



NCCA 2020 Enhancement Study: Water & Sediment Quality in Green Bay

Kansas Keeton¹, David Bolgrien², Jill Scharold², Sam Miller², James Gerads², Hugh Sullivan², Jonathon Launspach³

¹ORISE (Oak Ridge Institute for Science and Education) Participant, Oak Ridge, TN, 37831, USA

²Great Lakes Toxicology & Ecology Division, U.S. Environmental Protection Agency, Office of Research and Development, Duluth, MN 55804

³GDIT, Falls Church, VA, 22042



Abstract



- Water and sediment quality was assessed in Green Bay, Lake Michigan using NCCA design approach, methods, and assessment indicators
- Condition classes of Good, Fair, and Poor assigned to measurements of four ecological indicators based on reference thresholds for Lake Michigan
- 91.7% of the bay was in Good condition for near-bottom dissolved oxygen (BDO)
- 85.7% of the bay was in Poor condition for Secchi depth
- Green Bay nearshore has a higher percentage of waters rated poor for water quality than Lake Michigan nearshore





Objectives

Assess the condition of water and sediment quality in Green Bay to determine what percentage of the total area is in Good, Fair, and Poor condition based on key ecological indicators

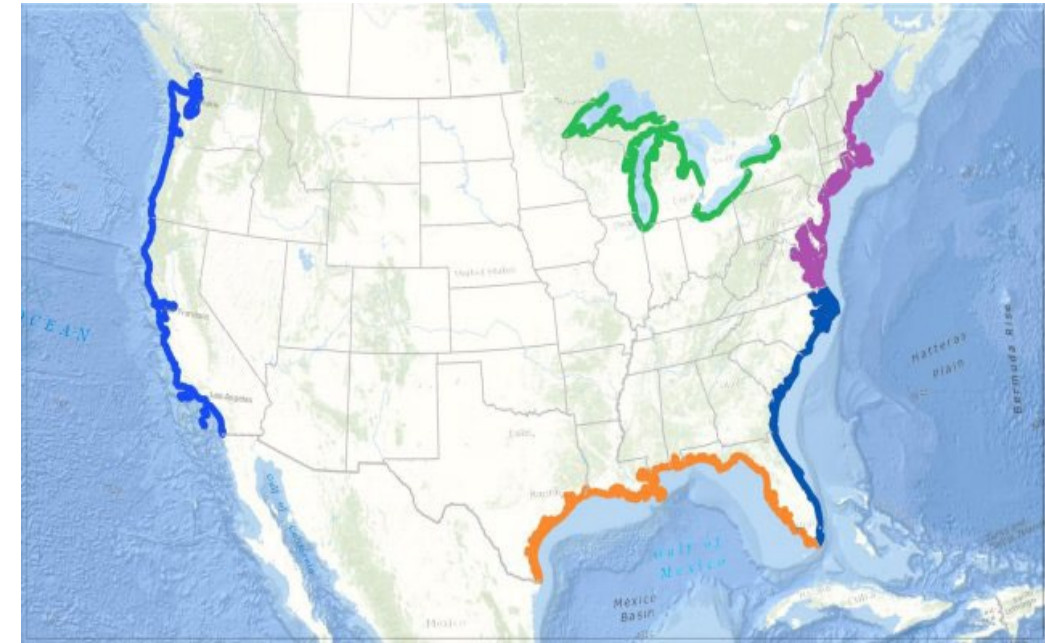
Study Area



Introduction: What is NCCA?



- National Coastal Conditions Assessment
 - 1 of 4 EPA National Aquatic Resource Surveys (NARS) designed to assess the conditions of American coastal and Great Lakes nearshore waters
 - Quinquennial surveys with states to assess proportions of Good, Fair, Poor as a percentage of the population (study area)
 - Nearshore = < 5km from shore and < 30 m in depth
- Survey includes four indices:
 - Biological Quality
 - Water Quality
 - Chlorophyll *a* (Chl *a*)
 - Total phosphorus (TP)
 - Secchi depth (water clarity)
 - Near-bottom dissolved oxygen (BDO)
 - Sediment Quality
 - Ecological Fish Tissue Quality
- NCCA methods and design approach can be applied to smaller study areas
 - Enhancement surveys
 - Assist partners and lake managers in assessing water and sediment quality in their area of interest





