Upper Mississippi River Pool 8

Long Term Resource Monitoring - 2018 Status Report

An element of the

Upper Mississippi River Restoration Program

Wisconsin Department of Natural Resources

Mississippi River Monitoring Field Station

2630 Fanta Reed Road, La Crosse, WI 54603

http://www.umesc.usgs.gov/field_stations/fs2/lacrosse.html

Executive Summary

This report summarizes the annual increment of monitoring work accomplished in 2018 by the Wisconsin Department of Natural Resources' La Crosse Field Station for the Long Term Resource Monitoring Element (LTRM) of the Upper Mississippi River Restoration Program (UMRR). Herein, we report data and observations for hydrology, water quality, aquatic vegetation, and fish in Navigation Pool 8 of the Mississippi River, emphasizing the current sampling year in the context of recent and historic trends.

Discharge was high in 2018, exceeding 100,000 cfs in May, June, and October. This resulted in the third highest mean daily discharge during the LTRM period of record, also during the May-September growing season. The spring flood was of average duration and magnitude, but continued a recent pattern of occurring later than usual, in May.

Water temperatures were cooler than normal during spring, summer, and fall. Total suspended solid concentrations were elevated during spring sampling and lower than normal in summer. Chlorophyll a concentrations were below normal, with summer being notably low, likely related to high discharge and cooler water temperatures. Total phosphorus concentrations were higher than normal in spring and lower than normal in summer. Total nitrogen concentrations were higher than normal, with notably high concentrations in fall, and were at or above the U.S. Environmental Protection Agency "healthy ecosystem" levels in all four seasons. Dissolved oxygen concentrations were normal (typically at or near 100% saturation), with very few sites having extreme high or low concentrations. Ice was much thicker than usual during the three-week sampling period in January, but snow depth was very thin (which may partially explain the thicker ice).

Prevalence (percent frequency occurrence) of all forms of aquatic vegetation remained high in 2018, despite high discharges and deep sampling depths. The prevalence of rooted/floating-leaved plants decreased from 40.2% in 2016 to 29.3% in 2018, and both non-rooted floating and filamentous algae life forms were noticeably lower in 2018 relative to 2016-2017. Submersed and emergent plants, however, remained at levels similar to those in 2016-2017. Two native aquatic plants, wild celery and wild rice play an especially important role in support of migratory waterfowl and other wildlife. Wild celery increased dramatically between 2000 and 2010 and remains detected at about 40% of sites. Wild rice detection frequencies have increased from near zero in 2005 to over 24% of sites in 2018. Invasive Eurasian watermilfoil and curly pondweed remain detected at about 15-20% of sites, although curly pondweed is approximately three times more abundant during its maximum biomass period in May.

Fish sampling yielded 19,539 fish, a large decline after 2017's record catch. Species richness remained about average, at 62 species. Bluegill and Weed Shiner dominated the catch, numerically, and Common Carp was the dominant species, by weight. Fish community diversity increased in 2018 to the highest level since the mid-1990's. Several rare fish species were collected, including a Crystal Darter, which is listed as endangered in Wisconsin. Among sportfishes, Flathead Catfish, Northern Pike, and Smallmouth Bass populations are trending up; whereas, most others are exhibiting stable trends. Management action to bolster populations seems warranted for Sauger, as catch-per-unit-effort has remained at low levels for almost two decades.

Hydrograph

Methods

Pre-1988 discharge data were previously obtained from the U.S. Army Corps of Engineers' (Corps) website for water information on the Mississippi River, but is no longer available. For 1988 and following, we requested a dataset of daily discharge data directly from St. Paul district Corps water personnel. For 2018, we used discharge estimates from Lock and Dam 8 at Genoa, WI, as we have done starting with the 2013 report. We report daily discharge values, using values recorded at 1300 or 1400 hrs for recent years, and at 0800 hrs from 1959-1987.

A historical hydrograph was constructed by computing the mean daily discharge values from the years 1959-2017. The daily discharge for 2018 was then overlain on the long-term daily mean to observe departure from typical conditions. Additional analyses examined annual, growing season (May–September), and spring flood discharge characteristics. Mean discharge was calculated from daily values, plotted for years 1993-2018 (LTRM period of record for stratified random sampling), and overlain on a plot containing the historic mean, 10th, and 90th percentiles for all years (1959 to 2018). Mean growing season discharge was calculated and plotted similarly to the mean annual discharge. The spring flood pulse was characterized according to timing, duration, and magnitude. The timing of the spring flood was ascribed to the month (March, April, or May) containing the preponderance of dates on which the ten highest discharge values were observed each spring. Duration of the spring flood was characterized by the number of days each spring in which the discharge exceeded the historic 75th percentile discharge value from March through May. Magnitude was reported as the maximum spring discharge value for each year.

Results

2018 was slightly warmer and much wetter than normal in La Crosse, especially during the May-September growing season (source: National Weather Service, http://www.weather.gov/arx/lse2018). Precipitation was at or below normal through April, but May, August, September, and October were all much above normal. April 2018 was tied for the coldest on record and set a record with 19" of snowfall. However, May through September were warmer than normal, especially May and June.

Discharge was high for a few weeks in late April and early May due to late, rapid melting of the snowpack (Figure 1a). Then, as has been common in recent years, large rainfall events, locally and upstream, affected the hydrograph during the growing season. The June-July discharge peak was caused by rainfall further north in the basin, but the late-summer peaks were caused by local rainfall. Discharge peaks occurred in late June, September, and October. This resulted in the third highest mean annual discharge of the LTRM era (Figure 1b), and third year in a row of very high discharge. Mean growing season discharge was also above the 90th percentile and was the third highest for the LTRM period (Figure 1c). Thus, water levels exceeded the historic hydrograph during all but a few days from late April to the end of the year.

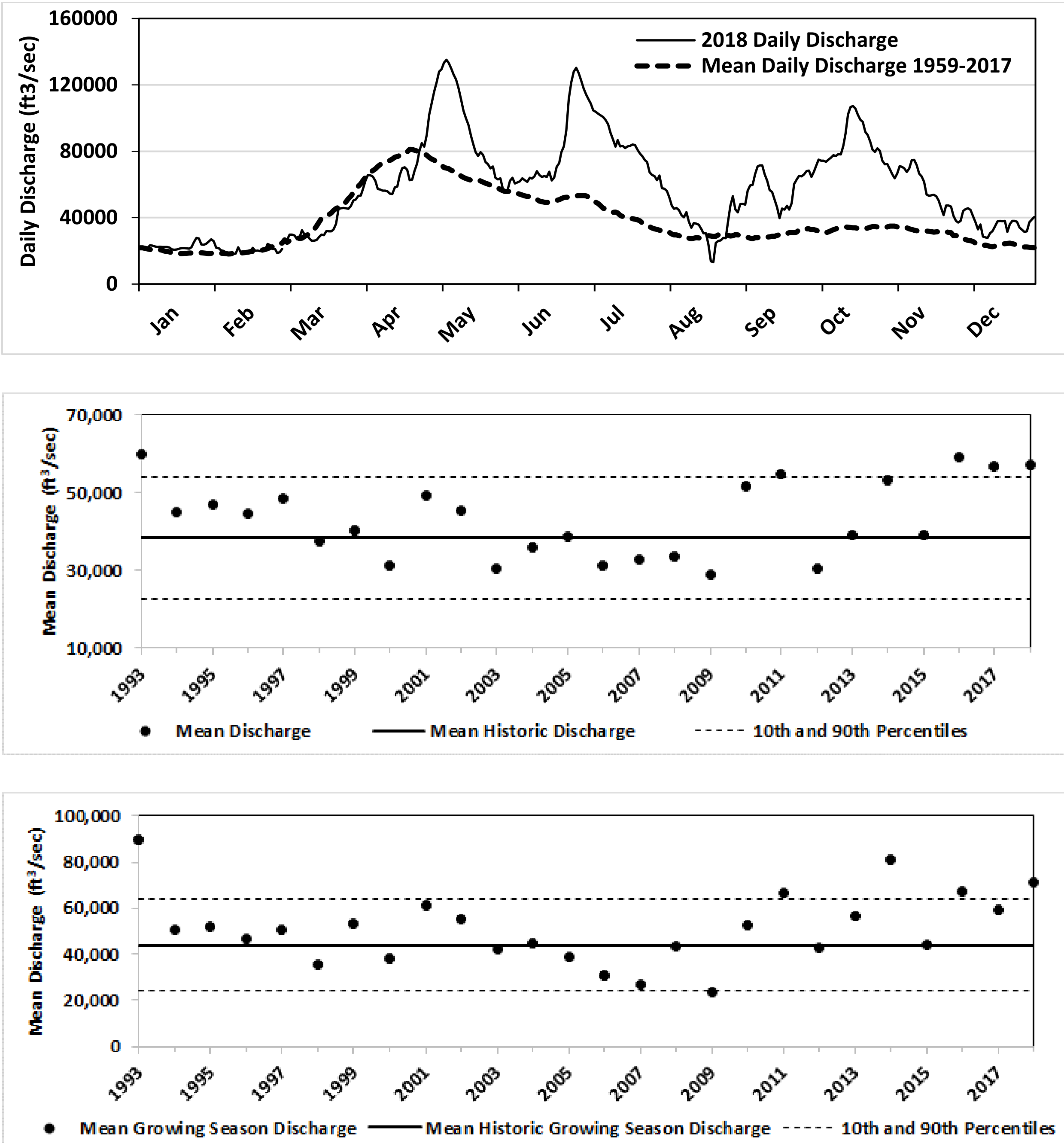


Figure 1. <u>Top panel</u> - Daily discharge at Lock and Dam 8 on the Upper Mississippi River for 2018 is represented by the solid line. Mean daily discharge by day of the year for 1959-2017 is represented by the dotted line. <u>Middle panel</u> - Mean discharge by year is represented by the black dots. The solid line represents mean historic discharge for 1959-2018. The dashed lines represent the 10th and 90th percentiles for 1959-2018 discharge. <u>Bottom panel</u> - Mean growing season discharge (May-Sept.) by year is represented by the black dots. The solid line represents mean historic growing season discharge for 1959-2018. The dashed lines represent the 10th and 90th percentiles for 1959-2018 growing seasons.

Six of the seven highest mean annual discharges during the LTRM period of record occurred in the past nine years, along with four of the five highest mean growing season discharges. These hydrologic extremes highlight the importance of continued long-term monitoring on the UMR. Bimodal and polymodal hydrographs have also become more common in the last decade, including fall (2016) and winter (2015) floods.

The 2018 spring flood analysis (Table 1) reflects the cold April mentioned above, as the peak discharge occurred during May. Water levels were elevated for 25 days during the spring, and the peak discharge was 135,100 cfs. This was another year where the duration and magnitude of the spring flood were normal, but the peak timing was atypically late. April floods have become scarce in recent years, occurring only once since 2010 (Table 1).

Table 1. Spring flood pulse statistics by year during the LTRMP period of record (1993-2018) for discharge at Lock and Dam 8 of the Upper Mississippi River. Duration represents the number of days each spring when discharge was above the 75th percentile from the long-term record (1959-2017). Timing represents the month when the preponderance of the ten highest discharge days were observed each spring. Magnitude represents the maximum discharge observed each spring.

Year	Duration	Timing	Magnitude
1993	56	April	116200
1994	20	May	107100
1995	27	May	86000
1996	29	April	140200
1997	40	April	188300
1998	22	April	122500
1999	32	May	110400
2000	0	March	66500
2001	54	April	225100
2002	18	April	121100
2003	23	May	116900
2004	3	April	80300
2005	19	April	96300
2006	24	April	104000
2007	18	April	87400
2008	40	May	101000
2009	11	April	83300
2010	26	March	114100
2011	67	April	168800
2012	0	May	76200
2013	50	May	116900
2014	49	May	133500
2015	1	May	79600
2016	14	March	106200
2017	50	May	129200
2018	25	May	135100

Water Quality

Methods

The focus of the LTRM water quality component is to collect limnological information relevant to the suitability of aquatic habitat for biota and transport of materials within the system. Since 1993, the LTRM water quality sampling design has incorporated year-round fixed-site sampling (FSS) and quarterly stratified random sampling (SRS). The mixed-model design provides information at both broad spatial scales with low temporal resolution (i.e., SRS) and at small spatial scales with higher temporal resolution (i.e., FSS). SRS tracks conditions at spatial scales corresponding to sampling strata or larger (i.e., whole pool or sampling reach) and at seasonal to annual time scales or longer. In contrast, FSS provides information at more frequent intervals (i.e., within season), at specific points of interest such as tributaries, tailwaters, impounded and backwaters with high habitat value. The data used for this report are weighted pool-wide median values from SRS sampling. Water temperature and dissolved oxygen (DO) concentrations used in this report were surface measurements taken at 0.20m. Water samples were collected near the surface (0.20m) to quantify total suspended solids (TSS), chlorophyll a, total phosphorus (TP) and total nitrogen (TN). More details on LTRM water quality sampling methods can be found in Soballe and Fischer (2004) at:
http://www.umesc.usgs.gov/documents/reports/2004/04t00201.pdf.

More in-depth graphical display of data pertaining to water quality metrics by season, reach and sampling stratum can be found by utilizing the LTRM Water Quality Graphical Data Browser at:
http://www.umesc.usgs.gov/data_library/water_quality/water_quality_page.html.

Results

Water quality in 2018 was strongly influenced by high discharge throughout the year (with the 3rd highest annual and 3rd highest growing season discharge since 1993; Figure 1). This was the third consecutive year with extraordinarily high water. Open-river conditions (dam not controlling flow) were reached during spring, summer and fall. Impacts of high flow on water quality variables are discussed below in the summaries of the major water quality variables.

Water temperature was near the long-term median for winter, but below average (near the 25th percentile) for spring, summer and fall (Figure 2a). Water temperature has direct and indirect effects on large river ecology. Warm water temperatures can result in higher respiration rates, leading to lower oxygen saturation concentrations, which can increase the frequency of hypoxic conditions (Houser et al., 2015; Likens, 2010). Water temperature also influences the rate of photosynthetic production in aquatic ecosystems (i.e. with lower rates of photosynthetic productivity at very low and very high water temperatures and higher rates of productivity at intermediate temperatures). The LTRM SRS data browser does not show any strong trends for pool-scale temperature over the period of record (1993-2018), although winter and summer have weak increasing trends while spring and fall show a weak decreasing trend.

Total suspended solids were relatively high in winter and spring, near the 75th percentile, but below the 10th percentile in summer and near the long-term median for fall (Figure 2b). While median winter TSS was relatively high at 2.81 mg/l, this is a relatively low level of TSS, especially when compared to other seasons. Nonetheless, winter TSS has been relatively high during the last three winters, likely

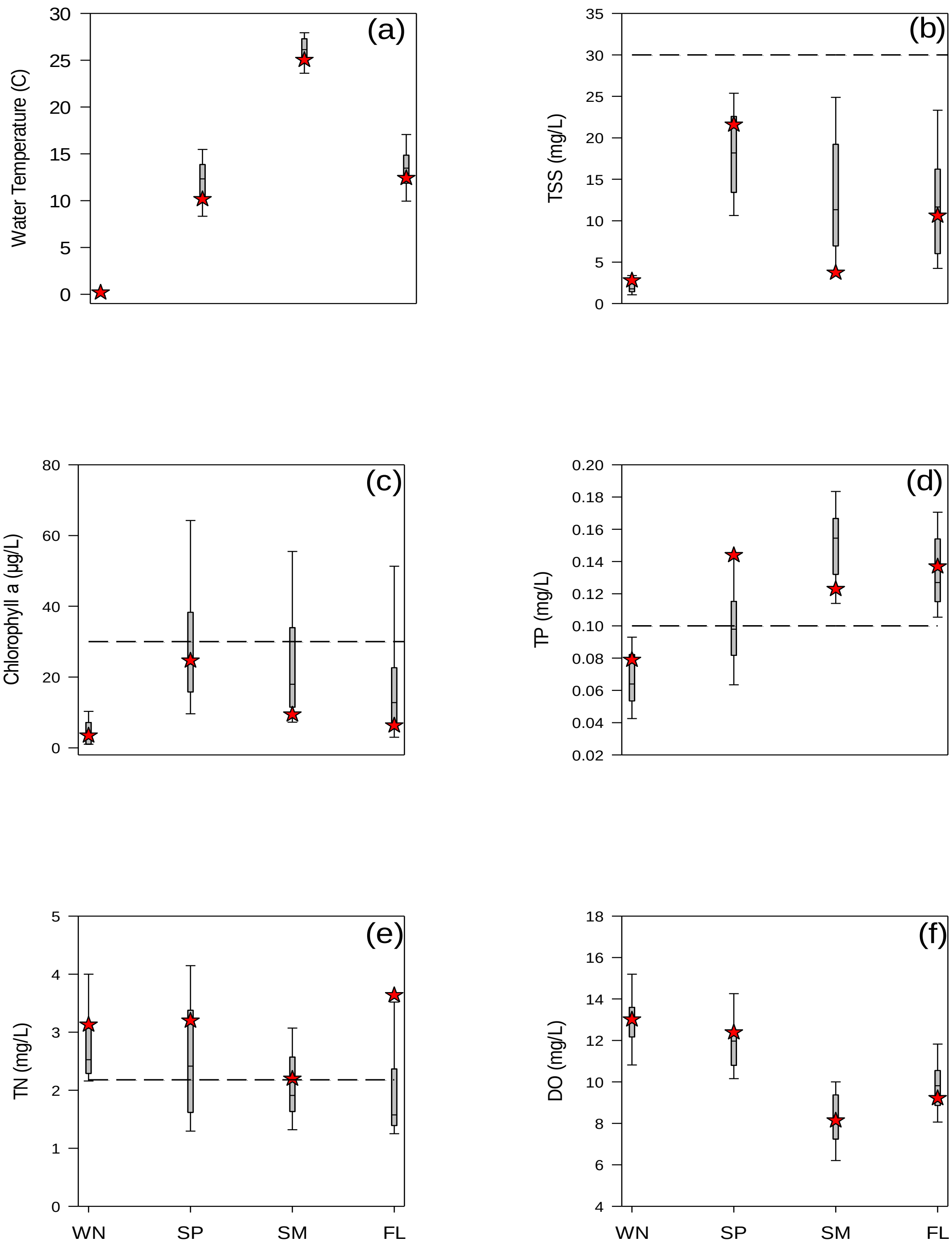


Figure 2. Box plots represent the 10th, 25th, 50th, 75th, and 90th percentiles of the medians by stratified random sampling season for the Upper Mississippi River Restoration Program - Long Term Resource Monitoring Element period of record (1993-2018). The star represents the weighted pool-wide median for each parameter by season for 2018. (b) The dashed line represents the upper limit to sustain submersed aquatic vegetation in the Upper Mississippi River from Giblin et al., 2010. (c) The dashed line represents the lower limit of the eutrophic range (as defined by Dodds et al. 1998). (d) The dashed line represents the total phosphorus criterion for non-wadeable rivers in Wisconsin as defined by NR 102.06. (e) The dashed line represents upper limit of the range suggested for total nitrogen as defined by the USEPA (2000).

due to increased runoff due to snow melt and/or precipitation on warmer winter days. Also notable was the extremely low pool-wide median TSS observed during summer SRS (3.74 mg/l). Summer sampling coincided with the descending leg of a period of sustained high water (Figure 1a). While TSS often decreases as floods recede, 3.74 mg/l was unusually low.

The prevalence of submersed aquatic vegetation remained high in 2018 with about 80% of sites supporting aquatic vegetation (Figure 5, aquatic vegetation section), which may have contributed to the lower summer TSS concentrations because it slows water velocity allowing sediment to fall out of the water column. Vegetation also stabilizes sediment and reduces sediment resuspension from wind and boat generated waves (Madsen et al., 2001). The physical influences that aquatic vegetation has on the river hydrology can create a positive feedback that allows more areas to be vegetated which further lowers TSS (Scheffer 1993, Giblin 2017). When compared to normal conditions (a 15-yr period 1994-2009), 2018 summer turbidity, TSS and volatile suspended solids (VSS) were very low in backwaters and low in the impounded area (Figure 3). In 2018 the percentage of vegetated sites was 92.7 and 87.6 for connected backwaters and impounded area respectively (Table 2, aquatic vegetation section). Prevalence of aquatic vegetation in these strata has been similarly high for over a decade yet TSS has been steadily decreasing. Further, pool-wide submersed aquatic vegetation (SAV) prevalence peaked in 2010 at ~ 90% but fell to a lower level after that and has been ~80% the last four years. Exactly what is driving the decreasing TSS trend is still unclear. The LTRM SRS data browser shows a strong decreasing trend in pool-wide TSS for spring, summer and fall and a weak decreasing trend for winter (pool 8, 1993-2018). Pool-wide median TSS concentrations are rarely above the criterion (<30 mg/L) required to sustain SAV in the Upper Mississippi River (UMR) during all seasons (Giblin et al., 2010).

