Upper Mississippi River Pool 8

Long Term Resource Monitoring - 2016 Status Report

An element of the

Upper Mississippi River Restoration - Environmental Management 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

Introduction

Fish, water quality, and vegetation data are collected each year through the Upper Mississippi River Restoration- Environmental Management Program - Long Term Resource Monitoring (LTRM). A complete description of the program can be found at: http://www.umesc.usgs.gov/LTRM.html. Personnel from the Wisconsin Department of Natural Resources collect data in Navigation Pool 8, one of 6 study reaches included in the program. Water quality and fish data have been collected under a stratified random framework since 1993 and vegetation data since 1998. This report summarizes the 2016 dataset in the context of how it relates to the entire LTRM sampling frame.

2016 Hydrograph

Methods

Discharge data were obtained from the U.S. Army Corps of Engineers' web site for water information on the Mississippi River (http://www.mvp-wc.usace.army.mil/). For 2016, we used discharge estimates from Lock and Dam 8 at Genoa, WI, as we have done starting with the 2013 report. Previously, we had used actual gage data from Lock and Dam 5, in Winona, MN, but those data are no longer available. This results in using a more local gage, but having a shorter time series and an unofficial gaging station.

A historical hydrograph was constructed by computing the mean daily discharge values from the years 1959-2015. The daily discharge for 2016 was then compared to the long-term daily mean to observe departure from typical conditions (Figure 1a). Additional analyses examined annual, growing season (May–September), and spring flood discharge characteristics. Mean discharge was calculated from daily values, plotted for years 1993-2016, and overlain on a plot containing the historic mean, 10^{th}, and 90^{th} percentiles for all years (1959 to 2016; Figure 1b). Mean growing season discharge was calculated and plotted similarly to the mean annual discharge (Figure 1c). 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 the dates in 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 75^{th} percentile discharge value from March through May. Magnitude was reported as the maximum spring discharge value for each year (Table 1).

Results

2016 was the wettest year on record in La Crosse, and third wettest in Rochester, Minnesota (source: National Weather Service, http://www.weather.gov/arx/lse2016). Abundant rainfall occurred throughout the UMR basin, and this precipitation greatly influenced discharge in Pool 8. The first half of the year roughly tracked the historic hydrograph (Figure 1a), except that the spring flood occurred almost a month early, and was followed by an unusual low water period in April. However, from early

July until the end of the year, water levels were significantly above normal. This extended period of high water in 2016 yielded the second highest annual mean discharge during the LTRM period of record (Figure 1b), and resulted in the third highest mean growing season discharge, as well (Figure 1c). The spiky nature of the hydrograph infers that at least 7 large precipitation events occurred upstream and locally, and the timing of these events was even enough to maintain high discharge for much of the year.

Four of the five highest mean annual discharges recorded during the LTRM period of record occurred in the past six years, along with three of the four highest mean growing season discharges. These climate extremes highlight the importance of continued long-term monitoring on the UMR.

A 2016 spring flood analysis (Table 1) reveals that, as stated previously, the spring flood occurred in March. Water levels were elevated for 17 days, and the peak discharge was slightly over 106,000 cfs. While the spring flood duration and magnitude have been essentially normal over the past few years, this was the fifth consecutive year where the timing differed from the historic hydrograph. Unlike 2012-2015, however, the spring of 2016 started early.

Table 1. Spring flood pulse statistics by year during the LTRM period of record (1993-2016) 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 75^{th} percentile from the long term record (1959-2016). 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	Year	Duration	Timing	Magnitude
1993	53	April	117500	2005	19	April	96300
1994	21	May	107100	2006	26	April	104000
1995	28	May	86000	2007	18	April	87400
1996	30	April	140200	2008	40	May	101000
1997	40	April	188300	2009	11	April	83300
1998	24	April	122500	2010	26	March	114100
1999	32	May	110400	2011	69	April	168800
2000	0	March	66500	2012	0	May	76200
2001	54	April	225100	2013	50	May	116900
2002	21	April	121100	2014	49	May	133500
2003	23	May	116900	2015	1	May	79600
2004	3	April	80300	2016	17	March	106200

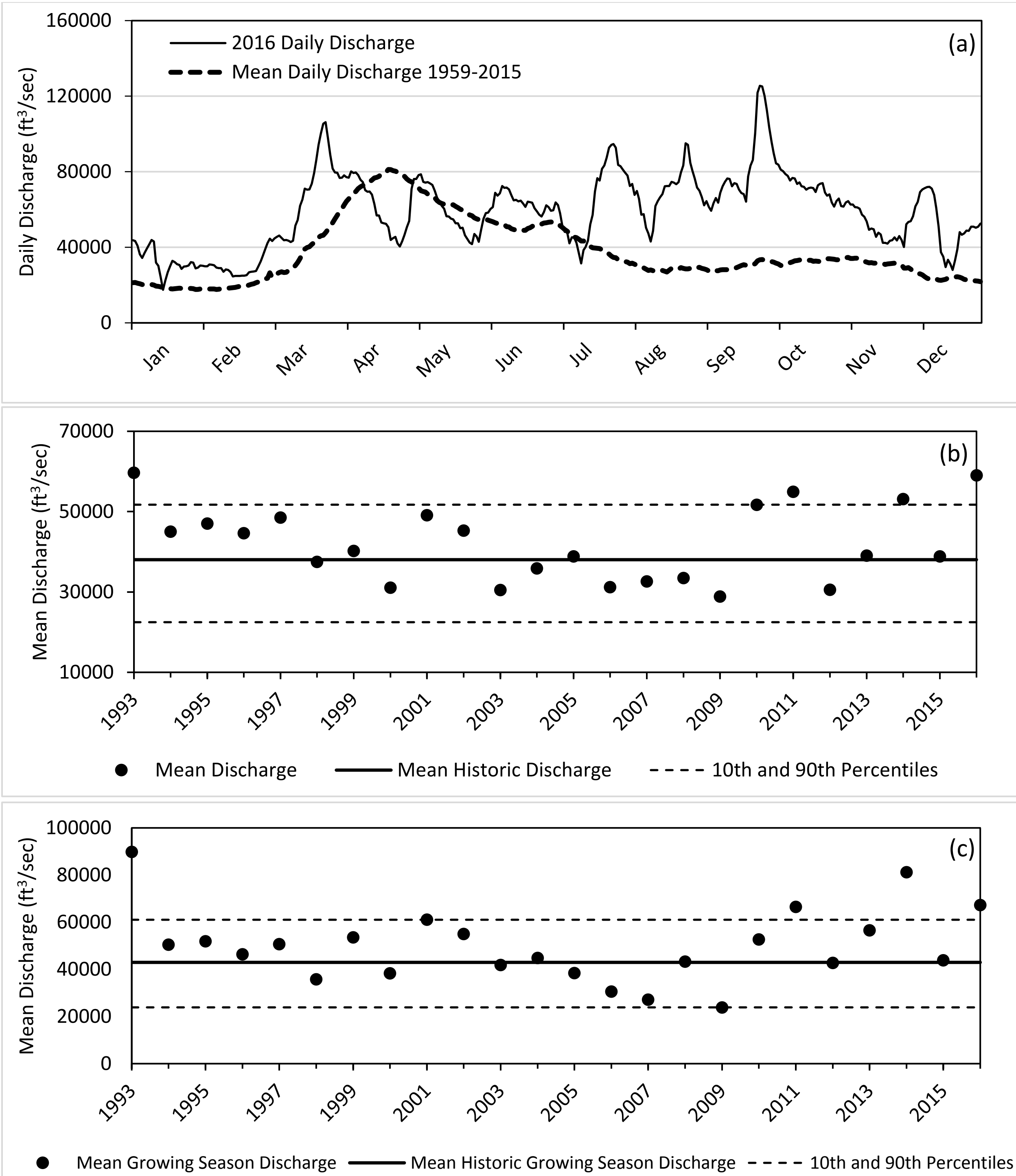

Figure 1. (a) Daily discharge at Lock and Dam 8 on the Upper Mississippi River for 2016 is represented by the solid line. Mean daily discharge by day of the year for 1959-2015 is represented by the dotted line. (b) Mean discharge by year is represented by the black dots. The solid line represents mean historic discharge for 1959-2016. The dashed lines represent the 10th and 90th percentiles for 1959-2016 discharge. (c) Mean growing season discharge (May-Sept.) by year is represented by the black dots. The solid line represents mean historic growing season discharge for 1959-2016. The dashed lines represent the 10th and 90th percentiles for 1959-2016 growing seasons.

2016 Water Quality

Methods

The focus of the water-quality component of the LTRM is to collect limnological information relevant to the suitability of aquatic habitat for biota and transport of materials within the system. The LTRM water-quality sampling design since 1993 incorporates 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 were surface measurements taken at 0.20m. Water was 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 2016 displayed a broad range of conditions, several of the seasonal median values were less than the 10^{th} or greater than the 90^{th} percentile for the LTRM period of record (Figure 2, Table 2). Many of these anomalous values are not surprising in light of the near record high discharge and erratic hydrograph (Figure 1). Median- seasonal water temperature and NHx were the only variables we monitor that did not exhibit anomalous conditions.

Water temperatures in 2016 were slightly warmer than the long term median, falling within the 60 to 75 percentile range during spring, summer and fall (Figure 2a). Median winter temperature was cooler falling near the 25^{th} percentile; the lower temperatures in winter, were likely due to the above average discharge and fluctuating water levels experienced during this period. Water temperature can have direct and indirect effects on large river ecology. Warm water temperatures can result in higher respiration rates, leading to lower oxygen 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. low rates of photosynthetic productivity at very low and very high water temperatures and high rates of productivity at intermediate temperatures).

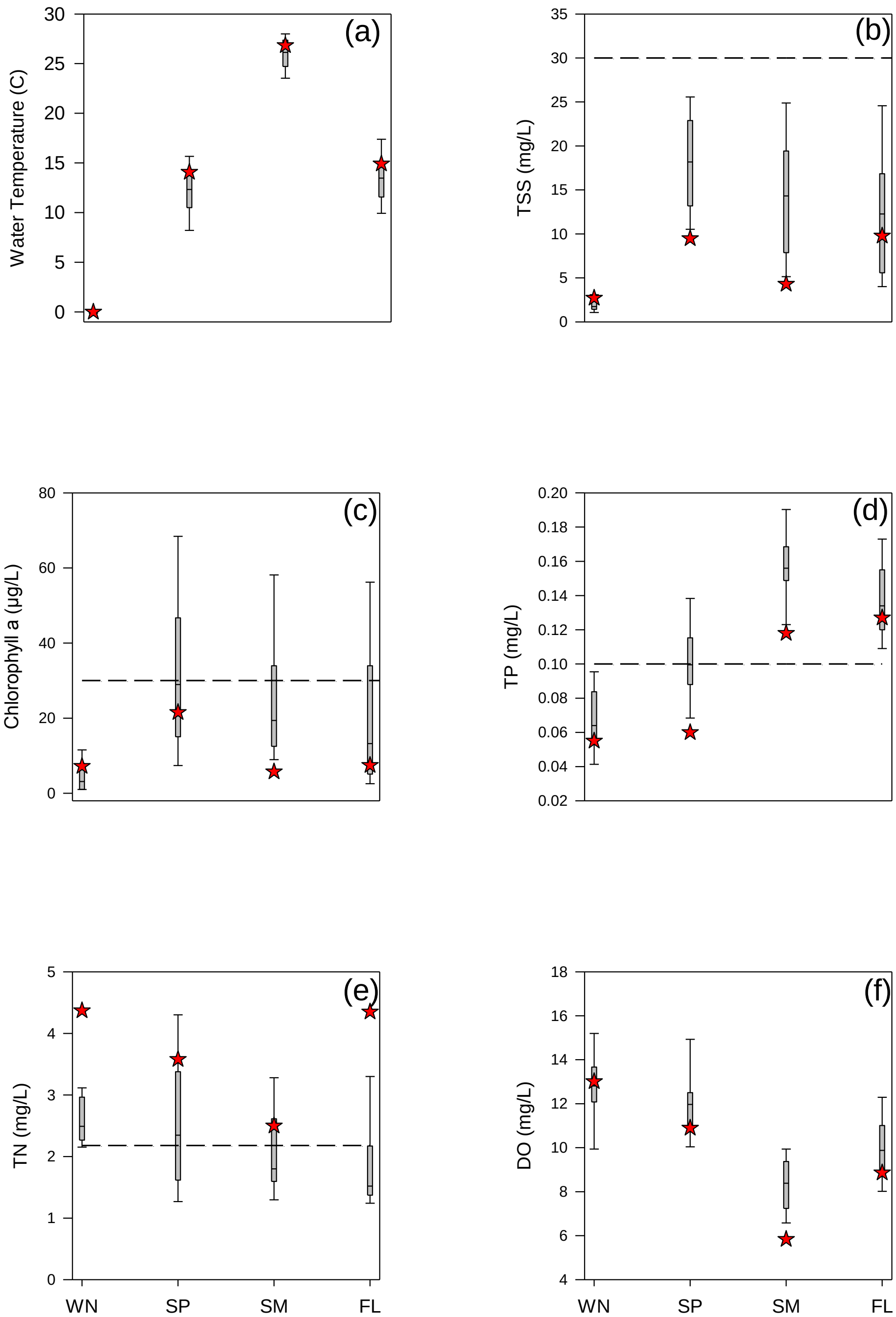

Figure 2. Box plots represent the 10th, 25th, 50th, 75th, and 90th percentiles of the medians by stratified random sampling season for the Long Term Resource Monitoring Program period of record (1993-2016). The star represents the weighted pool-wide median for each parameter by season for 2016. (b) The 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).

Table 2. Comparison of 2016 water quality conditions to normal conditions. 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
https://www.umesc.usgs.gov/reports_publications/ltrmp/water/2016_annual_unusual.html

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

The 2016 temperature and chlorophyll a summary data (the pool-wide medians) did not fit this paradigm well, chlorophyll a concentrations were lower during spring, summer (below 10th percentile) and fall even though 2016 water temperatures were near the long-term median. These lower concentrations are likely a function of dilution, mixing and flushing due to the high and erratic discharge during 2016 (Figure 1a). Winter chlorophyll a levels were near the 75th percentile despite the colder median water temperature during winter (Figure 2a and 2c). Figure 3a and 3b give more insight into this and show that chlorophyll a concentrations were lower at the colder (a) and higher velocity sites (b). This more in depth look at the winter data shows conditions are conforming to conventional paradigm i.e. higher primary productivity in the warmer more quiescent conditions; it also shows the limitation of summary statistics (in this case the pool-wide median) in depicting conditions. The relationships between velocity and winter water temperatures (Figure 3c) is not surprising and has been the focus of past UMRR investigations (Rogala et.al 1996, Knights et. al 1995). This work showed how backwater connectivity, temperature and velocity are covariates of river stage or flow, and how these parameters can affect the quality of centrarchid overwintering habitat. The strong correlation between temperature and chlorophyll a shown in Figure 3a shows differences in rates of primary productivity (for suspended algae), Figure 3b and c suggests that winter water temperature and primary productivity are somewhat velocity dependent. Further investigation may be warranted to determine how much of this variation is explained by physical processes (e.g. dilution, water movement, depth) and how much is attributed to physiological processes, where temperature can play a larger role in productivity rates.