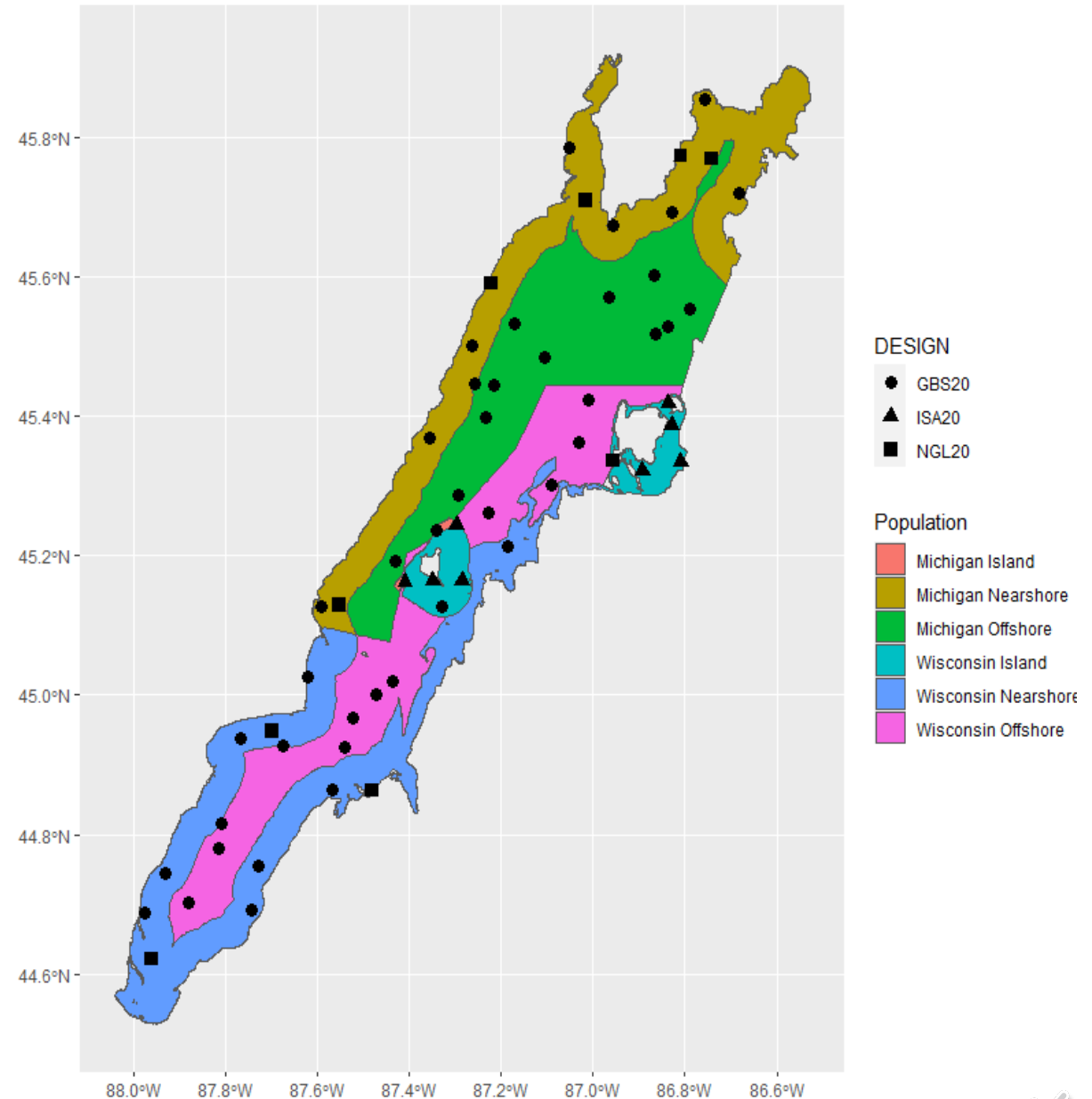
Study Area: Green Bay

- Largest freshwater estuary in the world (4,210 km²) between Michigan UP and Wisconsin
- Land use is mostly agriculture
- Watershed delivers 1/3 of Lake Michigan's TP load
- Fox River
 - Principal tributary, heavily polluted and nutrient loaded
- Popular recreational site for fishing, boating, swimming, etc.
- AOC for US EPA R5 and the state of Wisconsin