Chlorophyll a concentrations were below the long-term median throughout the year, with summer and fall having the lowest levels (~25th percentile). These lower concentrations are likely a function of dilution, mixing and flushing caused by the high and erratic discharge during 2018 (Figure 1a, 2c). Chlorophyll a is an indicator of phytoplankton biomass in the water column. As in lakes, light, temperature, nutrients, and hydraulic retention time are the primary factors determining phytoplankton biomass and growth (Houser et al. 2015; Likens, 2010, Soballe and Kimmel 1987). Median chlorophyll a values were also below the eutrophic range (>30 µg/L, Dodds et al., 1998) during 2018. Eutrophication is still a major water quality issue in the UMR, and while chlorophyll a concentrations in Pool 8 fell below the eutrophic range, this may not accurately characterize the trophic state of Pool 8 because most of the collections were made during high water. The LTRM SRS data browser shows weak decreasing trends for chlorophyll a in all seasons (pool-wide, 1993-2018).

Two other factors that may affect suspended algae productivity in Pool 8 include: allelopathy by SAV- which may be limiting suspended algae production because of its high frequency of occurrence especially in backwaters (Figure 5). Backwaters tend to be dominated by *Ceratophyllum demersum* and Elodea *canadensis*, and *Myriophyllum spicatum* is common. All three of these species are known to produce allelopathic algal toxins (Hilt and Gross 2007). Field station staff have made anecdotal observations of very clear water in backwaters even though nutrients (NOx and SRP) are often abundant. When compared to normal conditions (a 15-yr period 1994-2009), chlorophyll a was low in backwaters and impounded strata during summer (Figure 3), suggesting that aquatic vegetation may be limiting suspended algae. Secondly, we observed very few algal blooms from cyanobacteria (e.g. *Microcystis* and *Aphanizomenon*), which is not surprising because these blooms tend to be more prevalent during periods of low discharge combined with warm water temperatures- conditions that were rare in 2018.

Phosphorus is an essential plant nutrient that can limit the biomass of phytoplankton and aquatic macrophytes in aquatic ecosystems. Excessive phosphorus loading can result in increased biomass of phytoplankton, rooted and free-floating plants, increased incidence of fish kills, reduction in species diversity and reduction in perceived value of a water body (Smith and Schindler, 2009, Giblin et al. 2014). Total phosphorous levels were near the 75th percentile for winter, near the 90th percentile in spring, near the 15th percentile in summer, and just above the 50th percentile for fall (Figure 2d). The LTRM SRS data browser shows a fairly strong decreasing trend in TP for winter and fall and a weak decreasing trend for spring and summer (pool-wide, 1993-2018).

TP levels were below the Wisconsin TP criterion (0.10 mg/L) for wadeable rivers (Wisconsin administrative code NR 102.06) only in winter and were above this level during spring, summer and fall. It is noteworthy that even though median summer phosphorous levels were near the 15th percentile for the LTRM period of record (POR) they still exceeded the Wisconsin TP criterion.

A significant fraction of TP inputs come adsorbed to the TSS load, therefore, the concentration of TP tends to track well with TSS (compare Figure 2b and d). Heavy rain events can cause increased erosion/runoff in the watershed, therefore increased sediment delivery to the river. It was not surprising to see the higher TP levels in spring given the conditions we experienced (i.e. high discharge from spring runoff). The low TP observed in summer makes sense in that it tracks with the lower TSS, but as mentioned in the TSS section, this is somewhat surprising as we had above average discharge during the summer SRS sampling period.

While nutrient concentration is important, we must keep in mind the overall load of a given nutrient. For example, TP in summer was very low but discharge was between 50% and 75% higher than the mean historic discharge; the load of TP during summer SRS may not be lower than normal. Similarly, the TP load in fall would likely be notable as discharge was over twice the mean historic discharge during the fall sampling period. The LTRM water quality component does not calculate loads as part of its routine reporting, however this information would be useful, and warrants future effort. For example, Kreiling, R.M. and J.N. Houser (2016) calculated discharge-corrected concentrations (weighted regression on time, discharge and season to remove effects of variation in discharge when evaluating trends).

Elevated phosphorous concentrations are often attributed to inputs from point and non-point source pollution e.g. municipal treatment plants and agriculture runoff. There can also be significant phosphorous inputs from sediment microbial activity, especially in backwaters experiencing anoxic conditions during the warmer months, known as anoxic sediment release of phosphorous. High discharge in 2018 and therefore more water exchange between the well oxygenated channel water and backwater areas may have limited the existence of anoxic conditions which would reduce the rate of anoxic sediment release of phosphorous. We had very few sites with anoxic conditions in 2018.

Nitrogen, like phosphorous, is an essential plant nutrient that can limit the biomass of phytoplankton and aquatic macrophytes in aquatic ecosystems. Excessive delivery of nitrogen (mainly from agriculture) in the form of nitrate to groundwater and surface waters has been associated with several negative consequences for human and ecosystem health (Wolfe and Patz, 2002). Nitrogen concentration tends to increase with increasing discharge as non-point input from agriculturally dominated tributary watersheds is delivered to the UMR (Goolsby et al., 2000). Total nitrogen was high in winter and spring (75th percentile), near the 60th percentile in summer, and very high (> 90th

percentile) in the fall (Figures 2e, 3). In 2018, TN was substantially above the upper concentration recommended by the USEPA for ecosystem health (0.6-2.18 mg/L) during winter, spring and fall and right at the upper limit in summer (USEPA, 2000). Trends for TN are mixed, the LTRM SRS data browser show a strong increasing trend in winter, a weak decreasing trend in spring and summer and a weak increasing trend in fall (pool-wide 1993-2018).

Comparison of 2018 water quality conditions to normal conditions

Key:	**H = very high**
	h = high
	. = normal
	l = low
	L = very low

			TEMP	DO	COND	pH	TURB	SS	VSS	CHL	TN	NOX	NHX	TP	SRP
Pool 8	Winter	POOL	.	.	.	.	.	.	.	.	.	.	.	.	.
		MC	.	.	.	.	.	.	.	.	.	.	.	.	.
		SC	.	.	.	.	.	.	.	.	.	.	.	.	.
		BWC	.	.	.	.	.	.	.	.	.	h	.	.	.
		IMP	.	.	.	.	H	.	.	.	.	.	.	.	.
	Spring	POOL	.	.	.	.	.	.	.	.	.	.	.	.	.
		MC	L	.	.	.	.	.	.	.	.	.	.	.	.
		SC	l	.	.	.	.	.	.	.	.	.	.	H	.
		BWC	.	.	.	.	.	.	.	.	.	.	.	.	.
		IMP	.	.	.	.	.	.	.	.	.	.	.	.	.
	Summer	POOL	.	.	.	.	l	l	L	L	.	.	.	.	.
		MC	.	.	.	.	.	.	.	.	.	.	.	.	.
		SC	.	.	.	.	.	.	.	.	.	.	.	.	.
		BWC	.	.	.	.	L	L	L	l	.	.	.	.	.
		IMP	.	.	.	.	l	l	l	l	.	.	.	.	.
	Fall	POOL	.	.	.	.	.	.	.	.	h	h	.	.	.
		MC	.	.	.	.	.	.	.	.	h	h	.	.	.
		SC	.	.	.	.	.	.	.	.	.	.	.	.	.
		BWC	.	.	.	.	.	.	.	.	.	.	.	.	.
		IMP	.	.	h	.	.	.	.	.	h	h	.	.	.

Figure 3. Comparison of 2018 water quality conditions to normal conditions (from UMRR website https://www.umesc.usgs.gov/reports_publications/ltrmp/water/2018_annual_unusual.html). Data acquired over a 15-yr period (1994-2009; data missing in 2003) was used to determine annual 95% upper confidence limits (UCL) and 95% lower confidence limits (LCL) of the mean for each variable/reach/episode/stratum. Estimates of the 95% upper and lower confidence limit for the year of interest (e.g., 2010; a year outside the 15-yr period), along with the median, were compared to the 15-yr annual extremes to determine unusual conditions. Estimates where the median was higher than the highest annual 15-yr UCL or lower than the lowest annual 15-yr LCL were "low"(l) or "high" (h), respectively. Estimates where the LCL was higher than the highest annual 15-yr UCL or the UCL was lower than the lowest annual 15-yr LCL were "very low" (L) or "very high"(H), respectively. (.)=normal

Watershed management practices have had little success in lowering nitrogen delivery to ground water, rivers and ultimately the Gulf of Mexico. Further investigation into the high variation observed between years as well as the increasing winter and fall trend is needed.

Adequate dissolved oxygen (DO) is critical to sustain aquatic life. DO concentration can be reduced through decomposition of organic material from point and non-point sources, plant and animal respiration and demand from accumulated sediment. Median DO was not far off the 50th percentile in all seasons (Figure 2f). LTRM SRS data show an increasing trend in winter, no trend in spring and summer and a weak decreasing trend in fall (pool-wide 1993-2018). The high discharge in 2018 likely contributed to the very steady conditions in DO (usually at or near 100% saturation).

Ice and snow thickness can affect the concentration of DO in the underlying water column by reducing available light and thereby suppressing photosynthetic activity. Median ice thickness was slightly above the 75th percentile, while snow depth was near the 10th percentile (Figure 4). The thicker ice was no surprise giving the minimal snow cover and sub-zero temperatures we experienced in January.

The ice and snow conditions during winter 2018 appear to have been suitable for light transmission as median DO during winter was 13.01 mg/l and very few sites had DO below 5 mg/l; these low DO sites were largely in Blue Lake, an isolated backwater that is often hypoxic in winter, and the remainder were shallow sites with little available water depth below the ice. In a year with such low snow cover we would expect to see areas supersaturated with DO (due to the increased light available to SAV, and algae). Oxygen supersaturation has been implicated in past years as the cause of under-ice fish kills in Pool 8 as well as other pools. We had very few sites with supersaturated DO with the highest level being 198%. Even though the ice was thick at this site (45cm) it did not appear to limit light and snow depth was only 1cm. The small bump in discharge during winter SRS may have kept water exchange rates high enough, limiting excessive DO concentrations.

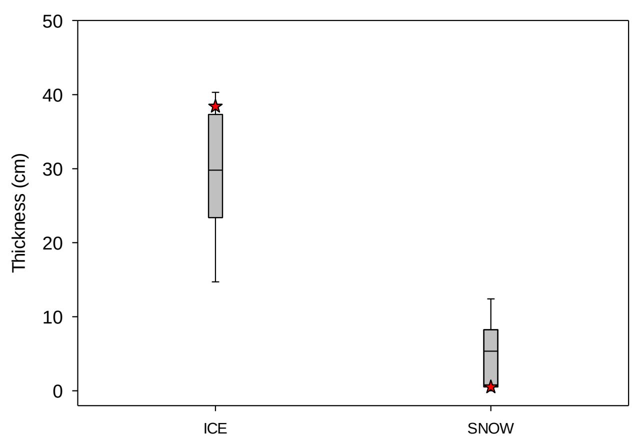


Figure 4. Box plot represents the 10th, 25th, 50th, 75th, and 90th percentiles of the medians for winter ice thickness and snow thickness above the ice sheet during winter for the Upper Mississippi River Restoration Program - Long Term Resource Monitoring Element period of record (1993-2018). The star represents the weighted pool-wide median for each parameter for the winter of 2018.

AQUATIC VEGETATION

Methods

Aquatic vegetation surveys are conducted at 450 sites in Pool 8 annually, and sites are visited between 15 June and 15 August to target the period of peak biomass. Methods are described briefly here, but more detail on LTRM vegetation sampling protocol can be found in Yin et al., 2000. Sites are randomly selected at established stratum-specific densities to reflect relative coverage in the Pool 8 ecosystem, based on LTRM probabilistic design (https://www.umesc.usgs.gov/ltrmp/stats/statistics.html). The boat is anchored within 10 m of site coordinates. Emergent species, rooted floating-leaf species and non-rooted floating-leaf species are assigned cover scores based on their abundance in a 2-meter ring around the boat. At each site, SAV is sampled in six subplots by pulling a modified garden rake over the sediment surface for a distance of ~1.5 m and SAV caught in the rake teeth is examined for species identification and abundance scoring. Vegetation caught on the rake is scored as "plant density" using a six-level ordinal scoring scheme. Increasing plant density values represent increasing levels of stem density on the rake; score = 0 when no plants are on the rake, and scores of 1-5 are assigned to increasing number of plant stems (irrespective of length or branching density) caught on the rake. Rake teeth are marked in 20% intervals and plant density is scored as 1 if SAV fills rake teeth up to the first mark, scored as 2 if plant stems fall between the first and second intervals, etc.

Specific features of the Pool 8 aquatic vegetation in 2018 are based on data spanning 1998 – 2018, and data were downloaded from the LTRM graphical data browser at:
(https://www.umesc.usgs.gov/data_library/vegetation/graphical/veg_front.html).

Results

We conducted surveys at 449 of 450 sites between 15 June and 7 August in 2018 (locations shown in Appendix A). One site was inaccessible as it was located under a boathouse in Lawrence Lake (the BWC stratum) and was excluded from calculations. Water was very high during most of the 2018 field season; mean depths measured during sampling were, on average, 45 cm deeper in 2018 than in 2017. Approximately 20 sites were too deep to sample (> 2.8 m) when they were first visited but were also <3.5 m, suggesting that they would be sampleable under more "normal" conditions. We returned to those sites and re-sampled after the water level had fallen somewhat in the late season.

Long-term patterns in vegetation abundance

Since LTRM probabilistic monitoring was initiated in 1998, the prevalence of all three major vegetation life forms (submersed, rooted floating-leaf, and emergent) have increased in Pool 8 (Figure 5). The "total aquatic plant index" is the sum of percent frequency occurrence of submersed, rooted floating-leaf, and emergent vegetation (Figure 6) and has also increased considerably since 1998. Because all three life forms can overlap in distribution, this index can exceed 100%, and has remained between 140 and 160% in recent years.

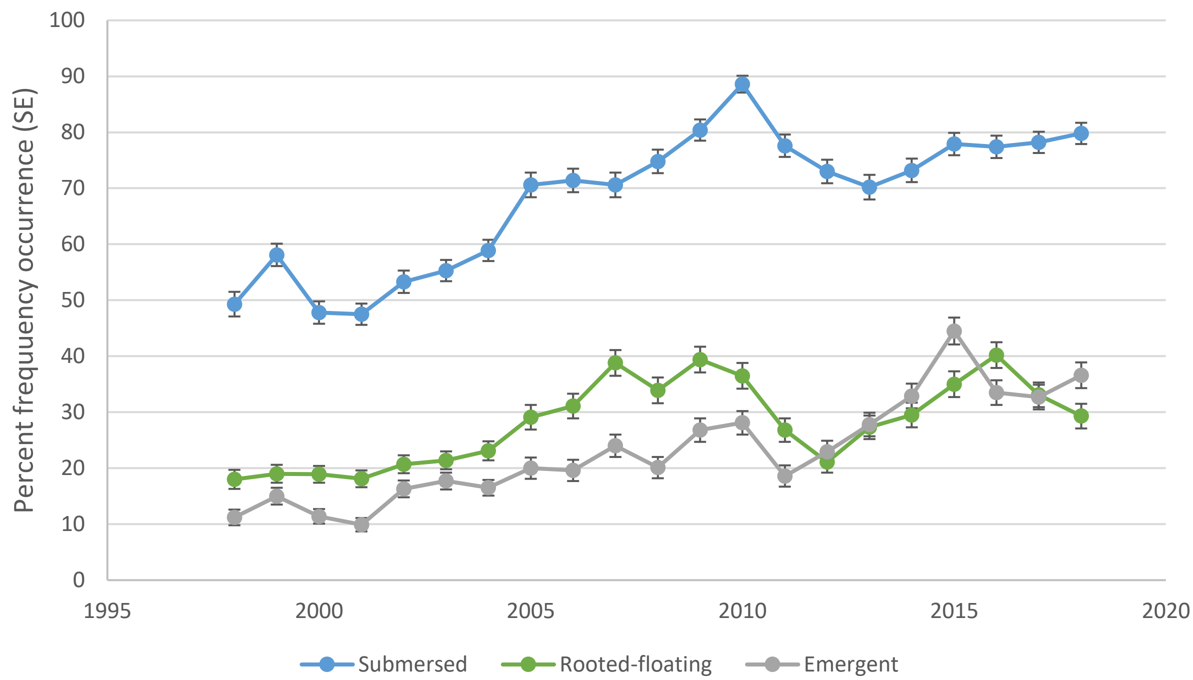


Figure 5. Prevalence of the three vegetation life forms over 21 years of LTRM probabilistic monitoring (±SE).

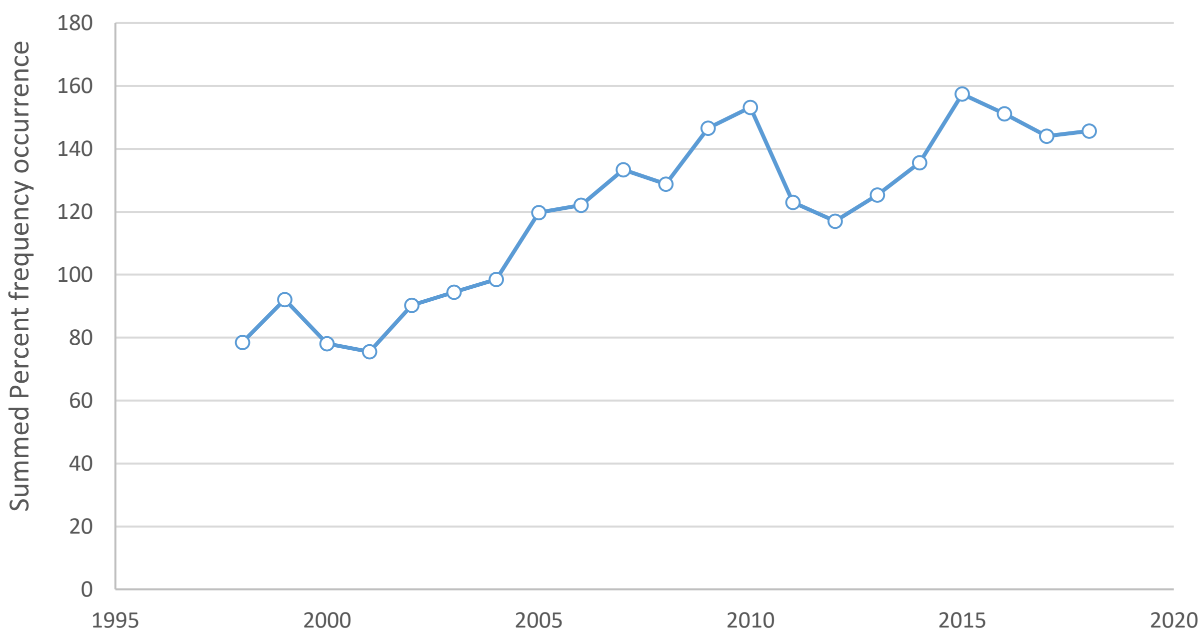


Figure 6. Total aquatic plant index over time is annual, summed percent frequency occurrence of the submersed, rooted floating-leaf, and emergent life forms. Because more than one life form can occur at the same site, the index can exceed 100%.

Aquatic vegetation in the LTRM strata

Vegetation abundance varied considerably between strata, with slow-moving and still waters (the backwater isolated, backwater contiguous, and impounded strata) generally supporting more vegetation than moving waters (side channels and the main channel borders) (Table 2). This is consistent with previous years.

Table 2. Summary of site distribution among strata for aquatic vegetation sampling in 2018. The column "% Vegetated" was calculated by subtracting the number of unvegetated sites from the total number of sites in each stratum and dividing by the number of sites sampled in that stratum. Depths were measured at time of sampling and are not corrected for river stage – reported depths provide only a general indication of differences.

