ECCC In-Lake Science Addressing Lake Winnipeg Nutrients & Algal Blooms

Caren Binding, Dave Depew, Arthur Zastepa

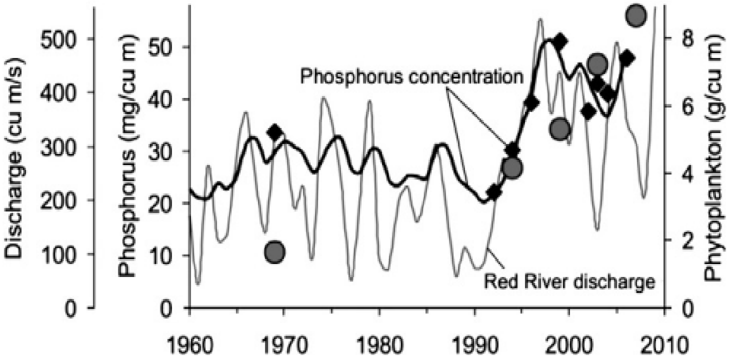
Environment and Climate Change Canada
Burlington, Ontario

LWBP Symposium
March 20-21, 2019

Background

LW has undergone rapid eutrophication:

- Municipal and industrial wastewaters, agricultural runoff
- Landscape alteration and increased frequency/ intensity of spring floods
- Dramatic increase in nutrient loading in 1990s → frequent severe algal blooms
- Zebra mussels, discovered in 2013, widely anticipated to impact lake nutrients and algae



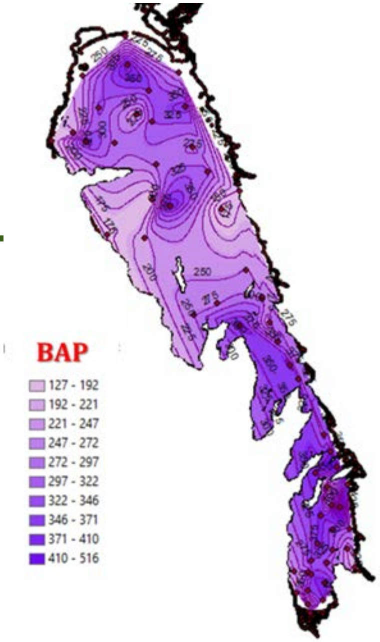
(Schindler et al 2012, JGLR)

LWBP - Key Questions/Objectives

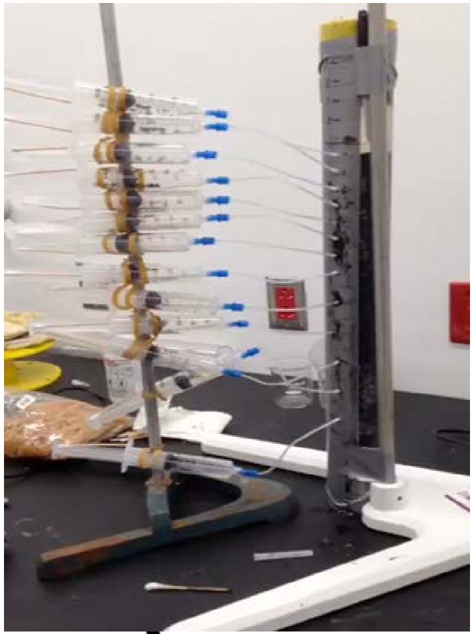
- Understand the influence of internal nutrient loading on the system and on anticipated lake recovery
- How are Dreissenid mussels expected to impact water clarity, algal blooms, and nutrient cycling?
- What is the spatio-temporal variability in phytoplankton community composition, function, and toxin production?
- Can remote sensing be used to document current and historical bloom conditions and determine the effectiveness of nutrient management practices in reducing blooms?
- What are the main drivers of bloom spatial and temporal variability?

Internal Nutrient Loading

- Quantified internal nutrient loading due to sediment resuspension using sediment traps and cores
- Internal TP loading comparable to the magnitude of external loading
- Results indicate that surficial sediments in LW will remain a significant source of nutrient loading for several decades
- Investigating potential for sediment P release during low oxygen events
- DO loggers & sediment cores in NB 2018/19 - data to inform P flux models