Methods: GBS20 Survey Design

- **Sampling sites selected using a generalized random tessellation stratified (GRTS) algorithm**
 - Spatially-balanced design minimizes clumping
 - Provides unbiased estimates
 - Each site assigned a weight reflecting the area of the strata it represents (A/n)
- **60 sites from three spatially-overlapping designs**
 - 11 existing from NGL20 (NCCA base survey)
 - 17 nearshore and 25 offshore sites (GBS20)
 - 7 sites from Lake Michigan Islands Enhancement Survey (ISA20)
- **Area divided into 6 populations**
 - Michigan & Wisconsin:
 - Island: < 5 km or < 30 m depth from island shoreline
 - Nearshore: < 5 km or < 30 m depth from GB shoreline
 - Offshore: > 5 km or > 30 m depth from GB shoreline



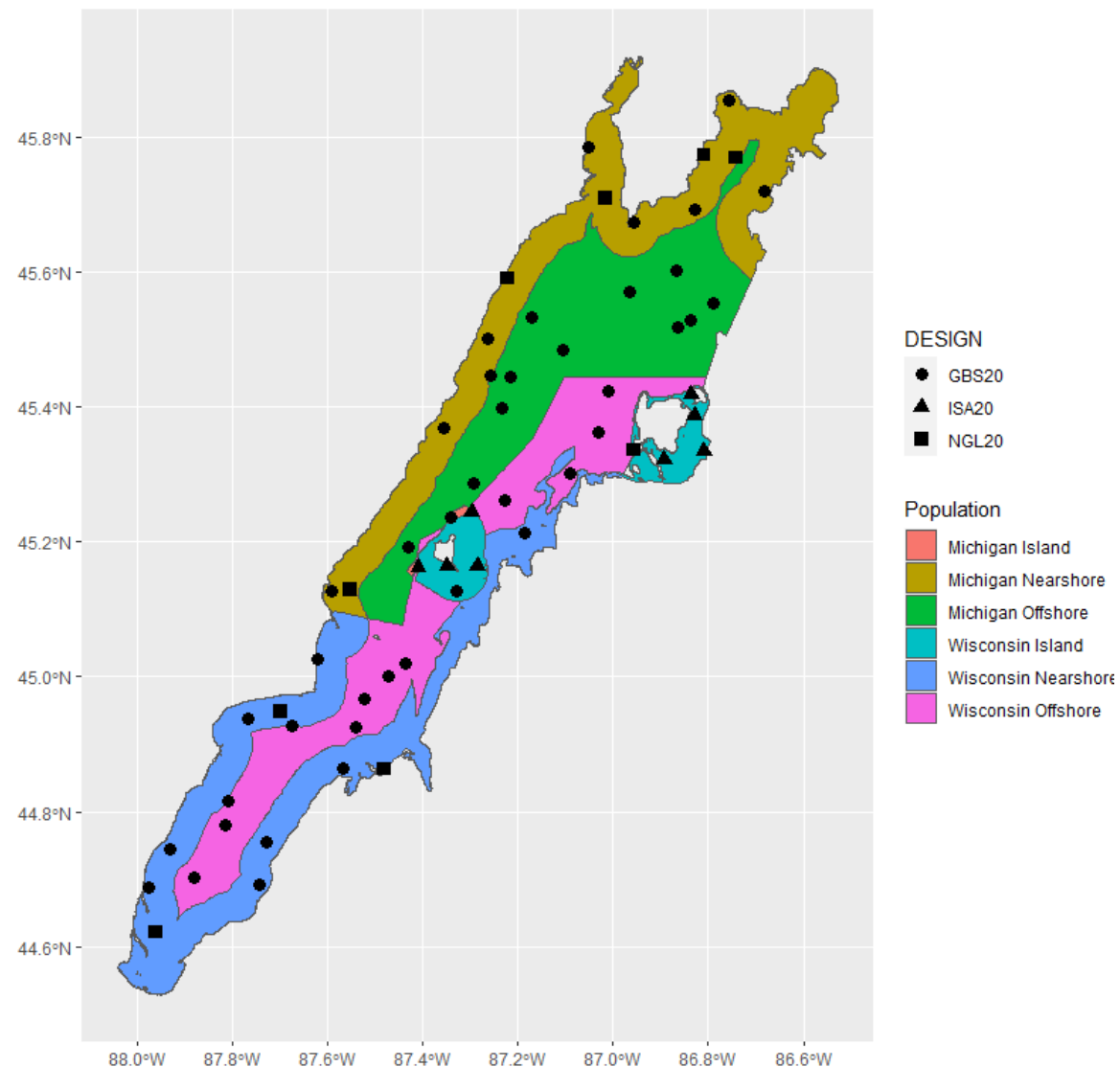
Methods: Indicators

- Condition class thresholds define water quality condition as Good, Fair, and Poor⁵
 - Fair/Good thresholds reflect the oligotrophic state of Lake Michigan
 - TP, chlorophyll *a*, Secchi depth = trophic condition
 - BDO = hypoxic condition

Great Lakes Water Quality Thresholds				
	Lake Area	Good	Fair	Poor
Surface Concentrations of Total Phosphorus (TP): Great Lakes Basins	Superior Huron	< 0.005 mg/L	0.005 – 0.01 mg/L	> 0.01 mg/L
	Michigan	< 0.007 mg/L	0.007 – 0.01 mg/L	> 0.01 mg/L
	Huron/Saginaw Erie/West	< 0.015 mg/L	0.015 – 0.032 mg/L	> 0.032 mg/L