Stratum	Number of sites	Average depth (m) (SD)	% Vegetated
Backwater contiguous (BWC)	109	1.42 (0.69)	92.7%
Backwater isolated (BWI)	20	0.65 (0.43)	100.0%
Impounded (IMP)	185	1.62 (0.58)	87.6%
Main channel border (MCB)	70	2.27 (1.39)	30.0%
Side channel (SC)	65	2.15 (1.23)	53.8%

As described in other sections of this report, 2016, 2017 and 2018 were years of high average growing season discharge. Apparently, however, this has not negatively affected the overall prevalence of aquatic macrophytes. When aquatic vegetation is categorized by life forms, the percent frequency occurrence of submersed species remained high, at 79.8% (Figure 5, Table 3) in 2018, and emergent species also remained high (Table 3). Over the last three years, however, the prevalence of rooted floating species has decreased from ~40% to ~30%. Non-rooted floating (duckweeds) and filamentous algae were both relatively low in 2018, with filamentous algae dropping substantially from 2016-2017 values.

The relative abundance of submersed, emergent, and rooted floating-leaf species varied by stratum (Figure 7), reflecting habitat-based variation in a number of interacting drivers, especially water velocity and light availability (e.g. Kreiling et al. 2007). For example, main channel and side channel areas are characterized by much higher water velocity than backwaters, and the impounded area is intermediate in terms of water velocity.

A total of 34 plant species (excluding algae) have been identified in Pool 8 over the course of LTRM monitoring. At individual vegetated sites, 4-8 species are generally detected. The maximum number of species found at a single site in 2018 was 19. The highest diversity sites usually include a large range of depths and include the transition from submersed species to emergent species (i.e. are near the edge of water).

Table 3. Pool-wide mean prevalence of vegetation by life form over the last three years (2016 – 2018) suggesting relative stability (also see Figure 5). All values except those for non-rooted floating are weighted by stratum to account for sample inclusion probability (https://www.umesc.usgs.gov/ltrmp/stats/means.html). Non-rooted floating values are not available on the browser and are calculated as a straight fraction of all sampled sites. Total aquatic plant index is the sum of submersed, rooted floating-leaf, and emergent life forms percent frequency occurrence.

	2016 Percent frequency occurrence	**2017 Percent frequency occurrence**	**2018 Percent frequency occurrence**
Submersed	77.4	78.2	79.8
Rooted Floating	40.2	33.1	29.3
Emergent	33.5	32.8	36.6
Non-rooted floating	28	25.3	20.0
Filamentous Algae	36.2	36.9	19.4
Total Aquatic Plant Index	151.1	144.1	145.7

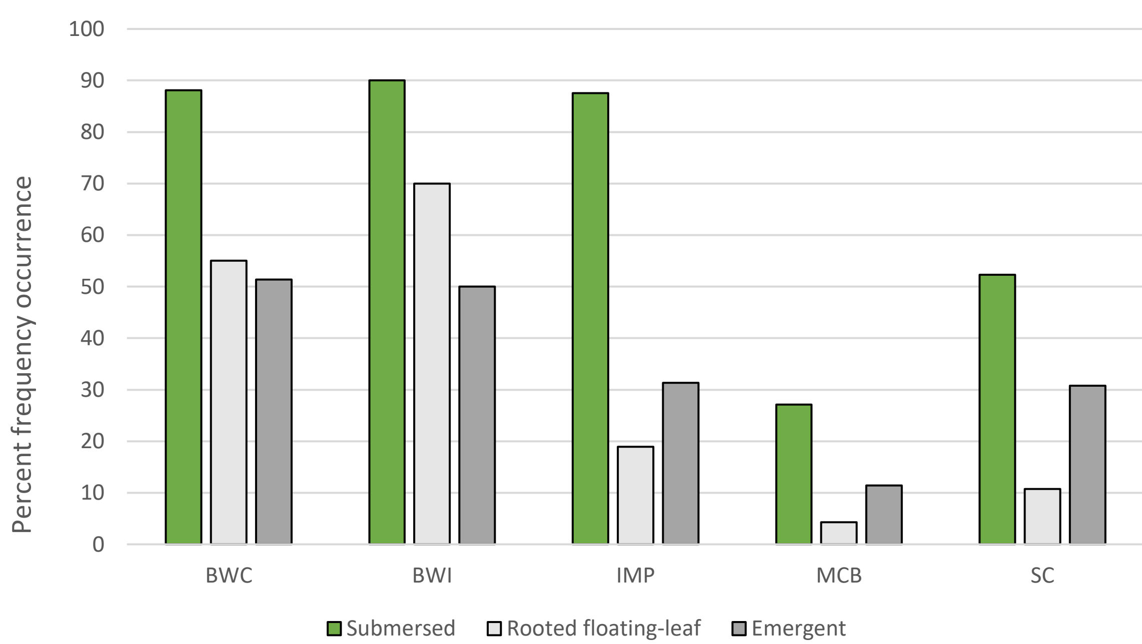


Figure 7. Percent frequency occurrence (prevalence) of vegetation life form by stratum.

A portion of the increase in aquatic vegetation over the LTRM monitoring period is attributable to the expansion of two native species of special interest – wild celery (*Vallisneria americana* Michx.), and wild rice (*Zizania aquatica* L.). Wild celery is a predominantly clonal, perennial plant, and has high specific value as forage for canvasback (*Aythya valisineria* Wilson) and other migrating waterfowl. Wild rice, an annual aquatic grass, can also be an important source of food and cover for wildlife. Long-term data show considerable increases in the prevalence of both species since 1998 (Figure 8). Prior to 2008, wild rice was only detected at 1-3% of sites annually, but in 2018 it was detected at 24% of sites. We note that it was detected in high abundance where it usually occurs, but also in low abundance (a few stems per site) at many more sites than usual throughout the impounded area. Wild rice is now the most frequently detected emergent species in Pool 8 LTRM surveys and is a substantial contributor to the total vegetation index (Figure 6). In our 2017 report we stated that "A possible explanation for lower wild rice abundance in 2016 and 2017 was high water during both spring periods when rice stems were elongating to reach the surface; in both years the rice stems were very long and delicate (personal observation) and may not have survived to reproductive stage." Given the even more extreme high-water conditions during the 2018 growing season, this now seems unlikely. The expansion of wild rice in Pool 8 is becoming a topic of increasing interest.

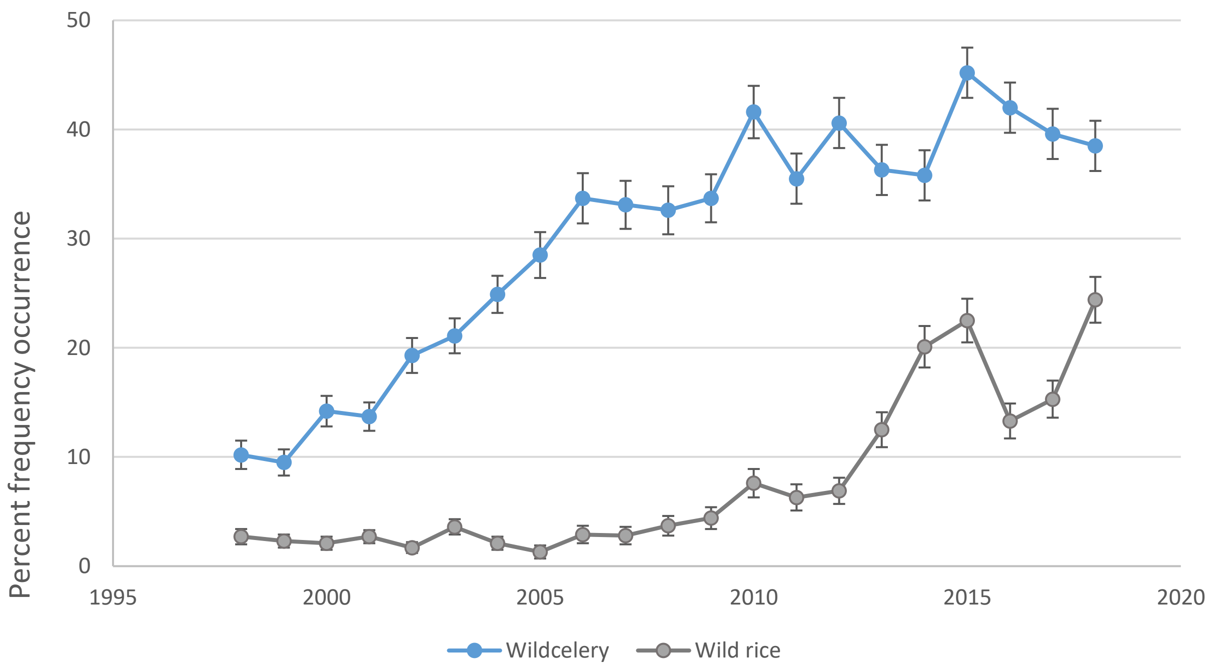


Figure 8. Positive trends in the detection of wild celery and wild rice (pool-wide means) in Pool 8 over the 21 years of LTRM monitoring.

The Pool 8 aquatic vegetation community is composed primarily of native species, with only two, locally abundant invasive species: Eurasian watermilfoil (*Myriophyllum spicatum*) and curly pondweed (*Potamogeton crispus*) (Figure 9). These have occurred at ~10-30% of Pool 8 sites annually, but have not increased as dramatically as the native species described above, or as much as the total vegetation index. Abundance of these species in 2018 was not strikingly different from recent years. Although sometimes locally abundant, they rarely appear to exclude native vegetation at the site level, and are virtually never the only species detected at a site. The maximum biomass of *P. crispus* occurs in early- to mid-May, and this species has senesced considerably by the time summer surveys are conducted. Due to its off-set phenology, the species is under-represented (in terms of percent frequency occurrence) by approximately 3-fold in summer surveys (Drake et al. 2017).

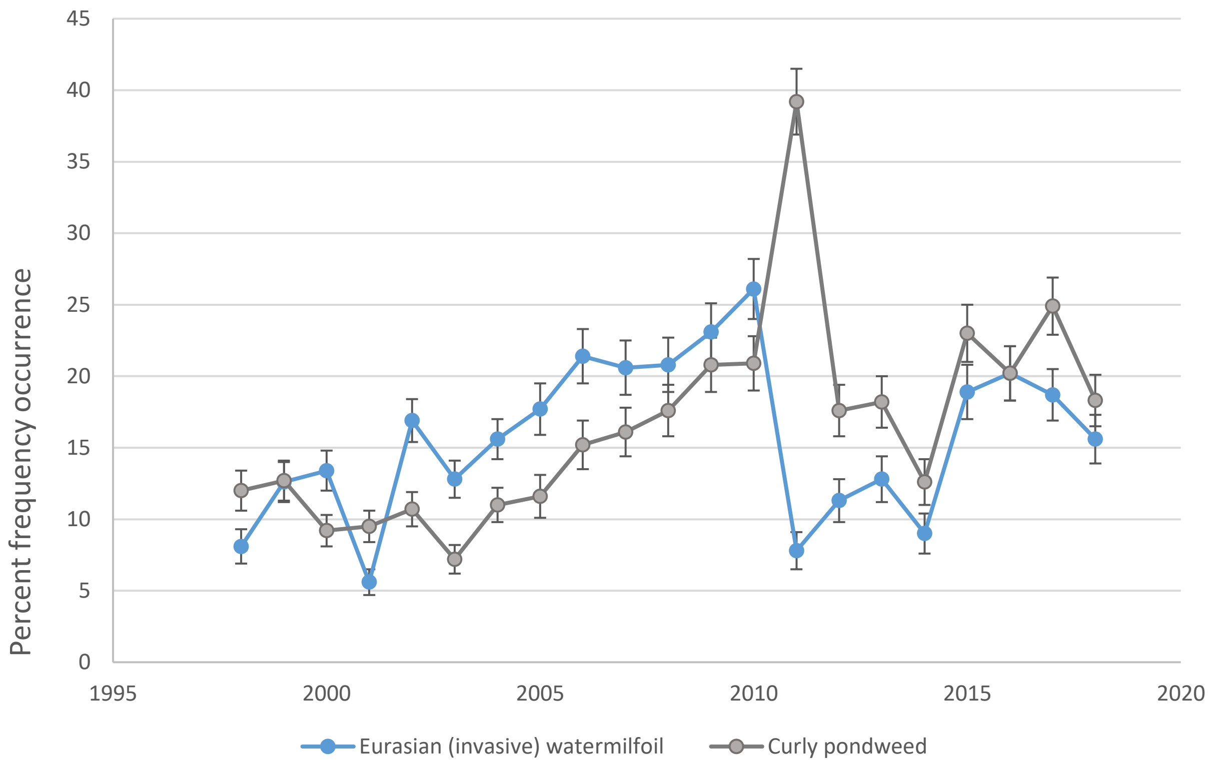


Figure 9. Prevalence of the two common invasive species in Pool 8 over LTRM monitoring.

The prevalence of native Northern watermilfoil (Figures 10 and 11) increased suddenly in 2015 and has remained at levels comparable to the invasive milfoil since then. Although we most frequently encounter individuals that are clearly either *M. sibiricum* (usually leaves with 6-8 leaflets) or *M. spicatum* (usually leaves with >16 leaflets), we also find hybrids with intermediate numbers of leaflets and other morphological features. Hybrids are assigned to a species whereby <12 leaflets on mature leaves indicate the native and 12 or more leaflets indicate the invasive.

Figure 10. Native *Myriophyllum sibiricum,* typically with 6-8 leaflets per leaf, is shown at the water's surface. This species has been relatively abundant in Pool 8 since 2015, and is shown here in a typical assemblage of dense, native SAV.

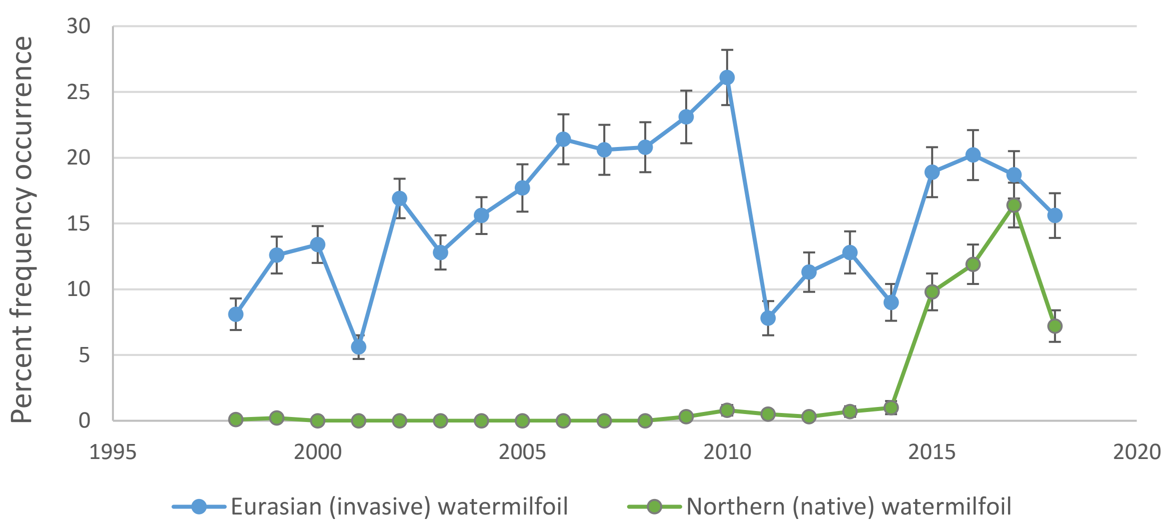


Figure 11. The native milfoil, *Myriophyllum sibiricum*, became suddenly abundant in 2015, and has remained relatively common in Pool 8.

The profusion of algae in freshwater systems is associated with eutrophication, a major concern for managers and users of Pool 8 and the greater Upper Mississippi River. Filamentous algae are often found in dense mats or clinging to vegetation, and late each summer blue-green algae appear as patchy films. The prevalence of filamentous algae has varied considerably over time in LTRM surveys (Table 3, Figure 12). Abundance of filamentous algae in 2018 was notably lower than in the three previous years, and was likely limited by the higher discharge and water velocity throughout the sampling season.

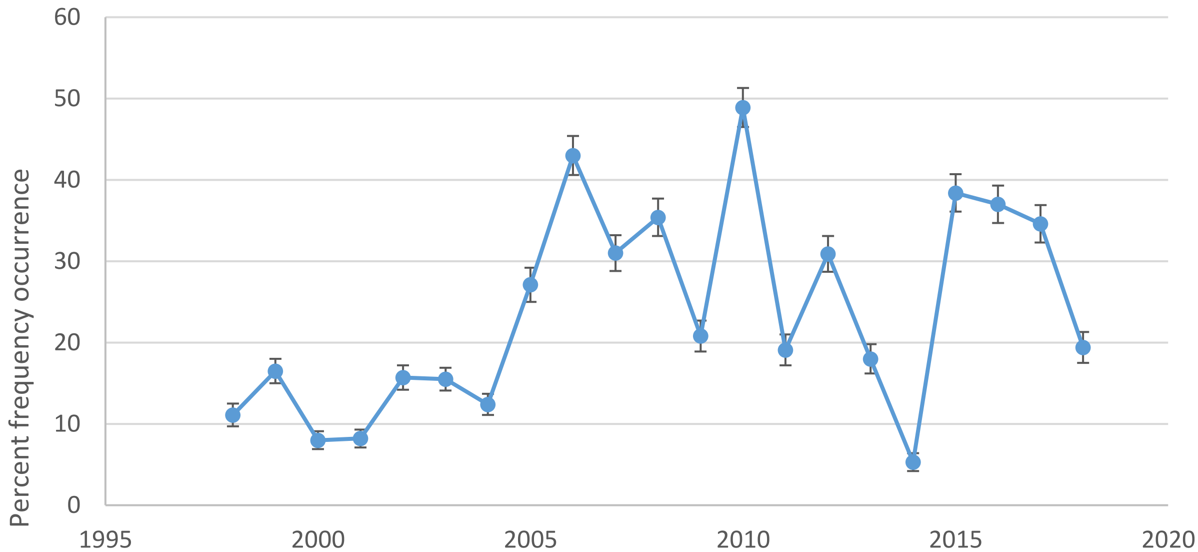


Figure 12. Prevalence of filamentous algae over the entire period of LTRM monitoring.

Fisheries

Methods

The LTRM fish component uses six standardized gear types, including daytime electrofishing, fyke nets, mini fyke nets, large- and small-hoop nets, and otter trawls, within a randomized sampling scheme and stratification based on broad habitat features. Fish sampling is conducted within three consecutive six-week episodes, from June 15 to October 31, to ensure both temporal, as well as spatial, interspersion of the sampling gear deployments. More detail on LTRM fish sampling procedures can be found in Ratcliff et al., 2014 at: https://pubs.usgs.gov/mis/ltrmp2014-p001/. A companion document (Ickes et al., 2014) describes the monitoring rationale, strategy, issues, and methods, and can be found at: https://pubs.usgs.gov/mis/ltrmp2014-p001a/.

The LTRM Fish Graphical Data Browser automates many routine analyses and provides on-demand analytical products for end users. This information can be accessed at: https://umesc.usgs.gov/data_library/fisheries/graphical/fish_front.html. Routine data analyses for overall fish community data include sample allocation, species richness, total catch by species, and community composition (presence/absence). Stock size designations defined in published manuscripts are among many useful descriptive parameters that can be found in the LTRM Fish Life History Database, available for download at https://umesc.usgs.gov/data_library/fisheries/fish_page.html. The life history database also contains a table with allometric growth information that allows conversion of length data to mass, which yields additional insight into fish community characteristics.

This report summarizes sampling effort, total catches, and species richness, as well as summaries of dominant species in the catch, by number and weight. Detection frequencies and data on species of special concern are also discussed. We also report any Asian carp collections, discuss Common Carp status, and report other anecdotal observations on the fish community. Shannon-Wiener Diversity Index (Zar 1984) scores are computed from day electrofishing collections to indicate fish community diversity relative to previous years.

Catch-per-unit-effort (CPUE) data are provided for ten common sport fish of interest to anglers and fish managers. CPUE is reported as estimates of gear-specific pool-wide means and standard errors, weighted for effort expended within each of the sampling strata. Herein, we present CPUE data for one or two effective gear types, as suggested by total catches from each gear. More detailed descriptions of CPUE calculations can be found at the Fish Monitoring Rationale and Fish Procedures web pages, listed above.

A stock-size analysis for these ten common sport fish of interest displays the catch of fish in each stock category, annually, in stacked bar graphs, with substock catches in separate figures due to their generally higher numbers. Stock categories are based upon those listed in the Life History Database, referenced above. The stock-size analysis includes catches from all gear types and sampling sites.