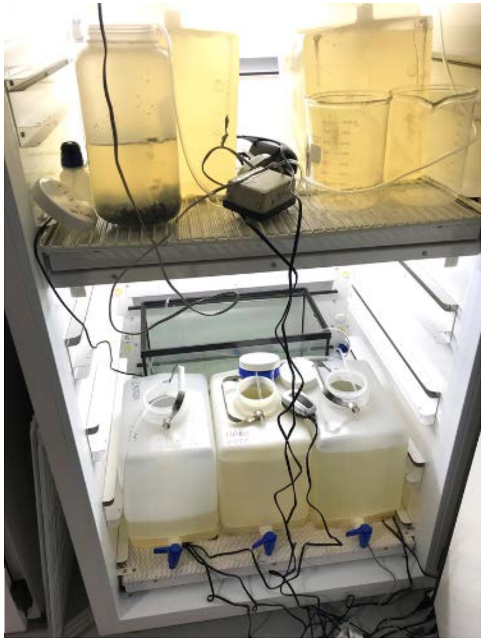
(Matissof et al STE, 2017)



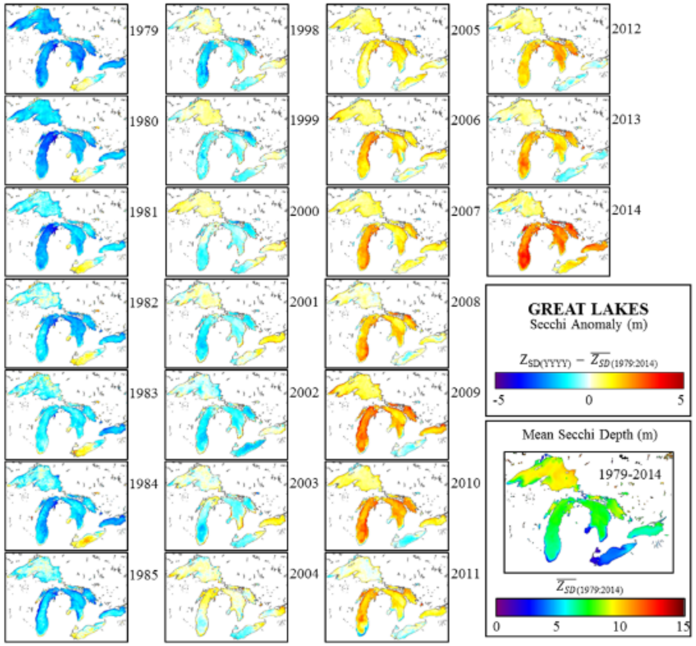
(Photo: D. Depew)

Dreissenid Mussels

- Invasive dreissenid mussels have the potential to increase water clarity, produce more favourable conditions for SAV, change phytoplankton community composition, increase risk of toxic cHABs and change nutrient cycling
- In-lake sampling to quantify abundance, distribution and biomass of mussels
- Research to further understand mussel impacts through laboratory experiments and remote sensing



Matson et al



Binding et al L&O 2015

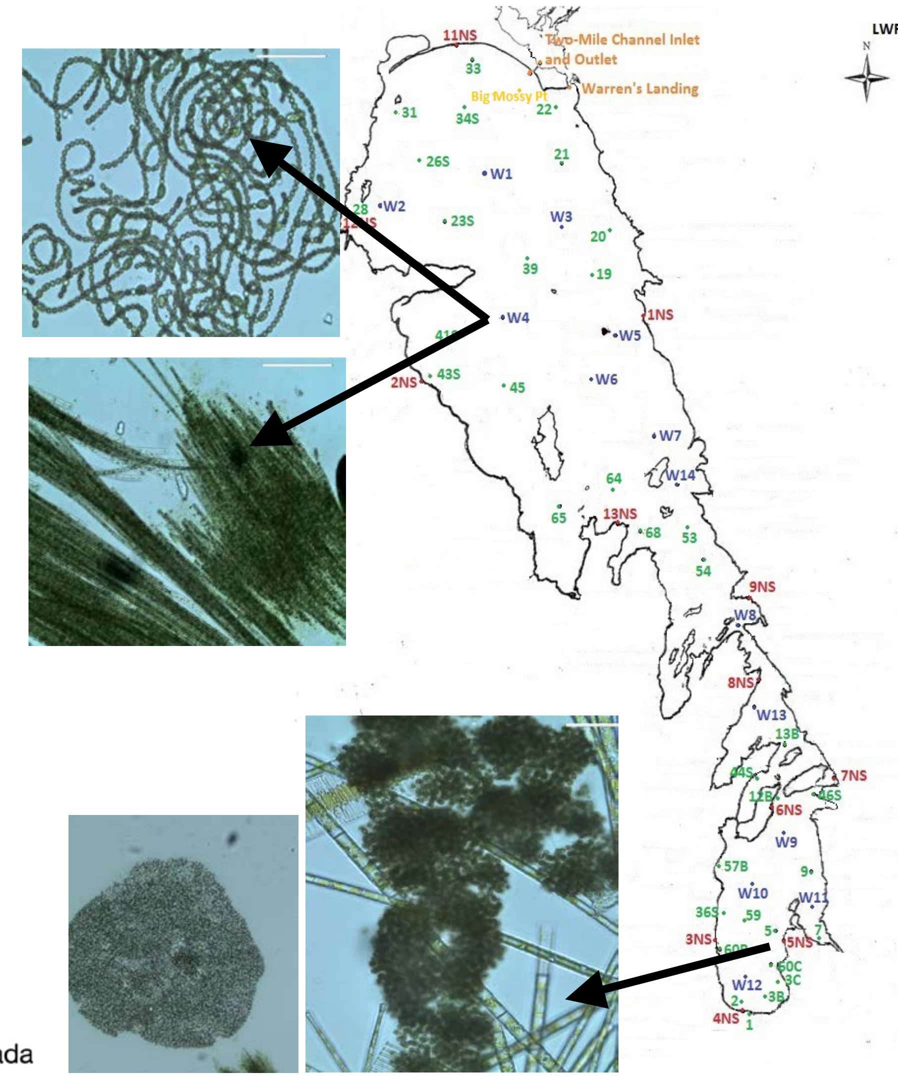
Spatio-temporal Variability of Algal Blooms

