spearing Muskellunge had become increasingly controversial as Brevoort was only one of a few lakes that had been closed to spearing in the past. As the anglers and resort owners expressed concern over the fishing quality in Brevoort Lake, the MI DNR conducted a ‘demonstration survey’ with a goal of showing the abundance and diversity of species present in Brevoort Lake. The demonstration survey also served as an opportunity to answer 15-years of fisheries management questions about growth abundance of various gamefish (e.g., Northern Pike, Muskellunge, Bass, Walleye) and panfish species (e.g., Yellow Perch). At that time all species were ‘holding their own’ in terms of growth with the exception of Yellow Perch which were growing below state average. This demonstration survey was marked as a success as many fisheries related questions were answered by MI DNR staff at this time. The survey was highly advertised, and information was shared through various media outlets to help inform those interested in the Brevoort Lake fishery.

During the late 1950s and early 1960s more Muskellunge were being caught and reported which provided information for the controversial discussion of whether or not to close the winter spearing season on Brevoort Lake. For example, in 1959 it was reported that Northern Pike spearing harvest was ‘high’ and that three or more Muskellunge were speared weighing from 35 to 36 pounds each. MI DNR staff received letters from those interested in maintaining the Northern Pike spear fishery, however realized that allowing Northern Pike spearing would undoubtedly compromise Muskellunge protection efforts given their similar appearance. Letters were also being received in support of closing the spear fishery in attempt to protect the Muskellunge population.

During the 1960s anglers reported Northern Pike as scarce and Yellow Perch as abundant and small. In an effort to help rebuild the Northern Pike population about 6,000 spring fingerling Northern Pike were stocked into Brevoort Lake via the Christiansen’s marsh over three years. Also, during the 1960s several Muskellunge over 30 pounds were reported captured by hook and line or by spear. During the mid to late 1960 there were several reports of dead aquatic organisms found in Brevoort Lake. For example, in 1961 dead alewives were discovered on the shore of Brevoort Lake near Worth’s Bay. Additionally, in 1965 a report of a ‘toxic algal bloom’ which killed several Brevoort Lake mussels (but not fish) occurred. Lastly in January of 1967 there were reports of a heavy die-off of Yellow Perch in Brevoort Lake. While Alewife mortalities may be explained by their life history, there were no conclusions as to the cause of the mussel or Yellow Perch mortalities.

By the 1970s interest to open the winter spear fishery in Brevoort Lake increased. After receiving petitions and letters on the matter either supporting or opposing closure of the winter spear fishery, the MI DNR proposed having a public hearing to discuss the state’s justification for the current management strategy. The reason for closing the Brevoort Lake spearing season was to retain a good spawning population of ‘big fish’ (namely, Muskellunge and Northern Pike) after surveys had found that numbers were depressed. The public meeting was noted as being contentious however ended on a quiet note with MI DNR staff providing information which supported closure of the spear fishery. By the late 1970s Brevoort Lake was surveyed (1976) in attempt to collect gametes from Muskellunge for the purposes of propagation. Additionally, MI DNR staff were interested in gathering growth data from Yellow Perch which had continued to increase in abundance but declined in average size. No Muskellunge were captured during the 1976 survey, however at this time fish were being captured by anglers. Yellow Perch were noted to be smaller and more numerous, however, growth was comparable to the state average and 12 percent of the Yellow Perch caught were greater than 8.0-inches.

By the late 1970s Brevoort Lake was being managed for Walleye, Yellow Perch, and Muskellunge. Attempts were made in 1976, 1978, 1979 and 1980 to collect eggs and milt from Muskellunge for the purpose of providing a source for stocking. In May of 1979 a total of 11 Muskellunge were captured including five females and six males. A total of 2.5 liters of eggs were collected for rearing. A total of 10,260 and 10,106 fingerling Muskellunge were stocked in Brevoort Lake in 1978 and 1979, respectively. Agency staff noted that vandalism at the Thompson State Fishery hatchery resulted in a total loss of Muskellunge production in 1980 and no fish were stocked. By 1978 a Walleye stocking program had been initiated by releasing approximately thirty-thousand and forty-thousand spring fingerling Walleye in 1978 and 1979, respectively.

During the 1980s only Walleye were stocked into Brevoort Lake. Initially, Walleye were stocked annually (in 1980, 1981, 1982 and 1983) to establish a few strong year classes, a common practice in fisheries management. Following the initial establishment phase, Walleye were stocked approximately every other year (in 1986, 1988, and 1989) to continue supplementing the current population, without overburdening year-classes already established through natural reproduction. During the mid-1980s two major habitat projects were proposed for Brevoort Lake. The first project was geared towards stabilizing the southern shore dunes in attempt to prevent sand from entering the lake littoral zone. Managers at that time reported that sand was ‘filling in’ the lake creating a ‘desert’ void of habitat that would otherwise provide refuge for abundant and diverse aquatic life. The sand dune stabilization project was not funded. In addition to the south shore dune stabilization, Brevoort Lake became a site for construction of the “Brevoort Lake Diversity Reef”.

The diversity reef, a 2000-ft rock structure, was constructed in 1984 and 1985 to increase spawning habitat for species such as Walleye, which would in turn provide additional angling opportunities in Brevoort Lake. Surveys conducted during the 1970s suggested that Brevoort Lake had the potential to provide a greater fishery but was limited in available spawning habitat. Due to increasing costs associated with fish production (e.g., stocking) habitat improvement (i.e., rock reef) was suggested as the alternative to improving fish production. The USFS provided $330,000 of the $350,000 needed for completion of the project while MI DNR supplied $20,000 and rock materials (USFS, unpublished report). The project was completed in June of 1985 while surveys were being conducted, using Walleye abundance, as an indicator to help determine the success of the diversity reef. By 1989, several fall and spring assessments had been conducted to evaluate the diversity reef. Data gathered from these assessments prompted managers to recommend a cessation in Walleye stocking for at least five years given that substantial natural reproduction had been documented. Additionally, managers recommended that additional census estimates be conducted for Walleye in the years 1991, 1994, and 1997. By this time, the reef was reported to be working properly as several year-classes of naturally produced Walleye were evident and 50 percent of the Walleye captured were reported to be ‘wild’ (versus ‘stocked’).