Data were omitted for 2003 in all cases because of reduced sampling that year. Also, catches of fish from wingdam and tailwater sites are reported in total catch and species richness, but are excluded from CPUE calculations because these strata were considered too small and unique for proper stratification of sampling effort. However, CPUE values for the individual strata, including wingdams and tailwater fixed sites, are available on the Fish Graphical Data Browser at the link provided above.

Results

Fish sampling in Pool 8 during 2018 was impeded by high water levels throughout much of the season. Wingdam daytime electrofishing was missed completely in Period 1 and only one of four wingdams was sampled during Period 3. Tailwater trawling was also not completed during Period 1. Finally, two small hoop nets were lost during Period 3, one at the tailwater east fixed site and the other at a side channel border site in the Raft Channel, where a large tree drifted through the set and dislodged the net. Thus, 257 of 270 allocated samples were completed for the year. High water undoubtedly also influenced catches and gear efficiency during much of the season.

The LTRM fish sampling allocation among gear types has remained stable for many years. Sampling effort was highest for daytime electrofishing (77 collections), followed by mini fyke nets (66 collections), and fyke nets (48 collections). Effort was greatest in the contiguous backwater stratum (84 collections), with side channel (59 collections) and main channel border (48 collections) also receiving considerable effort. The impounded shoreline stratum received the least effort. Please note that the strata names imply habitat features, but a wide variety of habitat conditions exist within each stratum.

Total catch in 2018 was 19,539 fish, which is the lowest total catch in Pool 8 LTRM sampling since all three periods were restored in 2010. The catch per sample value was the lowest since 1994 (Figure 13), contrasting the 2017 record high value. Day electrofishing (8,871) and mini fyke nets (7,669) had the highest catches, yielding almost 85% of the total catch, combined. Species richness in 2018 was 62, six fewer species than were caught in 2017, but about on par with other recent years.

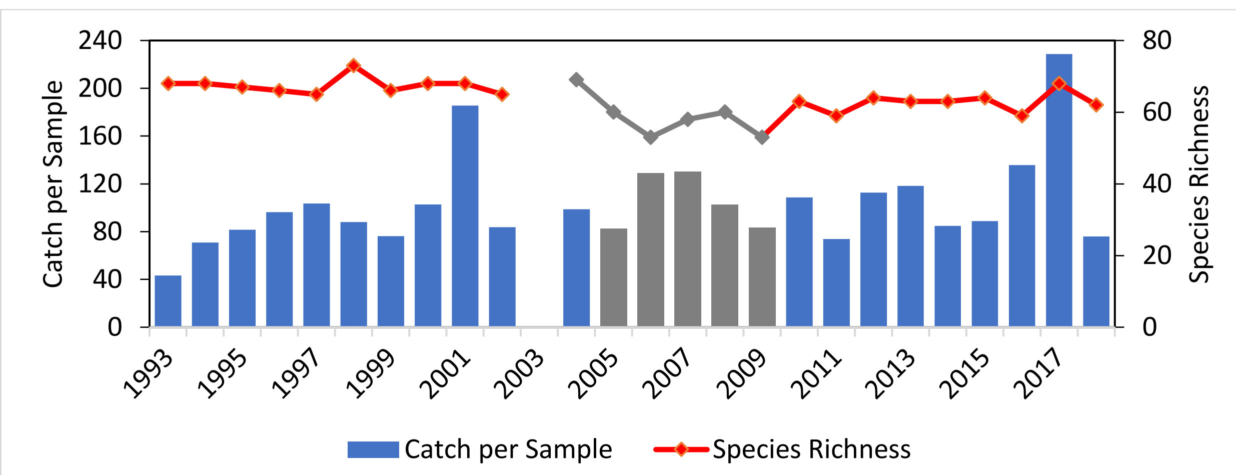


Figure 13. Catch per sample and annual species richness for Upper Mississippi River Restoration Program - Long Term Resource Monitoring Element fish collections in Pool 8 of the Upper Mississippi River. Data represent samples collected with daytime electrofishing, fyke nets, mini fyke nets, large and small hoop nets, and otter trawls. Data are omitted for 2003 due to limited sampling that year. Period 1 (June 15 – July 31) was not sampled from 2005-2009 (gray shaded bars).

Bluegill (4,242), Weed Shiner (4,203), Largemouth Bass (1,863), Spotfin Shiner (1,198) and Yellow Perch (795) were the top 5 species, in order of catch, in 2018 (Figure 14a). These top five species comprised 63% of the catch. Unidentified Centrarchids (predominantly YOY Bluegills), Black Crappie, Mimic Shiner, and Smallmouth Bass were also abundant.

By weight (Figure 14b), Common Carp (775 kg) ranked first in the catch, followed by Channel Catfish (315 kg), Bowfin (270 kg), Flathead Catfish (198 kg), and Freshwater Drum (181 kg). Other species yielding over 100 kg included Silver Redhorse, Northern Pike, Shorthead Redhorse, Largemouth Bass, and Bluegill. The top five species, by weight, accounted for about 57% of the total weight.

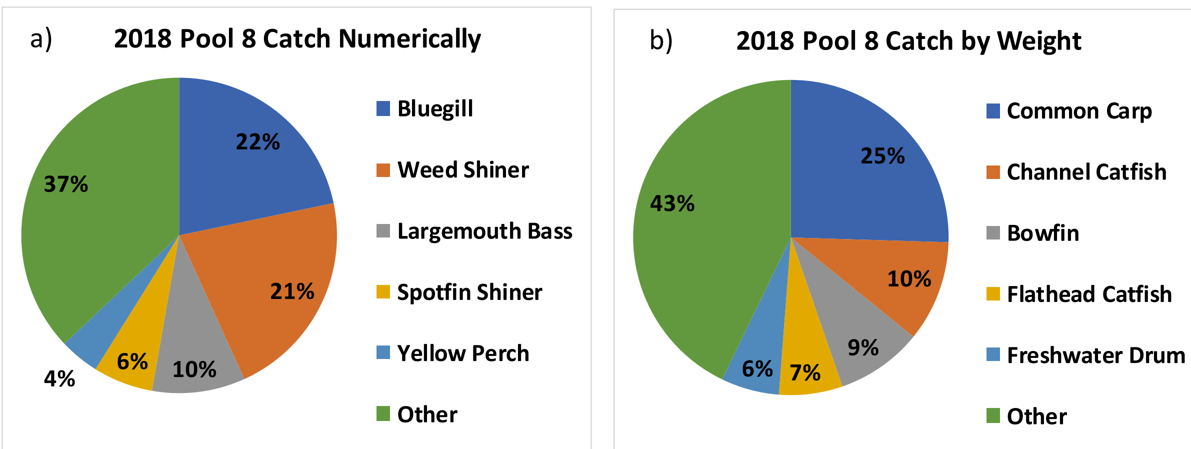


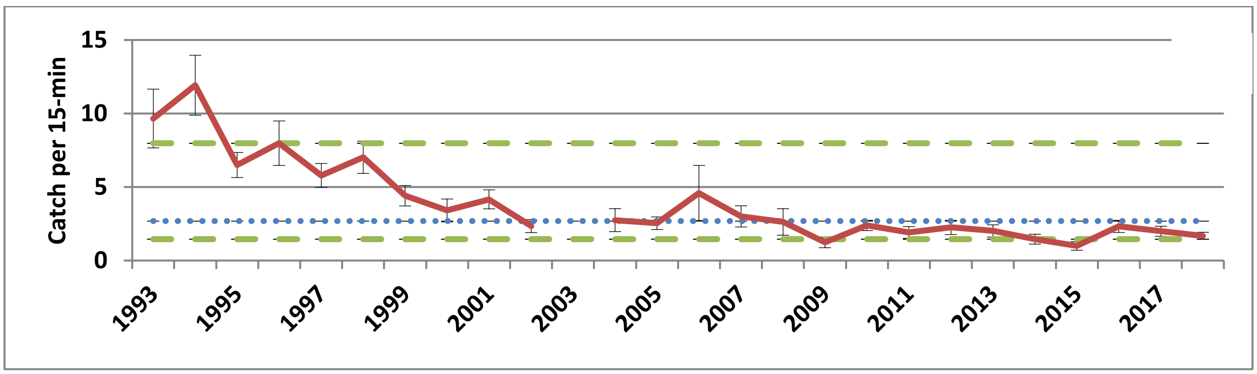
Figure 14. Top species for a) catch and b) weight in samples from Upper Mississippi River Restoration Program - Long Term Resource Monitoring Element fish collections in Pool 8 of the Upper Mississippi River during 2018. Data represent samples collected with daytime electrofishing, fyke nets, mini fyke nets, large and small hoop nets, and otter trawls.

Appendix B Lists all fish species collected in LTRM Pool 8 samples, and number of years collected. Historically, 37 species have been detected in Pool 8 LTRM samples every year since SRS began in 1993, and each of them were again collected in 2018. An additional 27 species have been detected in at least half of the years. However, of those, Orangespotted Sunfish has not been collected since 2014 and Sand Shiner has not been collected since 2013. Neither of them was collected in 2018.

Twenty-seven species have been detected in 12 or fewer years. Of that group of relatively rare species, we sampled the following in 2018 (most recent previous detection in parentheses): Troutperch (2017), Pirate Perch (2017), Speckled Chub (2016), Burbot (2015), Lake Sturgeon (2017), Yellow Bass (2017), Mississippi Silvery Minnow (2015) and Crystal Darter (1998, the only other year it was sampled with current gear types). From the list of more commonly caught species, we also encountered single specimens of Brown Bullhead and Highfin Carpsucker. Fewer than 10 individuals were sampled for an additional 12 species. Thus, about 35% of the species detected were very uncommonly encountered. No new species were collected in 2018. Thus, the LTRM fish species total in Pool 8 remains 91.

As mentioned above, we caught a Wisconsin-endangered Crystal Darter in a tailwater trawl haul on August 9, 2018. We were able to photograph and release this specimen alive. We caught two Wisconsin-listed threatened species, Blue Sucker (1) and River Redhorse (7), in the Pool 8 LTRM sampling this year. We also caught 1 Lake Sturgeon and 22 Mud Darters, both species of special concern.

Through 2018, the Pool 8 LTRM sampling efforts have not detected any Asian carp (Bighead, Silver, or Black). This year, we caught 253 Common Carp, currently the only non-native fish species of significance in Pool 8. Common Carp are thought to be in systemic decline in the UMR. However, they continue to dominate the catch, by weight, of all species in Pool 8. CPUE graphs of several gear types (Figure 15, top), provide a somewhat mixed picture. Day electrofishing CPUE for Common Carp does suggest a long-term decline; whereas, fyke net CPUE (Figure 15, bottom) shows perhaps a slight long-term decline, with a strong increase in the past three years. Shifting habitat utilization or a change in gear efficiency could be contributing factors to these data trends, although population decline still seems likely, given the trends in other LTRM study reaches.



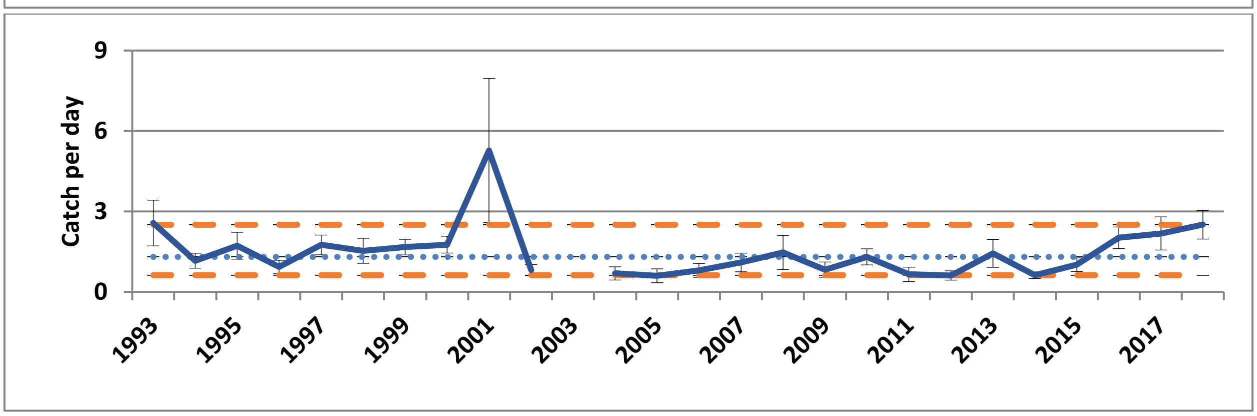


Figure 15. Catch per unit effort (± 1SE) of Common Carp by daytime electrofishing (top graph) and fyke netting (bottom graph) samples from the Upper Mississippi River Restoration Program - Long Term Resource Monitoring Element fish collections in Navigation Pool 8 of the Upper Mississippi River. Data are omitted for 2003 due to limited sampling that year. The long-dashed lines on the CPUE graphs represent the 10^{th} and 90^{th} percentiles and the dotted line represents the long-term average for the period of record (1993-2018).

Shannon-Wiener Diversity Index scores for day electrofishing in Pool 8 LTRM samples (Figure 16) increased in 2018, to the highest score since the mid-1990's, which continues a recent trend toward increasing diversity. Years 2007 and 2011 exhibited low diversity scores, and occurred during a period when aquatic vegetation had increased in Pool 8. Interestingly, 2007 was a year with relatively low mean annual discharge, and 2011 had one of the highest (Figure 1b); thus, any relationship between fish community diversity and discharge seems inconsistent. Linking fish community attributes to abiotic driving forces illustrates the necessity of monitoring over long time frames, as there are many short-term perturbations that do not necessarily indicate real trends.

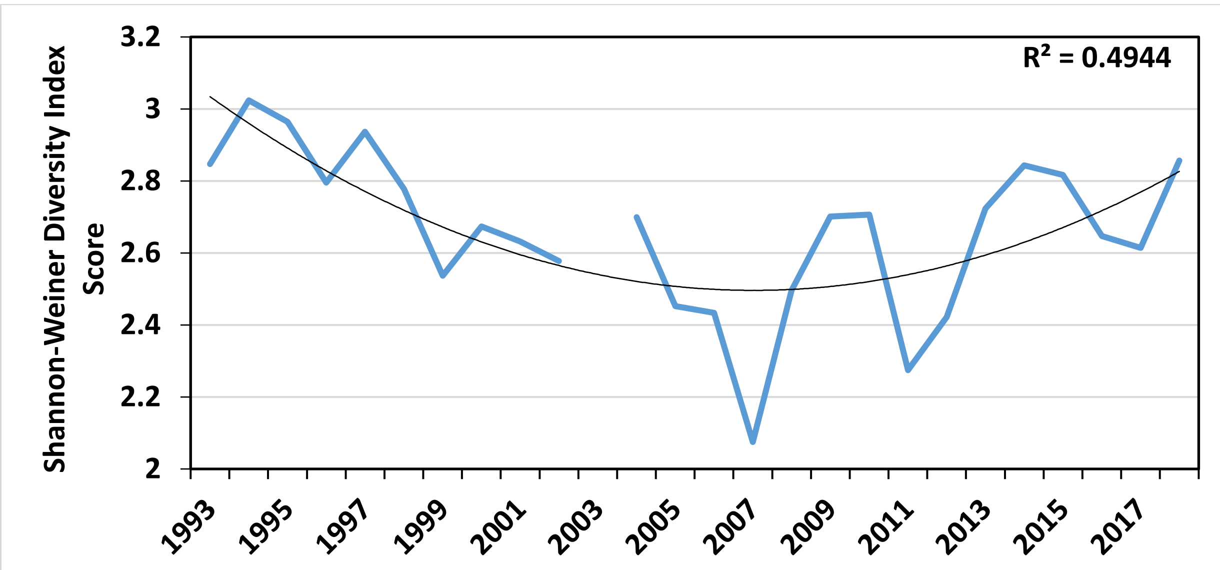


Figure 16. Shannon-Wiener Diversity Index Scores calculated from LTRM daytime electrofishing samples from 1993-2018 in Navigation Pool 8 of the Upper Mississippi River. Data are omitted for 2003 due to limited sampling that year. Trend line is a second-order polynomial representation of the data.

In summary, the Pool 8 fish community remained healthy again in 2018. Repeated high water events made sampling difficult and inefficient, leading to fluctuations in catches. However, the robust habitat and species diversity in pool 8 seems to have allowed the fish community to withstand these perturbations.

Species of Interest Data are presented on the following pages.

Black Crappie

Total catches of Black Crappie from all standard LTRM gear types combined have ranged from 269 in 2009 to 1,693 in 1994. We caught 526 Black Crappies in 2018. Black Crappie CPUE decreased in 2018 for both daytime electrofishing and fyke nets (Figure 17). Both gear types yielded catch rates near the 10th percentile for the LTRM period. There are more years below the long-term average in recent times than there were in the past.

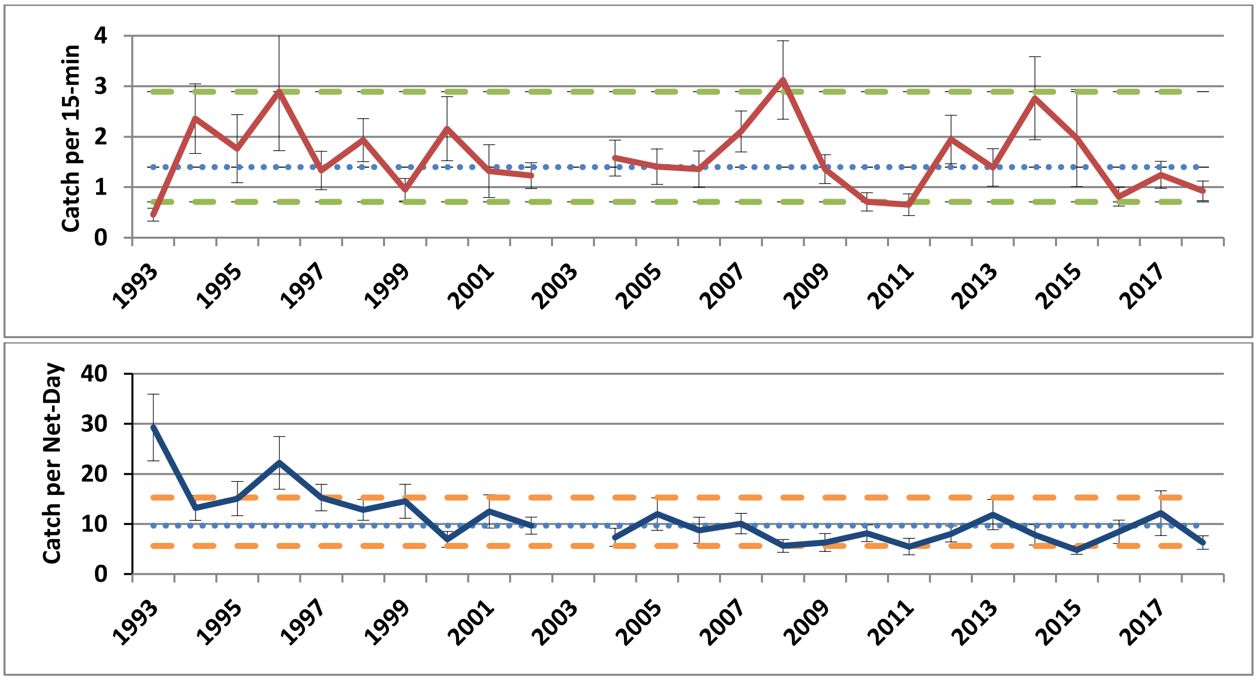


Figure 17. Catch per unit effort (± 1SE) of Black Crappie by daytime electrofishing (top graph) and fyke netting (bottom graph) samples from the Upper Mississippi River Restoration Program - Long Term Resource Monitoring Element fish collections in Navigation Pool 8 of the Upper Mississippi River. Data are omitted for 2003 due to limited sampling that year. The long-dashed lines on the CPUE graphs represent the 10th and 90th percentiles and the dotted line represents the long-term average for the period of record (1993-2018).

Catch of substock-size Black Crappie (Figure 18) was slightly below the long-term average in 2018, but moderate numbers of small fish were still caught. The substock graph suggests a mild propensity for Black Crappies to produce a strong year class every third or fourth year.

A small, but stable, proportion of the Black Crappie population reaches preferred- or memorable-size each year (Figure 19), indicating stability in the harvestable fishery. However, fewer fish have been present in the stock- and quality-size categories since about 2000. CPUE for daytime electrofishing (Figure 17 top) shows a stable trend over time, but fyke net CPUE does reflect a decline like that of the stock- and quality-size categories shown in Figure 19. Reasons for a decline of these intermediate sizes of Black Crappie are unknown, but, this trend would generally correspond with the rebound in submersed aquatic vegetation that occurred after a nearly complete crash in the early 1990's, suggesting an inverse relationship between stock- and quality-sized Black Crappies and the coverage and density of submersed aquatic vegetation. The catch of stock-sized Black Crappie was at an all-time low in 2018, and likely reflects a very low catch of substock-sized Black Crappie in 2017.