	Erie/Central Erie/East Ontario	< 0.01 mg/L	0.01 – 0.015 mg/L	> 0.015 mg/L
Surface Concentrations of Chlorophyll <i>a</i> : Great Lakes Basins	Superior Huron	< 1.3 µg/L	1.3 – 2.6 µg/L	> 2.6 µg/L
	Michigan	< 1.8 µg/L	1.8 – 2.6 µg/L	> 2.6 µg/L
	Huron/Saginaw Erie/West	< 3.6 µg/L	3.6 – 6.0 µg/L	> 6.0 µg/L
	Erie/Central Erie/East Ontario	< 2.6 µg/L	2.6 – 3.6 µg/L	> 3.6 µg/L
Water Clarity (Secchi Depth): Great Lakes Basins	Superior Huron	> 8.0 m	5.3 – 8.0 m	< 5.3 m
	Michigan	> 6.7 m	5.3 – 6.7 m	< 5.3 m
	Huron/Saginaw Erie/West	> 3.9 m	2.1 – 3.9 m	< 2.1 m
	Erie/Central Erie/East Ontario	> 5.3 m	3.9 – 5.3 m	< 3.9 m
Bottom Water Concentrations of Dissolved Oxygen: Great Lakes Basins	All	> 5 mg/L	2 – 5 mg/L	< 2 mg/L

Methods: Sampling Sites

- NGL20 sites
 - 11 sites
 - June 17 – July 28, 2020 (base survey)
- GBS20 sites
 - 43 sites (36 GBS20 and 7 ISA20)
 - June 3-18, 2021 (postponed due to COVID-19)



Methods: Data collection

Water quality characteristics:

- Temp
- pH
- DO
- Conductivity
 - Hydrolab Sonde
- Algal composition
 - bbe++ Fluoroprobe
- Water clarity
 - Secchi depth – 20 cm B&W Secchi disc
 - Light attenuation – LiCOR meter

Water samples

- Water chemistry
- Dissolved nutrients
- Chlorophyll *a*
- Phytoplankton taxonomy
- Algal toxins
 - NISKIN – 0.5 m below surface
- *Enterococci* fecal indicator
 - Dipping pole – 0.3 m below surface