During the early 1990s stocking of Walleye ceased following recommendations made after routine census surveys revealed a self-sustaining population had developed. However, by the mid-1990s additional census estimates suggested that the number of adult Walleye in Brevoort Lake subsequently declined to less than 35 percent of what managers determined the lake could support. Despite this decline in adult Walleye abundance, natural reproduction of Walleye continued through this period. Due to the decline in adult Walleye abundance, stocking was resumed, and spring fingerlings were stocked in 1997 and 1998, with a recommendation to resume stocking every three years (triennially) thereafter. Stocking of Walleye every three years was intended to be a conservative supplementation to a modest level of natural reproduction that was being documented in Brevoort Lake. By 1994, the Brevoort Lake water level was being discussed and was later reaffirmed at the court-ordered level of 625.00 feet above sea level. Following this reaffirmation of the water level and a continuation in stocking, managers and anglers discussed dispersing the reef in attempt to submerge more of the rock substrate.

During the period (late 1980s and early 1990s) when Walleye were observed utilizing the reef, spawning was observed at depths less than 2.5 feet deep. Therefore, biologists and anglers began discussing a way to increase the effectiveness of the reef given that much of the reef (40%) was above water due to the ‘break-wall’ design. The diversity reef was modified in the early 2000s by excavating several gaps in the reef which was expected to increase the amount of submerged rock by 65 percent. This modification was expected in increase conditions suitable for Walleye spawning along nearly 50 percent of the north side of the reef. This project was a collaborative effort completed by the Straits Area Sportsmen’s Club, USFS, and MI DNR.

By the late 1990s biologists had determined, after a number of census estimates had been conducted, that a healthy adult Walleye abundance for Brevoort Lake was 4,000 to 5,000 adult Walleye (or 1.0 to 1.25 adult Walleye per acre). Beyond this recommended density, growth of adult Walleye was shown to decline. Fisheries management in Brevoort Lake continued to focus on Walleye by supplementing some level of natural recruitment with stocking spring fingerlings every three years through the 2000s. Routine census estimates and natural recruitment evaluations continued throughout the 1990s and 2000s. Although Walleye were a main focus, a survey conducted in June of 1999 found the fish community to be in good health. For example, Smallmouth Bass were considered to be abundant offering a large density of harvestable fish. Walleye were reported to be in good abundance and anglers reported during the survey that 1999 had been the best year compared to previous years. Largemouth Bass and Black Crappie also had increased in abundance compared to previous survey catches. Following the 1990s, the 2000s were a tumultuous period for the Brevoort Lake ecosystem.

During the 2000s, recreational anglers provided mixed reviews of the fishery requesting additional stocking of Walleye, while some anglers and resort owners requested a cessation in stocking of predators due to the decline in the fishery since stocking began in the early 1980s. Agency staff also began receiving complaints from anglers regarding the growing number of cormorants residing in Brevoort Lake. Concerned about the degree to which cormorants prey upon gamefish species such as Walleye, a cormorant harassment program began in 2005 in attempt to deter cormorants from nesting or feeding near Brevoort Lake. In addition to issues related to cormorant abundance, the presence of Viral Hemorrhagic Septicemia (VHS) resulted in a near statewide moratorium on stocking of Walleye in inland waters. As a result, Walleye stocking ceased until the moratorium was lifted several years later. Invasive Zebra Mussels were first documented in Brevoort Lake in 2005 (USFS-MI DNR internal report) adding to concerns about the stability of the food web.

During the 2010s Walleye stocking continued following a moratorium which was enacted to prevent the spread of VHS. Since 2010, Walleye were stocked in 2011, 2013, 2014, 2015, 2017, and 2018 and consist of plants originating from state, tribal and private sources. Although Walleye are the main focus amongst angler groups, Brevoort Lake has been managed as a ‘mixed-bag’ fishery where Walleye, Northern Pike, Muskellunge, Yellow Perch and various panfish species offer diverse angling opportunities.

* 1. **Current Status of the Fishery**

Three surveys were used to determine the status of the Brevoort Lake fishery. First, a roving creel census survey was conducted in 2014 to quantify the level of harvest and angling pressure in Brevoort Lake. Second, an assessment of the adult Walleye population in Brevoort Lake was conducted by the Sault Ste. Marie Tribe of Chippewa Indians in collaboration with the USFS in 2015 (IFWD 2015). Lastly, a random large lake Status and Trends survey conducted in May 2018 was used to determine the water quality, availability of habitat and status of the Brevoort Lake fishery. Based on data collected from the 2014 creel survey Brevoort Lake received an estimated 19,913 hours of fishing pressure (boat mode). Additional harvest information by species gathered from the 2014 creel census may be found in Table 2. The spring population estimate survey, conducted from April to May 2015 estimated the total number of adult Walleye (age 3 and older) to be approximately 5,733 adults (95% C.I. 5,078 to 6,532) in Brevoort Lake (Table 5). The estimate of 5,733 adults may be translated to read as 1.43 adult Walleye per acre. Growth rates of Walleye were noted to be equal to or above the state average. The publication by Wehrly et al. 2015 was used throughout this document for regional and state comparisons as well as for outlining information and survey results.

Status and Trends survey netting efforts consisted of a total of 55 net nights, 6 seine hauls, and 30 minutes of electrofishing. A total of 1,892 fish totaling 2,046 pounds were captured during the June 2018 Status and Trends survey which included 25 fish species (Table 3). A summary of the Catch per Unit Effort (CPUE) data may be found in Table 4. Several adult Walleye population estimate (Table 5) and fall Walleye recruitment (Table 6) surveys were used as reference in the Analysis and Discussion section to evaluate long-term trend capture information. Previous netting assessments and creel surveys (Lockwood 2000) were also referenced to determine the status of the Brevoort Lake fishery.

Piscivore or gamefish species such as Walleye, Northern Pike, Smallmouth Bass and Muskellunge comprised 62 percent of the catch by number and 94 percent of the total biomass. Benthic species such as Common White Sucker, Logperch, Johnny Darter, and Brown Bullhead comprised 29 percent of the catch by number and 6 percent of the total biomass. Lastly, pelagic species (planktivore-insectivores) such as shiners, minnows, and panfish comprised 9 percent of the catch by number and less than one percent of the total biomass. Results showed that the stand crop of Brevoort Lake was approximately 29.3 pounds per acre.

A total of 5 Muskellunge averaging 42.8 inches comprised 0.3 percent of the catch by number and 6.2 percent of the total biomass. Muskellunge size ranged from 37.0 to 49.0 inches in length and 80 percent of the catch exceeded 42 inches. An insufficient number of age structures (e.g., fin ray, scales) were collected to make robust estimates of growth. A total of four age classes were represented in the catch (Age 9, 11, 12, and 16). The CPUE of Muskellunge captured in trap nets was 0.42 fish per net night. No Muskellunge were captured using any other gear type.

