Let There Be Light: Making the Case for Improved Water Quality and Targeted Restoration

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The positive relationship between water clarity and aquatic plants is well understood and the prevalence of aquatic plants drives a variety of ecological processes in aquatic ecosystems. Proliferation of aquatic plants has been shown to drive a variety of feedback mechanisms including reduced sediment resuspension, reduced phytoplankton, increased invertebrate biomass, increased refuge for zooplankton, increased denitrification, production of allelopathic substances, and increases in waterfowl abundance.

Water clarity and aquatic plant abundance are among the major factors driving fish community characteristics across the Upper Mississippi River. Widespread landscape disturbance, resulting in increased sediment loading, has been identified as driving declines in aquatic plant abundance. This results in declines of backwater specialists and predators with plant-dependent life cycles. Clear, vegetated systems tend to be dominated by visual predators such as yellow perch (*Perca flavescens*), northern pike (*Esox lucious*), and largemouth bass (*Micropterus salmoides)*. Predatory fishes such as northern pike, bowfin (*Amia calva*), largemouth bass and longnose gar (*Lepisosteus osseus*) are often able to substantially reduce recruitment among planktivorous fishes. This reduction in planktivorous fish can alter food webs and result in further increases in aquatic vegetation and water clarity. Alternatively, benthivorous fish such as common carp (*Cyprinus carpio*) tend to be abundant in turbid systems and can keep these systems in a turbid state due to resuspension during their feeding and spawning activities. Once substantial populations of common carp and other benthivores are high, establishing aquatic plants can become difficult due to poor water transparency.

The depth of one percent of surface light is generally viewed as the delineation between the photic and euphotic zones. Photosynthetically active radiation (PAR) was measured in micromoles s^{-1} m^{-2} a LI-192 Underwater Quantum Light Sensor and a LI-190R Quantum Light Sensor (LI-COR, Inc., 2006). A correction factor was applied to one cell to ensure both cells yielded the same response under identical light exposure. All light measurements were conducted between 1000 and 1500 hours. The underwater sensor was deployed over the side of the lock wall at Lock and Dam 8 and 9. The sensors were allowed to stabilize for 20 to 30 seconds and five readings were recorded for each site and later averaged. Light-extinction coefficient was calculated as:

$$k = [\ln(Io) - \ln(Iz)]/z,$$

where:

k	is light-extinction coefficient (1/m),
Io	is surface light measurement,
Iz	is light measurement at depth z, and
z	is depth interval between Io and Iz.

The depth of one percent of surface light ($z_{l1\%}$) was calculated as :

$$(z_{l1\%}) = \ln(100)/k.$$

Figure 1 provides a valuable look into the chronology of the River downstream of Lake Pepin since 1988. A great deal of insight can be gained from this dataset: from the collapse of vegetation post-1988, to the nearly ten years it took the Mississippi to reset back to a clearer state, to the extreme transparency observed in 2009 and 2010.

It appears that the fall 2010 flood was a reset event for the river, with 2011-2015 light penetration remaining consistent following the unusually clear water years of 2009 and 2010. The red line indicates the equivalent one percent of surface light value which corresponds to 17 mg/L total suspended solids (TSS)- a threshold, using Long Term Resource Monitoring (LTRM) data, where fundamental shifts in the native and recreational fish community tend to occur (Figures 2 and 3).