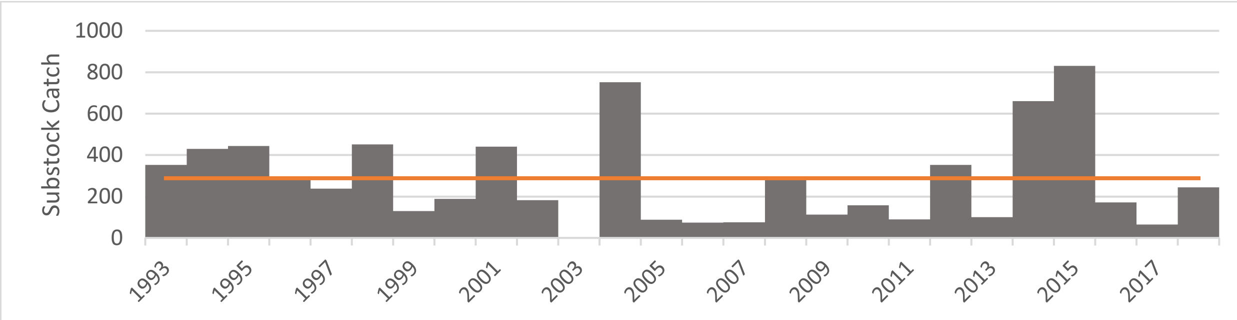


Figure 18. Catch of substock-sized Black Crappie annually in Navigation Pool 8 of the Upper Mississippi River by all gears combined from the Upper Mississippi River Restoration Program - Long Term Resource Monitoring Element. The horizontal line indicates long-term average catch of substock-sized fish.

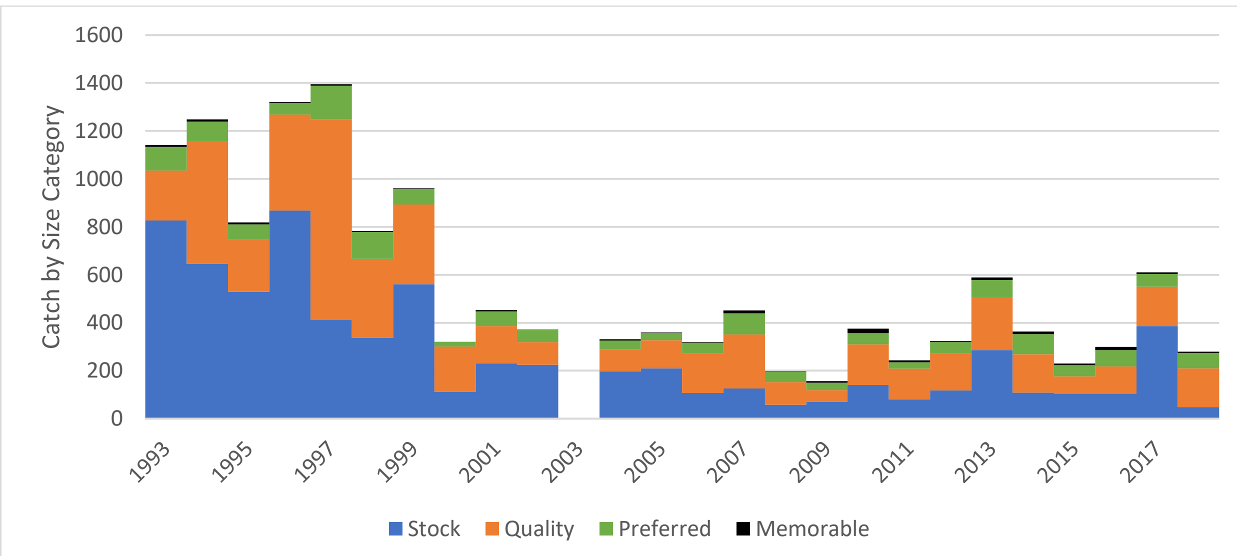


Figure 19. Catch of stock- through memorable-sized Black Crappie annually in Navigation Pool 8 of the Upper Mississippi River by all gears combined from the Upper Mississippi River Restoration Program - Long Term Resource Monitoring Element.

Bluegill

Total catches of Bluegill from all standard LTRM gear types combined have ranged from 1,685 in 1994 to 12,005 in 2010. We caught 4,241 Bluegill in 2018. Bluegill daytime electrofishing CPUE decreased in 2018 from that of 2017, continuing a general downward trend since 2008 (Figure 20 top). Fyke net CPUE (Figure 20 bottom) has shown a long-term pattern similar to that of electrofishing, and declined in 2018 to near the tenth percentile for the period. Low Bluegill catch rates in the early 1990's were attributed to the system-wide crash of submersed aquatic vegetation; however, vegetation is currently thriving, and catch rates have become low again. A possible explanation for the recent decline may be hydrology, specifically high summer flows (see Figure 1 bottom graph) that may be having deleterious effects upon survival or condition. An alternative explanation could also be predation by Yellow Perch. Research by the Minnesota Department of Natural Resources LTRM staff indicates that perch seem to be targeting age-0 Bluegills in winter (Steve Delain, MNDNR, personal communication). Yellow Perch have become abundant in Pool 8 in recent years.

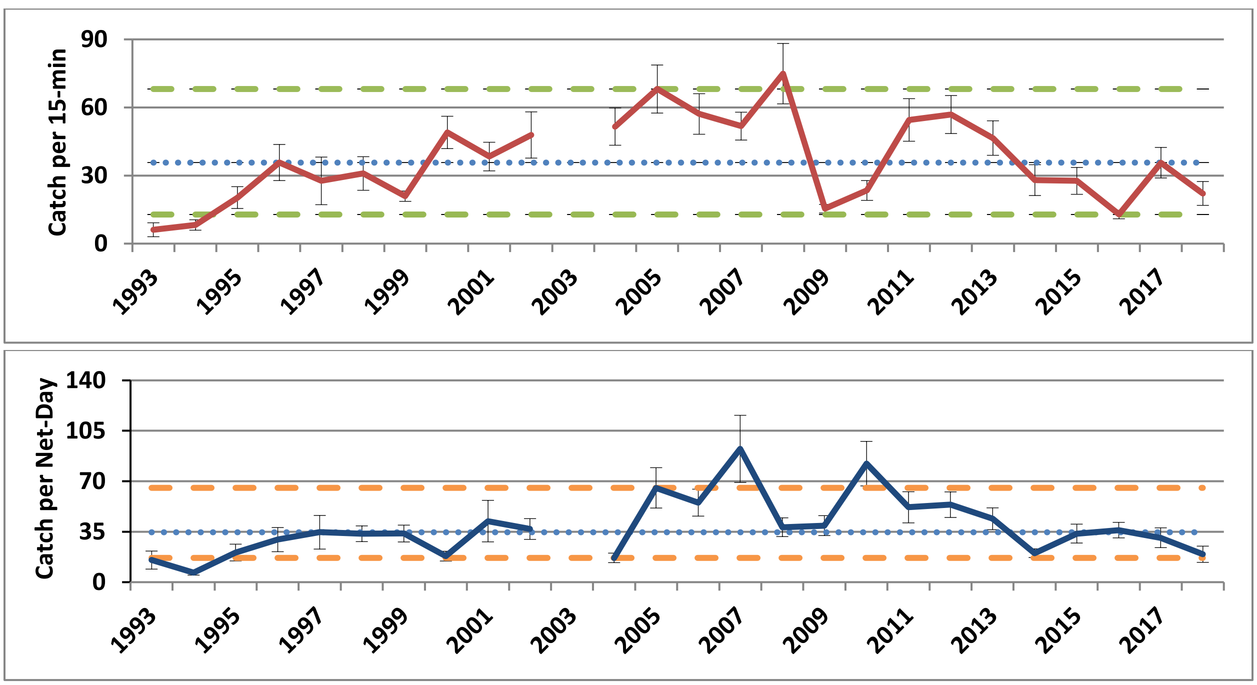


Figure 20. Catch per unit effort (± 1SE) of Bluegill by daytime electrofishing (top graph) and fyke netting (bottom graph) samples from the Upper Mississippi River Restoration Program - Long Term Resource Monitoring Element fish collections in Navigation Pool 8 of the Upper Mississippi River. Data are omitted for 2003 due to limited sampling that year. The long-dashed lines on the CPUE graphs represent the 10th and 90th percentiles and the dotted line represents the long-term average for the period of record (1993-2018).

Catches of substock-sized Bluegill have been below the long-term average in seven of the last ten years (Figure 21). However, no severe decline seems evident. Like Black Crappie, Bluegill seem to produce strong year classes every fourth year or so.

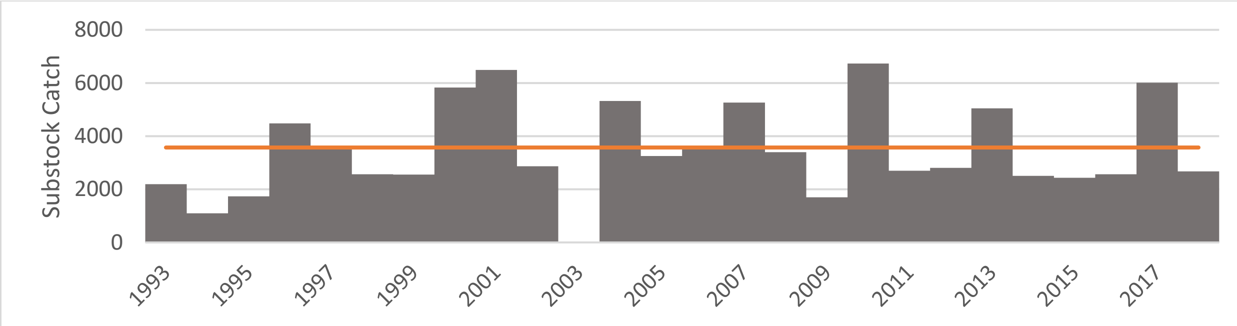


Figure 21. Catch of substock-sized Bluegill annually in Navigation Pool 8 of the Upper Mississippi River by all gears combined from the Upper Mississippi River Restoration Program - Long Term Resource Monitoring Element. The horizontal line indicates long-term average catch of substock-sized fish.

Preferred- and memorable-size Bluegill comprise a very small proportion of the overall catch (Figure 22) but have been slightly more present since 2010. The number of quality-sized Bluegill seems stable, relative to the high variability in the number of stock-sized fish. The number of substock-sized Bluegill does not seem to translate into stock-sized fish the next year or following. This would suggest that external forces are acting to shape the number of Bluegills that survive to larger sizes and would support the presumption that hydrology may be a factor. If Yellow Perch predation was having a population-level impact, we would expect to see a declining trend in substock Bluegills, which is not evident.

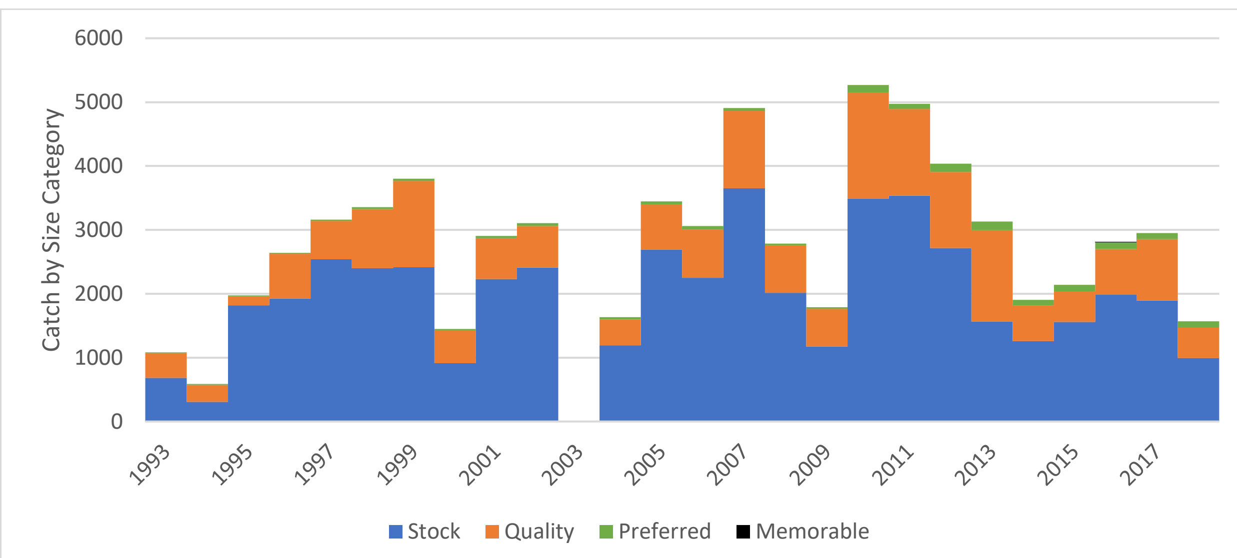


Figure 22. Catch of stock- through memorable-sized Bluegill annually in Navigation Pool 8 of the Upper Mississippi River by all gears combined from the Upper Mississippi River Restoration Program - Long Term Resource Monitoring Element.

Channel Catfish

Total catches of Channel Catfish from all standard LTRM gear types combined have ranged from 85 in 2009 to 785 in 1994. We caught 305 Channel Catfish in 2018. Channel Catfish CPUE increased in 2018 for both large- (Figure 23 top graph) and small-hoop netting (Figure 23 bottom graph). For the large nets, 2018 CPUE was near the 90th percentile. CPUE for small-hoop netting increased from near the 10th percentile to above the long-term mean, but was still lower than values throughout most of the 1990's. The overall CPUE trends suggest stability, with perhaps a shift from small hoop nets being more effective earlier to large hoop nets being better in recent years.

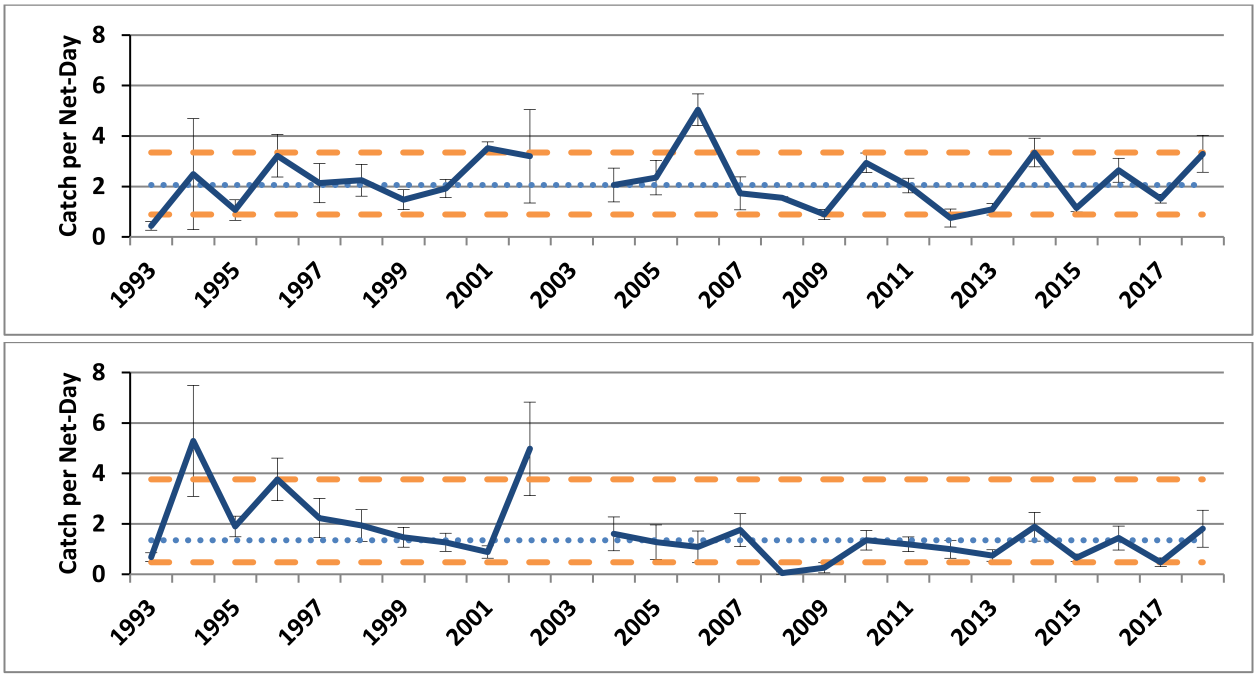


Figure 23. Catch per unit effort (± 1SE) of Channel Catfish by large-hoop netting (top graph) and small-hoop netting (bottom graph) samples from the Upper Mississippi River Restoration Program - Long Term Resource Monitoring Element fish collections in Navigation Pool 8 of the Upper Mississippi River. Data are omitted for 2003 due to limited sampling that year. The long-dashed lines on the CPUE graphs represent the 10th and 90th percentiles and the dotted line represents the long-term average for the period of record (1993-2018).

Substock-sized Channel Catfish were far more abundant in the Pool 8 catch during the first decade of SRS fish sampling for LTRM than since (Figure 24). Many of these were probably caught by trawling, although the CPUE for small-hoop nets does show a decline, as well. Catch of substock-sized Channel Catfish bears watching, as the population must generate some reproductive success occasionally to thrive. A positive sign was that more substock-size Channel Catfish were caught in 2018 than in any year since 2004.

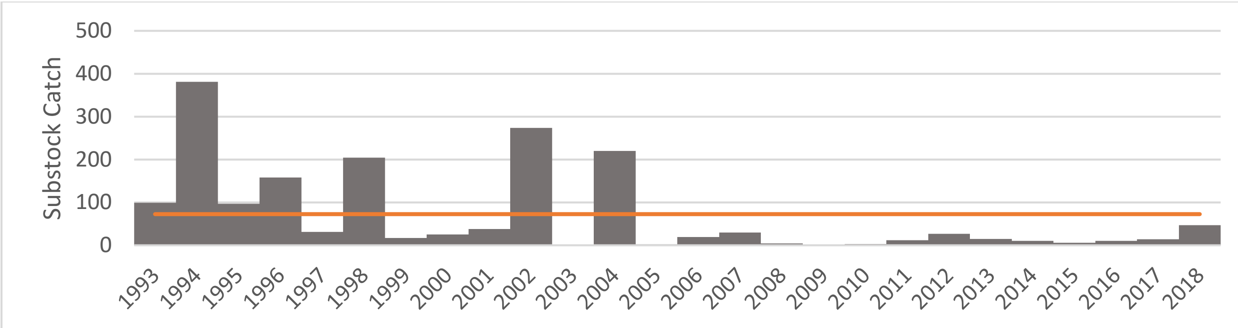


Figure 24. Catch of substock-sized Channel Catfish annually in Navigation Pool 8 of the Upper Mississippi River by all gears combined from the Upper Mississippi River Restoration Program - Long Term Resource Monitoring Element. The horizontal line indicates long-term average catch of substock-sized fish.

Stock- and quality-sized Channel Catfish dominated the LTRM Pool 8 catch through 2000 (Figure 25), but preferred- and memorable-sized fish have been relatively more common since then. Interestingly, stock- and larger sized Channel Catfish numbers seem to be holding their own, even without contributions from the substock-size group. This would suggest that the population may be aging.