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). In 2016, chlorophyll a levels were between the 50th and 75th percentile in winter, between the 25th and 50th percentile for spring and fall, and were very low in summer (< 10th percentile Figure 2c). As mentioned above in the water temperature discussion, chlorophyll a did not track as expected with temperature and the low levels observed in spring, summer and fall appear to be a result of dilution due to the high discharge in 2016. Median chlorophyll a values were well below the eutrophic range (>30 µg/L) (Dodds et al., 1998) during 2016.

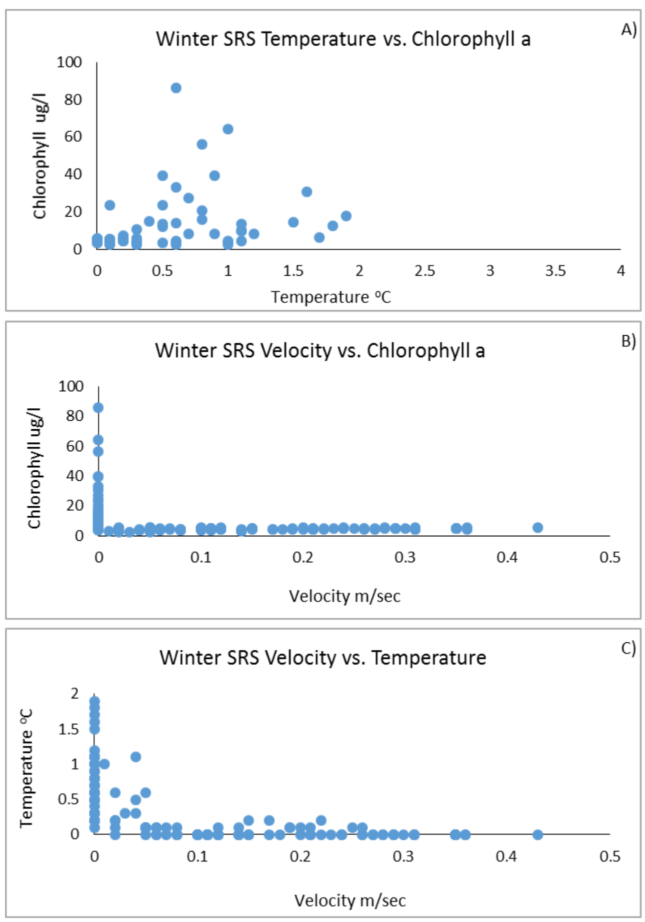

Figure 3. Winter 2016 SRS data plots showing correlations between velocity, temperature and chlorophyll a (a measure of suspended algae primary productivity).

Total suspended solids (TSS) was below the 10^{th} percentile during spring and summer and between the 25^{th} and 50^{th} percentile for fall (Figure 2b). High TSS concentration can limit primary productivity by blocking light. It also negatively affects macroinvertebrate respiration and behavior, results in habitat loss, and affects fish by reducing feeding efficiency and smothering spawning habitat (Walters, 1995). Despite the high discharge, low TSS values were observed in 2016. This is likely due to the nature of precipitation events (e.g. less intense rain events locally), and much of the flow was generated far north in the basin, giving it time to clarify (especially as it moves through Lake Pepin) before reaching pool 8. Aquatic vegetation levels remained high in 2016 with 75% of sites being vegetated (Figure 5). Aquatic vegetation can contribute to the decrease of TSS concentrations as it slows water velocity allowing sediment to fall out of the water column. It also stabilizes sediment and reduces sediment resuspension from wind and boat wakes. These physical influences aquatic vegetation have on the river hydrology can create a positive feedback loop that allows more areas to be vegetated which further lowers TSS (Giblin 2017). 2016 TSS concentrations were well below the criterion (<30 mg/L) required to sustain submersed aquatic vegetation (SAV) in the Upper Mississippi River (UMR) during all seasons (Giblin et al., 2010).

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 (TP) were low during 2016, with winter near the 25^{th} percentile, fall between the 25^{th} and 50^{th} percentile and spring and summer below the 10^{th} percentile (Figure 2d). Elevated phosphorous levels experienced in most years are largely due to inputs from point and non-point source pollution e.g. municipal treatment plants and agriculture runoff. There can also be significant release of phosphorous from the sediments, especially in backwaters during the warmer months, due to microbial activity. Mid-summer senescence of curly pondweed can contribute a significant amount of phosphorous and nitrogen to the ecosystem as well (Drake et.al 2017).

A significant fraction of TP inputs come adsorbed to the TSS load, so TP tends to track well with TSS, thus TP concentrations are also tied to severity of rain events (gully washer or runoff fraction). It was not surprising to see the lower TP levels given the conditions we experienced (i.e. high discharge and low TSS water being delivered to pool 8). TP levels were well below the Wisconsin TP criterion (0.10 mg/L) for non-wadeable rivers (Wisconsin administrative code NR 102.06) in winter and spring and just above in summer and fall. It is noteworthy that even though summer phosphorous levels were below the 10^{th} percentile for the LTRM period of record they still exceeded the Wisconsin TP criterion.

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 in the form of nitrate to groundwater and surface waters has been associated with a number of 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 (TN) was very high in 2016 with winter and fall well beyond the 90^{th} percentile and spring and summer near the 75^{th} percentile (Figure 2e). In 2016, TN was above the upper concentration recommended by the USEPA for ecosystem health (0.6-2 .18 mg/L) during all seasons (USEPA, 2000). Again high discharge throughout the year appears to have played a key role in the high TN in 2016. The opposite trends between TP and TN (i.e. low TP, high TN year) are not unusual as nitrogen is known to track more closely with discharge. Watershed management practices have had little success in lowering nitrogen delivery to rivers and ultimately the Gulf of Mexico. Further investigation into the extreme winter and fall levels may give valuable insights to this issue. Winter, spring and fall total nitrogen concentrations far exceeded the upper limit of the range suggested for total nitrogen as defined by the USEPA (2000).

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 near the long-term median during winter, near the 25th percentile in spring and fall and below the 10th percentile in summer (Figure 2f). It was surprising to have such low DO (even had fish kills reported) in summer with the high discharge, good water clarity and abundant aquatic vegetation. Biologists from the Mississippi River Team in La Crosse, WI, attributed the low summer DO and associated fish kills to a rapid drop in discharge in late July (Figure 1a), that drained warm, low-DO water, with high organic content (i.e. high BOD), out of the shallow-marsh areas. We did observe a rebound in DO the week after summer SRS, as discharge rapidly increased. This was interesting to see how erratic fluctuations in discharge can cause extreme conditions (including fish kills). It may be necessary to explore management actions that could potentially temper conditions in these backwaters to avoid future fish kills.

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 and snow thickness were near the long-term median during the winter of 2016 (Figure 4). The ice and snow conditions during winter sampling appear to have been suitable for light transmission, as median DO during winter was 13.01 mg/l, and only a few sites had DO below 5 mg/l. The low DO sites were largely in Blue Lake, an isolated backwater that is often hypoxic in winter; the remainder of low DO sites were shallow sites with little available water depth below the ice, and due to mixing with the sediments, were very turbid. This mixing elevates biological oxygen demand due to microbial respiration, and reduces oxygen levels.

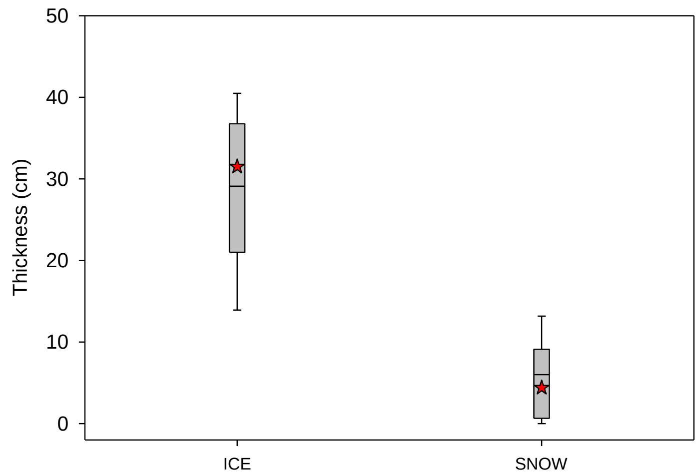

Figure 4. Box plot represents the 10^{th}, 25^{th}, 50^{th}, 75^{th}, and 90^{th} percentiles of the medians for winter ice thickness and snow thickness above the ice sheet during winter for the Long Term Resource Monitoring Program period of record (1993-2014). The star represents the weighted pool wide median for each parameter for the winter of 2015.

2016 Aquatic Vegetation

Methods

Aquatic macrophyte data for 450 sites were collected from June 15 to August 5, 2016. Sites are randomly selected at established stratum-specific densities to reflect relative coverage in the Pool 8 ecosystem (Appendix A). Sites are selected annually based on LTRM probabilistic design (www.umesc.usgs.gov/ltrmp/stats/statistics.html). The sampling area (a 2-m area around the boat) was searched visually. Six subsampling locations were sampled within the 2-m area with rake grabs. All species on the rake and observed during the visual search were identified and recorded. Each submersed species retrieved on the rake was also given an abundance score of 1-5 based on calibration marks on the rake teeth. More detail on LTRM vegetation sampling protocol can be found in Yin et al., 2000 at: http://www.umesc.usgs.gov/documents/reports/1995/95p00207.pdf

Results

As described in other sections of this report, 2016 was a year of high discharge throughout the summer sampling season. Water depth potentially affects both growth and detection of aquatic vegetation. In terms of vegetation sampling, measured depths during 2016 were, on average, 9 cm deeper in 2016 than in 2015 (1.34 vs 1.26 m, respectively). The prevalence (percent frequency occurrence) of aquatic vegetation, however, continued to be relatively high in 2016. When submersed, emergent and rooted-floating life forms are combined, aquatic vegetation was detected at 339 of 450 sites (75.3%; Figure 5, Appendix A) – which is essentially equal to the 2015 detection rate (341 of 450 sites, 75.5%). Percent frequency occurrence of the specific life forms was also similar to 2015 observations, with, perhaps, a downtick in emergent and an uptick in rooted-floating leaf species (Table 3). The Pool 8 aquatic vegetation community is composed primarily of native species, with only locally abundant invasive species. An increase in aquatic vegetation abundance since ~2002-2003 has been coupled with a decrease in suspended sediments (clearer water) and nutrient concentrations, increasing abundance of native fishes, and decreasing abundance of invasive carp biomass (refer to the Fisheries section of this report). The general indication is that the ecological conditions of Pool 8 have improved markedly since the early 2000s.

Specific features of the Pool 8 aquatic vegetation in 2016 are described in this section. Data spanning 1998 – 2015 were downloaded from the LTRM graphical data browser (https://www.umesc.usgs.gov/data_library/vegetation/graphical/veg_front.html), and 2016 data were downloaded from https://www.umesc.usgs.gov/data_library/vegetation/srs/veg_srs_1_query.shtml on 20 Feb 2016.

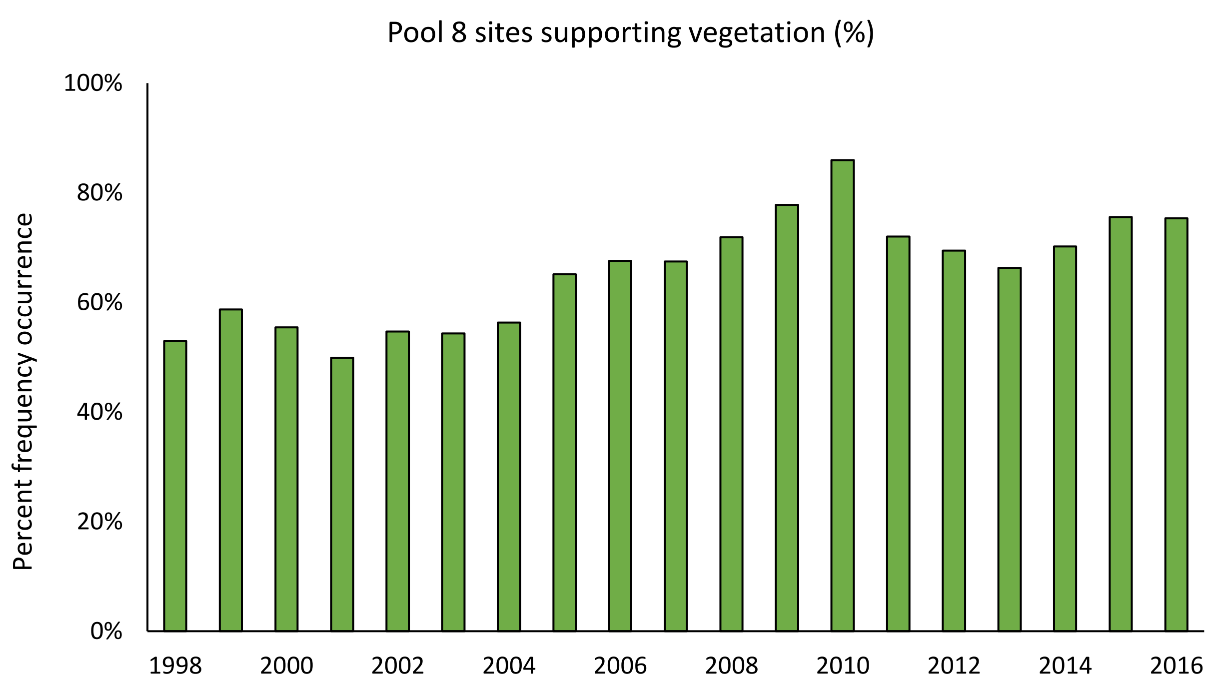

Figure 5. Aquatic vegetation prevalence over the 19 years of LTRM vegetation monitoring. This figure includes all native and invasive species, and the submersed, emergent and rooted floating-leaf growth forms (filamentous algae and non-rooted floating life forms are excluded).