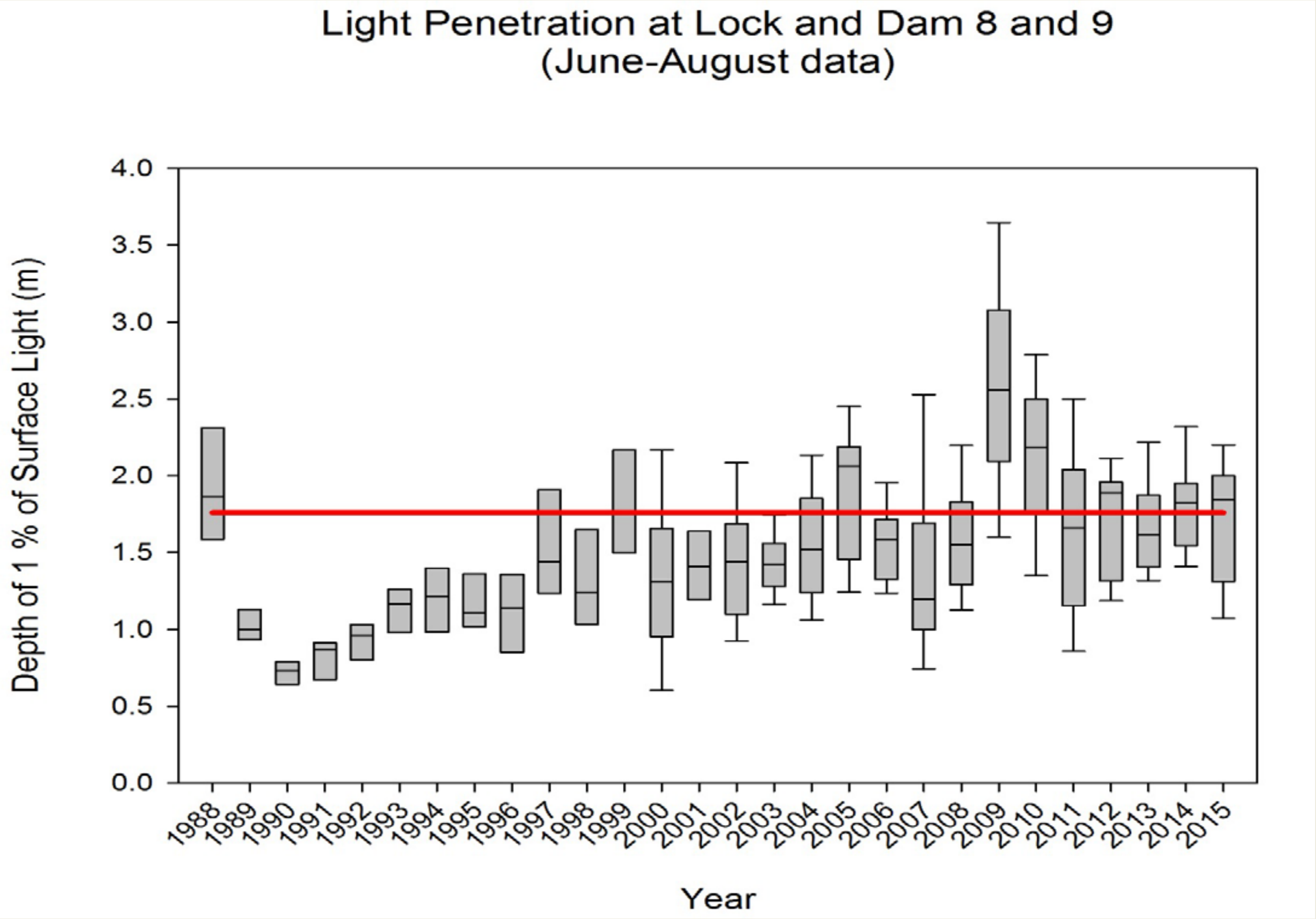


Figure 1. Long term trends in one percent of surface light at Lock and Dam 8 and 9. The red line indicates the one percent of surface light value corresponding to 17 mg/L total suspended solids (Giblin et al., 2010).