- Lake-wide surveys for phytoplankton analyzed for species composition, abundance, toxicity
- Combined with satellite imagery to document seasonal variability
- Spring bloom in SB & Narrows, dominated by turbid adapted diatoms
- Blooms in Narrows and NB where nutrient-rich waters of turbid SB reach more favourable light conditions in clearer NB
- Widespread cyanobacteria blooms occur in the summer/fall in both N & S basins
- Accumulation along NE shore of NB consistent with flow and prevailing winds

Spatio-temporal Variability of Algal Blooms

(photo: A. Zastepa)

- Nitrogen-fixing taxa (*Dolichospermum, Aphanizomenon)* dominating in the NB
- Non nitrogen-fixing cyanobacteria (*Microcystis, Planktothrix)* dominating in the SB
- Low N:P ratios → increase in nitrogen fixing cyanobacteria
- Relatively low microcystin typically observed but elevated concentrations have been measured in surface scums

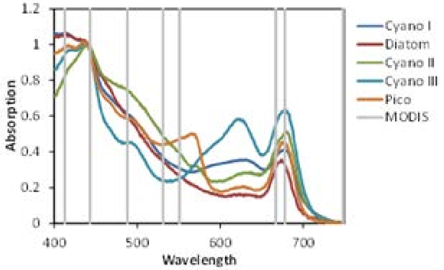


Aquatic Optics & Satellite Remote Sensing

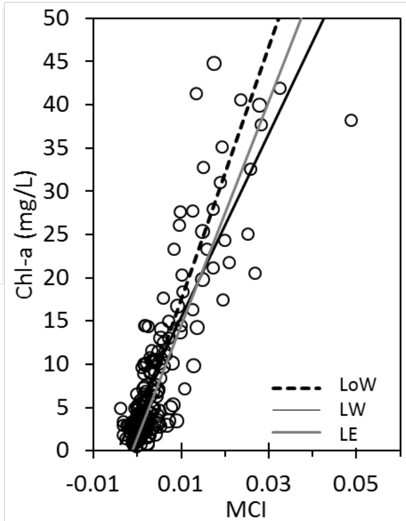
MERIS, August 29 2011

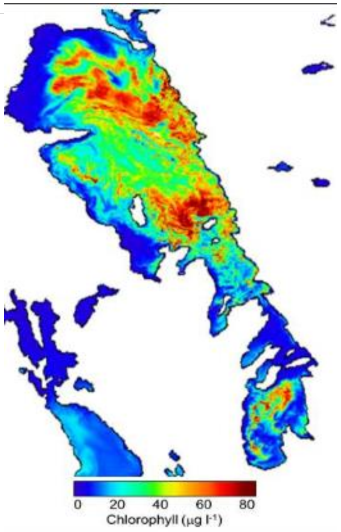
- Satellite imagery effectively captures blooms
- Extracting quantitative information on algal bloom conditions requires algorithm development to detect unique spectral signature of algae

Field measures of algal and optical properties → Optical theory, algorithm development & validation → Mapped bloom products