A total of 107 Northern Pike averaging 24.0 inches comprised 5.7 percent of the catch by number and 16.5 percent of the total biomass. Northern Pike size ranged from 10.0 to 37.0 inches and 35 percent of the catch exceeded the minimum size for harvest (24.0 inches). Age distribution indicated sufficient natural recruitment with a total of 9 age classes represented. Three-year-old Northern Pike were determined to be growing more than a half-inch above state average. Four and five-year-old Northern Pike were found to be growing slightly below state average. The average total length of Northern Pike age 3, 4, and 5 was 21.4, 23.1, and 25.0 inches, respectively. The average total length of Northern Pike captured in fyke nets was 23.2 inches. The CPUE of Northern Pike captured in fyke nets was 0.61 fish per net night.

A total of 220 Smallmouth Bass averaging 16.1 inches comprised 11.6 percent of the catch by number and 29.0 percent of the total biomass. Smallmouth Bass size ranged from 8.0 to 21.0 inches in length and 84 percent of the catch met the minimum size for harvest (14.0 inches). Age distribution indicated sufficient natural recruitment with a total of 12 age classes represented. Smallmouth Bass age groups including 2, 3, 4, 5, and 10-year old fish were growth approximately 2 to 3 inches above state average. The catch per unit effort (CPUE) of Smallmouth Bass using electrofishing (0.13 fish per minute) was below average compared to similar sized waterbodies in the region and across the state. CPUE of Smallmouth Bass using trap (9.33 fish per net lift) and fyke (3.71 fish per net night) nets was higher compared to similar sized waterbodies in the region and across the state. No Smallmouth Bass were captured using mini fyke nets, experimental gill nets, or seines.

A total of 96 Yellow Perch averaging 4.9 inches comprised 5.1 percent of the catch by number and 0.2 percent of the total biomass. Yellow Perch size ranged from 1.0 to 11.0 inches in length and 11.0 percent of the catch met the minimum preferred size for harvest (6 inches). Age distribution indicated average natural recruitment with six age classes represented. Four-year-old Yellow Perch were growing about a half-inch below state average. The CPUE of Yellow Perch using electrofishing (0.73 fish per minute) was below average compared to similar sized waterbodies in the region and across the state. CPUE of Yellow Perch using experimental gill net (2.78 fish per net night) was below average compared to similar size waterbodies in the region and across the state. CPUE of Yellow Perch using mini fyke nets (8.2 fish per net night) was high compared to large deep lakes (0.50 fish per net night), however low compared to large shallow lakes across the state (18.9 fish per net night).

A total of 52 Walleye averaging 19.2 inches comprised 2.7 percent of the catch by number and 7.1 percent of the total biomass. Walleye size ranged from 7.0 to 26.0 inches in length and 85 percent of the catch met the minimum size for harvest (15 inches). Age distribution indicated 13 age classes ranging from 1 to 13 years old (2005 to 2017). Ten-year-old Walleye were growing slightly below average. The CPUE of Walleye using electrofishing (0.07 fish per minute) was below average compared to similar sized waterbodies in the region and across the state. The CPUE of Walleye using fyke nets (0.93 fish per net night) was above average compared to similar size waterbodies in the region and nearly three times higher compared to similar sized waterbodies across the state. The CPUE of Walleye in experimental gill nets (0.44 fish per net night) was below average compared to similar sized waterbodies in the region and across the state. The CPUE of Walleye in trap nets (1.67 fish per net night) was slightly below average compared to similar sized waterbodies in the region. However, CPUE of Walleye in trap nets was nearly double compared to similar sized waterbodies across the state.

* 1. **Analysis and Discussion**

**Brevoort Lake water quality and habitat –** Based upon chemical, physical, and biological parameters measured, Brevoort Lake is characterized as being a large, shallow, oligotrophic lake where primary production is limited by the low availability of nutrients (i.e., chlorophyll-a, total phosphorus). Brevoort Lake habitat values (i.e., trees per mile, percent armoring, dwellings per mile) suggest that the lake has not been greatly impacted by human development. However, much of the armoring, construction of dwellings and docks, as well as the removal of submerged trees has occurred along the northern shore which was historically noted as being the more productive shore containing a mix of rock and sand substrate with intermittent growth of bulrush rush (Bassett 1987). The south shore is largely comprised of sand substrates which tends to offer less habitat for macroinvertebrates and fish despite a greater abundance of large woody debris. Since the 1940s Brevoort Lake has been characterized as being a large shallow water body capable providing management opportunities for warmwater fish species (MI DNR, internal report 1943). This classification of being a ‘warmwater’ fishery is best supported by the lack of thermal stratification (e.g., less habitat for cool- or cold-water fishes) during the summer months. Temperature and DO in Brevoort Lake in 2018 was similar to that recorded in the 1940s which showed 70°F (+/- 1°F) water temperatures from the surface of the water to the bottom with sufficient oxygen at all depths to support aquatic organisms.

**Status of lake fishes –** The number of fish species (or species richness) captured (n = 25) suggests Brevoort Lake has above average fish diversity compared to similar sized waterbodies in the region (average 17.3) and across the state (average 13.2). There were two fish (Cisco and Brown Bullhead) captured listed as Species of Great Conservation Concern (SGCN). Comparatively, 61 percent of lakes of similar size in Michigan contain at least one SGCN. One invasive fish species (Sea Lamprey) was captured which is not surprising given that the water-level control structure in Brevoort Lake does not serve as a barrier to Lake Michigan year-round. Approximately 20 percent of the large shallow lakes in Michigan contain at least one invasive species.

The proportional biomass of predators is high (94 percent) compared to available prey (6 percent) which suggests that the fish community in Brevoort Lake is becoming ‘predator heavy’. This is a concern for a waterbody such as Brevoort Lake given the relatively low nutrient availability, low standing crop biomass, current predator stocking levels, and high metabolic demand of predators (4 or 8 to 1 conversion ratio) in the lake. Currently, Brevoort Lake growth rates from gamefish appear satisfactory with some species (e.g., Smallmouth Bass, Rock Bass, and Walleye) growing well compared to other waterbodies in the region and across the state. However, there are examples from Michigan’s NLMMU which suggest that low productivity (Johnson 2019) and a high abundance of predators (Kramer 2005) can negatively affect a fish community, especially when overstocked.