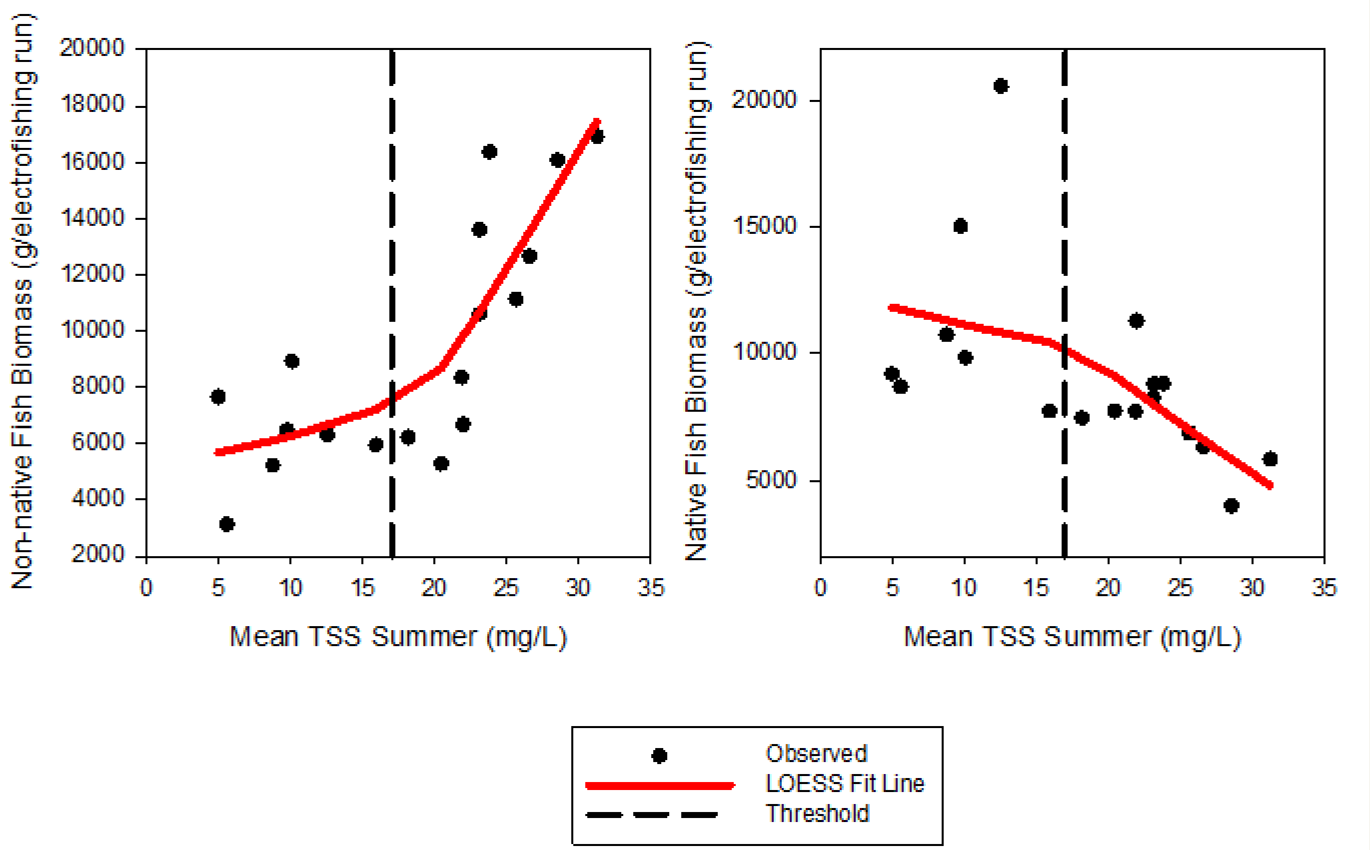


Figure 2. Relation between mean annual non-native and native fish biomass per electrofishing run and mean summer TSS in Pool 8 of the Upper Mississippi River (1993-2011). The solid line indicates the LOESS regression trend. The dotted line indicates the observed threshold (17 mg/L TSS; Giblin et al., *In Review*).