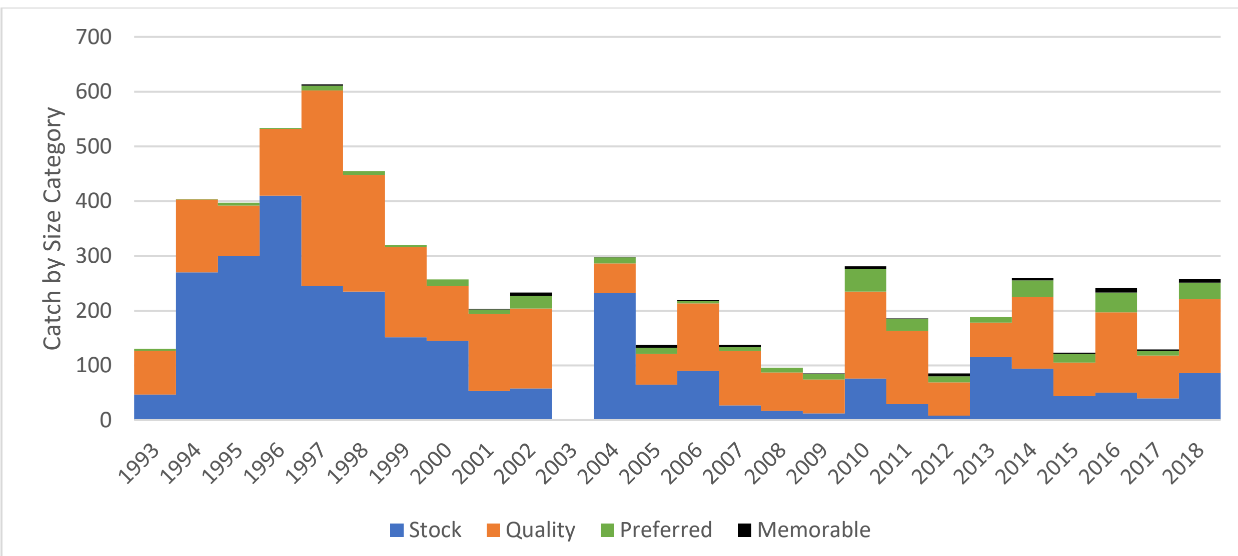


Figure 25. Catch of stock- through memorable-sized Channel Catfish annually in Navigation Pool 8 of the Upper Mississippi River by all gears combined from the Upper Mississippi River Restoration Program - Long Term Resource Monitoring Element.

Flathead Catfish

Total catches of Flathead Catfish from all standard LTRM gear types combined have ranged from 8 in 2006 to 100 in 1998. We caught 67 Flathead Catfish in 2018. Daytime electrofishing CPUE for Flathead Catfish continued to increase in 2018 over the previous year's record catch rate (Figure 26 top). CPUE from large hoop nets (Figure 26 bottom) dipped to the 90th percentile from the previous year but is still high. It is likely that high flows reduced hoop net catch rates in 2018. Regardless, Flathead Catfish are thriving in Pool 8.

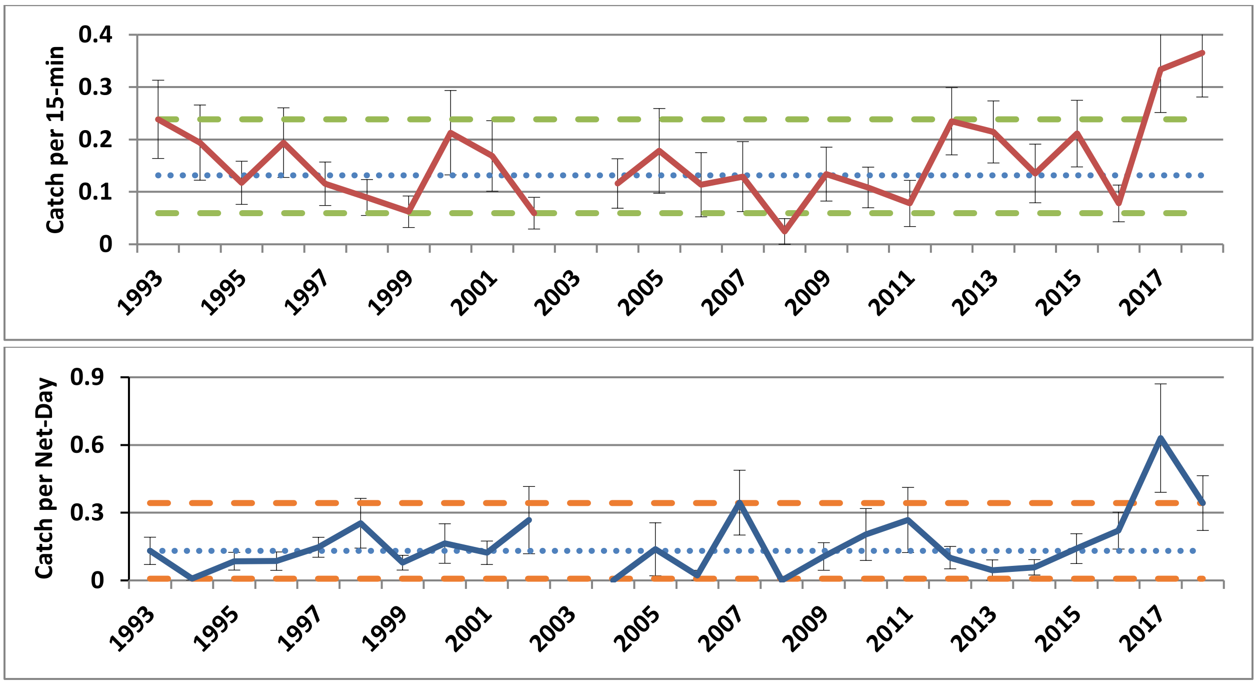


Figure 26. Catch per unit effort (± 1SE) of Flathead Catfish by daytime electrofishing (top graph) and large-hoop netting (bottom graph) samples from the Upper Mississippi River Restoration Program - Long Term Resource Monitoring Element fish collections in Navigation Pool 8 of the Upper Mississippi River. Data are omitted for 2003 due to limited sampling that year. The long-dashed lines on the CPUE graphs represent the 10th and 90th percentiles and the dotted line represents the long-term average for the period of record (1993-2018).

Catches of substock-sized Flathead Catfish (Figure 27) were higher in the 1990's, then dipped, and have rebounded since 2011. Judging from the flat or increasing trends of the CPUE graphs, higher overall sampling effort in the 1990's may have been the cause for those early numbers of young fish.

Perhaps the most striking feature of the adult stock-size graph for Flathead Catfish (Figure 28) is the number of memorable-sized fish present in the catch. A few very large fish have always been caught, but these have become a larger component in recent years. The stock- and quality-size categories reflect the substock graph well, showing the decline during the middle decade of LTRM fish sampling. Variability in catch, reflected in the adult stock-size graph as well as the CPUE's, is expected in a species that grows large and has lower populations than smaller fishes.

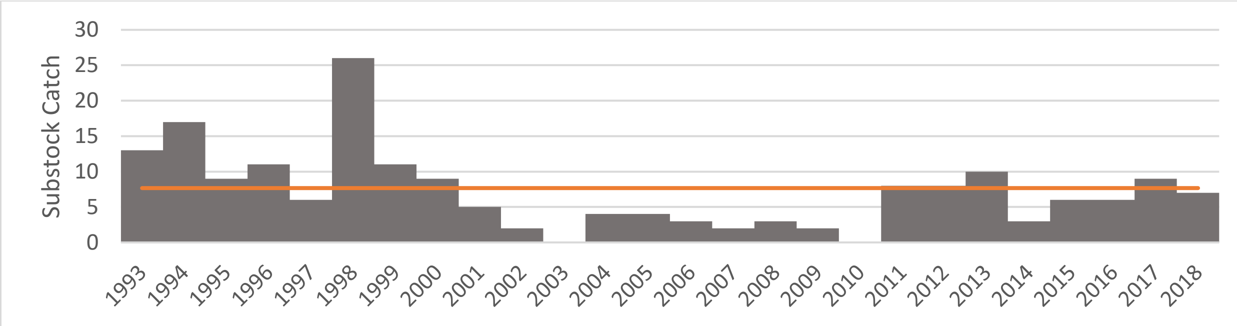


Figure 27. Catch of substock-sized Flathead Catfish annually in Navigation Pool 8 of the Upper Mississippi River by all gears combined from the Upper Mississippi River Restoration Program - Long Term Resource Monitoring Element. The horizontal line indicates long-term average catch of substock-sized fish.

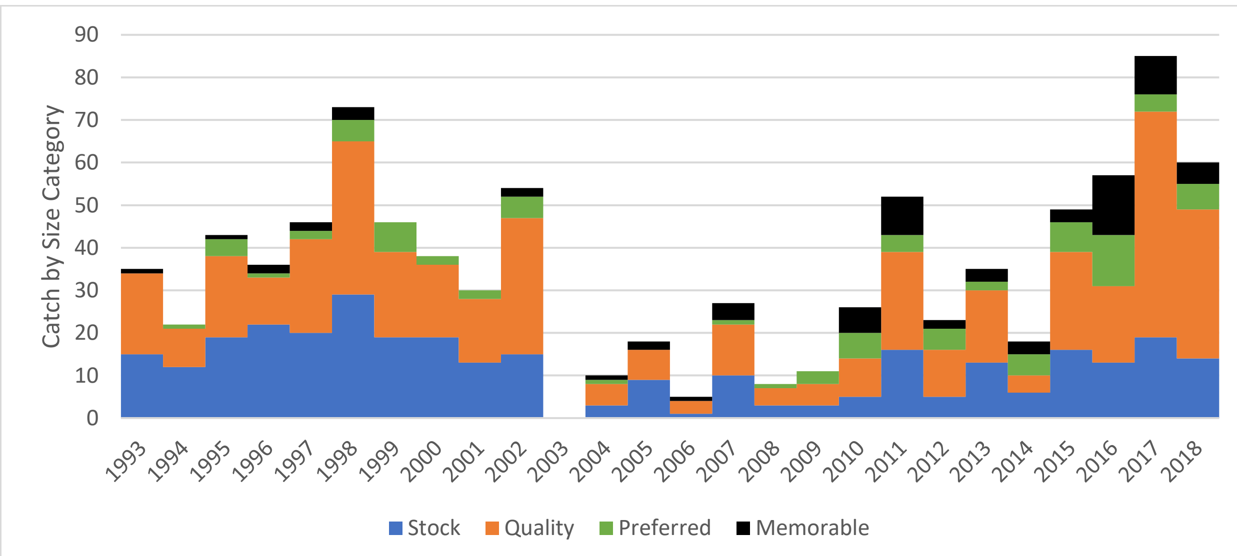


Figure 28. Catch of stock- through memorable-sized Flathead Catfish annually in Navigation Pool 8 of the Upper Mississippi River by all gears combined from the Upper Mississippi River Restoration Program - Long Term Resource Monitoring Element.

Largemouth Bass

Total catches of Largemouth Bass from all standard LTRM gear types combined have ranged from 292 in 1993 to 7,714 in 2016. We caught 1,863 Largemouth Bass in 2018. Largemouth Bass CPUE for daytime electrofishing increased slightly in 2018 from 2017, remaining above the long-term mean (Figure 29), and sustaining a catch rate at, or above, the long-term average for 13 of the last 15 years.

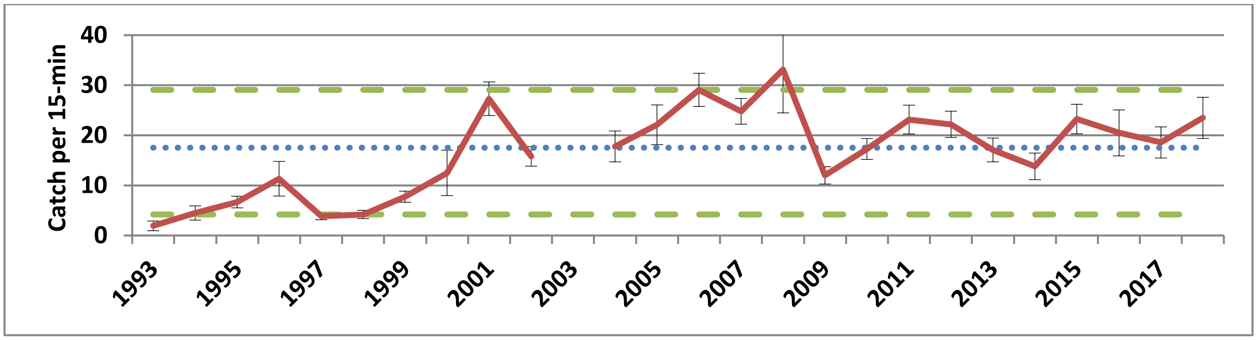


Figure 29. Catch per unit effort (± 1SE) of Largemouth Bass by daytime electrofishing samples from the Upper Mississippi River Restoration Program - Long Term Resource Monitoring Element fish collections in Navigation Pool 8 of the Upper Mississippi River. Data are omitted for 2003 due to limited sampling that year. The long-dashed lines on the CPUE graphs represent the 10th and 90th percentiles and the dotted line represents the long-term average for the period of record (1993-2018).

The catch of substock-sized Largemouth Bass (Figure 30) was dominated by an epic haul in 2016. Despite that anomaly, most years since 2010 have been at or above the long-term average, including 2018. This stands in stark contrast to the years before 2010, when that average was only reached once.

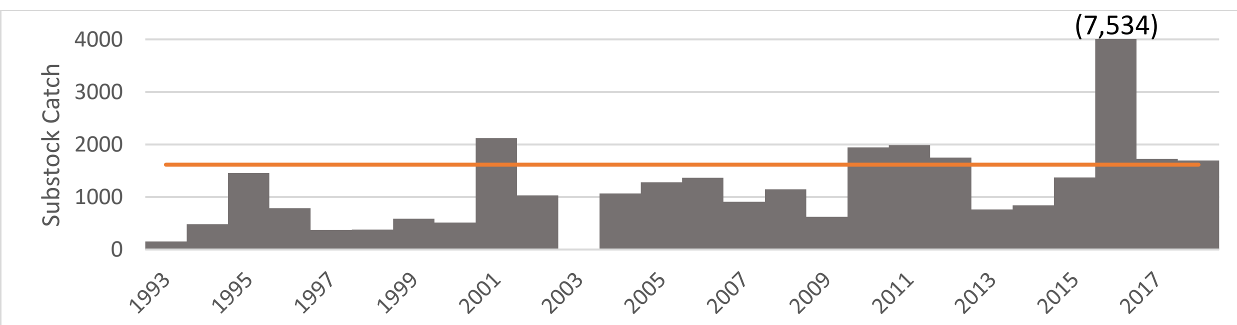


Figure 30. Catch of substock-sized Largemouth Bass annually in Navigation Pool 8 of the Upper Mississippi River by all gears combined from the Upper Mississippi River Restoration Program - Long Term Resource Monitoring Element. The horizontal line indicates long-term average catch of substock-sized fish.

The graph of stock- through memorable-sized Largemouth Bass (Figure 31) shows a variable stock-size group that roughly lags the substock-sized graph by one year, indicating good recruitment in most years. Catches of quality- and preferred-sized Largemouth Bass are consistent, and reflect the CPUE graph, which also depicted a peak population in the late 2000’s. Of note for Largemouth Bass is the lack of memorable-sized fish. Tournament anglers routinely comment that Largemouth Bass fishing is easy in Pool 8 and surrounding waters, but that big fish are few and far between. The LTRM data bear them out.

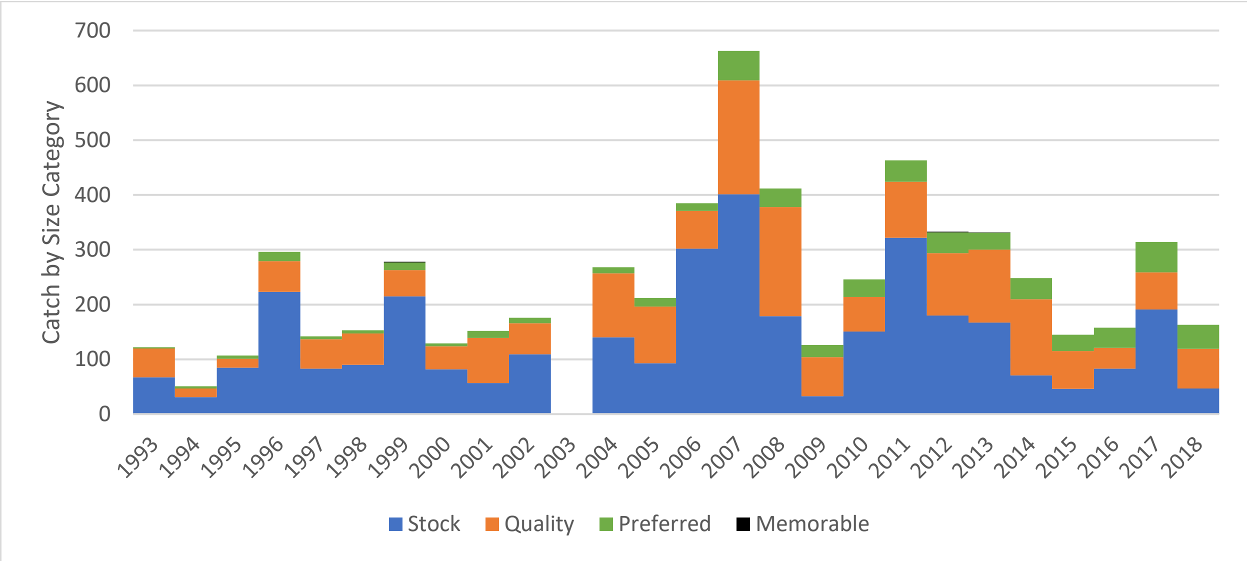


Figure 31. Catch of stock- through memorable-sized Largemouth Bass annually in Navigation Pool 8 of the Upper Mississippi River by all gears combined from the Upper Mississippi River Restoration Program - Long Term Resource Monitoring Element.

Northern Pike

Total catches of Northern Pike from all standard LTRM gear types combined have ranged from 51 in 2000 to 195 in 2018, the most on record. Northern Pike daytime electrofishing CPUE has exhibited several multi-year declines in recent years, with subsequent rebound years (Figure 32 top). Fyke netting CPUE (Figure 32 bottom) declined once during the past decade but has increased for the last three years. Electrofsihing CPUE is still within the 90th percentile, but fyke netting CPUE entered uncharted territory in 2018, establishing an all-time high.

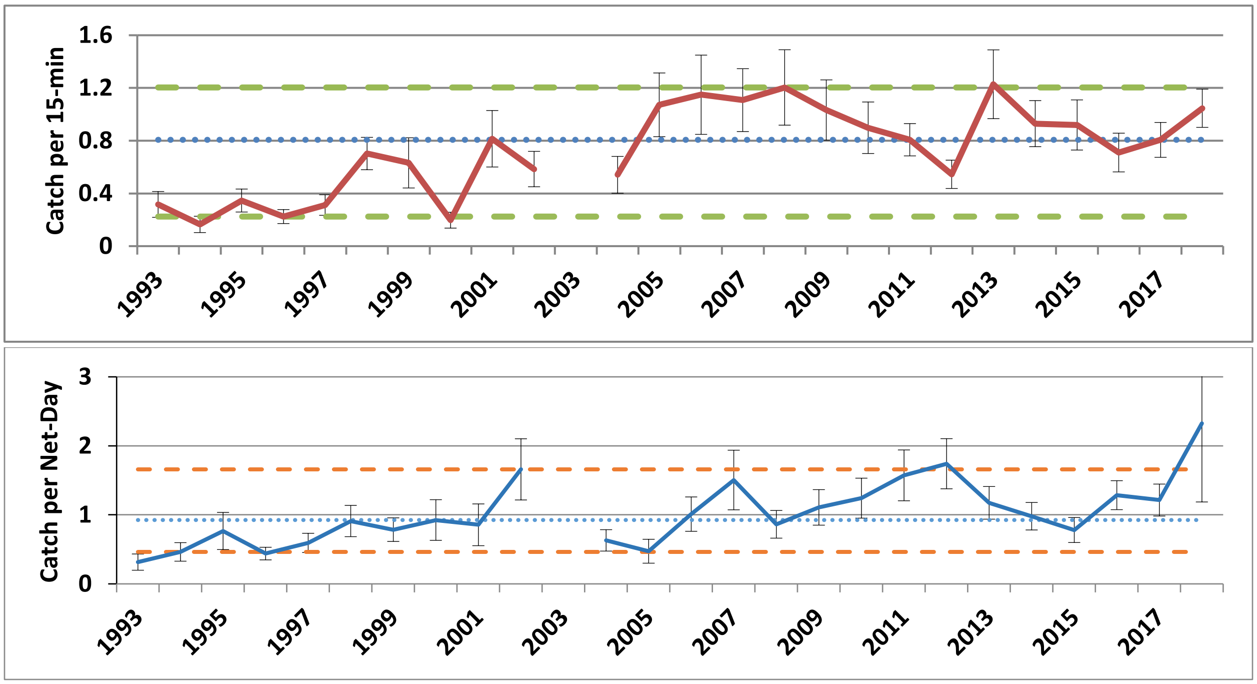


Figure 32. Catch per unit effort (± 1SE) of Northern Pike by daytime electrofishing (top graph) and fyke netting (bottom graph) samples from the Upper Mississippi River Restoration Program - Long Term Resource Monitoring Element fish collections in Navigation Pool 8 of the Upper Mississippi River. Data are omitted for 2003 due to limited sampling that year. The long-dashed lines on the CPUE graphs represent the 10th and 90th percentiles and the dotted line represents the long-term average for the period of record (1993-2018).