Similar to Brevoort Lake, Lake Michigamme is a large unproductive waterbody located in Marquette and Baraga counties. Although Lake Michigamme has a higher algal biomass compared to Brevoort Lake, it too has limited nutrients, a predator heavy fish population and a low standing crop biomass. Gamefish (i.e., Walleye) growth rates are well below state average in Lake Michigamme given that it may take 7 years or more for a Walleye to reach legal size. Poor growth rates in Lake Michigamme are likely the result of a large biomass of predators and limited productivity needed to produce enough forage. The proportion of predators in Lake Michigamme was recorded in 2002 and 2016 and was reported to be 87 and 89 percent biomass, respectively. South Manistique Lake is more productive than Brevoort Lake and Lake Michigamme, however the history of fisheries management by local sports groups provides an example whereby continued stocking of predators (i.e., Walleye) at high rates negatively affected the fish community by reducing available forage. During the late 1980s and 1990s South Manistique Lake was heavily stocked with Walleye subsequently causing a crash of the forage base resulting in Walleye growth rates 3.0 inches below state average (Kramer 2005).

Good growth of gamefish suggests that Brevoort Lake, in its current state, supports a healthy abundance of forage (e.g., food, minnows) to maintain a fish community dominated by predators. However, managers of Brevoort Lake should proceed with caution regarding stocking in attempt to avoid a collapse of the forage base. Prudent management of stocked gamefish (i.e., Walleye) will help to ensure the fish community in Brevoort Lake remains in healthy balance.

**Muskellunge**

Historically, Brevoort Lake was well known as an attractive Muskellunge fishery up until the 1970s. During the early half of the 20th century Brevoort Lake provided a year-round fishery including winter spearing and summer hook-and-line opportunities. The mid-20th century was a period when anglers and managers alike debated the opportunity provided versus the potential risk of spearing Muskellunge during the winter spear fishery. During the later half of the 20th century the number of Muskellunge seemed to be declined prompting efforts to stock Brevoort Lake using eggs and milt gathered from the lake during the early spring. These efforts resulted in several stockings in the late 1970s and in 1994. Currently, the abundance of Muskellunge in Brevoort Lake is unknown. Although a total of 5 fish were captured during a 2018 survey, the surveyed conducted and the methods used are not typically used to make robust inferences about the abundance of Muskellunge.

In recent years, there has been limited discussion as to whether Brevoort Lake could serve as a potential brood-source for future stocking. However, there is currently not enough information relative to the Muskellunge population to justify such a decision. Should Brevoort Lake be considered in the future as a brood source, data are needed relative to the population size and genetic diversity of the population prior to the onset of gamete collection. Importantly, Brevoort Lake should contain a self-sustaining population of Muskellunge prior to being considered for gamete collection. Based upon the size of Brevoort Lake (4,001 acres) and what we understand to be a healthy density (Smith et al. 2016a) of Muskellunge in the region (0.13 to 0.33 adults per acre) Brevoort Lake should contain a self-sustaining population of at least 520 to 1,320 individuals prior to being considered as a brood source. Should a survey be conducted to gather census information, tissue samples may also be collected and later analyzed for genetics analysis which may be used to guide future stocking decisions.

Generally, the Northern Lake Michigan Management Unit provides several opportunities to capture Muskellunge. These angling opportunities include small-lake casting (Bauman 2018a, Bauman 2018b) as well as large-lake trolling options. Brevoort Lake offers large-lake trolling and small-lake casting by focusing along the north shore and bays, respectively. This opportunity is for Muskellunge is unique for the central and eastern upper peninsula. Based on lake size and access, a Muskellunge angler could troll the entire shoreline, stop for lunch at a nearby diner, and then return to troll for the evening bite in Brevoort Lake. Based on angler reports, Brevoort Lake experienced 18 trips targeting Muskellunge from 2016 to 2017. A total effort of 125 hours in 18 trips resulted in 7 fish being reported captured (angling CPUE = 18 hours per fish) in Brevoort Lake. In conjunction with the state of Michigan’s Muskellunge Management Plan (Smith et al. 2016a) future management efforts should focus on preserving the available littoral habitat that is available for spawning, while working to engage the public in activities that promote shoreline protection and improvement. Angler groups should be encouraged to continue sharing catch and release reports for Muskellunge captured in Brevoort Lake.

**Northern Pike**

The Brevoort Lake Northern Pike population is growing at a rate comparable to or above state average while supporting a low-density population. There are several metrics used to gauge the status of Northern Pike populations which in turn provides guidance for current regulations. For example, one metric used to evaluate Northern Pike population size includes comparing the average size of fish captured using fyke nets. Northern Pike populations with low densities have average lengths in fyke net catches of 22 inches or greater (Smith et al. 2016b). Northern Pike captured in Brevoort Lake using fyke nets averaged 23.2 inches. These data suggest that the Northern Pike population in Brevoort Lake is at low density (hence, higher average size). An additional metric for evaluating Northern Pike density includes comparisons of fyke net CPUE compared to the median state fyke net CPUE. The CPUE for Northern Pike captured in Brevoort Lake using fyke nets was below the states median catch rate which again suggests that densities are low. Lastly, growth metrics of ages 3, 4, and 5-year-old Northern Pike may be used to gauge the rate of growth in a waterbody. Average total lengths of ages 3, 4, and 5-year-old Northern Pike are above the state median which suggests that the Brevoort Lake Northern Pike population has above average growth, suggesting that densities are low and forage is abundant enough to support higher than average growth rates. Based on the state of Michigan’s Northern Pike Management Plan (Smith et al. 2016b), current Northern Pike regulations are appropriate to continue meeting the Northern Pike management goals in Brevoort Lake.

**Smallmouth Bass**

The Smallmouth Bass population in Brevoort Lake is in a healthy state considering growth, mortality rate, and CPUE values observed. For example, growth of Smallmouth Bass in the upper peninsula of Michigan is often slightly below the state average for most gamefish species. However, Smallmouth Bass are growing 2 to 3 inches above state average. Also, fishery managers consider natural and harvest mortality to be low for a species when 8 to 10 or more age classes are represented in the survey catch. There were 12 age classes of Smallmouth Bass represented in Brevoort Lake suggesting that harvest and natural mortality are low, and fish often recruit from one year to the next. The CPUE of Smallmouth Bass in trap and fyke nets suggests that Brevoort Lake has a Smallmouth Bass population higher in abundance compared to other waterbodies in the region and across the state. These findings support documentation from previous years which states that Brevoort Lake provides exceptional Smallmouth Bass angling opportunities. Within the last decade, Brevoort Lake has had 19 Master Angler awards and more than 50 percent of those entries were Smallmouth Bass ranging in size from 21 to 25 inches.