Benthic samples

- Benthic macroinvertebrate assemblage
- Sediment chemistry
- Sediment toxicity
- Grain size
 - PONAR
- Underwater video
 - GoPro camera





Methods: Data Analysis

- Near-Bottom DO
 - DO concentrations at 0.5 m from bottom recorded by sonde⁵
- Secchi Depth
 - Average of three measurements⁵
 - Where Secchi Depth was “clear to bottom”
 - Estimated using incident PAR data measured from LiCor³
 - $Secchi\ Depth_{est} = 1.3891 \times K_d^{-0.983}$

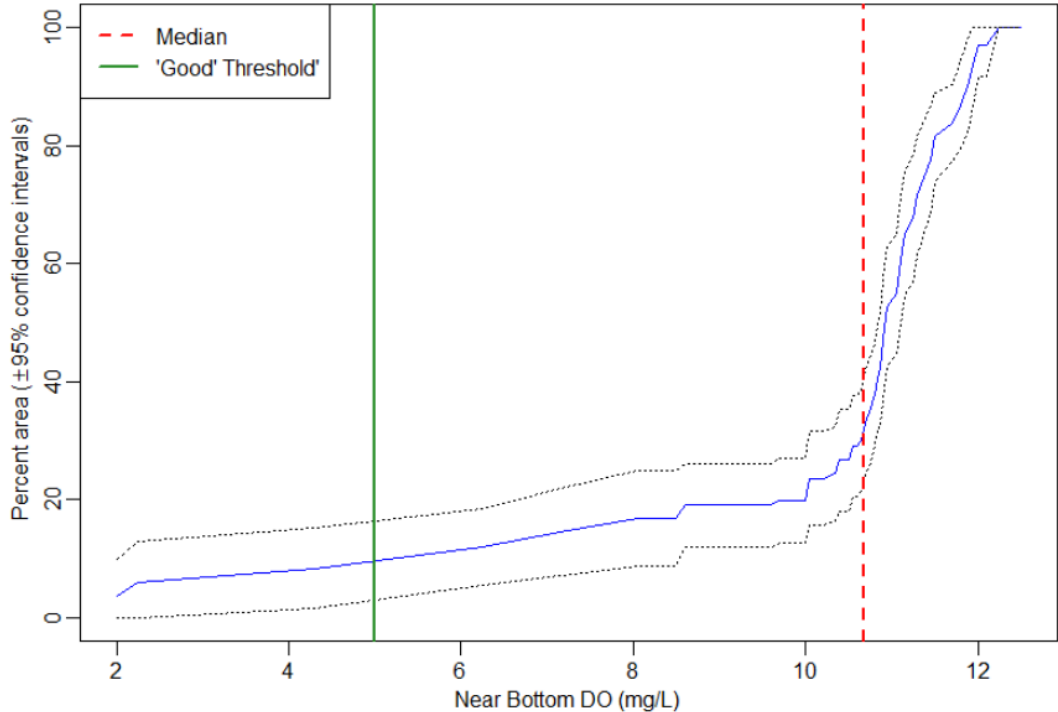
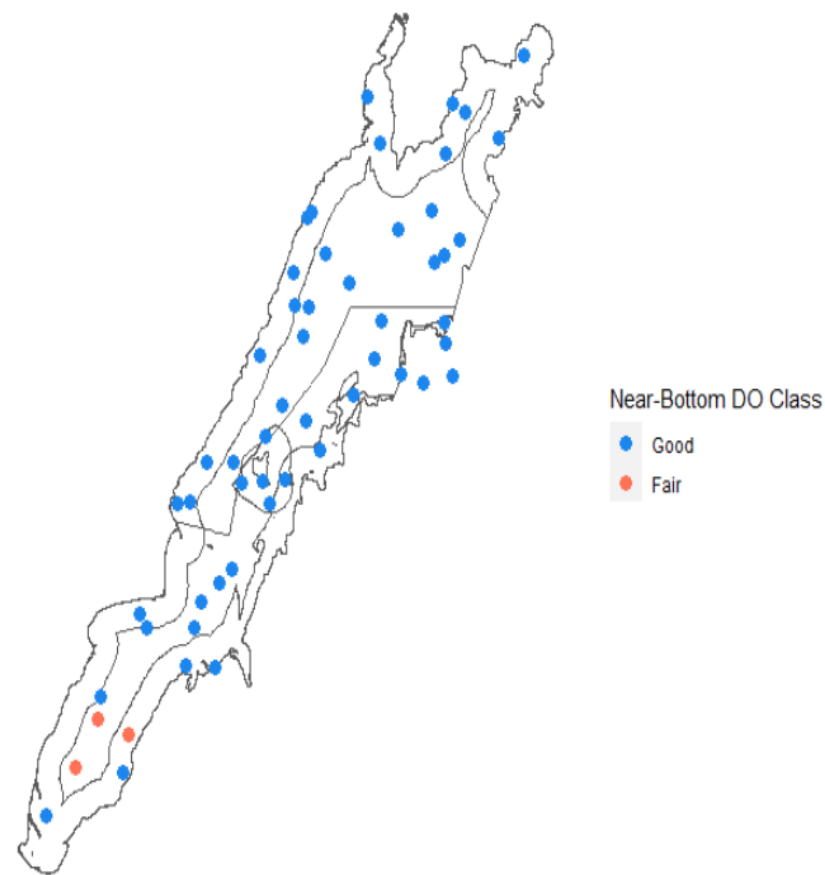