The catch of substock-sized Northern Pike (Figure 33) has been consistent, with exception of a few years where few or no small fish were caught. In most of those years, the spring flood was either very late, very early, of short duration, or small in scale, which would tend to limit spawning success. The catch of substock-sized Northern Pike in 2018 was second only to that of 2001, which had the second largest spring flood on record for Pool 8. Thus, it seems evident that the abundance of small northern Pike is linked with spring floods of appropriate timing, magnitude, and duration.

Catches of stock-sized Northern Pike (Figure 34) also seem linked to substock catches from the previous year; whereas quality- and preferred-sizes of pike are remarkably consistent. Memorable-sized

Northern Pike were slightly more prevalent in the first few years of SRS but are still present in most years. In 2018, despite the record catch, no memorable-sized Northern Pike were collected.

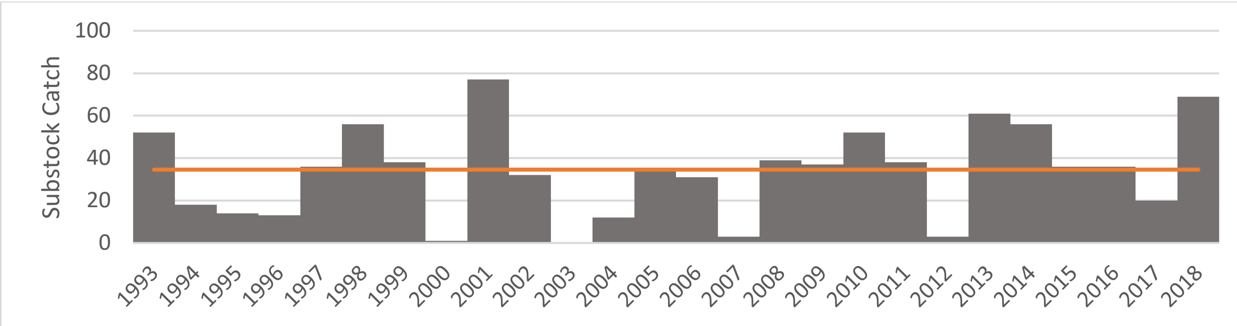


Figure 33. Catch of substock-sized Northern Pike annually in Navigation Pool 8 of the Upper Mississippi River by all gears combined from the Upper Mississippi River Restoration Program - Long Term Resource Monitoring Element. The horizontal line indicates long-term average catch of substock-sized fish.

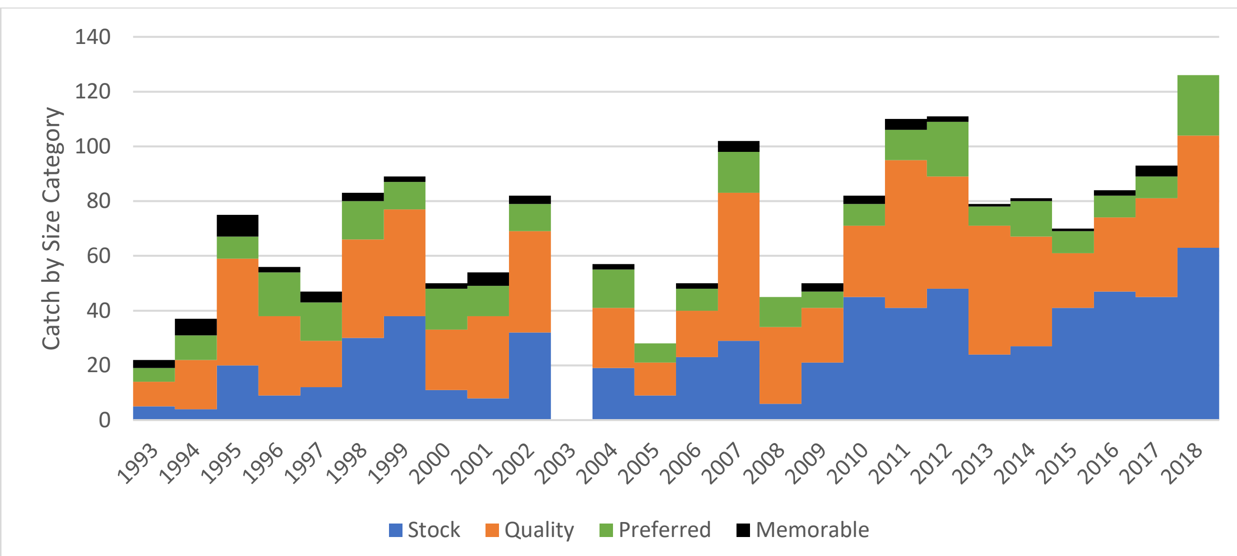


Figure 34. Catch of stock- through memorable-sized Northern Pike annually in Navigation Pool 8 of the Upper Mississippi River by all gears combined from the Upper Mississippi River Restoration Program - Long Term Resource Monitoring Element.

Sauger

Total catches of Sauger from all standard LTRM gear types combined have ranged from 4 in 2006 to 311 in 1998. We caught 18 Sauger in 2018. Sauger CPUE for daytime electrofishing has, for many years, been below that of the 1990's (Figure 35) and has remained below the historic LTRM mean since 2008. While the current LTRM gear/stratum combinations do not achieve high catch rates or large sample sizes for Sauger, they do likely reflect the Sauger population. Low variability in catch rates, as indicated by the consistently small standard errors, supports the notion that the sampling effort is not simply "missing" fish that are there to be captured. While it is possible that the 1990's catch rates were inflated by several successful year classes, and were thus, unusually high, the consistently low catch rates over the past twenty years suggests the need for some type of management action.

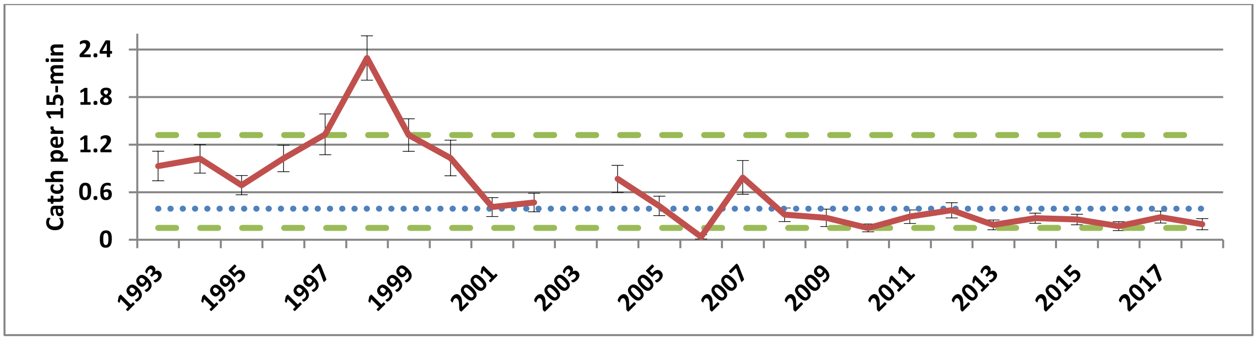


Figure 35. Catch per unit effort (± 1SE) of Sauger by daytime electrofishing samples from the Upper Mississippi River Restoration Program - Long Term Resource Monitoring Element fish collections in Navigation Pool 8 of the Upper Mississippi River. Data are omitted for 2003 due to limited sampling that year. The long-dashed lines on the CPUE graphs represent the 10th and 90th percentiles and the dotted line represents the long-term average for the period of record (1993-2018).

The graph of substock-sized Sauger catch (Figure 36) illustrates why Sauger CPUE has been in decline in Pool 8. Since 2000, catch of immature Sauger has been largely non-existent. Only twice in 19 years did the catch reach the average value, not at all since 2007. For some reason, reproductive failure seems evident.

The graph of stock- through memorable-sized Sauger catch (Figure 37) also shows that prior to the turn of the century, stock-sized Sauger constituted a large proportion of the catch. Since that time, stock-sized fish have been a far lesser constituent of the catch, often fewer in number than the quality-sized fish. Figure 32 also shows, however, that preferred- and larger-sized Sauger have been few in the catch since the onset of LTRM sampling, which may indicate high mortality. Given the popularity of this fish among anglers, efforts to conserve this species are warranted.

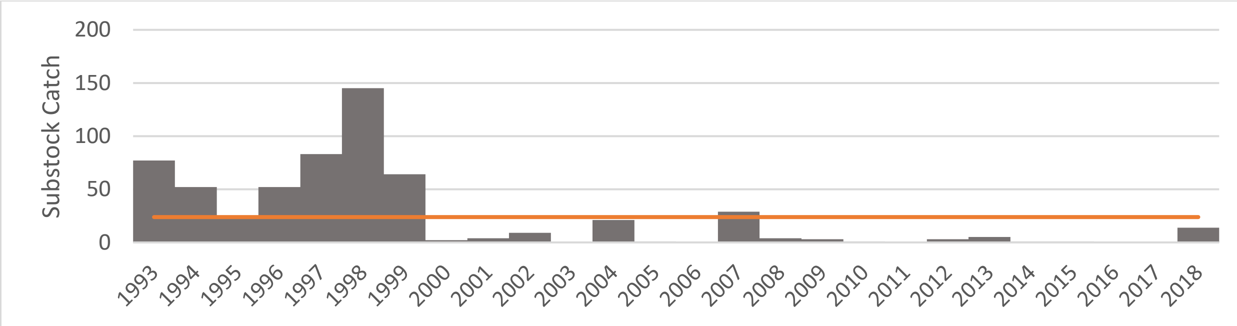


Figure 36. Catch of substock-sized Sauger annually in Navigation Pool 8 of the Upper Mississippi River by all gears combined from the Upper Mississippi River Restoration Program - Long Term Resource Monitoring Element. The horizontal line indicates long-term average catch of substock-sized fish.

Figure 37. Catch of stock- through memorable-sized Sauger annually in Navigation Pool 8 of the Upper Mississippi River by all gears combined from the Upper Mississippi River Restoration Program - Long Term Resource Monitoring Element.

Smallmouth Bass

Total catches of Smallmouth Bass from all standard LTRM gear types combined have ranged from 80 in 2009 to 550 in 1998. We caught 498 Smallmouth Bass in 2018. Smallmouth Bass daytime electrofishing CPUE has generally been on the increase since low points in 2009 and 2013 (Figure 38). The 2018 CPUE was the highest on record, by far, and more than double the long-term average.

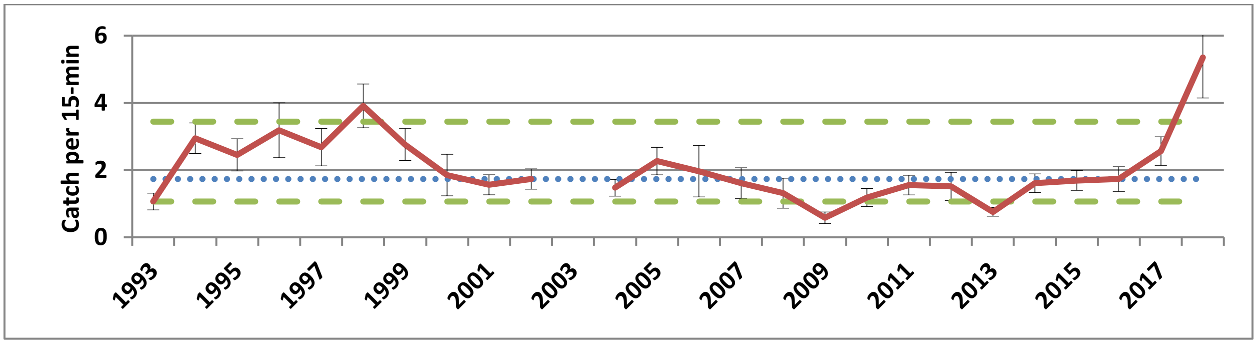


Figure 38. Catch per unit effort (± 1SE) of Smallmouth Bass by daytime electrofishing samples from the Upper Mississippi River Restoration Program - Long Term Resource Monitoring Element fish collections in Navigation Pool 8 of the Upper Mississippi River. Data are omitted for 2003 due to limited sampling that year. The long-dashed lines on the CPUE graphs represent the 10th and 90th percentiles and the dotted line represents the long-term average for the period of record (1993-2018).

Substock-sized Smallmouth Bass catch (Figure 39) was the second-highest on record in Pool 8 LTRM samples in 2018. This marks a second consecutive year above the long-term average, and only the fourth time in several decades of exceeding that average.

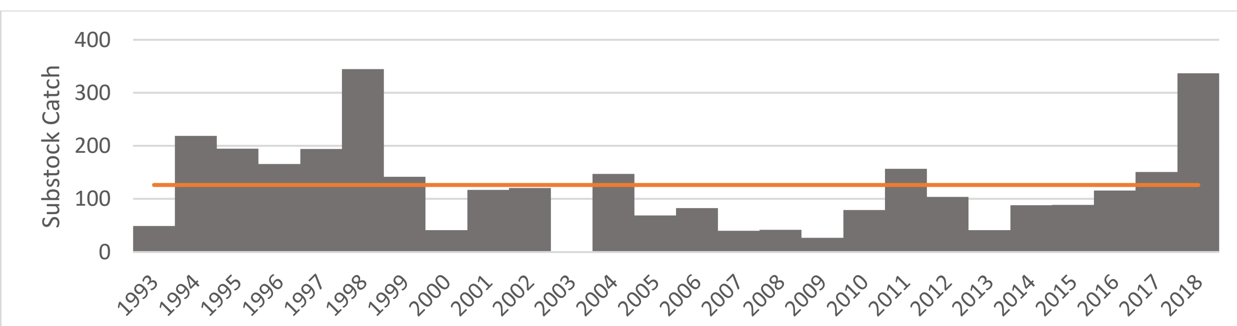


Figure 39. Catch of substock-sized Smallmouth Bass annually in Navigation Pool 8 of the Upper Mississippi River by all gears combined from the Upper Mississippi River Restoration Program - Long Term Resource Monitoring Element. The horizontal line indicates long-term average catch of substock-sized fish.

The catch of stock-sized and longer Smallmouth Bass (Figure 40) has quite stable over time, despite some low numbers from 2008-2010 and 2013-2014. The greatest variation seems to be in the stock-size category, which reached a low point in 2009 and dropped again five years later. Conversely, the preferred- and memorable-sized Smallmouth Bass catches have been very consistent, offering anglers good opportunities to catch large fish year after year.

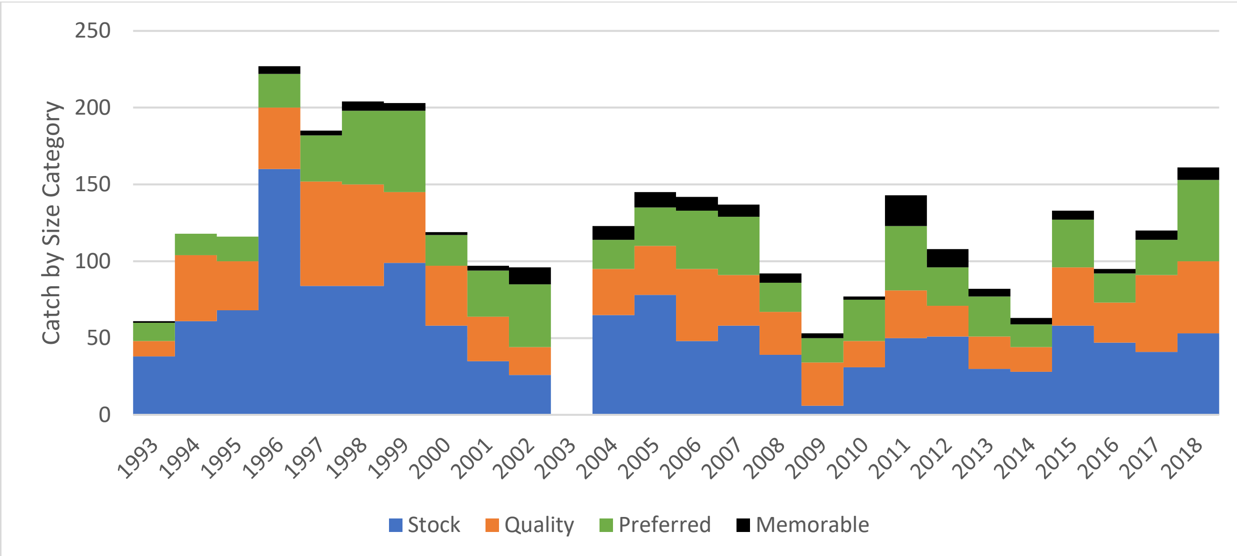


Figure 40. Catch of stock- through memorable-sized Smallmouth Bass annually in Navigation Pool 8 of the Upper Mississippi River by all gears combined from the Upper Mississippi River Restoration Program - Long Term Resource Monitoring Element.

Walleye

Total catches of Walleye from all standard LTRM gear types combined have ranged from 10 in 2009 to 137 in 1997. We caught 83 Walleyes in 2018. Walleye daytime electrofishing CPUE increased dramatically in 2018 (Figure 41 top), exceeding the long-term mean for the third time in four years, and exceeding the 90th percentile in 2018. The fyke net CPUE graph (Figure 41 bottom) exhibits more variability than electrofishing and has remained within the 10th and 90th percentile band nearly every year. Despite continuing low catch rates for both daytime electrofishing and fyke netting, the recent trend, if anything, is an upward trajectory. This is a different pattern than what was evident for the closely-related Sauger. Thus, management intervention seems less urgent for Walleye.

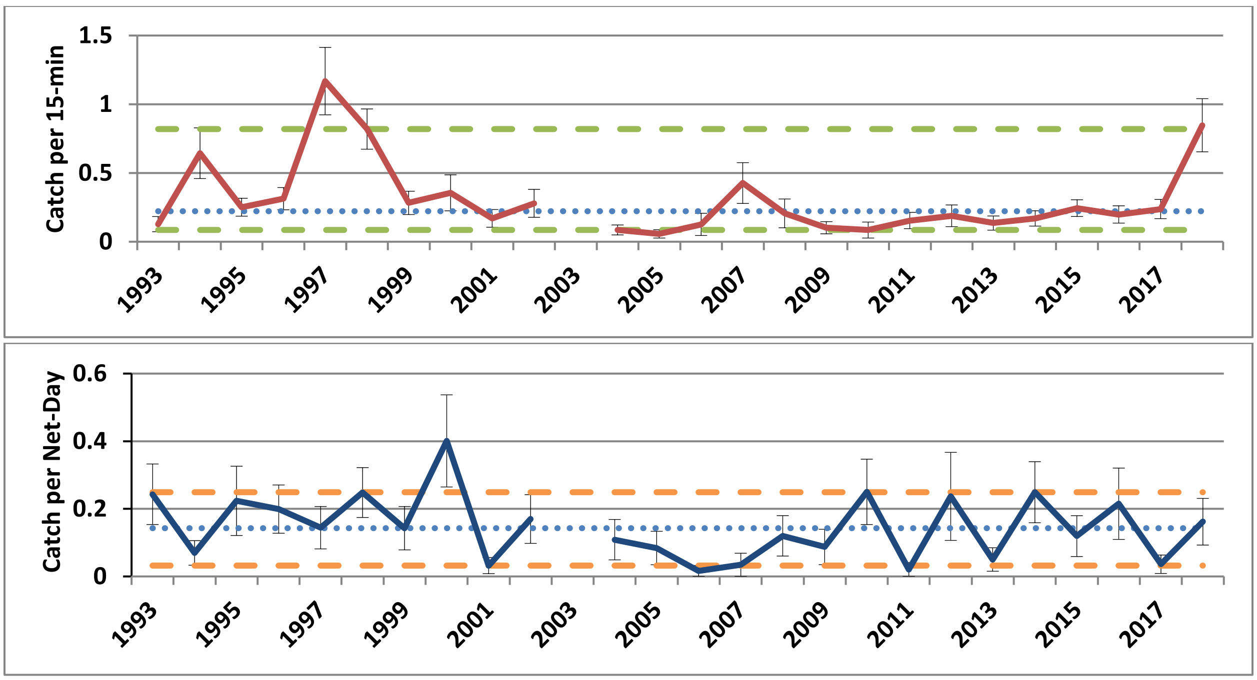


Figure 41. Catch per unit effort (± 1SE) of Walleye by daytime electrofishing (top graph) and fyke netting (bottom graph) samples from the Upper Mississippi River Restoration Program - Long Term Resource Monitoring Element fish collections in Navigation Pool 8 of the Upper Mississippi River. Data are omitted for 2003 due to limited sampling that year. The long-dashed lines on the CPUE graphs represent the 10th and 90th percentiles and the dotted line represents the long-term average for the period of record (1993-2018).