Table 3. Descriptive statistics comparing prevalence of vegetation and specific life forms in 2015 and 2016 - overall prevalence was very similar, but emergents were perhaps lower in 2016 and rooted floating-leaf somewhat higher. Vegetated* sites include those supporting any submersed, rooted floating-leaf or emergent vegetation species – one site supporting only filamentous algae in 2016 was excluded from this count. Vegsum (the total aquatic plant index) is the sum of submersed, rooted floating-leaf, and emergent life forms percent frequency observed.

	2015		**2016**	
	Percent frequency occurrence	*Number of sites*	*Percent frequency occurrence*	*Number of sites*
*Vegetated **	76.2%	343	75.3%	339
Unvegetated	23.8%	107	24.7%	111
Submersed	72.0%	324	71.6%	322
Rooted floating	33.1%	149	36.4%	164
Emergent	41.1%	185	31.6%	142
Non-rooted floating	20.9%	94	28.0%	126
Filamentous algae	34.9%	157	35.1%	158
Vegsum	146.2%	-	139.6%	-

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 boundaries) (Table 4). This is consistent with previous years. The relative abundance of submersed, emergent, and rooted floating-leaf species varied by stratum (Figure 6), as aquatic vegetation responds to a number of interacting drivers, especially water velocity and light availability (e.g. Kreiling et al. 2007).

Table 4. Summary of site distribution among strata for aquatic vegetation sampling in 2016. The column "% vegetated" was calculated by subtracting the number of unvegetated sites from the total number of sites in each stratum and dividing by stratum site number. 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	Depth (m) Average (±SD)	% Vegetated
Backwater connected (BWC)	110	0.89 (0.50)	90.0%
Backwater isolated (BWI)	20	0.71 (0.27)	95.0%
Impounded (IMP)	185	1.36 (0.64)	86.5%
Main channel border (MCB)	70	2.10 (1.32)	30.0%
Side channel (SC)	65	1.47 (1.13)	63.1%

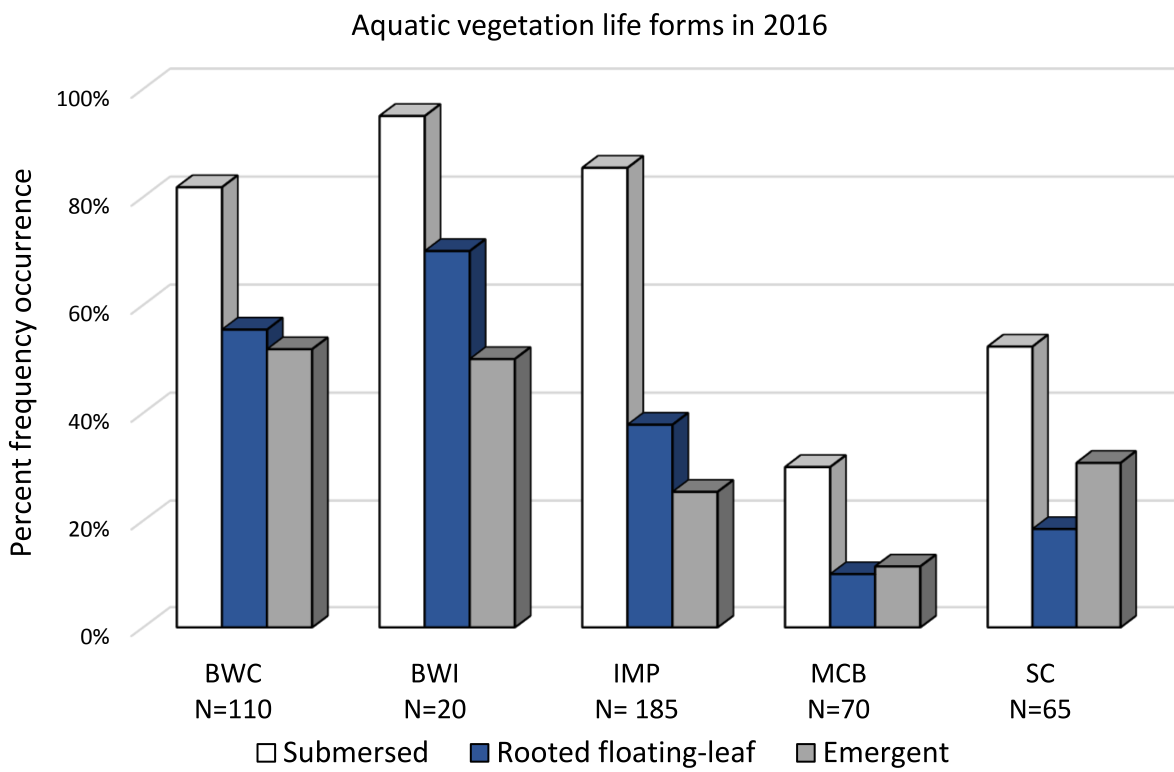

Figure 6. Percent frequency occurrence (prevalence) of vegetation types by stratum.

Long-term patterns in vegetation abundance

Since LTRM probabilistic monitoring began in 1998, the prevalence of all three vegetation life forms (submersed, rooted floating leaf, and emergent) has increased in Pool 8 (Figure 7). In 2016, 72% of sites overall supported submersed vegetation, 36% of sites supported rooted floating-leaf species and 32% of sites supported emergent vegetation. Percent frequency occurrence and associated standard errors for 2016 were calculated here, while values from 1998 – 2015 were downloaded from the Upper Mississippi Environmental Science Center LTRM data repository at: www.umesc.usgs.gov/data_library/vegetation/graphical/percent_frequency_query.shtml

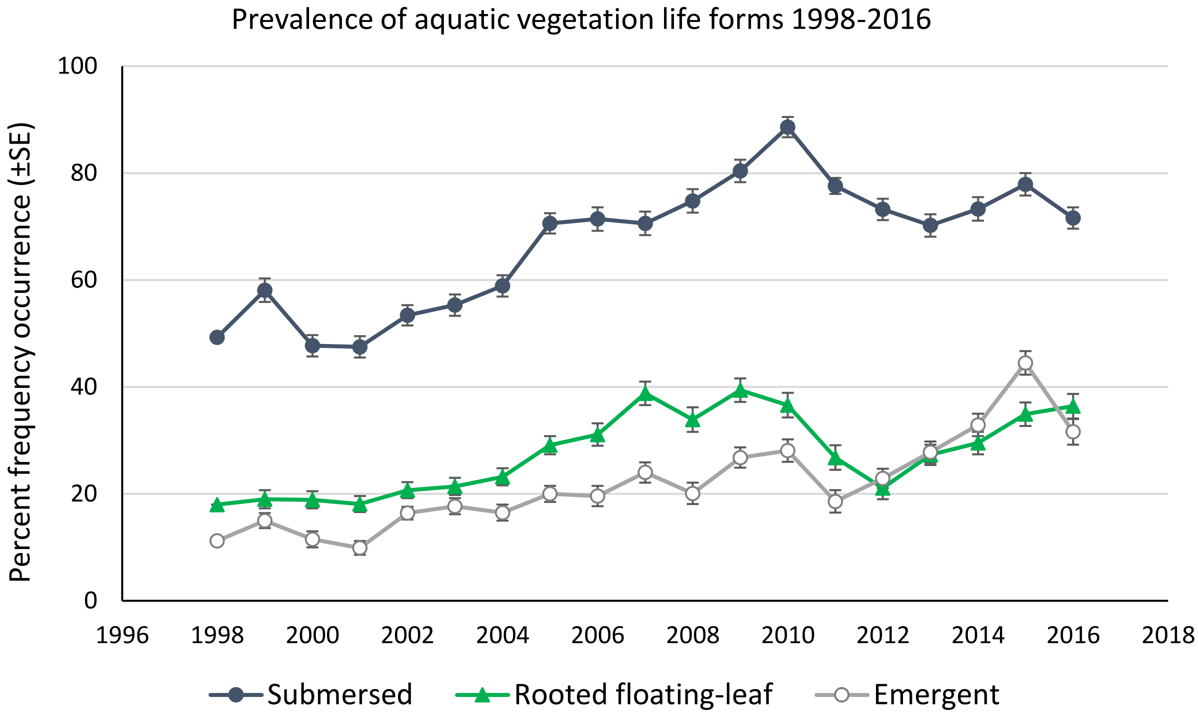

Figure 7. Prevalence of the three vegetation life forms over all 19 years of LTRM probabilistic monitoring (±SE).

The percent frequency occurrence of submersed, rooted floating-leaf, and emergent vegetation were summed to generate an annual “total aquatic plant index” (Figure 8). Because all three life forms can overlap, this index can exceed 100%. The 2016 index value (~140%) was approximately average for the last decade. The decrease from 2015 was largely driven by wild rice (*Zizania aquatica*) which is described below.

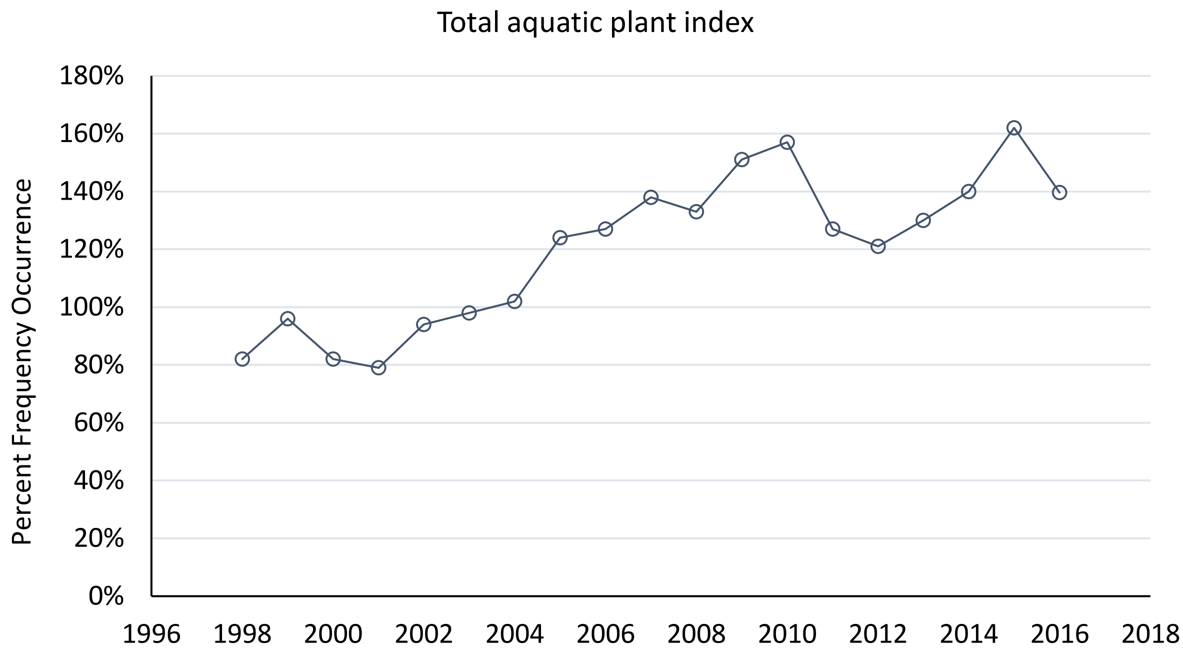

Figure 8. Total aquatic plant index (vegsum) over time is annual, summed percent frequency occurrence of the submersed, rooted floating-leaf, and emergent life forms. Because more than one life form can occur at the same site, the index can exceed 100%.

A coarse comparison of composited data from the first part of the record (1998 – 2004) to more recent years (2005-2016) shows an overall increase in the prevalence of aquatic vegetation and a decrease in the prevalence of unvegetated sites (Table 5).

Table 5. Average percent frequency occurrence of vegetation life forms during the first 7 years and the last 12 years of LTRM monitoring. Vegetation surveys were conducted at 443 - 1034 sites annually.

Period of record	Submersed	Rooted floating-leaf	Emergent	Unvegetated
1998-2004	52.9%	19.9%	14.0%	44.0%
2005-2016	75.0%	32.1%	26.4%	24.5%

A portion of the increase in aquatic vegetation over time is attributable to two native species of special interest in the ecology of Pool 8 – 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 9). Prior to 2009, wild rice was only detected occasionally in surveys. Since then, it has increased to be ~5-6 times more abundant than it was from 1998 – 2007, and the most frequently detected emergent species in Pool 8 LTRM surveys. It is now a substantial contributor to the total vegetation index (Figure 8). The highest recorded abundance of both of these native species occurred in 2015. Notably, wild rice decreased by about 35% (from 22.4% to 14.4%) in 2016, possibly due to high water in the spring when rice stems were elongating to reach the surface (this is only a personal observation).

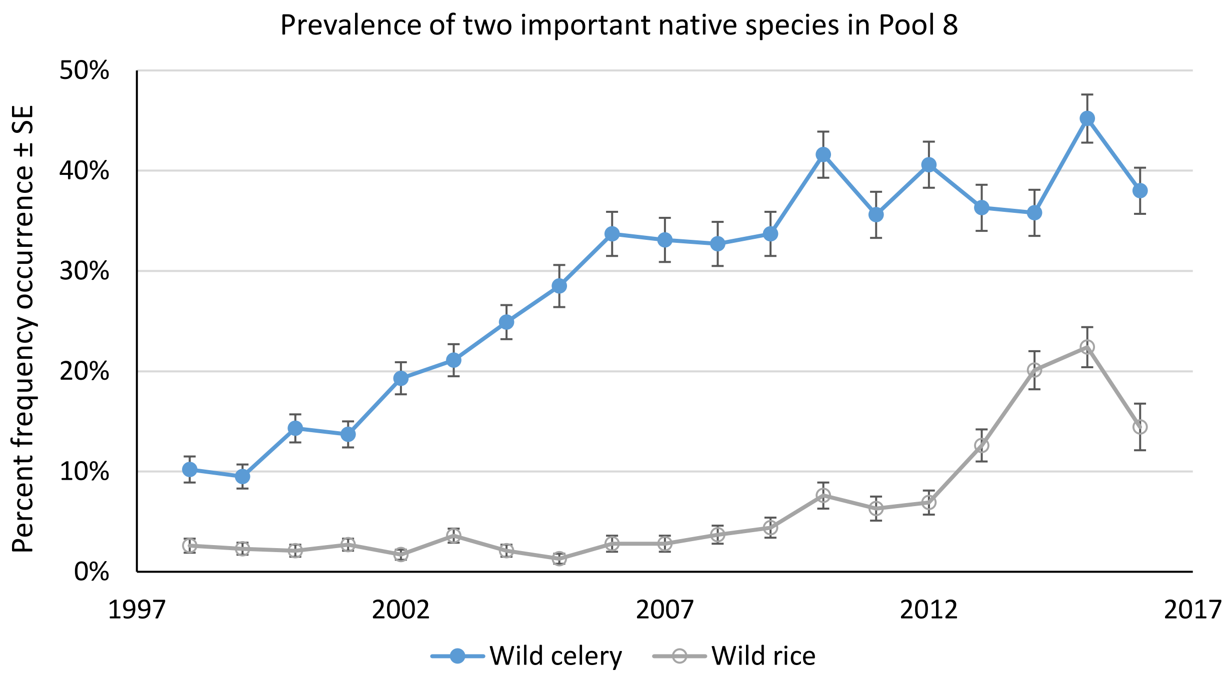

Figure 9. Positive trends in the detection of wild celery and wild rice in Pool 8 over the period of LTRM monitoring.