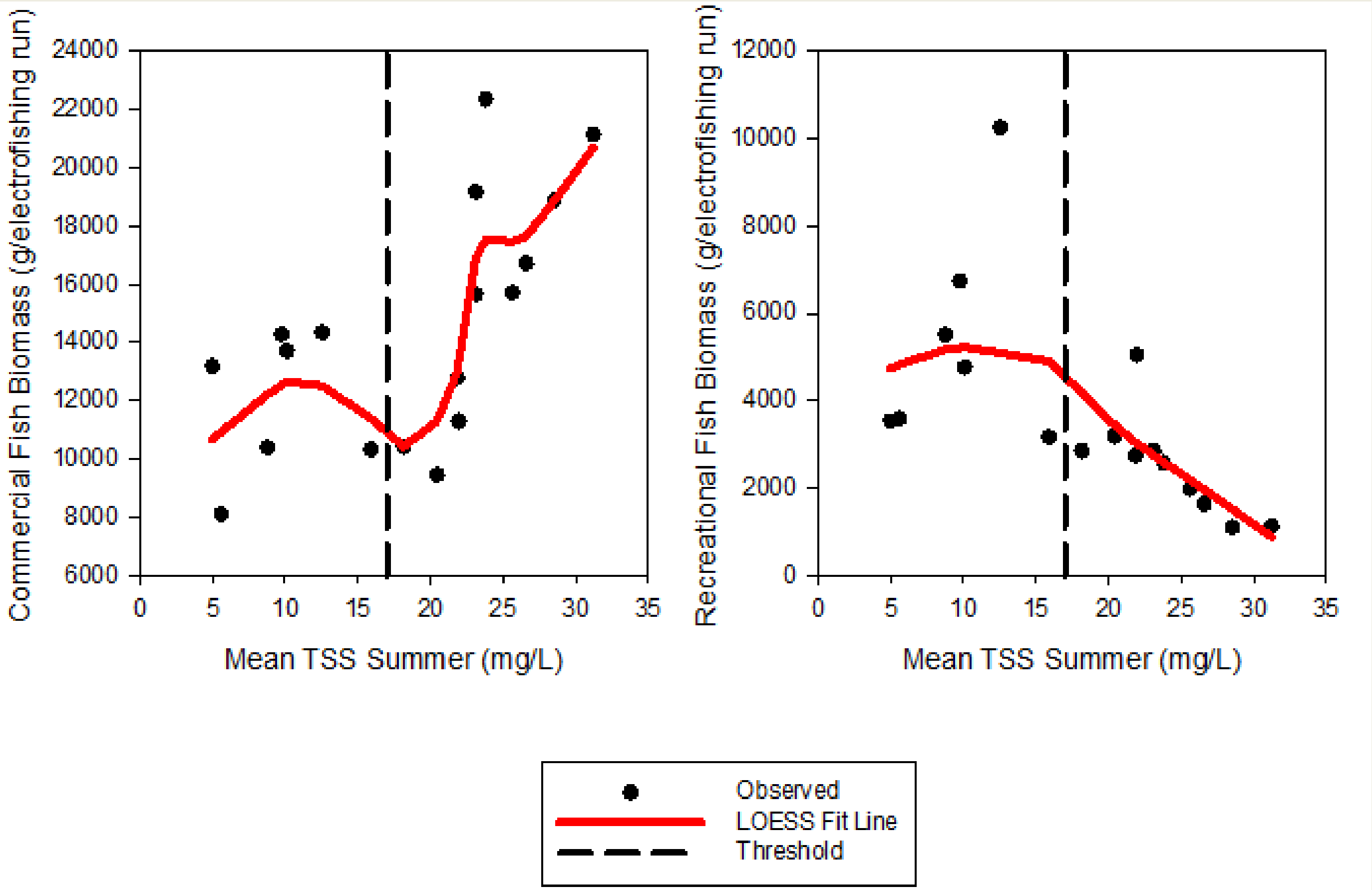
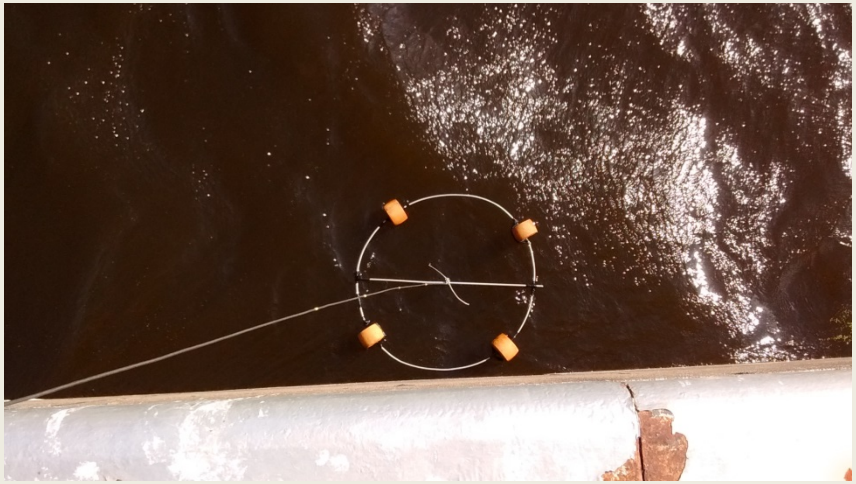