Figure 42 indicates that 2018 was an excellent year for substock-sized Walleyes in Pool 8, the first good year in a long time. In fact, only two other years produced as many small Walleyes, and they were the consecutive years 1997 and 1998. Obviously, some reproduction occurs in most years, or the species would disappear. However, more frequent large year classes would be helpful to bolster Walleye populations.

The stock- and larger graph (Figure 43) for Pool 8 Walleyes is somewhat similar to the same analysis for Sauger, in that the catch of stock-sized fish was much greater in the 1990's than since. However, stock-sized Walleyes still constitute a significant proportion of the catch in many years. Even more telling is that the catch of preferred- and even memorable-sized Walleyes has persisted. Thus, while both Sauger and Walleye populations appear to be affected by weak year classes, large Walleyes in Pool 8 may be less affected by high mortality than Sauger.

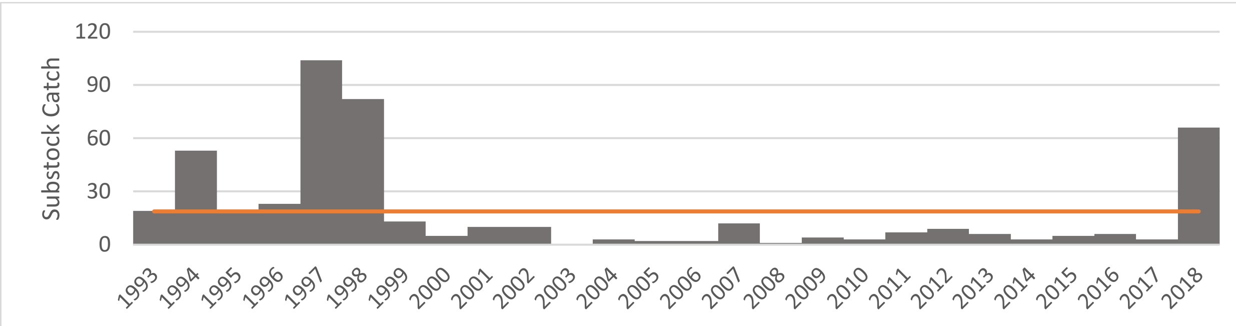


Figure 42. Catch of substock-sized Walleye annually in Navigation Pool 8 of the Upper Mississippi River by all gears combined from the Upper Mississippi River Restoration Program - Long Term Resource Monitoring Element. The horizontal line indicates long-term average catch of substock-sized fish.

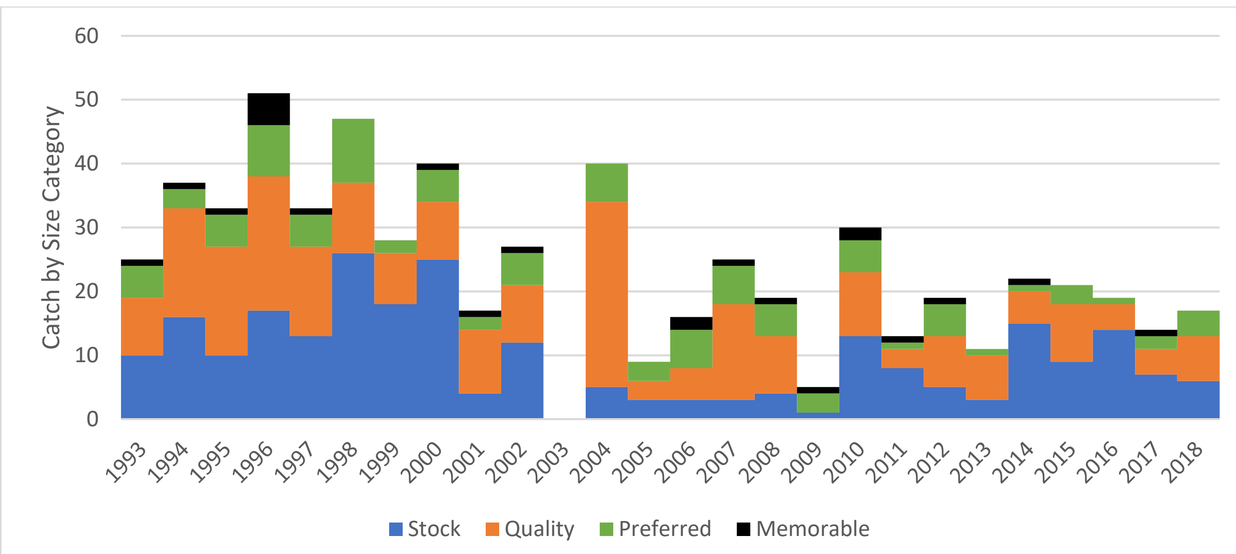


Figure 43. Catch of stock- through memorable-sized Walleye annually in Navigation Pool 8 of the Upper Mississippi River by all gears combined from the Upper Mississippi River Restoration Program - Long Term Resource Monitoring Element.

Yellow Perch

Total catches of Yellow Perch from all standard LTRM gear types combined have ranged from 53 in 2000 to 1,579 in 2015. We caught 795 Yellow Perch in 2018. Daytime electrofishing CPUE (Figure 44 top) dipped in 2018, but was still near the 90th percentile, where it has been in most years since 2009. Fyke net CPUE for Yellow Perch (Figure 39 bottom) remained slightly above the long-term mean, where it has been for the past seven years.

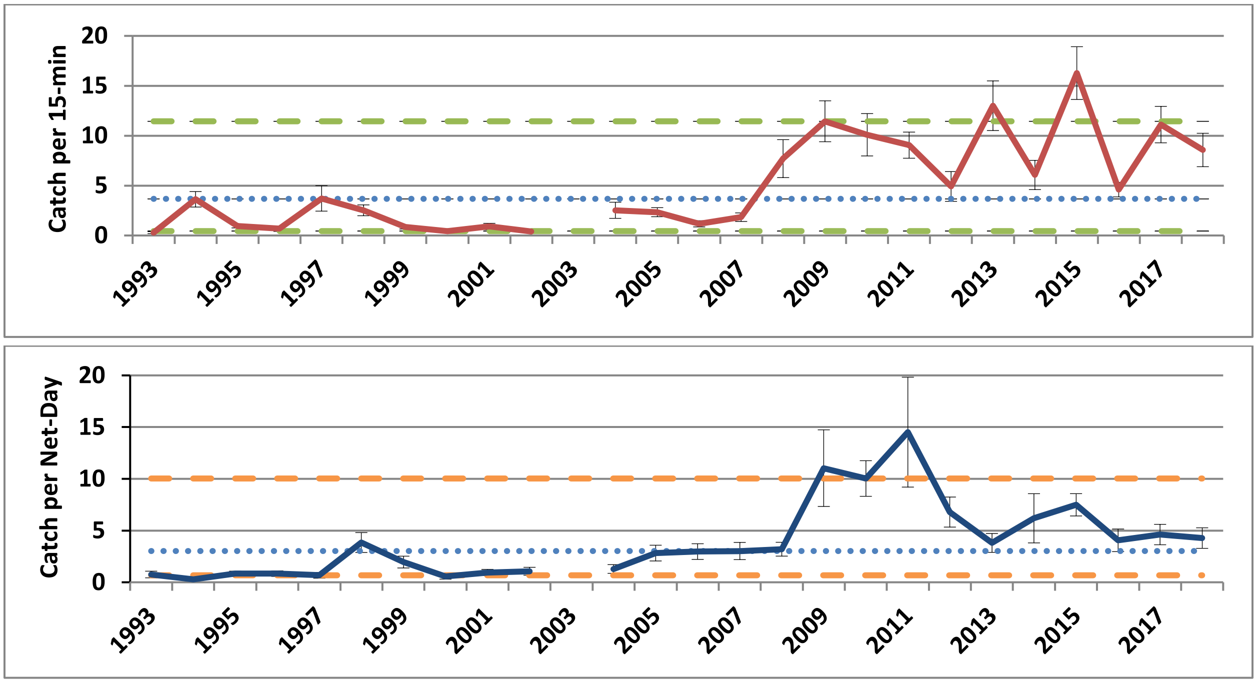


Figure 44. Catch per unit effort (± 1SE) of Yellow Perch by daytime electrofishing (top graph) and fyke netting (bottom graph) samples from the Upper Mississippi River Restoration Program - Long Term Resource Monitoring Element fish collections in Navigation Pool 8 of the Upper Mississippi River. Data are omitted for 2003 due to limited sampling that year. The long-dashed lines on the CPUE graphs represent the 10th and 90th percentiles and the dotted line represents the long-term average for the period of record (1993-2018).

The 2018 catch of substock-sized Yellow Perch (Figure 45) was well above the long-term average, but only about half that of the 2013 and 2015 classes. Yet, consecutive above-average classes should bode well for future Yellow Perch populations. In fact, only three times since 2008 have substock-sized Yellow Perch catches been below-average. Thus, barring recruitment failures, the population should be stable to increasing.

Recruitment from substock-sized Yellow Perch to adults is usually evident in Pool 8. For example, substock-sized perch in 1997 and 1998 were evident as stock-sized fish in 1998 and 1999 (Figure 46). This pattern repeated in 2008-2010 and 2009-2011. Again, the pattern repeated from 2013 to 2014. However, the largest catch of substock-sized Yellow Perch from 2015 were not evident as stock-sized fish in 2016 and following, nor, apparently, was the third highest substock-sized catch from 2017 recruited in 2018. The Pool 8 Yellow Perch population can likely withstand occasional recruitment failures, but if these continue, the population will likely diminish quickly, as it does not appear to be a long-lived population. Although preferred-size Yellow Perch have remained a considerable part of the catch in the past decade, few Yellow Perch attain memorable-size.

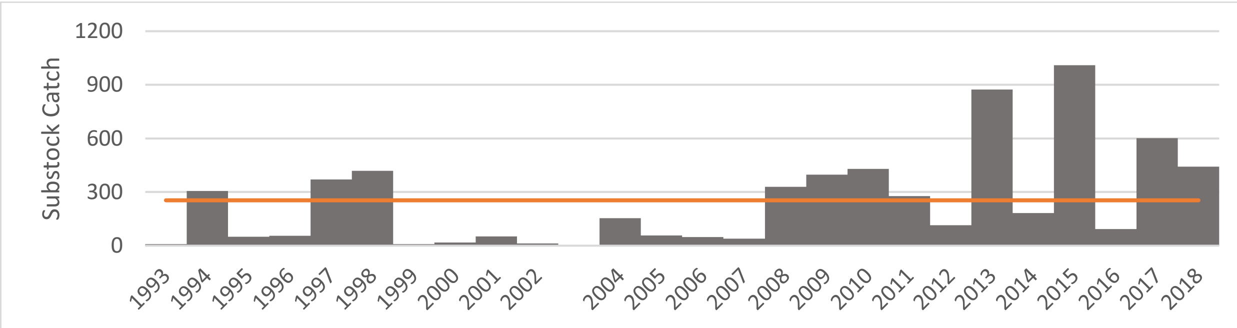


Figure 45. Catch of substock-sized Yellow Perch annually in Navigation Pool 8 of the Upper Mississippi River by all gears combined from the Upper Mississippi River Restoration Program - Long Term Resource Monitoring Element. The horizontal line indicates long-term average catch of substock-sized fish.

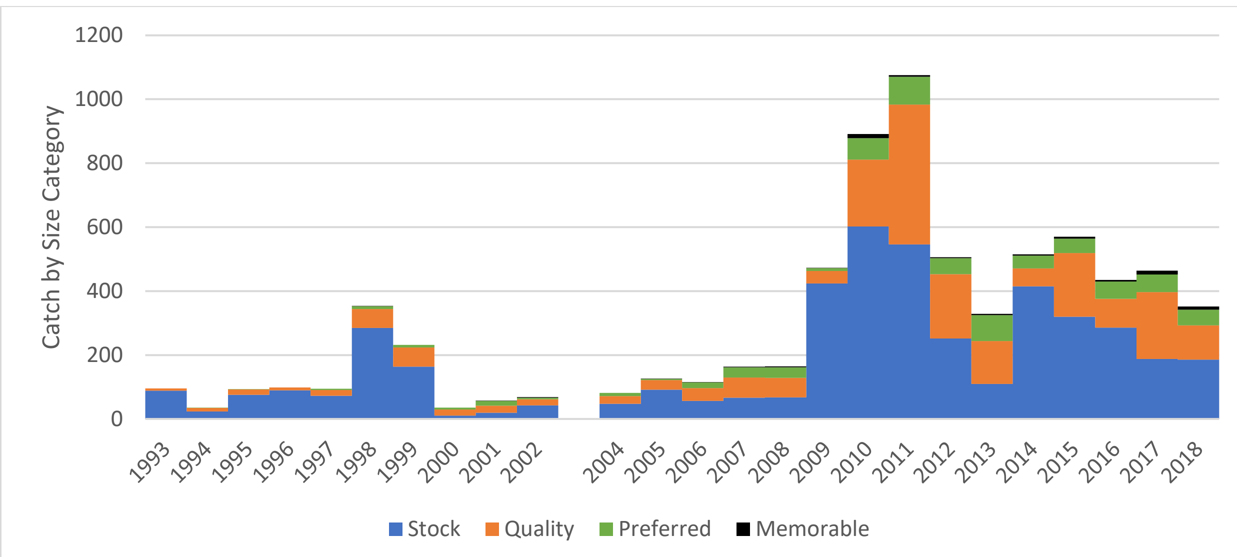
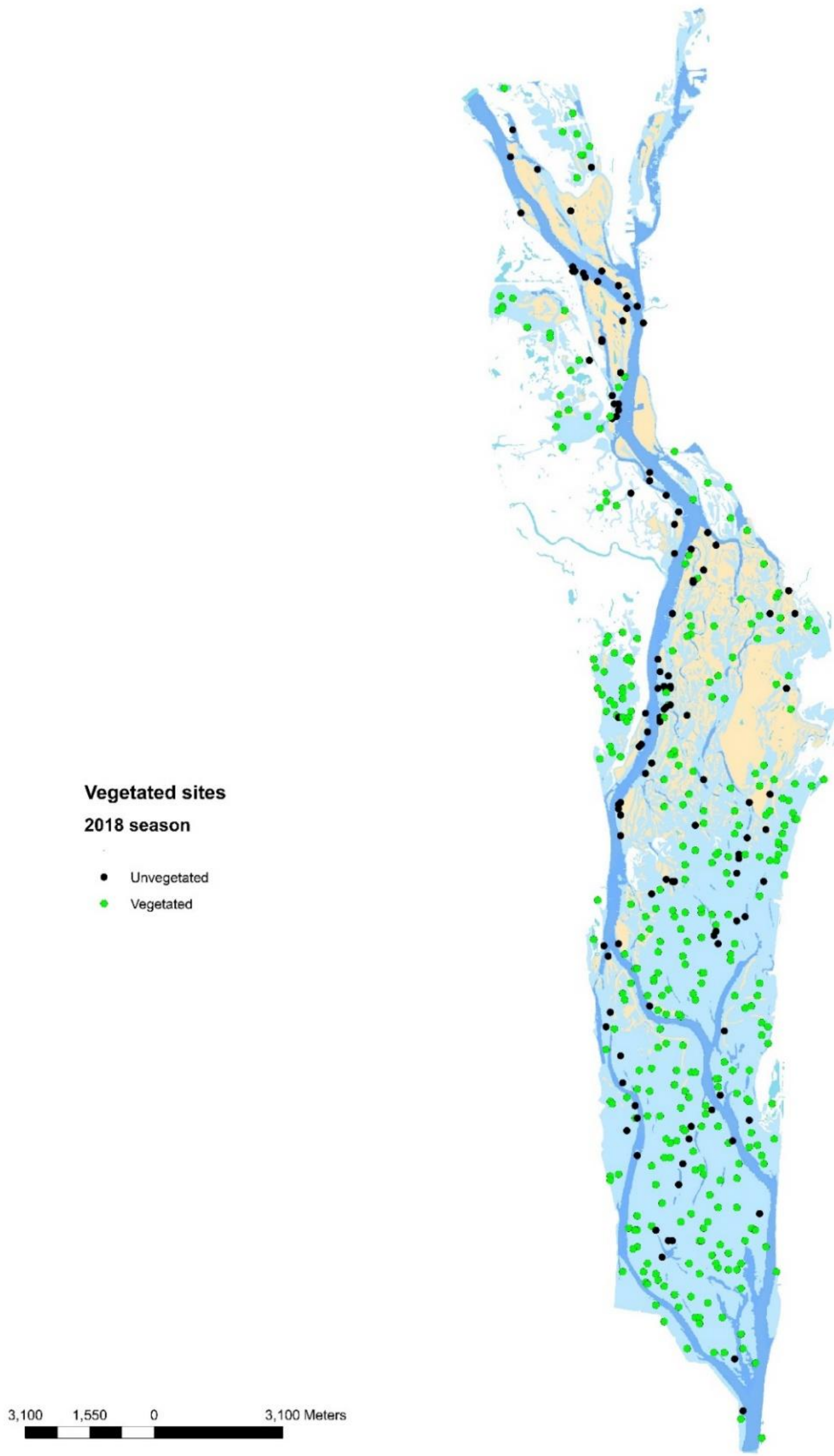


Figure 46. Catch of stock- through memorable-sized Yellow Perch annually in Navigation Pool 8 of the Upper Mississippi River by all gears combined from the Upper Mississippi River Restoration Program - Long Term Resource Monitoring Element.

Appendix A. Locations of the 449 sites visited in 2018 aquatic vegetation surveys – vegetated sites (339) are marked in green and unvegetated sites (110) are in black. Most of the unvegetated sites were located in the main channel and side channels with high water velocity and depth.



Appendix B. Species list and years detected in LTRM Pool 8 samples. Species in green rows have been detected every year, those in blue have been detected in half or more of years, those in orange less than half of years, and those in gray only single years.

Common Name	Years
Black Crappie	26
Bluegill	26
Bowfin	26
Brook Silverside	26
Bullhead Minnow	26
Channel Catfish	26
Common Carp	26
Emerald Shiner	26
Freshwater Drum	26
Gizzard Shad	26
Golden Redhorse	26
Golden Shiner	26
Green Sunfish	26
Johnny Darter	26
Largemouth Bass	26
Logperch	26
Longnose Gar	26
Mimic Shiner	26
Northern Pike	26
Pumpkinseed	26
Quillback	26
River Redhorse	26
River Shiner	26
Rock Bass	26
Sauger	26
Shorthead Redhorse	26
Silver Redhorse	26
Smallmouth Bass	26
Smallmouth Buffalo	26
Spotfin Shiner	26
Spottail Shiner	26
Spotted Sucker	26
Tadpole Madtom	26
Walleye	26
Weed Shiner	26
White Bass	26
Yellow Perch	26
Flathead Catfish	25
Mud Darter	25
Shortnose Gar	25
Warmouth	25
Pugnose Minnow	24
Yellow Bullhead	24
Chestnut Lamprey	23
River Carpsucker	23

Common Name	Years
Shovelnose Sturgeon	23
Slenderhead Darter	23
Fathead Minnow	22
Mooneye	22
White Sucker	22
Central Mudminnow	21
River Darter	21
Western Sand Darter	21
White Crappie	21
Bigmouth Buffalo	20
Black Bullhead	19
Silver Lamprey	19
Blue Sucker	16
Orangespotted Sunfish	16
Highfin Carpsucker	15
Sand Shiner	15
Silver Chub	15
Banded Darter	13
Brown Bullhead	13
Trout Perch	12
Bluntnose Minnow	9
Iowa Darter	9
Northern Hog Sucker	9
Pirate Perch	9
Speckled Chub	9
Burbot	8
Lake Sturgeon	8
Blackside Darter	7
Stonecat	7
Yellow Bass	7
Mississippi Silvery Minnow	6
American Brook Lamprey	5
Brook Stickleback	5
Black Buffalo	2
Brassy Minnow	2
Brown Trout	2
Crystal Darter	2
Fantail Darter	2
Pallid Shiner	2
American Eel	1
Central Stoneroller	1
Creek Chub	1
Goldeye	1
Largescale Stoneroller	1
Rainbow Smelt	1
Skipjack Herring	1

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