Methods: Categorical Analysis

- Population-based estimates in R package `spsurvey`
 - Calculates categorical classes for each indicator as a percentage of the population



Results: Area-Weighted Near-Bottom Dissolved Oxygen (BDO)



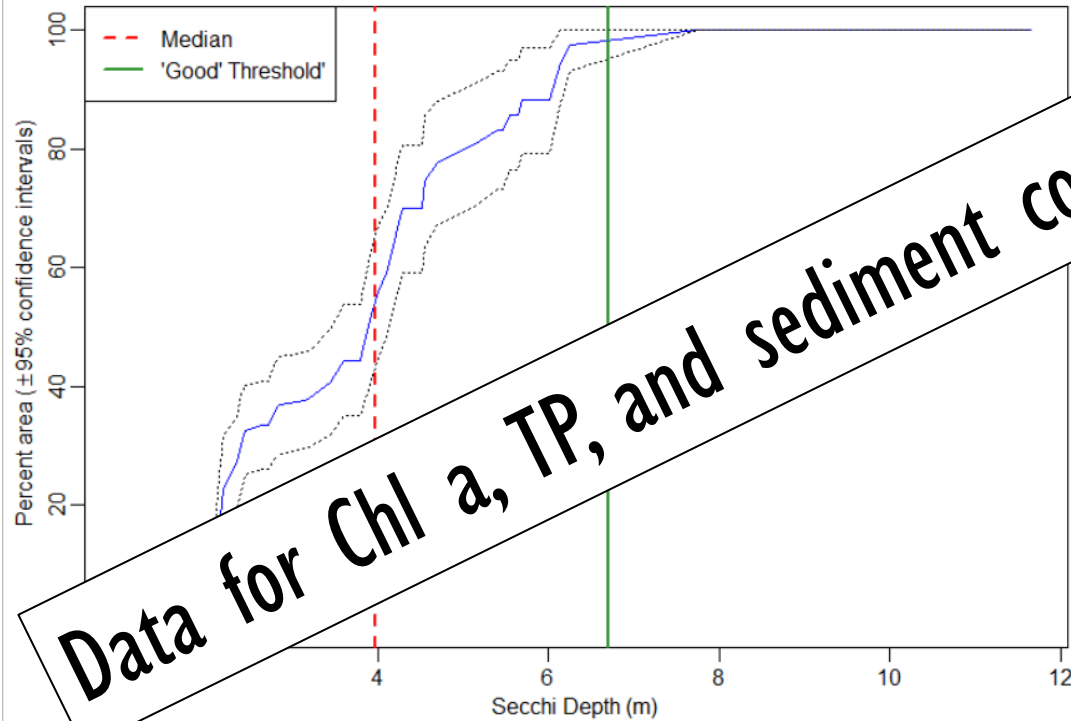
Class	Threshold	Estimate	Sites	StdError
Good	> 5 mg/L	91.7%	52	3.5%
Fair	2-5 mg/L	8.3%	3	3.5%