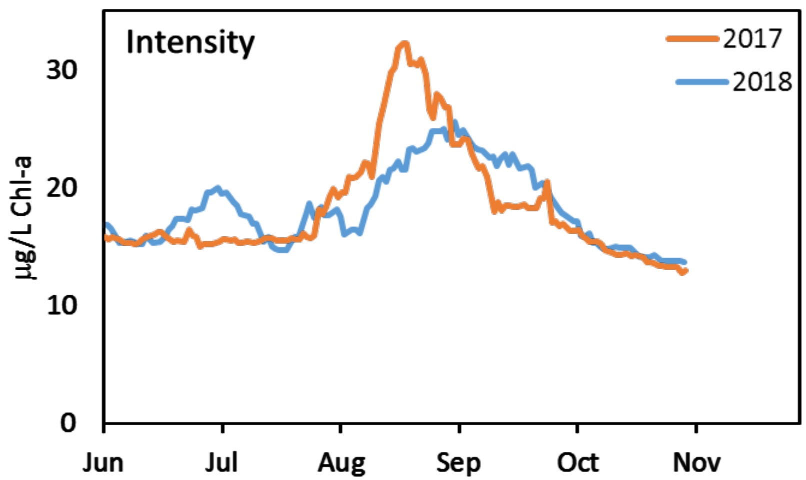


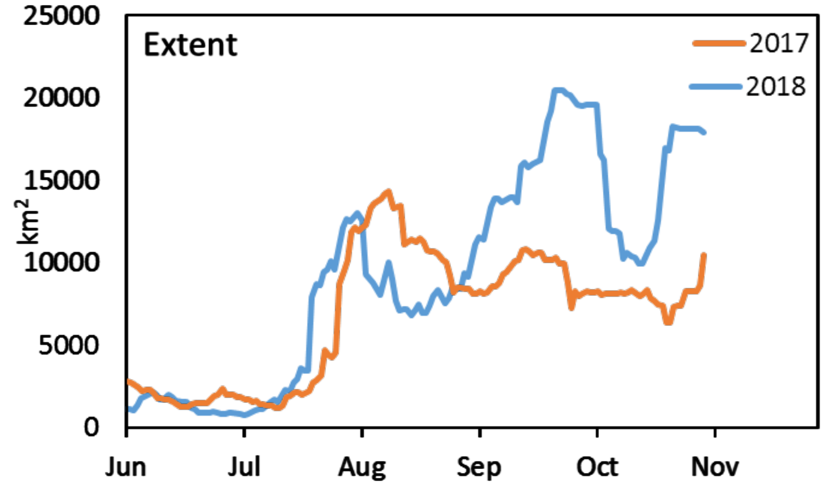
$$\begin{bmatrix} Chla \\ DOM \\ TSS \end{bmatrix} \Leftrightarrow f\{b_b/a\}$$