Two invasive species, Eurasian watermilfoil (*Myriophyllum spicatum*) and curly pondweed (*Potamogeton crispus*) occur at ~10-30% of Pool 8 sites annually (Figure 10), but have not increased as dramatically as the native species described above or as much as the total vegetation index. 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 it has senesced considerably by the time summer surveys are conducted. It is thus under-represented in summer surveys. A correction factor relating prevalence in summer surveys to prevalence during its spring maximum biomass is currently under development.

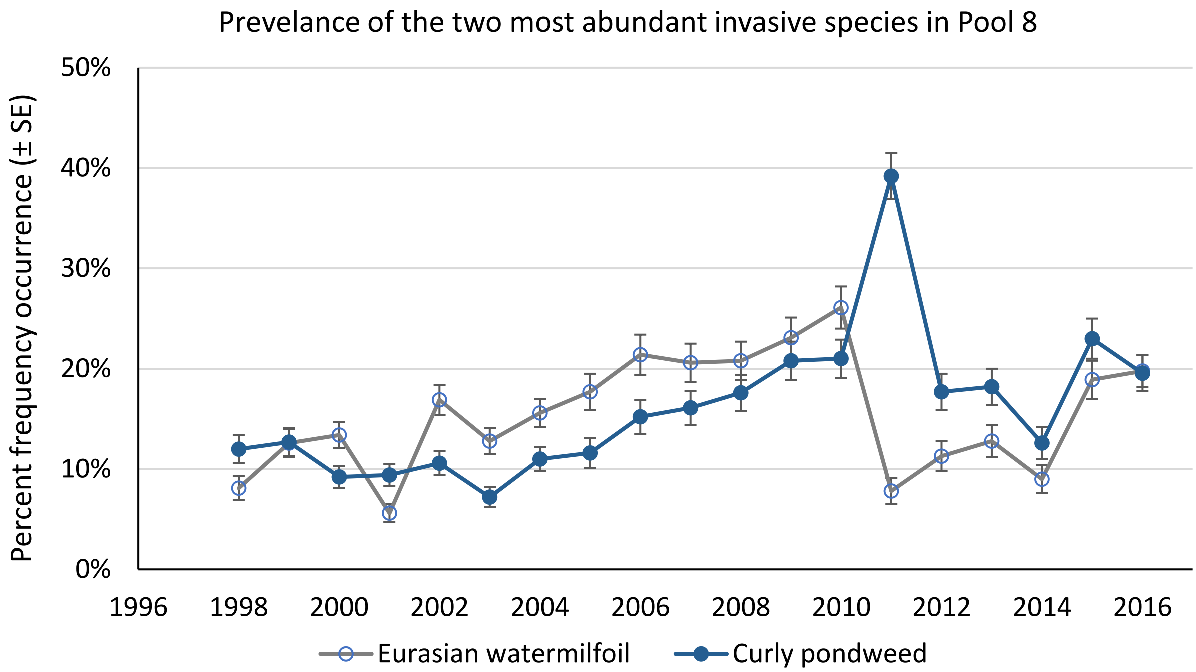

Figure 10. Prevalence of the two most common invasive species in Pool 8 over LTRM monitoring.

A total of 34 plant species (excluding algae) have been identified in Pool 8 over the course of LTRM monitoring. At individual vegetated sites, between 4-8 species are generally detected. The maximum number of species found at a single site in 2016 was 19 (including algae and one invasive species), and the maximum number of native species (excluding algae) found at an individual site was 17.

The profusion of algae in freshwater systems is associated with eutrophication, a growing concern for managers and users of Pool 8 and the greater Upper Mississippi River. Filamentous algae is often found in dense mats or clinging to vegetation, and late in the summer blue-green algae appear as patchy films. Mats of filamentous algae are included in the observation of algae in vegetation surveys (it is given a rake score when found in abundance). The prevalence of algae has varied considerably over time (Figure 11), but has not clearly tracked increases in vegetation.

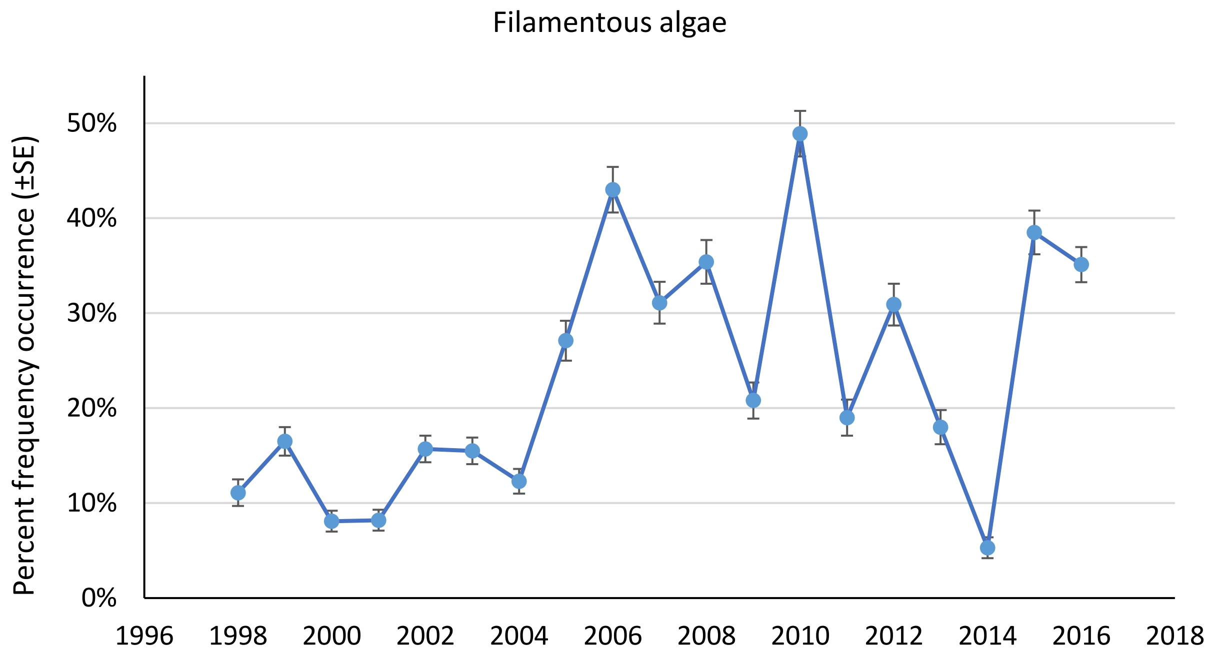

Figure 11. Prevalence of filamentous algae over the entire period of LTRM monitoring.

2016 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 can be found in Gutreuter et al., 1995 at: http://www.umesc.usgs.gov/documents/reports/1995/95p00201.pdf.

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: http://www.umesc.usgs.gov/data_library/fisheries/graphical/fish_front.html.

Routine data analyses for overall fish community data include species richness, total catch by species, and community composition (presence/absence). Catch per unit effort (CPUE) and frequency of occurrence are calculated for all species, and proportional stock density (PSD) is calculated for species of interest. Proportional Stock Density (PSD) is a measure of species size structure. The metric is a ratio (expressed as percentage) between the number of quality-sized or larger individuals and stock-sized individuals. Stock and quality size designations vary by species, and were defined in published manuscripts (see the LTRM Fish Life History Database for details:

http://www.umesc.usgs.gov/data_library/fisheries/graphical/LTRM_fish_life_history.mdb). This life history database also contains a table with allometric growth information that allows conversion of length data to mass, and, thus, biomass computations, which yield additional insight into fish community characteristics.

This report summarizes sampling effort, overall catch rates and species richness, as well as abundance and biomass summaries, and data on species of special concern. We also report any Asian carp collections and other anecdotal observations on the fish community. Shannon-Wiener Diversity Index (Zar 1984) scores were computed from day electrofishing collections to indicate fish community diversity relative to previous years. CPUE, mass per unit effort (MPUE), and PSD trends from day electrofishing data are provided for ten common sport fish of interest to anglers and fish managers.

Data were omitted for 2003 in all cases because of reduced sampling that year. Also, catches of fish from daytime electrofishing on wingdams and several gears at fixed 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. 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

The prolonged high water during 2016 (Figure 1) made it a difficult year to sample, throughout the season. Wingdam electrofishing samples were completed during a small window of opportunity during Period 1, but were not possible in Periods 2 and 3. Tailwater trawling was also only possible during the first time period. Finally, two large hoop nets and a small hoop net became dislodged from the substrate and were lost. Thus, only 251 of 270 scheduled samples were completed for the year.

The planned sampling allocation among gear types has remained stable for many years. Sampling effort was highest for daytime electrofishing (76 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 (58 collections) and main channel border (47 collections) also receiving considerable effort. Please note that the strata names imply habitat features, but a wide variety of habitat conditions exist within each stratum.

Total catch in 2016 was 34,077 fish, which is the highest total catch since 2001. The catch per sample value was, therefore, the second highest during the stratified random sampling (SRS) era.   Mini fyke nets were particularly effective, providing about half of the total annual catch. Species richness in 2016 was only 59, perhaps due to the high water. A long-term, slight, declining trend in species richness from the first decade of the program until now does seem evident (Figure 12).

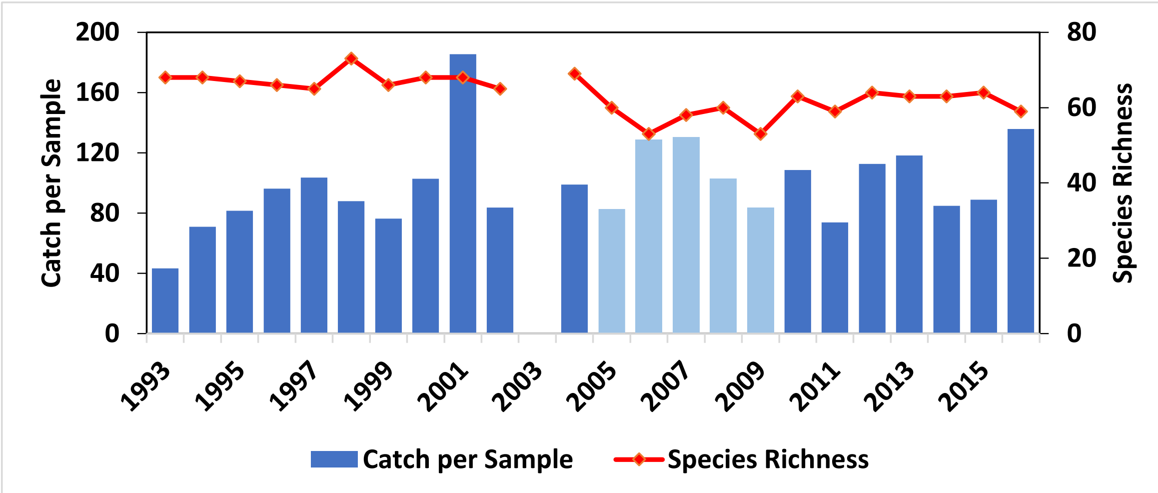

Figure 12. Catch per sample and annual species richness, for Upper Mississippi River Restoration – EMP-LTRM fish collections in Pool 8 of the Upper Mississippi River. Data represent samples collected with daytime electrofishing, fyke nets, mini fyke nets, large and small hoop nets, and otter trawls. Data are omitted for 2003 due to limited sampling that year. Period 1 (June 15 – July 31), as indicated by the lighter-colored bars, was not sampled from 2005-2009.

Largemouth bass (7709), weed shiner (7225), Bluegill (4854), Emerald shiner (2099) and Common carp (2049) were the top 5 species, in order of catch, in 2016 (Figure 13a). One mini fyke net contained over 5,800 juvenile Largemouth Bass (<40 mm TL), a second contained over 3500 Weed shiners, and a third contained over 1500 juvenile Common carp (< 40 mm TL). Other notable species in the top 10 for catch were Mimic and Spotfin shiner, Pumpkinseed, Yellow perch, and Black crappie. For biomass (Figure 13b), Common carp (722 kg) ranked first in the catch, followed by Channel catfish (280 kg), Flathead catfish (259 kg), Shorthead redhorse (233 kg), and Bowfin (220 kg). Other "heavyweights" in the catch were Silver redhorse, Bluegill, Largemouth bass, Freshwater drum, and Golden redhorse.

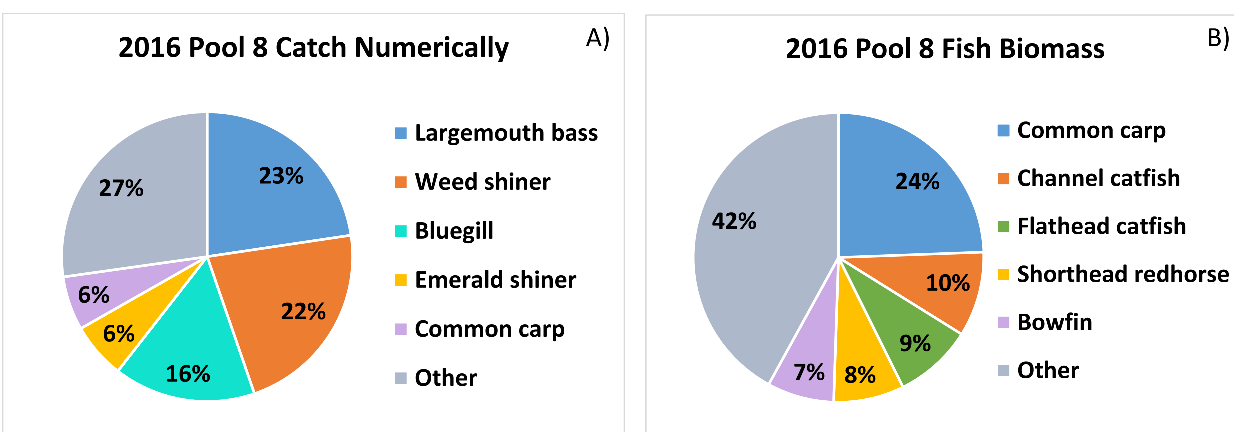

Figure 13. Top species for catch (a) and biomass (b) in samples from Upper Mississippi River Restoration – EMP-LTRM fish collections in Pool 8 of the Upper Mississippi River during 2016. Data represent samples collected with daytime electrofishing, fyke nets, mini fyke nets, large and small hoop nets, and otter trawls.