**Walleye**

The Walleye population in Brevoort Lake is in a healthy state considering, growth, mortality, CPUE, as well as data from historical and recent adult and juvenile surveys. For example, growth of Walleye from recent surveys was found to be equal to or slightly higher compared to the state average. Also, fishery managers consider natural and harvest mortality to be low for a species when 8 to 10 age classes are represented in the survey catch. There were 13 age classes of Walleye represented in Brevoort Lake suggesting that harvest and natural mortality are low, and fish often recruit from one year to the next. Common and effective methods used to capture Walleye for abundance estimates include the use of fyke nets, and trap nets. The CPUE for Walleye captured using each of these gear types during the 2018 Status and Trends survey was above the regional and state average for similar sized waterbodies.

From 1984 to 2015, there have been 12 population estimate surveys conducted to quantify the abundance of adult Walleye (age 3 and older) in Brevoort Lake. Over that period, the average density of adult Walleye was 1.09 adults per acre (or 4,357 adults) with a range of 0.4 to 2.1 adults per acre (Tables 5 and 6). Based upon previous population estimates, coupled with age and growth analysis, a density of 1.2 adults per acre is what is considered healthy for Brevoort Lake. As adult Walleye abundance approaches 1.5 to 2.0 adults per acre growth begins to decline as forage abundance declines. The current (2015) density of 1.43 adult Walleye per acre is higher compared to the long-term average and compared to other unproductive waterbodies in the region (Bauman 2018c, Bauman 2019). Therefore, the current status of the adult Walleye in Brevoort is considered to be in a healthy state.

The current density of adult Walleye also tends to correspond with reports of favorable fishing success, however angler reports are highly variable and often inconsistent. For example, a creel census conducted in 1996 (Lockwood 2000) found that the harvest rate of Walleye in Brevoort Lake was 1 adult Walleye per 68 hours of angling effort. The 1996 harvest rate corresponds to when the density of adult Walleye was 0.42 adult Walleye per acre (low abundance). Comparatively, a creel census conducted in 2014 found that the harvest rate of Walleye was 1 adult Walleye per 147 hours of angling effort. The 2014 harvest rate corresponds to when the density of adult Walleye was near 1.43 adults per acre (high abundance). Therefore, higher or lower rates of harvest (e.g., fishing success) do not relate to Walleye density and may not be a reliable indicator of fish abundance in Brevoort Lake. Similar conditions exist in other waterbodies where the density of adult Walleye does not correlate with angler catch rates. For example, VanDeValk et al. (2005) found that angler catch rates were better explained by the density of prey and subsequent growth rates of adult Walleye. As prey became limited and Walleye growth rates declined, angler catch rates increased in Lake Oneida. The relationship of prey abundance, growth rates of Walleye, and angler catch rates may explain any unfavorable angler reports received from Brevoort Lake in recent years.

In addition to a healthy adult Walleye population, Brevoort Lake has intermittent natural reproduction and documented survival of stocked spring fingerlings. For example, in 2008 a population estimate survey found a density of 1.94 adult Walleye per acre in Brevoort Lake. Of those adult Walleye captured, 90 percent were from the 2005 year-class when no stocking had occurred. This large year-class of natural reproduction was likely a result of a successful cormorant harassment program which began in 2005 when numbers of adult Walleye were low. Low population numbers of adult Walleye coupled with a cormorant harassment program ensured that food resources would be available to young Walleye naturally produced. Additionally, an example which serves to demonstrate the success of spring fingerling stocking includes population estimates which were conducted during the late 1980s. Based on back-calculated ages from captured adults, spring fingerlings were reported to survive to adulthood at an average rate of 15 percent ranging from 2 to 28 percent (Bassett 2006). These data pertaining to natural reproduction and high survival of stocked spring fingerlings, in part, guides the current spring fingerling stocking rate (10 per acre). Additional metrics are used to evaluate survival of stocked and naturally produced Walleye in Brevoort Lake and also help to guide managers in establishing data-driven stocking rates.

Aside from adult census estimates, monitoring fall survival of stocked and naturally produced spring fingerlings has occurred 15 times since 1984 using a Serns indices (Serns 1982). Serns is a crude index used to estimate the survival and abundance of young of year and Age 1 Walleye using data collected during the fall. In more recent years, stocked Walleye have been marked with oxytetracycline which enables managers to differentiate between stocked and wild fingerlings. The average density of young of year Walleye in Brevoort Lake was 3.0 per acre which is indicative of good recruitment in a nutrient limited lake (i.e., Brevoort Lake) (Gilbert and Hennessy 2014). During years when stocking did not occur, the average density of young of year Walleye in Brevoort Lake was 2.3 young of year per acre, compared to years when spring fingerlings were stocked when the average density was 3.8 per acre. Therefore, on average, stocking of spring fingerlings at the conservative rate of 5 to 10 fish per acre results in a fall fingerling density increase of 65 percent compared to non-stocked years. Data from Serns indices, adult census estimates, documented natural reproduction, and the back-calculated estimates of spring fingerling survival have provided information needed to guide stocking levels in Brevoort Lake from the 1980s through the 2010s.

More recently, a fall survey conducted in 2015 (IFWD 2015) demonstrated the success of stocking spring fingerling Walleye by capturing young of year and juvenile age classes which were largely of stocked origin. For example, of the young of year and juvenile fish captured in fall of 2015, more than 93 percent were stocked as spring fingerlings which was verified by the presence of oxytetracycline marks. From 2011 back to 2002, Brevoort Lake was stocked only three times (i.e., 2003, 2006, and 2011) at a conservative rate of approximately 5 spring fingerling Walleye per acre. Serns estimates in addition to data from the 2015 survey suggest that stocked spring fingerling Walleye are surviving. Therefore, the current spring fingerling stocking rate (10 fish per acre) and frequency are appropriate especially since some natural recruitment exists. Most importantly, these results suggest that more recent (2013 to present) stocking rates of spring fingerlings and increased interest in stocking fall fingerlings may be in excess of what is needed to maintain a healthy abundance of adult Walleye in Brevoort Lake.

There has been considerable interest in stocking fall fingerlings in addition to spring fingerlings. For example, in 2018 the Straits Area Sportsmen’s Club (with MI DNR permit) stocked 3,000 fall fingerling Walleye into Brevoort Lake due to concerns associated with spring fingerling survival. Given that the average abundance of fall fingerling Walleye in Brevoort Lake is 12,178 (from 1984 to 2013), that stocking event likely increased the number of fall fingerlings in Brevoort Lake by 27 percent. There is additional interest on behalf of the Strait’s Area Sportsmen’s Club to rear and stock fall fingerling Walleye again in 2019 in addition to stocking spring fingerlings. This is concerning given the current state of the Brevoort Lake fish community (e.g., predator-heavy, healthy Walleye population). Stocking fall fingerlings two years consecutively is typically not approved in several states (MDNR 2004, Gilbert and Hennessy 2014) due to the increased likelihood that the fish community will be negatively affected. This rate of stocking fall fingerlings, in additional to prescribed stocking of spring fingerlings, could negatively impact young age classes of Walleye by increasing competition subsequently compromising growth and survival.