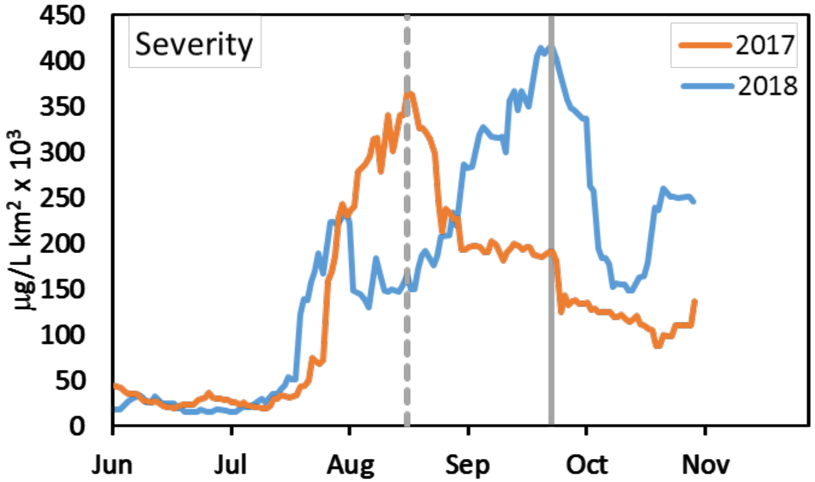




Remote Sensing Algal Bloom Indices

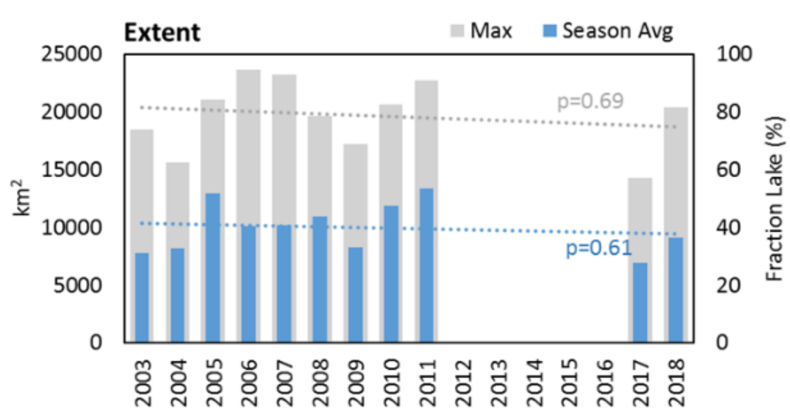


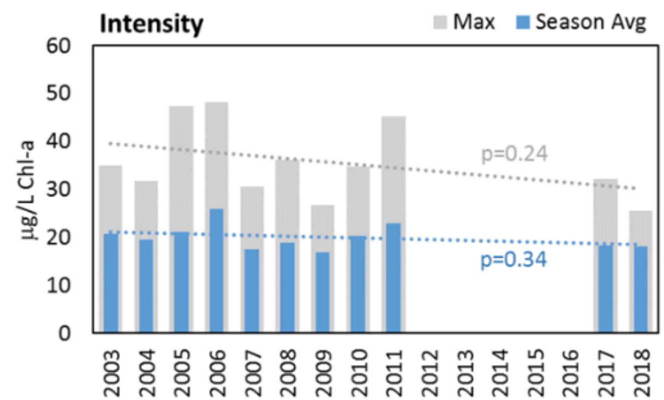


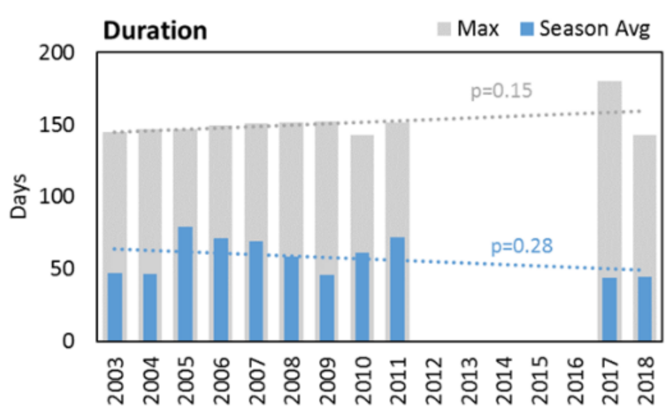


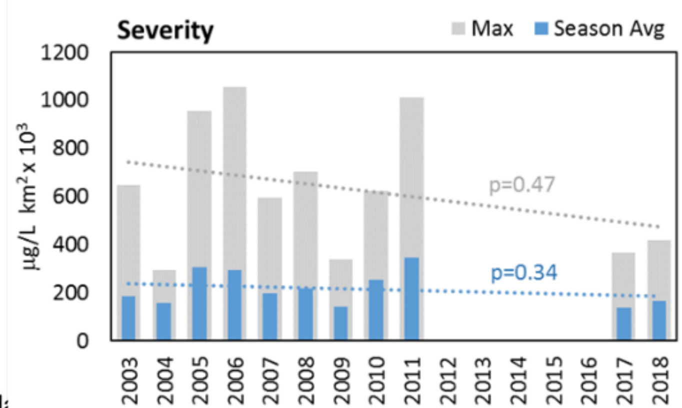
Historical Bloom Conditions

- Quantitative assessment of inter-annual variability and with future imagery will enable assessment of the effectiveness of nutrient management actions in reducing blooms