Historically, 37 species have been detected in Pool 8 LTRM samples every year since SRS began in 1993, and an additional 25 species have been detected in at least half of the years. Those numbers held true in 2016, as well. There are 28 species that have been detected in 12 or fewer years. Speckled chub (8 years) and Pirate perch (7 years) are the only species from that group that were sampled in 2016. We did not observe any species in 2016 that have been absent from the catch for a number of years.

Single specimens of the following species were sampled in 2016: Blue sucker, Bigmouth buffalo, Speckled chub, and River darter. Fewer than 10 individuals were sampled for an additional 18 species. Thus, about 37% of the species detected were very uncommonly encountered.

Two Wisconsin-listed threatened species, blue sucker (1) and river redhorse (23), were collected in the Pool 8 LTRM catch this year.

To date, the Pool 8 LTRM sampling efforts have not detected any Asian carp (bighead and silver). We caught 2051 common carp this year, which was by far the most in many years. However, as mentioned above, more than 1500 of those were caught as juveniles in a single mini fyke net. The long-term decline of Common carp, the only current non-native fish species of significance in Pool 8, continues, and is illustrated in Figure 14. There was a small increase in CPUE for Common carp in both day electrofishing and fyke netting in 2016. Future sampling will divulge whether the 2016 year class begins a sustained rebound for this mass-dominant species.

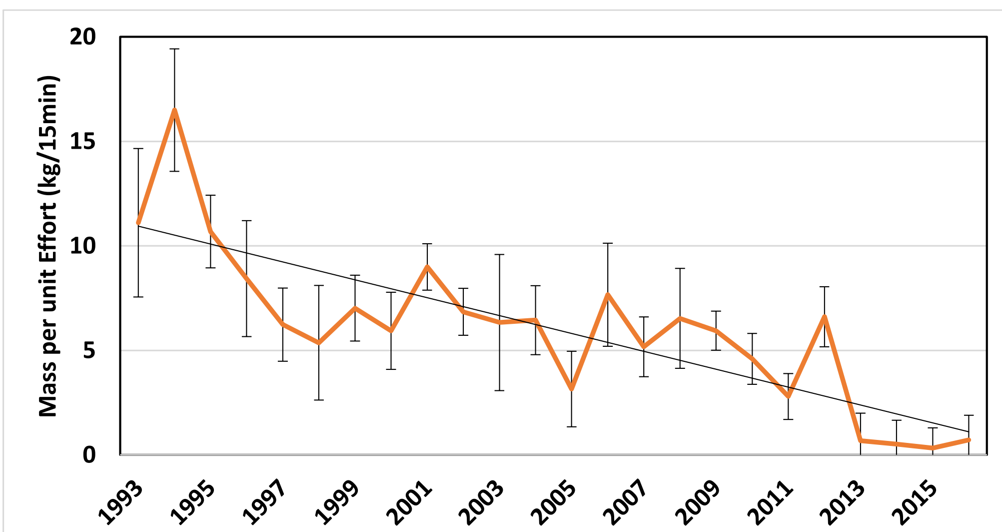

Figure 14. Mass per unit effort (MPUE) of Common carp in daytime electrofishing samples from Upper Mississippi River Restoration – EMP-LTRM fish collections in Pool 8 of the Upper Mississippi River, 1993-2016.

Shannon-Wiener Diversity Index scores for day electrofishing in Pool 8 LTRM samples (Figure 15) suggest that diversity began to decline in the late 1990’s thru 2007, but has rebounded more recently. Another feature of the diversity scores is that they seem to be fluctuating more in the past decade than in the first 10-15 years of the program. The resurgence of aquatic vegetation during the late 1990's and continuing into recent years has undoubtedly influenced fish community composition in Pool 8, and thus, diversity. However, a reduction in LTRM fish sampling from 2005-2009 may also have influenced the data, as time period 1 was eliminated (no sampling in June and July) for those years. A third factor that may be involved is river discharge, as the general pattern that occurs in diversity also seems evident in river discharge. Fish community diversity declined in 2016, the second year in a row; yet, 2016 had the second highest mean discharge recorded during the LTRM era. So, the next few years will be informative to see if the diversity-discharge trajectories remain similar or begin to diverge.

Overall, the Pool 8 fish community remains healthy. Catch rates were high in 2016, despite challenging sampling conditions. Species richness is on a slight decline, but is still good. Diversity is good, and has recently been on an increasing trajectory. Rare and protected species are caught each year, and the only invasive species present in detectable numbers is doing poorly.

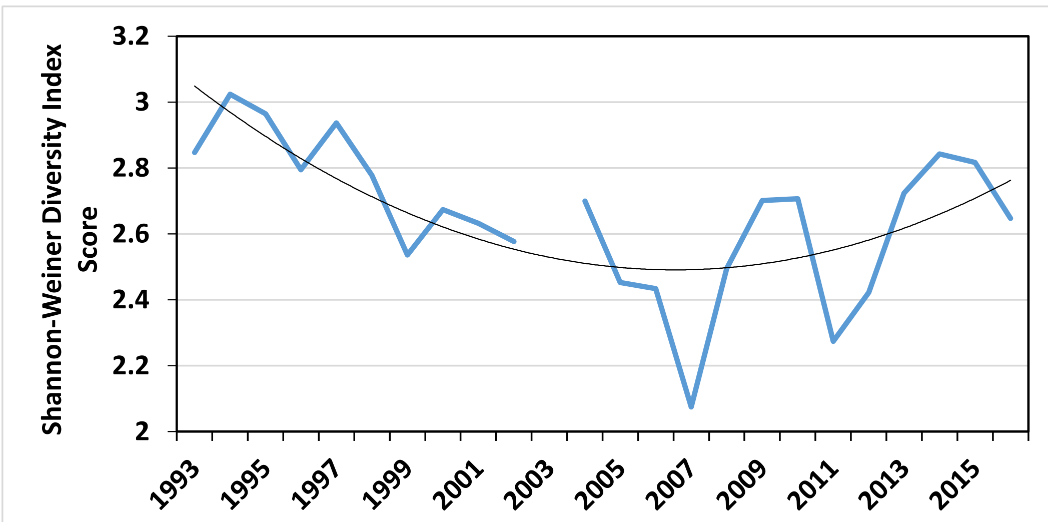

Figure 15. Shannon-Wiener Diversity Index Scores calculated from LTRM Pool 8 day electrofishing samples from 1993-2016. Data are omitted for 2003 due to limited sampling that year. Trend line is a second-order polynomial representation of the data.

Species of Interest

Trend data for 10 fish species of interest to anglers are briefly discussed on the following pages. These are cursory examinations, using daytime electrofishing data for consistency and a second gear for comparison. CPUE includes all sizes of fish collected; therefore juvenile fish could potentially have great influence on the catch rates. Further, sample size is very limited for PSD calculations in some instances. Thus, caution is suggested in the interpretation of these results. Additional examination of patterns and trends may be possible through data from other LTRM gear types by means of the LTRM graphical fish database browser, referenced in the Methods section above.

Black crappie

Black crappie daytime electrofishing CPUE declined in 2016 to near the 10th percentile (Figure 16a). However, fyke net CPUE (Figure 16b) rebounded from the 10th percentile to near the long-term mean. Overall, the electrofishing trend seems stable, while the fyke netting trend indicates a gradual long-term decline. The PSD graph for Black crappie (Figure 16c) indicates only a slight increase over time, and is mostly stable (Figure 16c).

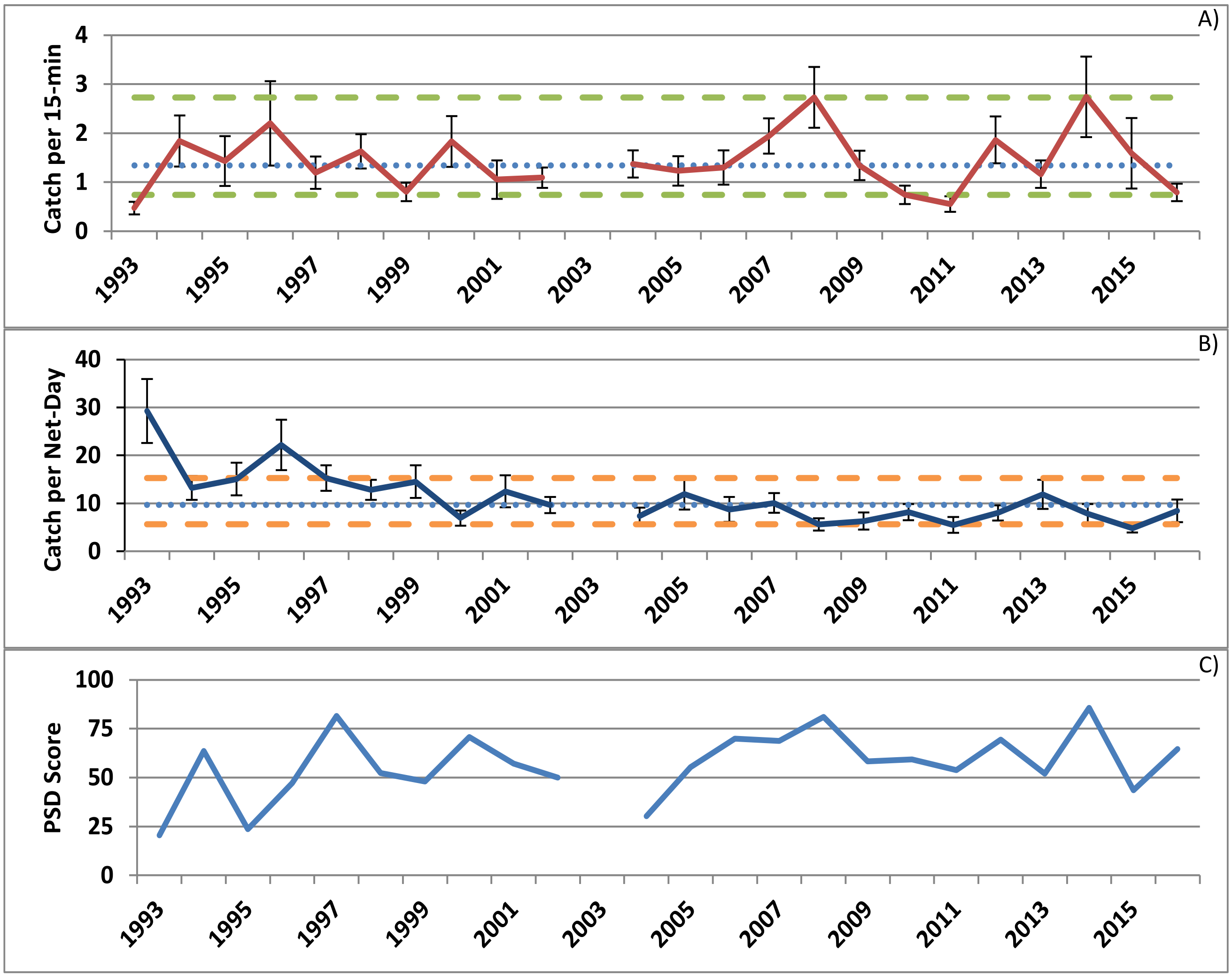

Figure 16. Catch per unit effort (± 1SE) for daytime electrofishing (a), catch per unit effort (± 1SE) for fyke netting (b), and proportional stock-density (c) of Black crappie collected by day electrofishing in Navigation Pool 8, Upper Mississippi River, by the Upper Mississippi River Restoration – EMP-LTRM. 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 (1993-2016).

Bluegill

Bluegill daytime electrofishing CPUE in 2016 continued to decline from the most recent peak in 2011, and was below the long-term mean for the third consecutive year (Figure 17a). CPUE is now at the 10th percentile. Fyke net CPUE (Figure 17b) has shown a similar long-term pattern as electrofishing, but has rebounded in the past two years to near the long-term mean. PSD values for Bluegill have been remarkably consistent and low for most of the LTRM time frame, coming in at 19 for 2016 (Figure 17c). The general decline in Bluegill catch rates since the early 2000's warrants scrutiny, as Bluegill are considered a representative species for backwater habitats.