Given Walleye adult abundance, adult growth, and documented success of stocking spring fingerlings, there is no biological justification for stocking fall fingerlings in Brevoort Lake at this time. Also, the high proportion of predators (94%) and low productivity of the lake suggests that the current rate (2013 to present) and frequency by which Brevoort Lake has been stocked may be higher than what is biologically or economically necessary.

**Yellow Perch**

Brevoort Lake, like many inland lakes in Michigan, has a Yellow Perch population which fluctuates from being overabundant and undersized to less abundant with above average growth. These fluctuations are natural and are likely the result of a fluctuating predator populations (e.g., Northern Pike and Walleye) which consume Yellow Perch as prey at multiple life periods. Preliminary discussions with anglers suggest that the number of undersized Yellow Perch that exist in Brevoort Lake was underrepresented in the 2018 Status and Trends survey effort. Therefore, it is likely that Brevoort Lake is currently experiencing a period characterized by overabundant and undersized or ‘stunted’ Yellow Perch. Currently, 1 in 10 Yellow Perch is of the preferred size for harvest (6 inches). Since 2013 a more consistent stocking program has existed for Walleye in Brevoort Lake. Walleye, which are a well-known regulator of Yellow Perch abundance will begin to recruit to the population and consume Yellow Perch. This abundant and undersized Yellow Perch population will likely shift to a less abundant, larger sized population in upcoming years. A decrease in Yellow Perch abundance could be followed by an increase in Walleye angler catch rates (VanDeValk et al. 2005).

1. **Management Direction**

Table 1. Species, date, year, and number of fish stocked in Brevoort Lake, Mackinac County, Michigan.

|  |  |  |  |
| --- | --- | --- | --- |
| Species | Date | Year | Number Stocked |
| Walleye | 5-16-1889 | 1889 | 2220000 |
| Lake Trout | 4-6-1894 | 1894 | 9000 |
| Lake Trout | 4-16-1895 | 1895 | 10000 |
| Lake Trout |  | 1905 | 45000 |
| Largemouth Bass |  | 1905 | 800 |
| Walleye |  | 1905 | 350000 |
| Smallmouth Bass |  | 1910 | 1000 |
| Brook Trout |  | 1933 | 7000 |
| Brook Trout |  | 1933 | 8000 |
| Brook Trout |  | 1933 | 4500 |
| Walleye |  | 1933 | 150000 |
| Walleye |  | 1933 | 150000 |
| Yellow Perch |  | 1933 | 2000 |
| Yellow Perch |  | 1934 | 4400 |
| Yellow Perch |  | 1934 | 510000 |
| Walleye |  | 1935 | 180000 |
| Walleye |  | 1935 | 120000 |
| Walleye |  | 1936 | 300000 |
| Yellow Perch |  | 1936 | 10500 |
| Yellow Perch |  | 1936 | 9600 |
| Walleye |  | 1937 | 630000 |
| Bluegill |  | 1938 | 22500 |
| Large/Smallmouth Bass |  | 1938 | 625 |
| Large/Smallmouth Bass |  | 1938 | 800 |
| Walleye |  | 1938 | 500000 |
| Bluegill |  | 1939 | 15000 |
| Large/Smallmouth Bass |  | 1939 | 1800 |
| Walleye |  | 1939 | 1200000 |
| Yellow Perch |  | 1939 | 11000 |
| Bluegill |  | 1940 | 9000 |
| Large/Smallmouth Bass |  | 1940 | 375 |
| Walleye |  | 1940 | 750000 |
| Bluegill |  | 1941 | 10000 |
| Large/Smallmouth Bass |  | 1941 | 1000 |
| Large/Smallmouth Bass |  | 1941 | 139 |
| Walleye |  | 1941 | 360000 |
| Large/Smallmouth Bass |  | 1942 | 2000 |
| Northern Pike |  | 1961 | 35 |
| Northern Pike |  | 1962 | 32 |
| Northern Pike |  | 1963 | 60 |
| Northern Pike |  | 1964 | 60 |
| Northern Pike |  | 1965 | 60 |
| Northern Pike |  | 1967 | 100 |
| Northern Pike |  | 1968 | 42 |
| Northern Pike |  | 1969 | 65 |
| Northern Pike |  | 1970 | 200000 |
| Northern Pike |  | 1974 | 8000 |
| Northern Pike |  | 1976 | 7500 |
| Northern Pike |  | 1977 | 15000 |
| Muskellunge |  | 1978 | 10260 |
| Walleye |  | 1978 | 32613 |
| Muskellunge | 10/15/1979 | 1979 | 14 |
| Muskellunge | 07/02/1979 | 1979 | 10,106 |
| Walleye | 08/29/1979 | 1979 | 39,817 |
| Walleye | 08/18/1980 | 1980 | 25,864 |
| Walleye | 08/18/1980 | 1980 | 24,165 |
| Walleye | 08/20/1981 | 1981 | 5,394 |
| Walleye | 05/25/1982 | 1982 | 2,081,300 |
| Walleye | 07/19/1982 | 1982 | 10,581 |
| Walleye | 08/11/1983 | 1983 | 6,800 |
| Walleye | 07/22/1983 | 1983 | 15,339 |
| Walleye | 06/29/1986 | 1986 | 31,070 |
| Walleye | 07/01/1986 | 1986 | 18,467 |
| Walleye | 07/02/1986 | 1986 | 15,732 |
| Walleye | 07/12/1986 | 1986 | 34,812 |
| Walleye | 06/28/1988 | 1988 | 43,768 |
| Walleye | 07/05/1989 | 1989 | 10,155 |
| Muskellunge | 11/02/1994 | 1994 | 1,420 |
| Walleye | 07/04/1997 | 1997 | 20,534 |
| Walleye | 06/29/1998 | 1998 | 8,160 |
| Walleye | 06/20/2000 | 2000 | 22,665 |
| Walleye | 06/28/2003 | 2003 | 19,433 |
| Walleye | 06/21/2006 | 2006 | 9,787 |
| Walleye | 06/23/2006 | 2006 | 12,158 |
| Walleye | 06/23/2011 | 2011 | 22,000 |
| Walleye | 07/09/2013 | 2013 | 14,285 |
| Walleye | 07/10/2013 | 2013 | 6,180 |
| Walleye | 07/11/2013 | 2013 | 5,400 |
| Walleye | 07/12/2013 | 2013 | 1,740 |
| Walleye | 07/16/2013 | 2013 | 10,730 |
| Walleye | 06/25/2014 | 2014 | 10,000 |
| Walleye | 06/28/2015 | 2015 | 28,158 |
| Walleye | 06/29/2015 | 2015 | 23,104 |
| Walleye | 06/27/2017 | 2017 | 19,752 |
| Walleye | 06/27/2017 | 2017 | 30,498 |
| Walleye | 10/09/2018 | 2018 | 3,000 |