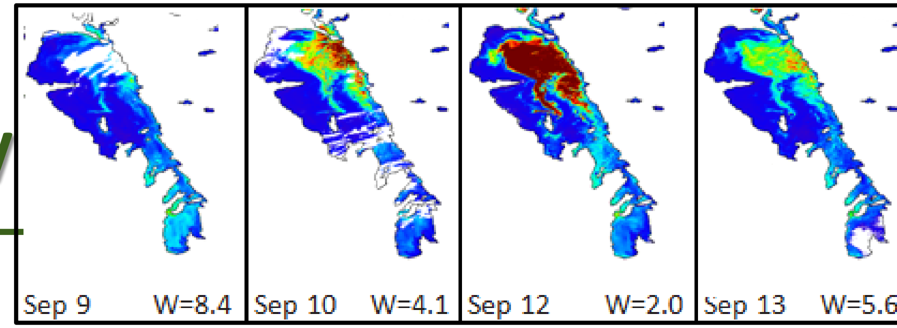




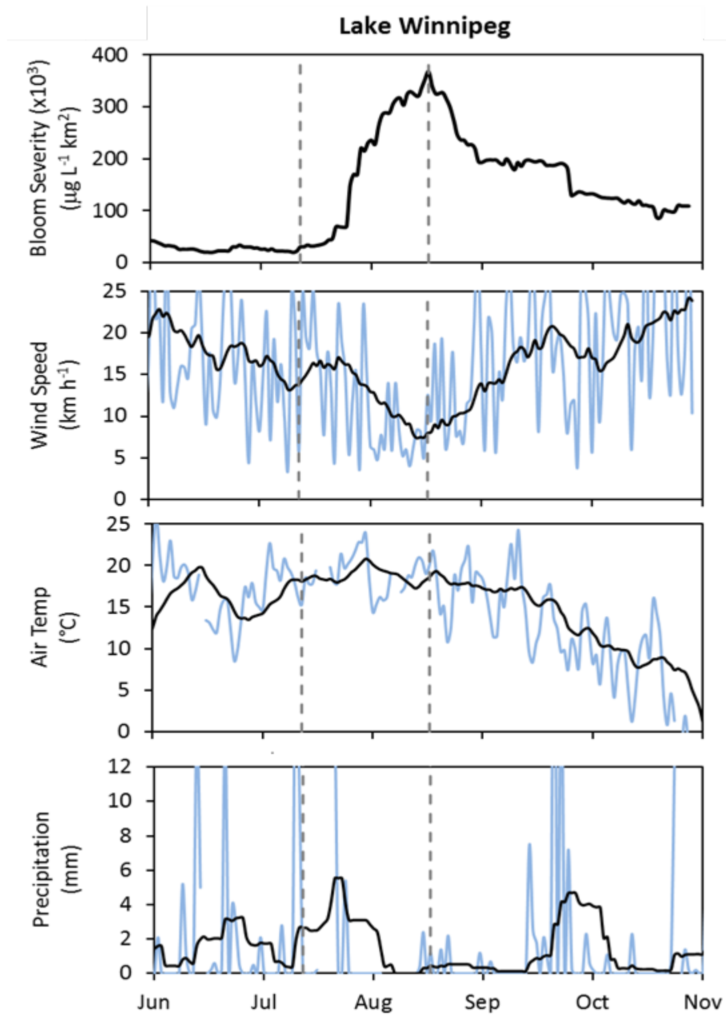




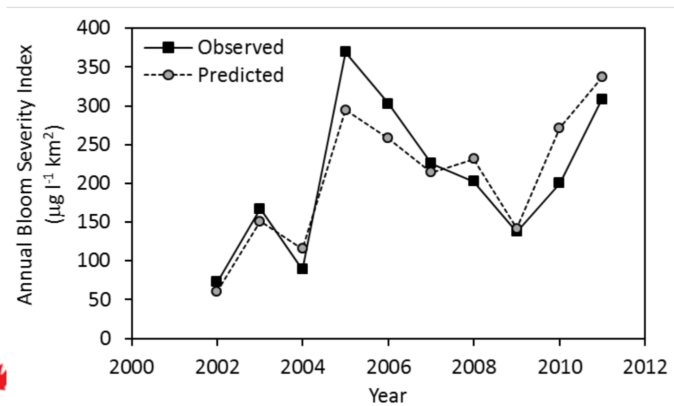
Drivers of Bloom Variability



- Day to day wind-driven variability
- Peak seasonal severity coincident with prolonged period of reduced wind mixing
- TP Loadings and summer temperature appear to be good predictors of annual bloom severity