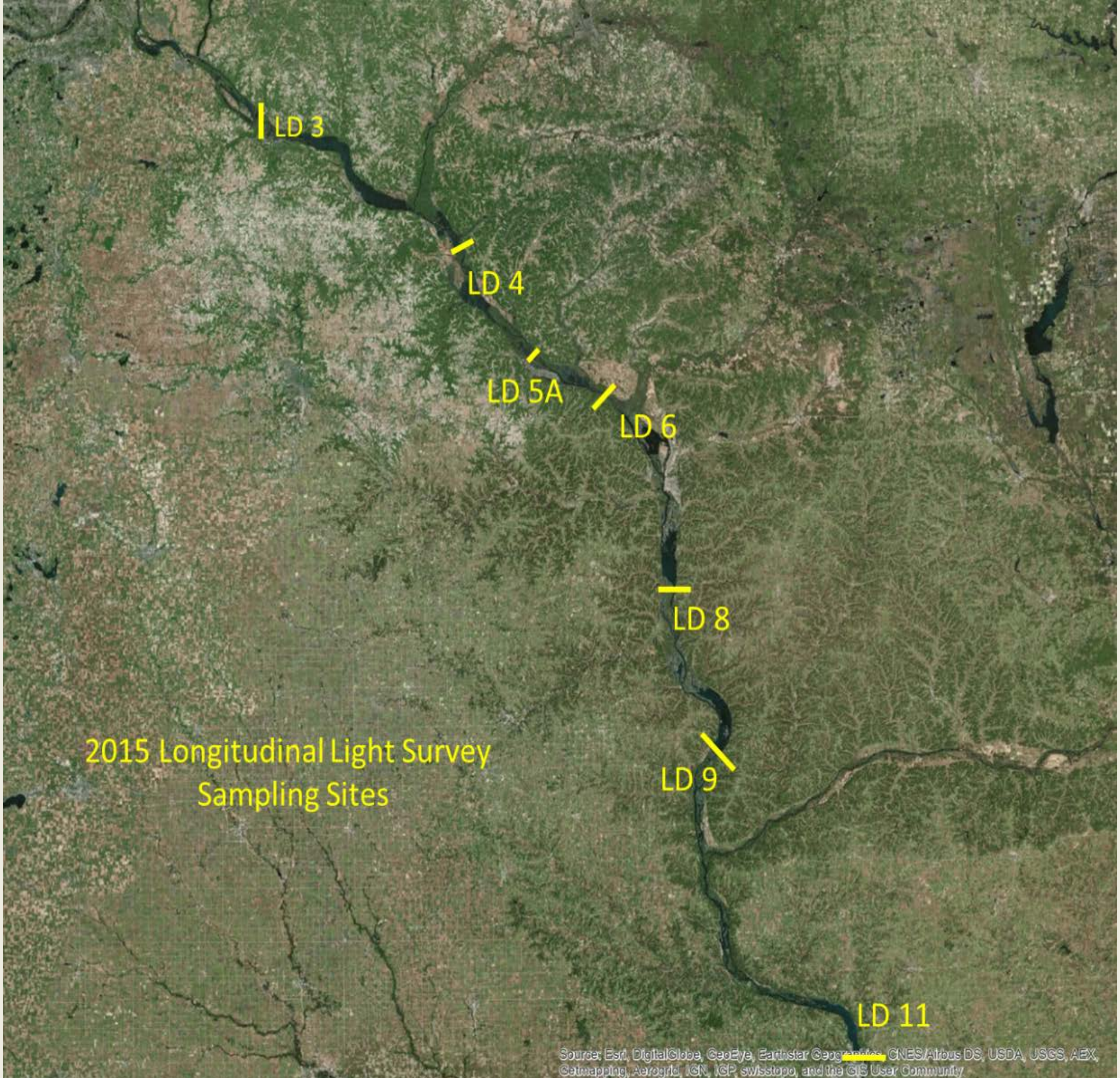
Figure 3. Relation between mean annual commercial and recreational fish biomass per electrofishing run and mean summer TSS in Pool 8 of the Upper Mississippi River (1993-2011). The solid line indicates the LOESS regression trend. The dotted line indicates the observed threshold (17 mg/L TSS; Giblin et al., *In Review*).

During the summer of 2015, WDNR Staff conducted a longitudinal survey of water clarity within Wisconsin waters (Lock and Dams 3-11). This survey method provides an efficient way to quickly assess transparency within a large geographic area. Water clarity increased substantially between Lock and Dams 3 and 4, as a result of the high sediment trapping efficiency of Lake Pepin (Figure 4). Water clarity continued to improve from LD4 to LD6, when peak transparency was reached near Trempealeau, WI. Downstream of LD6, water clarity steadily declined to the Illinois border. Slope analysis of water transparency allows for the identification of reaches where transparency is changing most quickly as a function of river mile (Table 1).

This dataset also provides insight into the depth water that would be required to establish plant edge habitat. The depth required to establish this critical habitat is very different in Pool 6 as compared to Pool 11. Longitudinal gradients in light climate need to be a consideration in habitat project planning.