Table 2. Species catch (harvest) per hour and number captured by month (boat mode) during the 1996 and 2014 creel survey on Brevoort Lake, Mackinac County.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Catch per Hour** | **May** | **June** | **July** | **August** | **Sept** | **Season** |
| **Species** | 1996 | 2014 | 1996 | 2014 | 1996 | 2014 | 1996 | 2014 | 1996 | 2014 | 1996 | 2014 | 1996 | 2014 |
| Walleye | 0.0146 | 0.0068 | 82 | - | 259 | 62 | 11 | 47 | 30 | 26 | - | 0 | 383 | 135 |
| Northern pike | 0.0078 | 0.01 | 49 | - | 70 | 94 | 45 | 13 | 40 | 73 | - | 19 | 204 | 200 |
| Largemouth bass | - | 0.0002 | - | - | - | 0 | - | 0 | - | 0 | - | 4 | - | 4 |
| Smallmouth bass | 0.0043 | 0.0082 | 0 | - | 36 | 69 | 37 | 19 | 40 | 25 | - | 50 | 113 | 163 |
| Yellow Perch | 0.2699 | 0.4895 | 88 | - | 290 | 560 | 1,314 | 2,691 | 5,415 | 2,724 | - | 3,773 | 7,106 | 9,748 |
| Bluegill | 0.0151 | 0.0893 | 0 | - | 4 | 299 | 127 | 479 | 267 | 819 | - | 181 | 398 | 1,778 |
| Pumpkinseed | 0.0025 | 0.0007 | 0 | - | 0 | 0 | 26 | 0 | 39 | 0 | - | 14 | 65 | 14 |
| Rock bass | 0.0137 | 0.0112 | 16 | - | 151 | 22 | 92 | 60 | 102 | 141 | - | 0 | 362 | 222 |
| Brown bullhead | 0.0008 | 0.0016 | 0 | - | 3 | 0 | 2 | 14 | 16 | 18 | - | 0 | 20 | 32 |
| Green Sunfish | - | 0.0071 | - | - | - | 0 | - | 132 | - | 9 | - | 0 | - | 141 |
| Total Harvest | **0.3287** | **0.6246** | **235** | **0** | **813** | **1,106** | **1,654** | **3,455** | **5,949** | **3,835** | **0** | **4,041** | **8,651** | **12,437** |

Table 3. Species and number of fish captured by gear type including electrofishing (boom), trap net (trap), large mesh fyke net (LM Fyke), small mesh fyke net (SM Fyke), experimental gill net (Exp Gill), and Seine. Data were collected during a random Status and Trends survey conducted in spring of 2018.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Species | Boom | Trap | LM Fyke | SM Fyke | Exp Gill | Seine | Total |
| Bluegill | 0 | 4 | 2 | 13 | 0 | 0 | 19 |
| Bluntnose Minnow | 5 | 0 | 0 | 27 | 0 | 0 | 32 |
| Bowfin | 0 | 20 | 4 | 0 | 0 | 0 | 24 |
| Brown Bullhead | 3 | 402 | 25 | 1 | 2 | 0 | 433 |
| Brook Stickleback | 0 | 0 | 0 | 2 | 0 | 1 | 3 |
| Common Carp | 0 | 2 | 0 | 0 | 0 | 0 | 2 |
| Cisco | 0 | 0 | 0 | 0 | 2 | 0 | 2 |
| Common Shiner | 10 | 0 | 0 | 16 | 0 | 0 | 26 |
| White Sucker | 3 | 10 | 16 | 0 | 15 | 0 | 44 |
| Emerald Shiner | 2 | 0 | 0 | 3 | 0 | 0 | 5 |
| Golden Shiner | 3 | 0 | 0 | 4 | 0 | 0 | 7 |
| Johnny Darter | 0 | 0 | 0 | 496 | 0 | 0 | 496 |
| Largemouth Bass | 4 | 14 | 0 | 0 | 0 | 0 | 18 |
| Logperch | 2 | 0 | 0 | 12 | 0 | 0 | 14 |
| Central Mudminnow | 2 | 0 | 0 | 22 | 0 | 0 | 24 |
| Muskellunge Great Lakes | 0 | 5 | 0 | 0 | 0 | 0 | 5 |
| Northern Pike | 0 | 52 | 17 | 0 | 38 | 0 | 107 |
| Rock Bass | 4 | 15 | 168 | 21 | 3 | 0 | 211 |
| Sand Shiner | 19 | 0 | 0 | 2 | 0 | 2 | 23 |
| Sea Lamprey | 0 | 1 | 2 | 0 | 0 | 0 | 3 |
| Smallmouth Bass | 4 | 112 | 104 | 0 | 0 | 0 | 220 |
| Splake Hybrid | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| Spottail Shiner | 1 | 0 | 0 | 24 | 0 | 0 | 25 |
| Walleye | 2 | 20 | 26 | 0 | 4 | 0 | 52 |
| Yellow Perch | 22 | 0 | 0 | 49 | 25 | 0 | 96 |