Bloom Severity = - 687+0.035TP+35.6Temp
R^2=0.88 $p < 0.01$ n=10



Summary & Future Directions

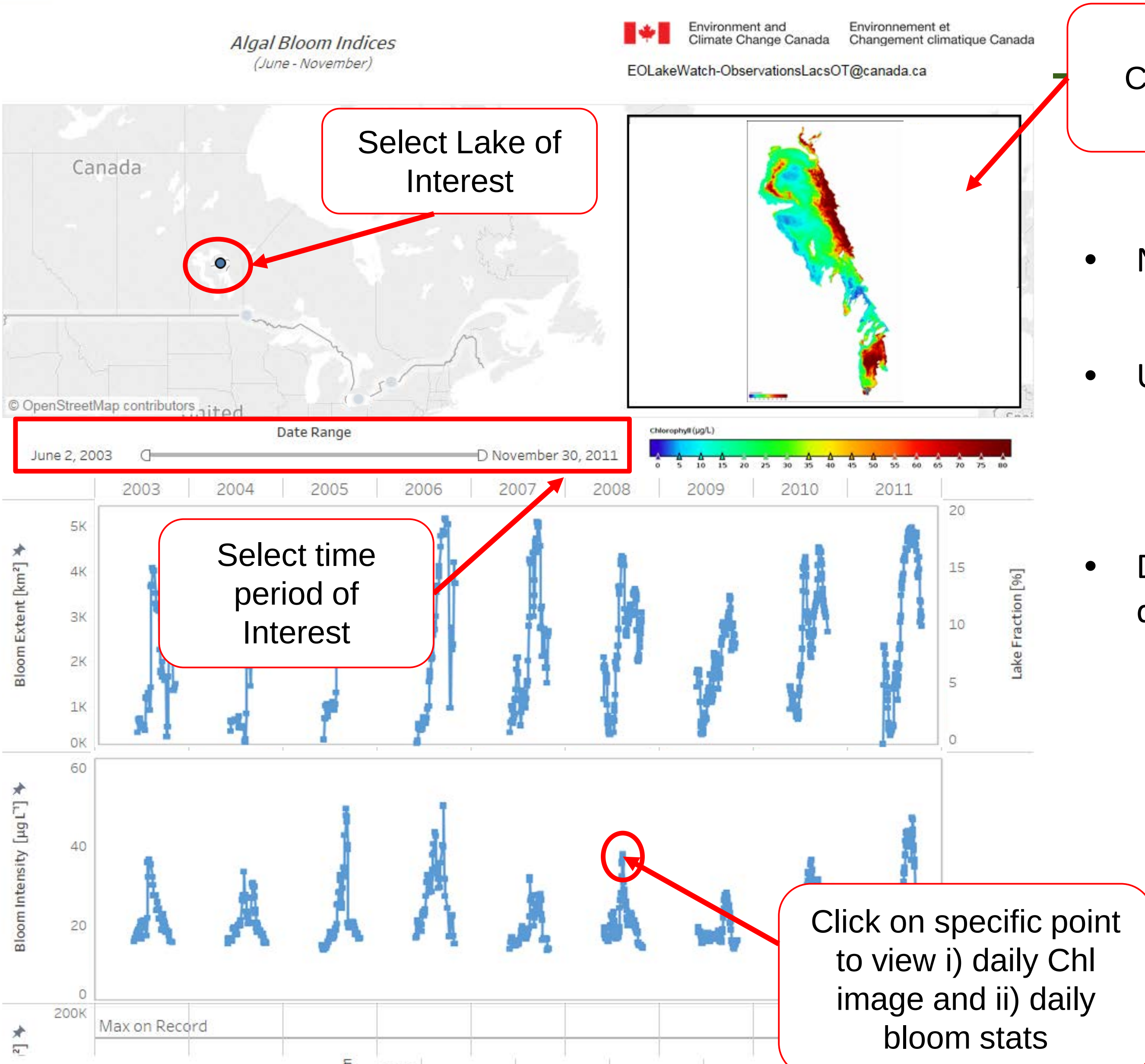
- In-lake research has addressed specific knowledge gaps to gain a better understanding of nutrient sources and cycling, and the status and drivers of algal blooms
- Results have contributed to: nutrient objectives, LW indicator series, SOL reporting, and will enable the assessment of the effectiveness of nutrient management actions
- Continue to provide robust measures of algal bloom conditions on LW using remote sensing
- Continue with spatiotemporal surveys of phytoplankton for taxonomic and cyanobacterial metabolite screening
- Ongoing mussel surveys and grazing experiments to determine potential impacts of dreissenids on phytoplankton community and water clarity
- Continued research on the influence of internal nutrient loading on anticipated lake recovery

Thanks! Any Questions?

caren.binding@canada.ca

@EOLakeWatch

An Experimental Web Tool



- Near-real time updates
- User defined parameters
  - Date Range
  - Lake
- Dynamically updated dashboard displaying:
  - Bloom extent
  - Bloom intensity
  - Bloom Severity
  - Daily Chl image

Canada

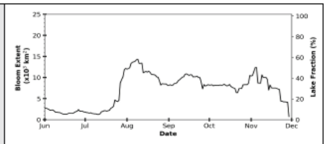
Annual Bloom Reports

Environment and Climate Change Canada | Environnement et Changement climatique Canada

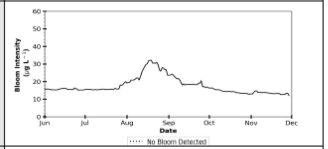
2017 Algal Bloom Report - Lake Winnipeg

Satellite-derived algal bloom indices (see Table 1 for definitions) for Lake Winnipeg have been estimated using data from the OLCI (Ocean Land Colour Instrument) satellite sensor on the European Space Agency's (ESA) Sentinel-3 satellite. Daily satellite images were combined to produce a 14-day rolling average of bloom conditions from June 1 to November 29. See Table 2 for historical bloom indices derived from ESA's MERIS (MEdium Resolution Imaging Spectrometer) sensor (2002 - 2011).