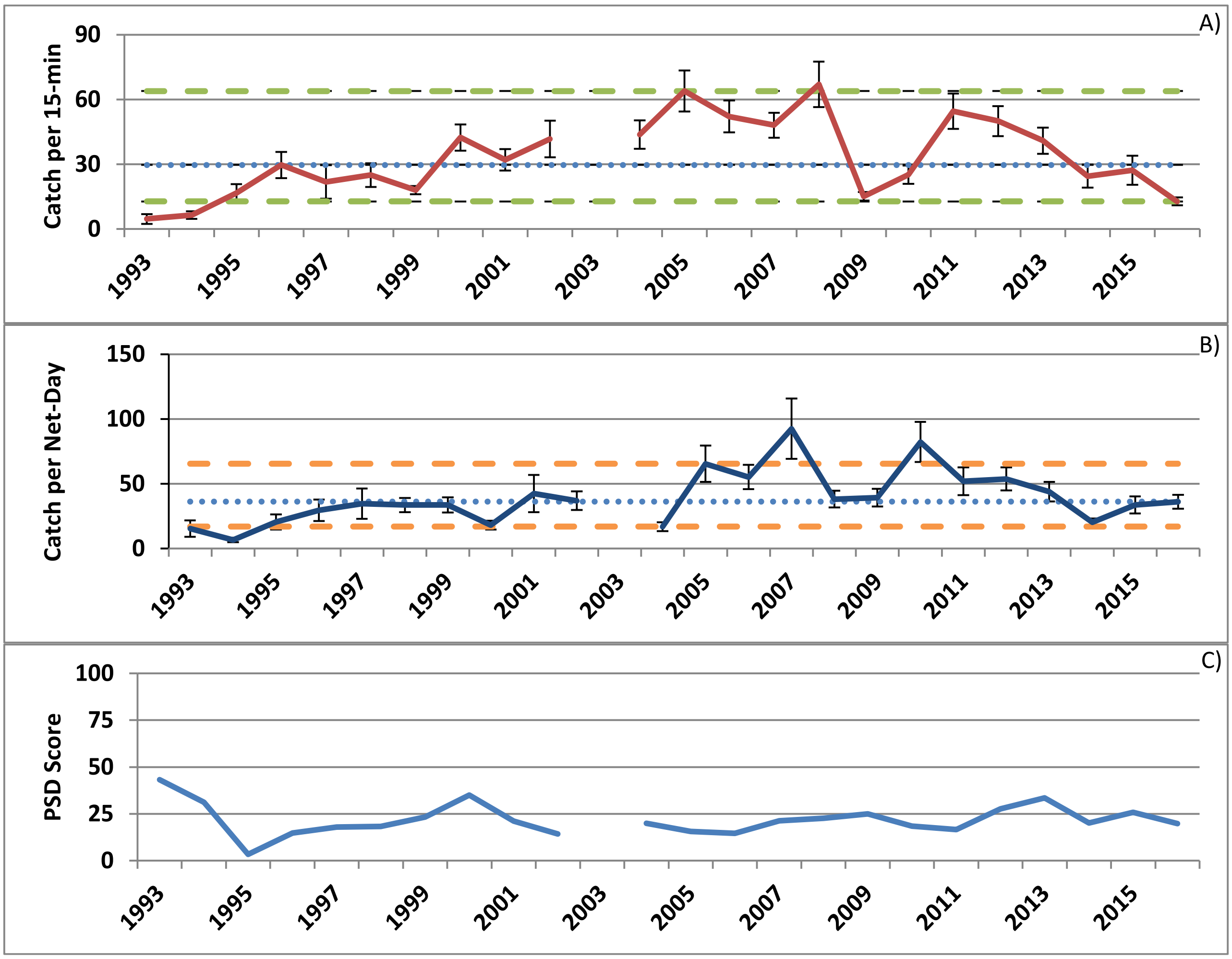

Figure 17. Catch per unit effort (± 1SE) for daytime electrofishing (a), catch per unit effort (± 1SE) for fyke netting (b), and proportional stock-density (c) of Bluegill collected by day electrofishing in Navigation Pool 8, Upper Mississippi River, by the Upper Mississippi River Restoration – EMP-LTRM. 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 (1993-2016).

Channel catfish

Channel catfish CPUE for daytime electrofishing declined in 2016, and was below the long-term average in Pool 8 for the second time in three years (Figure 18a). Catch rates for Channel catfish with day electrofishing have been generally low, but stable, over time. Wide error bars also indicate variability among sites within given years, as many sites sampled with daytime electrofishing do not provide good habitat for Channel catfish (I.e., low flow rates). CPUE for small hoop netting (Figure 18b) shows a decline from the earliest years of the program, but mostly stable trend since 2003. PSD values from daytime electrofishing for Channel catfish remained remarkably consistent, and high, over time (Figure 18c). These observations would suggest a very stable size structure, with a high percentage of quality-sized fish, for Channel catfish in Pool 8.

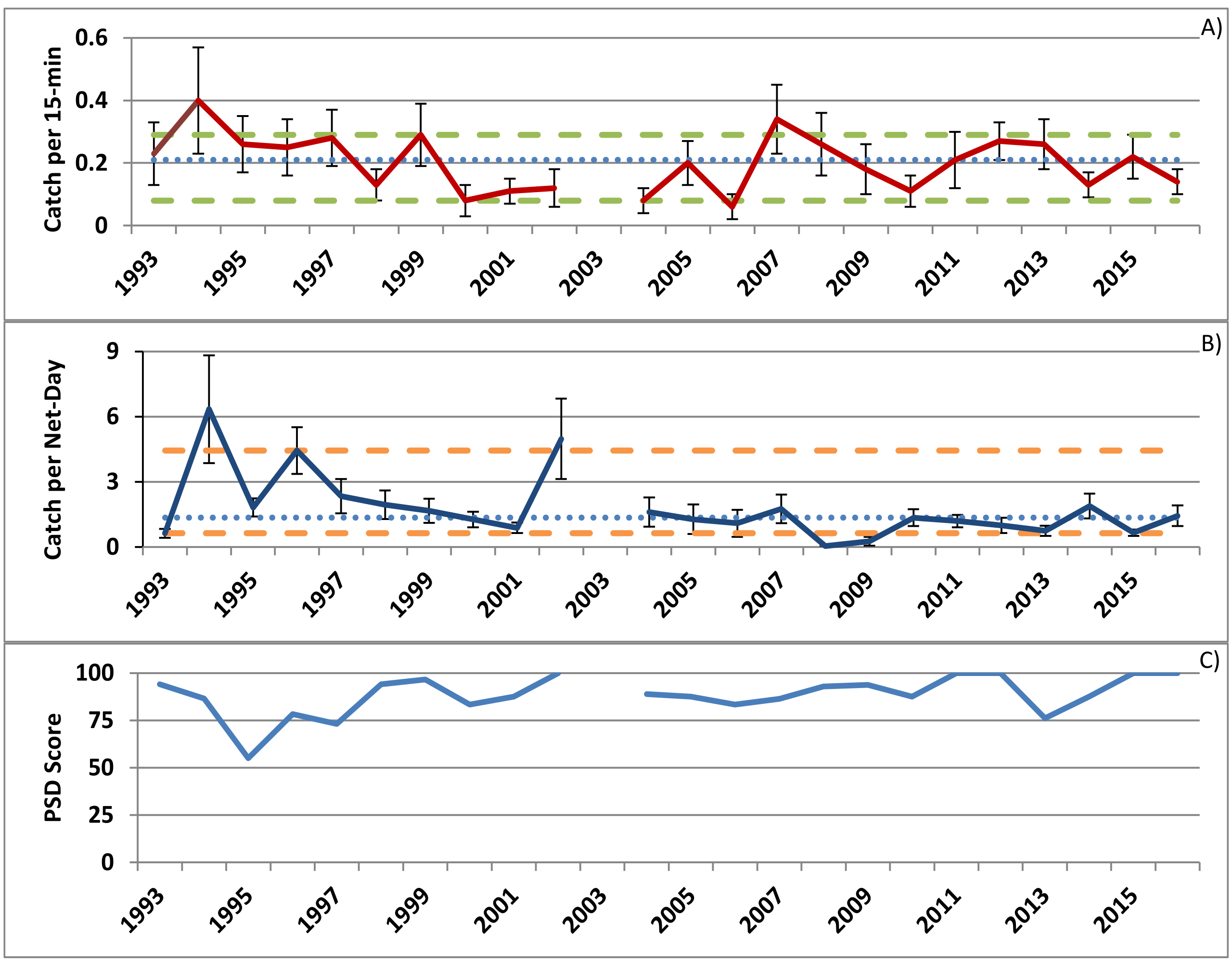

Figure 18. Catch per unit effort (± 1SE) for daytime electrofishing (a), catch per unit effort (± 1SE) for small hoop netting (b), and proportional stock-density (c) of Channel catfish collected by day electrofishing in Navigation Pool 8, Upper Mississippi River, by the Upper Mississippi River Restoration – EMP-LTRM. 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 (1993-2016).

Flathead catfish

Daytime electrofishing CPUE for Flathead catfish declined sharply in 2016, to near the 10th percentile (Figure 19a). This large species has varied in catch rates among years and among sites within years, as evidenced by the wide error bars. CPUE from large hoop nets (Figure 19b) shows even more variability within years, but has exhibited an increasing trend since 2013. PSD score for Flathead catfish in 2016 was zero, indicating no quality-sized fish were caught (Figure 19c). High water throughout the sampling season likely had some effect on these Flathead catfish catch data; most likely, these short-term fluctuations in catch rate and size structure are just random.

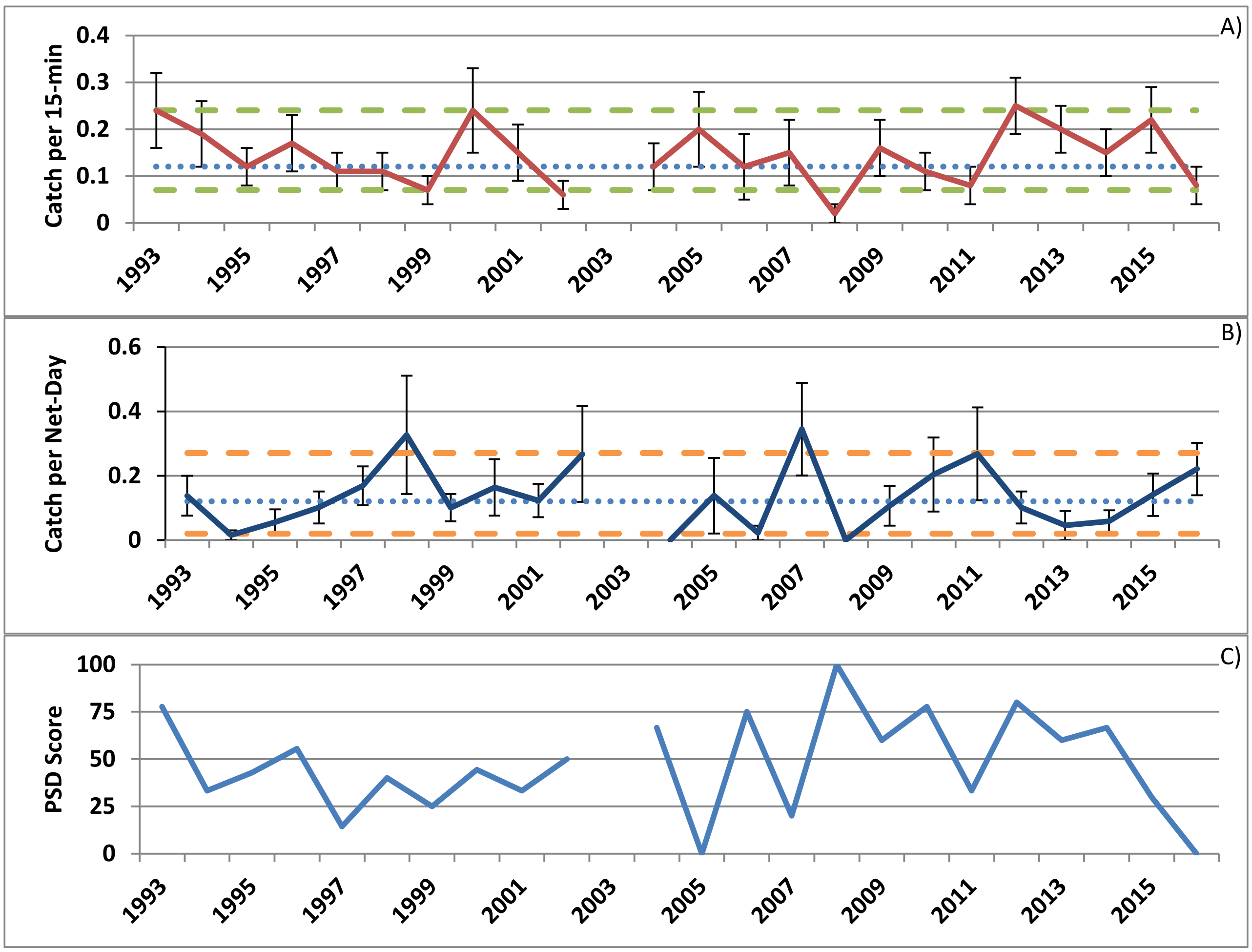

Figure 19. Catch per unit effort (± 1SE) for daytime electrofishing (a), catch per unit effort (± 1SE) large hoop netting (b), and proportional stock-density (c) of Flathead catfish collected by day electrofishing in Navigation Pool 8, Upper Mississippi River, by the Upper Mississippi River Restoration – EMP-LTRM. 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 (1993-2016).

Largemouth bass

Largemouth bass CPUE for daytime electrofishing was above the long-term mean again in 2016 (Figure 20a). Fyke netting CPUE (Figure 20b) shows some Largemouth bass in the catch from 2005 through 2013, a period when electrofishing CPUE was also high. Though CPUE values have fallen from their peak in 2005-2009, they have been on a slow and steady long-term increase. The time period where CPUE values were highest corresponds to the time when Period 1 sampling was eliminated, and could be sampling artifacts. Stable, to slightly increasing PSD trend over time indicates good or improving size structure over time (Figure 20c).

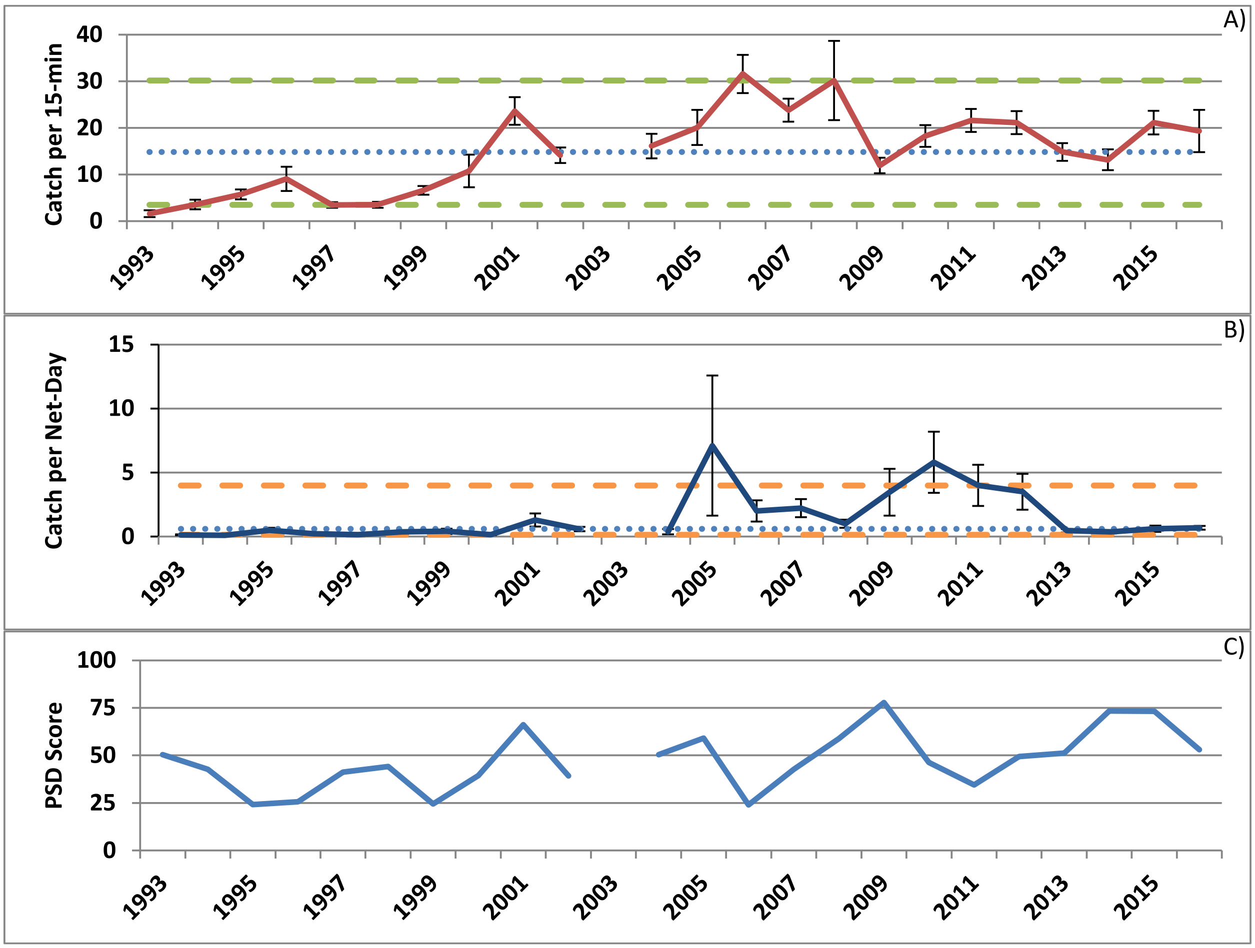

Figure 20. Catch per unit effort (± 1SE) for daytime electrofishing (a), catch per unit effort (± 1SE) fyke netting (b), and proportional stock-density (c) of Largemouth bass collected by day electrofishing in Navigation Pool 8, Upper Mississippi River, by the Upper Mississippi River Restoration – EMP-LTRM. 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 (1993-2016).