Results: Area Weighted Water Clarity (Secchi Depth)



Class	Threshold	Estimate	Sites	StdError
Good	> 6.7m	2.5%	3	4.3%
Fair	5.3 - 6.7m	11.9%	8	2.4%
Poor	< 5.3m	85.7%	43	4.3%



Data for Chl a, TP, and sediment coming fall 2022

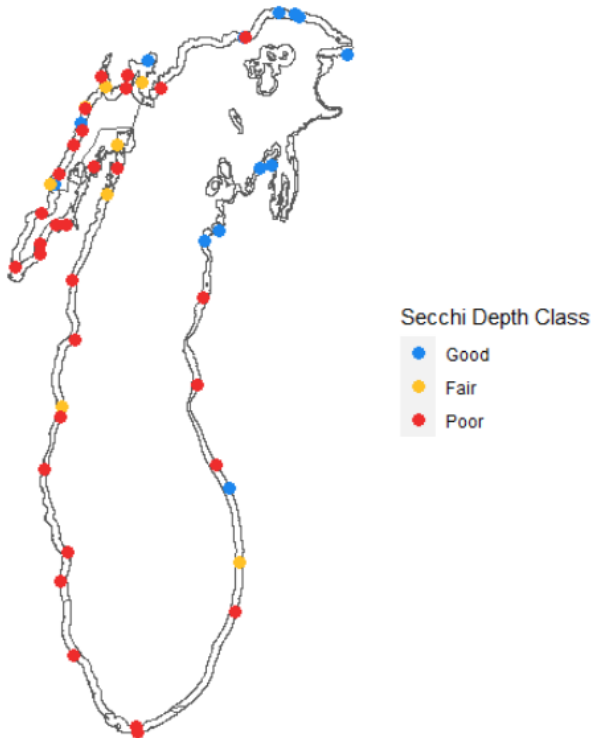


Secchi Depth Class

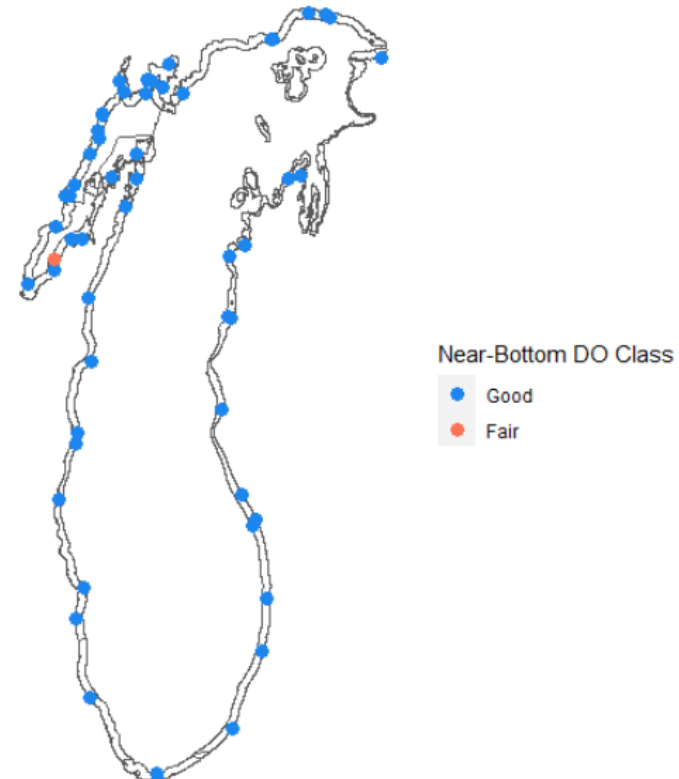
- Good
- Fair