LI-COR sampling equipment used to measure 1 % of surface light.




LD 3
LD 4
LD 5A
LD 6
LD 8
LD 9
LD 11
2015 Longitudinal Light Survey
Sampling Sites
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

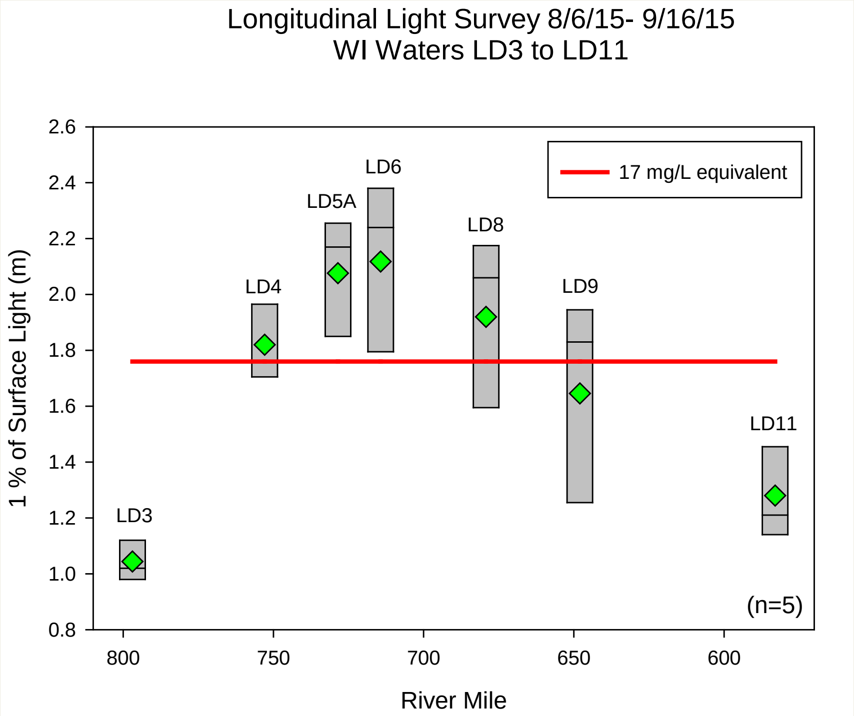


Figure 4. Longitudinal one percent of surface light data collected from Lock and Dams 3-11 during the summer of 2015.

Table 1. Ranked slope analysis of change in water transparency as a function or river mile (Pools 3-11).

Rank	Location	Regression Equation
1	LD3 to LD4	1 % of Surface Light (m) = 15.098 – (0.0176*River Mile)
2	LD4 to LD5A	1 % of Surface Light (m) = 9.719 – (0.0105*River Mile)
3	LD8 to LD9	1 % of Surface Light (m) = -4.045 + (0.00878*River Mile)
4	LD6 to LD8	1 % of Surface Light (m) = -1.911 + (0.00564*River Mile)
5	LD9 to LD11	1 % of Surface Light (m) = -2.003 + (0.00563*River Mile)
6	LD5A to LD6	1 % of Surface Light (m) = 4.231 - (0.00296*River Mile)

In relation to meeting the light threshold of 17 mg/L TSS to move the fish community to a more robust native species assemblage, we failed to meet our light goal upstream of Lake Pepin (Pools 3 and Upper 4) and again in Pools 9-11. This speaks to the need for projects to improve water clarity in these reaches of river through a combination of habitat projects (e.g. island building in windswept impounded areas of Pools 9 and 11) and watershed improvements. In areas where we are meeting our water clarity goals (Pools Lower 4-8), projects to improve water clarity do not appear to be needed at this time and we should consider directing our habitat activities toward other projects, like backwater dredging, to increase off-channel depth lost due to sedimentation. We should still strive to implement watershed improvements in this reach to extend the geographic extent of areas meeting our water clarity goals.

References

Giblin, S.M., Hoff K., Fischer J. and Dukerschein T. 2010. Evaluation of light penetration on Navigation Pools 8 and 13 of the Upper Mississippi River. U.S. Geological Survey Long Term Resource Monitoring Program Technical Report 2010-T001. 16 p.

Giblin, S.M., Ickes, B.S. and Drake D.C. Evidence of Ecological Thresholds in a Large Floodplain River during a Transition from a Turbid to Clear Water State. In Review.