Northern pike

Northern pike daytime electrofishing CPUE continued a three-year decline in 2016, but was still at the long-term mean (Figure 21a). Fyke netting CPUE (Figure 21b) rebounded in 2016, after a three-year decline. These recent fluctuations in CPUE may be a result of year classes recruiting into and out of the effective size range for the gears, as the trends seem to oppose each other. Despite these fluctuations, CPUE values for both gears are still higher than values from the late 1990's when the fish community was transitioning from a lotic to more lentic composition. The PSD value for northern pike remained low in 2016 at 30, suggesting a younger population (Figure 21c).

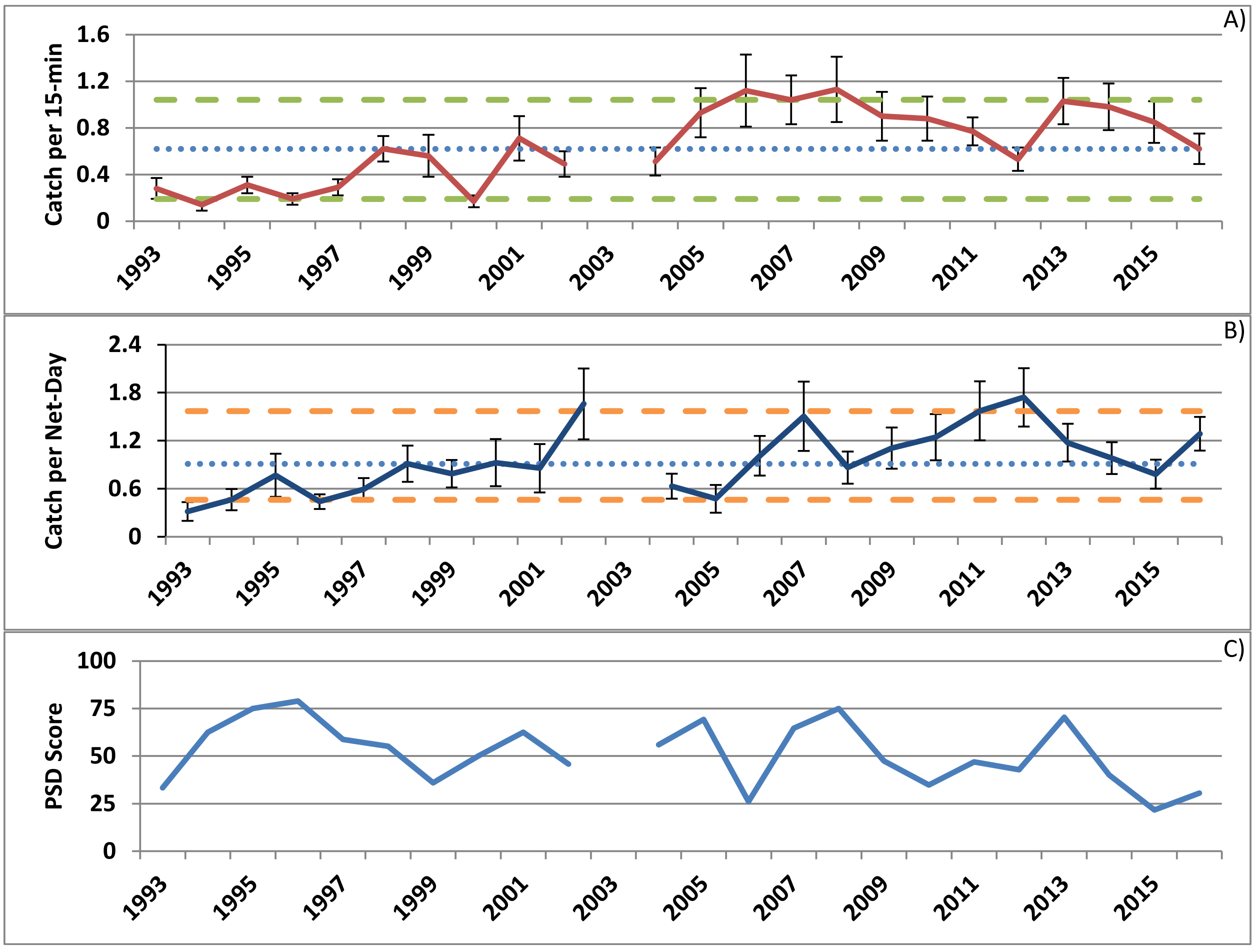

Figure 21. Catch per unit effort (± 1SE) for daytime electrofishing (a), catch per unit effort (± 1SE) fyke netting (b), and proportional stock-density (c) of Northern pike collected by day electrofishing in Navigation Pool 8, Upper Mississippi River, by the Upper Mississippi River Restoration – EMP-LTRM. 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 (1993-2016).

Sauger

Sauger CPUE for daytime electrofishing has, for many years, been below that of the 1990's (Figure 22a). Fyke netting CPUE (Figure 22b) paints a similar, dismal picture. However, a viable population remains, as the species persists. Sauger PSD continues to be variable, and fluctuates around the 50 score (Figure 22c). Stable CPUE and PSD suggest low numbers of fish in all current age classes. Small sample size for both of these gear types advises caution in interpreting these data as absolutely indicative of the true population.

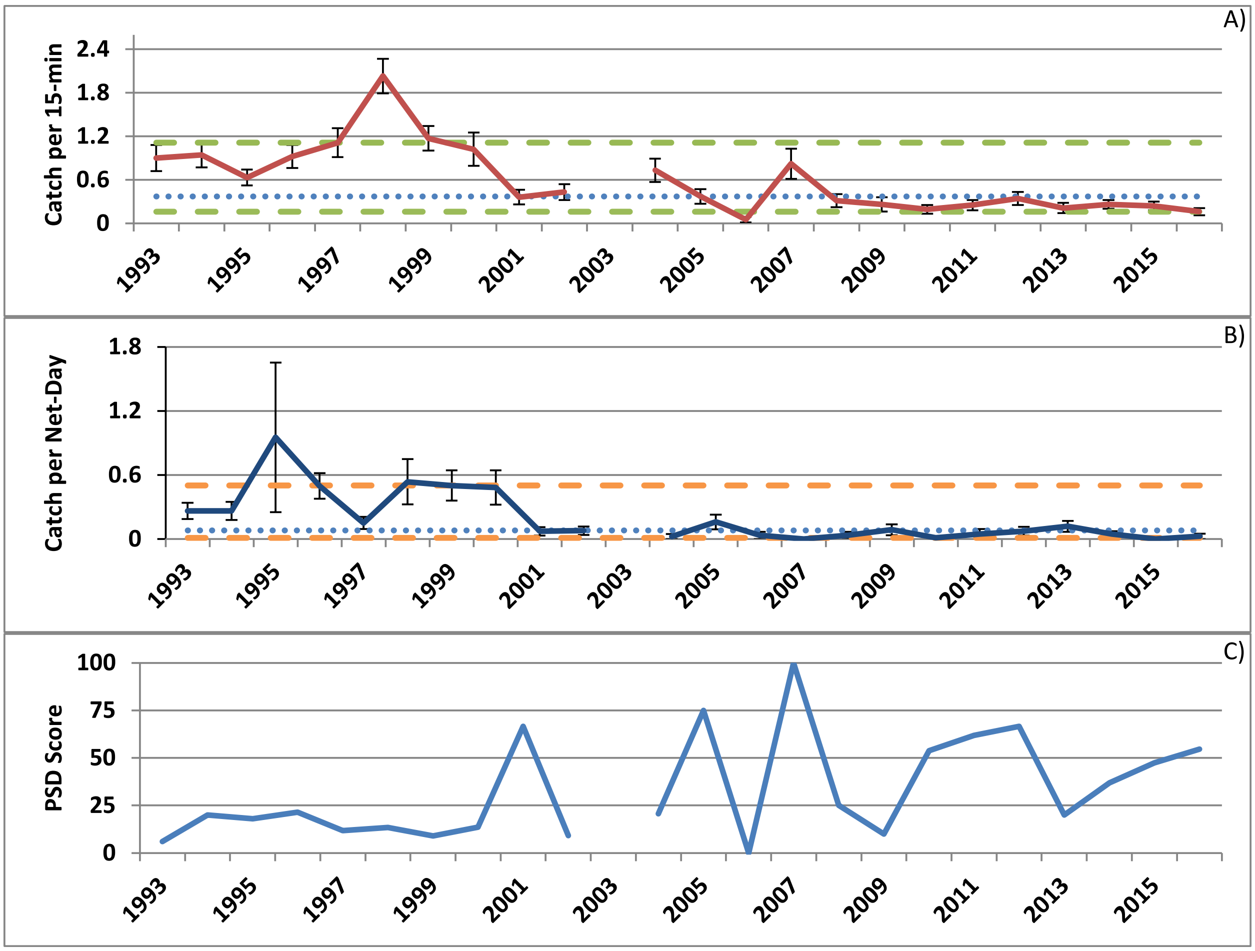

Figure 22. Catch per unit effort (± 1SE) for daytime electrofishing (a), catch per unit effort (± 1SE) fyke netting (b), and proportional stock-density (c) of Sauger collected by day electrofishing in Navigation Pool 8, Upper Mississippi River, by the Upper Mississippi River Restoration – EMP-LTRM. The 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 (1993-2016).

Smallmouth bass

Smallmouth bass daytime electrofishing CPUE tracked the long-term mean in 2016 (Figure 23a), remaining essentially on a flat trajectory since 2000, despite lows in 2009 and 2013. Large hoop netting was the only other gear type that collected many Smallmouth bass. Although not a very efficient sampling gear for Smallmouth bass, large hoop netting CPUE (Figure 23b) shows an increase in catch rate since 2010. The PSD graph suggests a stable size structure, with about half of the stock-sized fish captured being of quality size (Figure 23c).

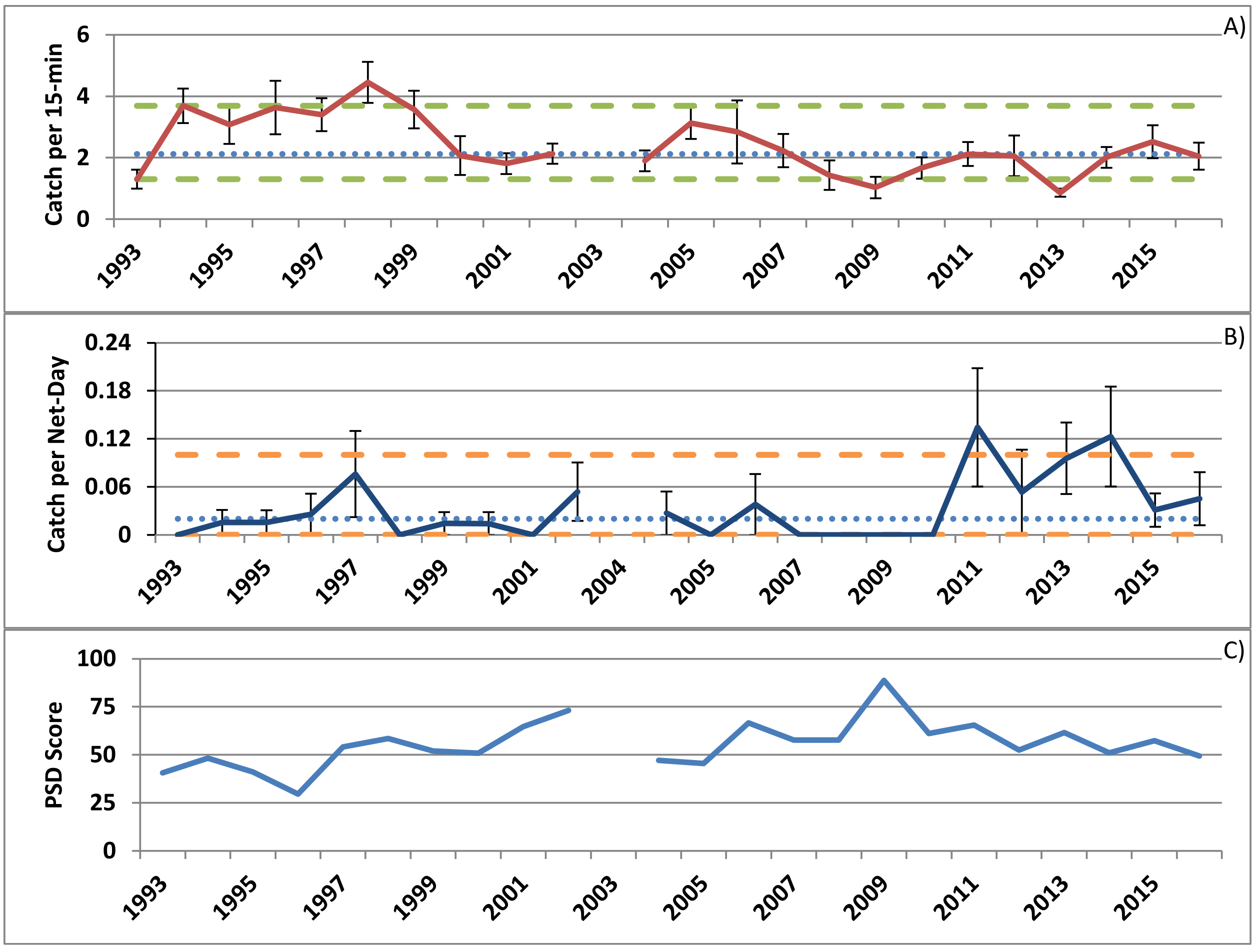

Figure 23. Catch per unit effort (± 1SE) for daytime electrofishing (a), catch per unit effort (± 1SE) large hoop netting (b), and proportional stock-density (c) of Smallmouth bass collected by day electrofishing in Navigation Pool 8, Upper Mississippi River, by the Upper Mississippi River Restoration – EMP-LTRM. 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 (1993-2016).