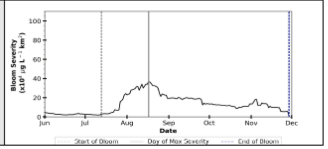
Bloom Extent (km^2) (Fraction of Lake) — Average = 8624 (35.1%), Maximum = 14313 (58.3%)



Bloom Intensity ($\mu g\ L^{-1}$) — Average = 18.2, Maximum = 32.2

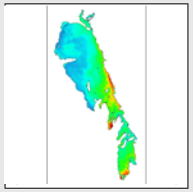


Bloom Severity ($\mu g\ L^{-1} km^2$) — Average = 163267, Maximum = 366114

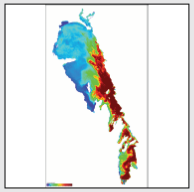


Bloom Duration (June - November)

Average Chlorophyll (June - November)



Chlorophyll at Max Bloom Severity Aug 17



Environment and Climate Change Canada | Environnement et Changement climatique Canada

2017 Algal Bloom Report - Lake Winnipeg

Table 1. Algal Bloom Indices and Definitions

Bloom Index	Description
Bloom Flag	Chlorophyll > 10 $\mu g\ L^{-1}$
Bloom Extent (km^2)	Total area of pixels flagged as bloom
Bloom Intensity ($\mu g\ L^{-1}$)	Average chlorophyll concentration within area flagged as bloom
Bloom Severity ($\mu g\ L^{-1} km^2$)	Bloom Intensity x Bloom Extent
Start of Bloom	First day of ten consecutive days where bloom severity is greater than double the average bloom severity from the start of the season (June 1st) to that date.
End of Bloom	First day, after the day of maximum bloom severity, when bloom severity is less than or equal to the bloom severity at the start of the bloom. If no End of Bloom is detected (*) it is reported as the last day of image processing (November 29).
Bloom Duration (days)	Number of days between the start and end of the bloom

Table 2. Annual (June to November) Average and Maximum Bloom Indices

Bloom Indicies										
Year	Average			Maximum			Bloom Timing			
	Extent (km^2)	Intensity ($\mu g\ L^{-1}$)	Severity ($\mu g\ L^{-1} km^2$)	Extent (km^2)	Intensity ($\mu g\ L^{-1}$)	Severity ($\mu g\ L^{-1} km^2$)	Start of Bloom (Date)	Max Severity (Date)	End of Bloom (Date)	Bloom Duration (Days)
2003	7033	5.4	161162	18504	34.9	646083	Jun 02	Aug 01	Nov 30*	181
2004	7658	8.5	142213	15628	31.8	293071	Jun 01	Sep 07	Nov 30*	182
2005	12637	9.8	294621	21066	47.5	955344	Jun 02	Sep 03	Nov 21*	172
2006	10345	24.9	287422	23648	48.3	1057631	Jun 04	Sep 16	Nov 25*	174
2007	10618	16.6	193943	23255	30.6	594132	Jun 16	Sep 20	Nov 30*	167
2008	13221	18.1	253074	19689	36.2	703213	Jul 17	Aug 13	Nov 30*	136
2009	8446	10.0	139946	17259	26.7	337255	Jun 01	Sep 19	Nov 30*	182
2010	14314	21.9	315756	20641	34.7	623486	Jul 09	Aug 01	Nov 01	115
2011	12883	21.8	323350	22706	45.3	1011108	Jun 03	Sep 09	Nov 22	172
Average	10795	15.2	234610	20266	37.3	691258	Jun 13	Aug 31	Nov 25	165
2017	8624	18.2	163267	14313	32.2	366114	Jul 13	Aug 17	Nov 29	139

For further details, contact us at ec.eolakewatch-observationslacsot.ec@canada.ca, Water Science and Technology Directorate, Environment and Climate Change Canada

- Annual reports from 2003 onwards
- Seasonal summary plots/images of bloom indices

- Definitions of all the reported metrics
- Table of summary statistics