Table 4. Species and Catch per Unit Effort (CPUE) of fish captured by gear type including electrofishing (boom), trap net (trap), large mesh fyke net (LM Fyke), small mesh fyke net (SM Fyke), experimental gill net (Exp Gill), and Seine. Data were collected during a random Status and Trends survey conducted in spring of 2018.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Species | Boom | Trap | LM Fyke | SM Fyke | Exp Gill | Seine |
| Bluegill | 0.00 | 0.33 | 0.07 | 2.17 | 0.00 | 0.00 |
| Bluntnose Minnow | 0.17 | 0.00 | 0.00 | 4.50 | 0.00 | 0.00 |
| Bowfin | 0.00 | 1.67 | 0.14 | 0.00 | 0.00 | 0.00 |
| Brown Bullhead | 0.10 | 33.50 | 0.89 | 0.17 | 0.22 | 0.00 |
| Brook Stickleback | 0.00 | 0.00 | 0.00 | 0.33 | 0.00 | 0.17 |
| Common Carp | 0.00 | 0.17 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cisco | 0.00 | 0.00 | 0.00 | 0.00 | 0.22 | 0.00 |
| Common Shiner | 0.33 | 0.00 | 0.00 | 2.67 | 0.00 | 0.00 |
| White Sucker | 0.10 | 0.83 | 0.57 | 0.00 | 1.67 | 0.00 |
| Emerald Shiner | 0.07 | 0.00 | 0.00 | 0.50 | 0.00 | 0.00 |
| Golden Shiner | 0.10 | 0.00 | 0.00 | 0.67 | 0.00 | 0.00 |
| Johnny Darter | 0.00 | 0.00 | 0.00 | 82.67 | 0.00 | 0.00 |
| Largemouth Bass | 0.13 | 1.17 | 0.00 | 0.00 | 0.00 | 0.00 |
| Logperch | 0.07 | 0.00 | 0.00 | 2.00 | 0.00 | 0.00 |
| Central Mudminnow | 0.07 | 0.00 | 0.00 | 3.67 | 0.00 | 0.00 |
| Muskellunge Great Lakes | 0.00 | 0.42 | 0.00 | 0.00 | 0.00 | 0.00 |
| Northern Pike | 0.00 | 4.33 | 0.61 | 0.00 | 4.22 | 0.00 |
| Rock Bass | 0.13 | 1.25 | 6.00 | 3.50 | 0.33 | 0.00 |
| Sand Shiner | 0.63 | 0.00 | 0.00 | 0.33 | 0.00 | 0.33 |
| Sea Lamprey | 0.00 | 0.08 | 0.07 | 0.00 | 0.00 | 0.00 |
| Smallmouth Bass | 0.13 | 9.33 | 3.71 | 0.00 | 0.00 | 0.00 |
| Splake Hybrid | 0.00 | 0.00 | 0.04 | 0.00 | 0.00 | 0.00 |
| Spottail Shiner | 0.03 | 0.00 | 0.00 | 4.00 | 0.00 | 0.00 |
| Walleye | 0.07 | 1.67 | 0.93 | 0.00 | 0.44 | 0.00 |
| Yellow Perch | 0.73 | 0.00 | 0.00 | 8.17 | 2.78 | 0.00 |

Table 5. Brevoort Lake adult Walleye (age three and older) density, number (N) of adults per acre, and 95% confidence limit estimates conducted by USFS, tribal, and state staff.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Year | Adult Walleye | N Adults per Acre | LCI | HCI |
| 1985 | 5775 | 1.44 | 1.14 | 1.97 |
| 1986 | 8518 | 2.13 | 1.78 | 2.66 |
| 1989 | 5532 | 1.38 | 1.02 | 1.68 |
| 1991 | 5049 | 1.26 | 0.95 | 1.86 |
| 1994 | 2900 | 0.72 | 0.58 | 0.98 |
| 1996 | 2097 | 0.52 | 0.42 | 0.71 |
| 1998 | 1702 | 0.43 | 0.30 | 0.71 |
| 2001 | 1759 | 0.44 | 0.34 | 0.63 |
| 2005 | 1233 | 0.31 | 0.25 | 0.39 |
| 2008 | 7780 | 1.94 | 1.66 | 2.35 |
| 2011 | 4251 | 1.06 | - | - |
| 2015 | 5773 | 1.44 | 1.27 | 1.63 |
| **AVG** | **4364** | **1.09** | **0.88** | **1.42** |

Table 6. Year, adult Walleye (WAE) per acre, number of spring fingerling WAE stocked (SF WAE), WAE stocking rate, young of year WAE per Mile (YOY/Mile), YOY abundance in Brevoort Lake from 1984 to 2018. Adult abundance is based on several multi-agency (mostly USFS) census surveys Number of SF WAE Stocked was derived from MI DNR Stocking database, number of YOY per Mile was derived from multi-agency fall recruitment assessments, YOY abundance are estimates based on Serns (1982).

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Year | Adult WAE/acre | SF WAE Stocked | Stocking Rate | YOY/Mile | YOY Abundance |
| 1984 | - | 0 | - | 6.65 | 6,229 |
| 1985 | 1.44 | 0 | - | 5.48 | 5,131 |
| 1986 | 2.13 | 100,081 | 8.70 | 6.23 | 5,837 |
| 1987 | - | 0 | - | 3.24 | 3,036 |
| 1988 | - | 43,768 | 10.94 | 30.02 | 28,102 |
| 1989 | 1.38 | 10,155 | 2.54 | 33.38 | 31,250 |
| 1990 | - | 0 | - | - | - |
| 1991 | 1.26 | 0 | - | 17.58 | 16,463 |
| 1992 | - | 0 | - | 19.13 | 17,911 |
| 1992 | - | 0 | - | 10.63 | 9,947 |
| 1993 | - | 0 | - | - | - |
| 1994 | 0.72 | 0 | - | - | - |
| 1995 | - | 0 | - | 33.25 | 31,130 |
| 1996 | 0.52 | 0 | - | - | - |
| 1997 | - | 20,534 | 5.13 | 3.41 | 3,197 |
| 1998 | 0.43 | 8,160 | 2.04 | - | - |
| 1999 | - | 0 | - | - | - |
| 2000 | - | 22,665 | 5.66 | - | - |
| 2001 | 0.44 | 0 | - | - | - |
| 2002 | - | 0 | - | - | - |
| 2003 | - | 19,433 | 4.86 | - | - |
| 2004 | - | 0 | - | - | - |
| 2005 | 0.31 | 0 | - | - | - |
| 2006 | - | 21,945 | 3.04 | 23.76 | 22,248 |
| 2007 | - | 0 | - | - | - |
| 2008 | 1.94 | 0 | - | 2.06 | 1,928 |
| 2009 | - | 0 | - | 0.07 | 260 |
| 2010 | - | 0 | - | - | - |
| 2011 | 1.06 | 22,000 | 5.50 | - | - |
| 2012 | - | 0 | - | - | - |
| 2013 | - | 38,335 | 3.57 | 0.00 | 0.00 |
| 2014 | - | 10,000 | 2.50 | - | - |
| 2015 | 1.44 | 51,262 | 12.81 | - | - |
| 2016 | - | 0 | - | - | - |
| 2017 | - | 50,250 | 12.56 | - | - |
| 2018 | - | 3,000**\*** | 0.75 | - | - |

**\*** denotes fall fingerling stocking (fall 2018).

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