Walleye

Daytime electrofishing CPUE was more of the same in 2016 for Walleye (Figure 24a), as the catch rate continued to hover near the long-term mean. The fyke net CPUE graph (Figure 24b) shows a little more variability than electrofishing, although the pattern is similar. Walleye PSD values depict a stable, albeit fluctuating, pattern over time, with scores ranging from about 40 to 80 (Figure 24c). The 2016 PSD score of 10 represents one quality-sized fish of ten stock-sized walleyes caught. Obviously, sample size is not adequate enough to have confidence that this value represents the population.

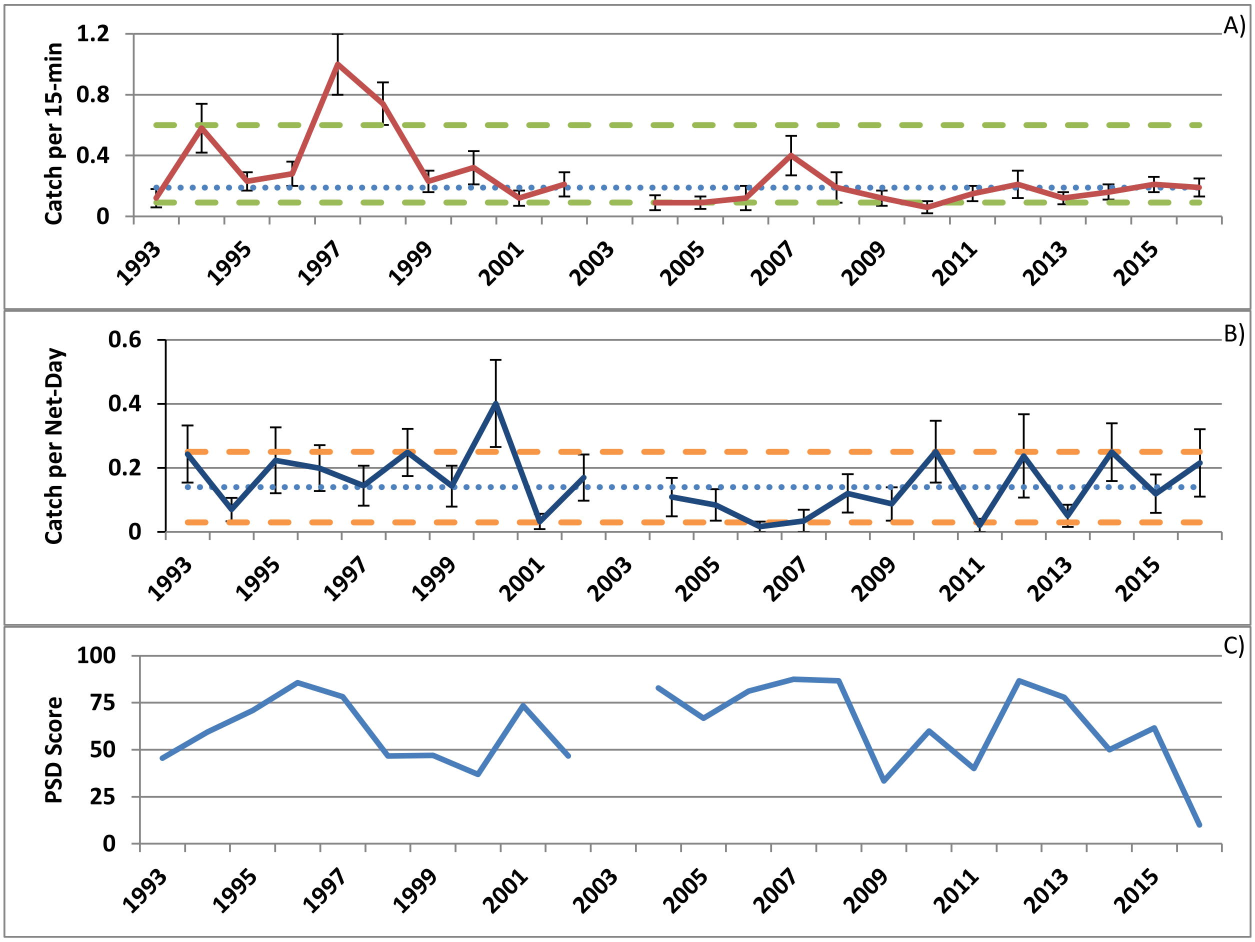

Figure 24. Catch per unit effort (± 1SE) for daytime electrofishing (a), catch per unit effort (± 1SE) fyke netting (b), and proportional stock-density (c) of Walleye collected by day electrofishing in Navigation Pool 8, Upper Mississippi River, by the Upper Mississippi River Restoration – EMP-LTRM. 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 (1993-2016).

Yellow perch

Daytime electrofishing CPUE for Yellow perch has been fluctuating widely in recent years, and 2016 was a third downturn in the last five years (Figure 25a). That said, the catch rate was still above the long-term average. Fyke net CPUE for Yellow perch (Figure 25b) peaked in 2011 and has been trending toward the long-term mean since. The PSD graph has shown some fluctuations, but generally still indicates a general pattern of increase through time (Figure 25c). Less than 50% of adult fish captured have been of quality size in most years, suggesting high recruitment, high adult mortality, or both.

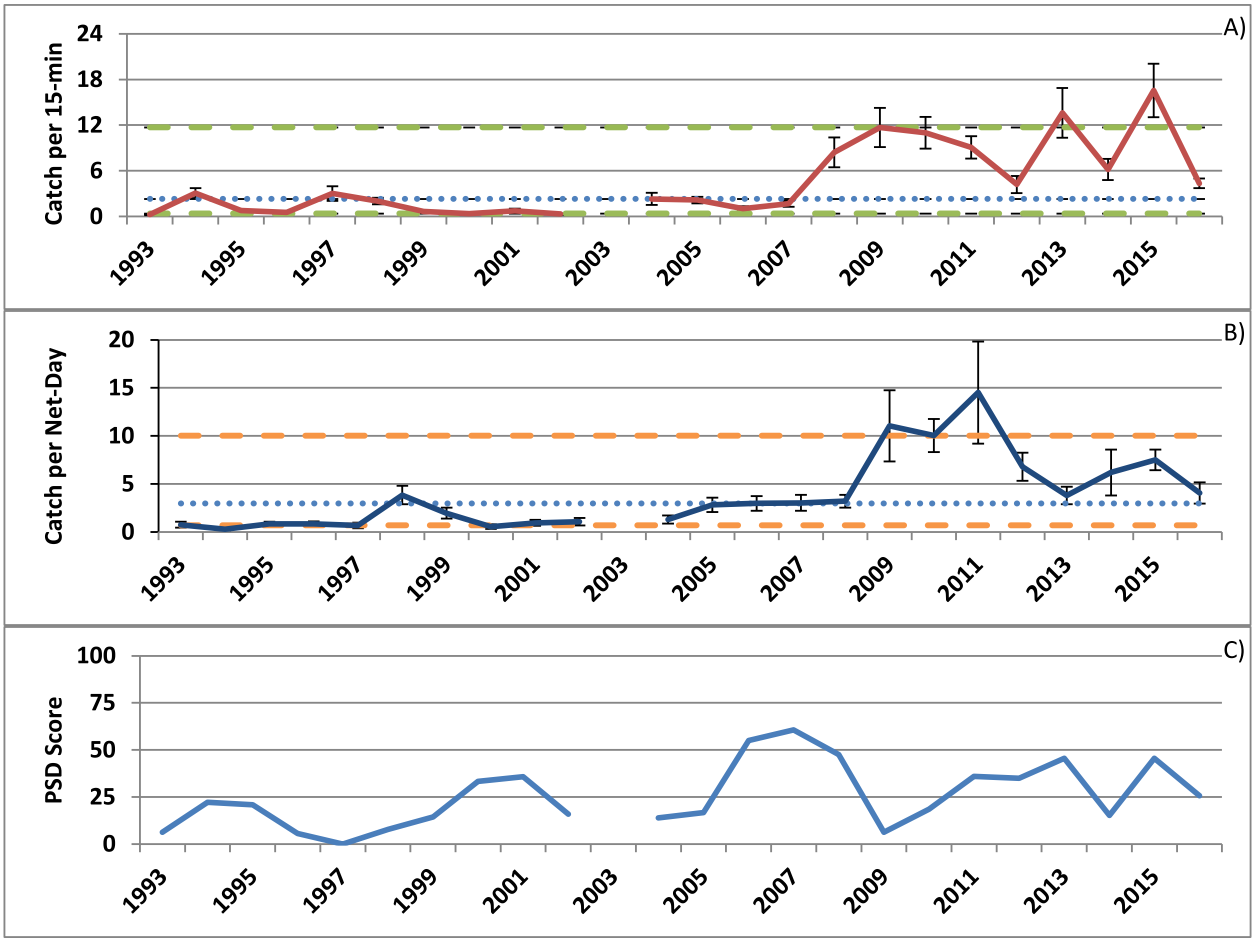

Figure 25. Catch per unit effort (± 1SE) for daytime electrofishing (a), catch per unit effort (± 1SE) fyke netting (b), and proportional stock-density (c) of Yellow perch collected by day electrofishing in Navigation Pool 8, Upper Mississippi River, by the Upper Mississippi River Restoration – EMP-LTRM. 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 (1993-2016).

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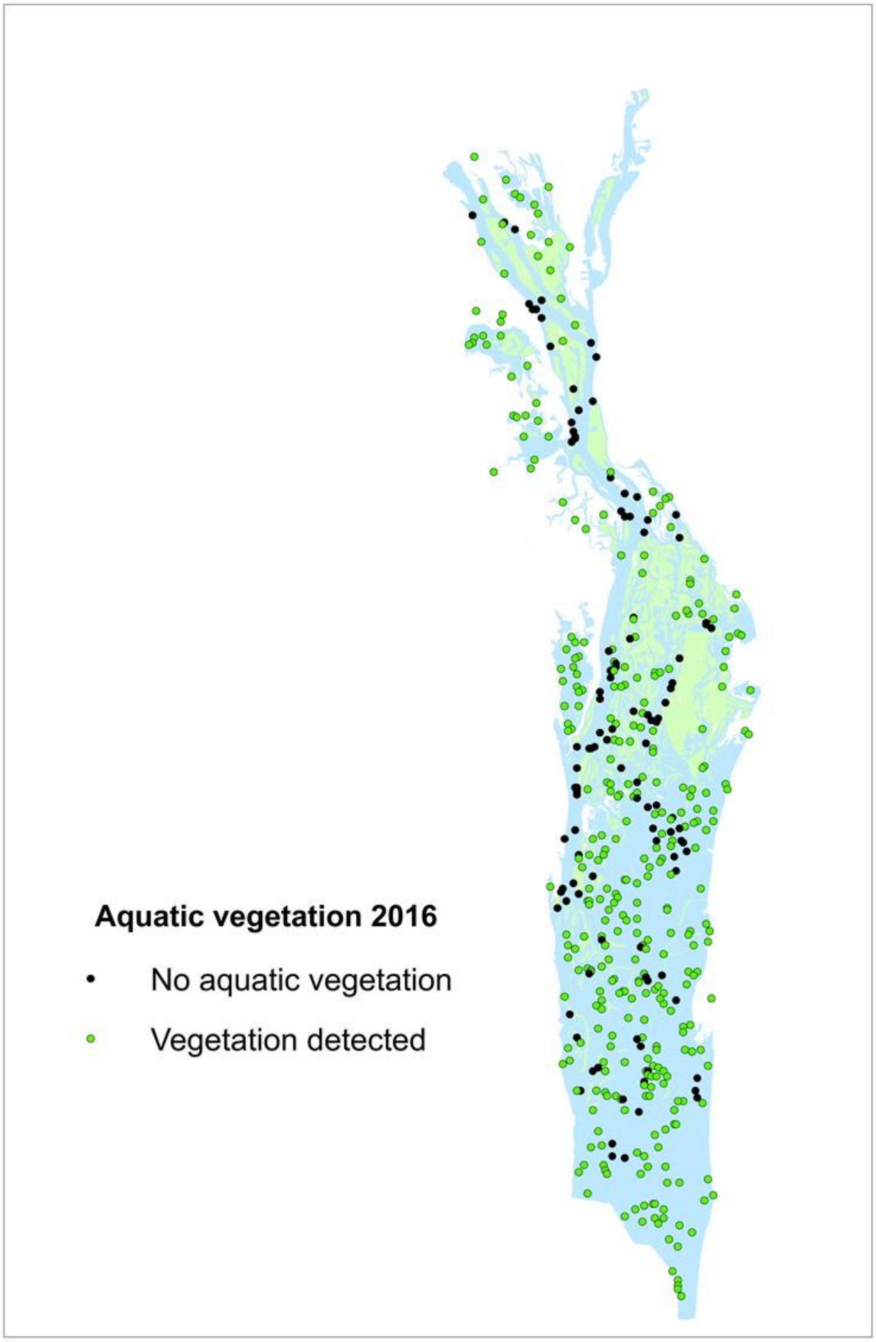
Appendix



Appendix A. Locations of the 450 sites visited in 2016 aquatic vegetation surveys – vegetated sites (339) are marked in green and unvegetated sites (111) are in black. Most of the unvegetated sites were located in the main channel with high water velocity and depth.