- Poor



Green Bay Nearshore vs. Lake Michigan Nearshore

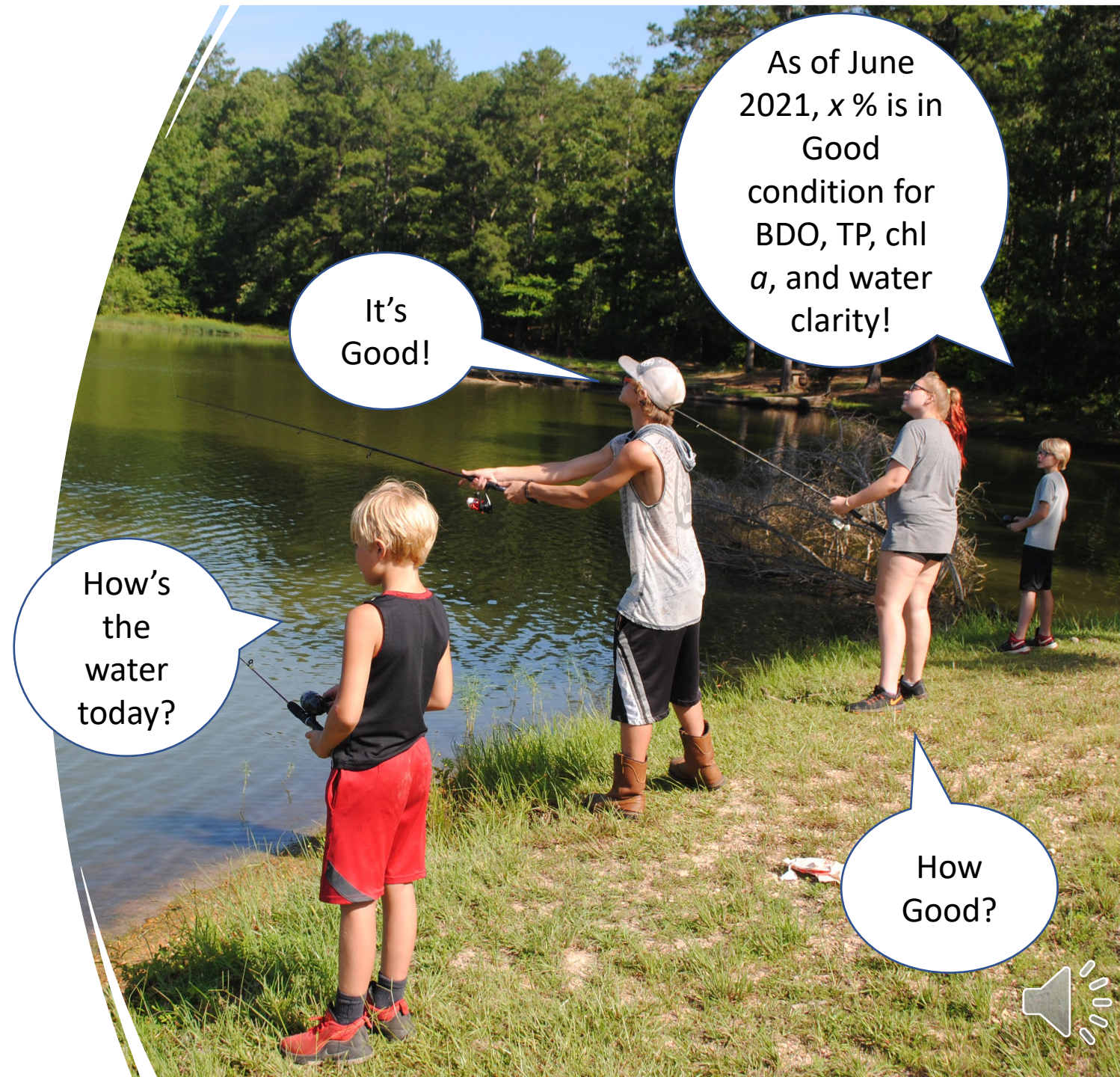


Study	Good	Fair	Poor
Area Weighted Dissolved Oxygen (mg/L)			
Green Bay	88.4%	11.6%	0%
Lake Michigan	100%	0%	0%
Area Weighted Secchi Depth (m)			
Green Bay	7.7%	15.3%	77.0%
Lake Michigan	29.6%	9.9%	60.5%



Discussion: Why Is This Useful?

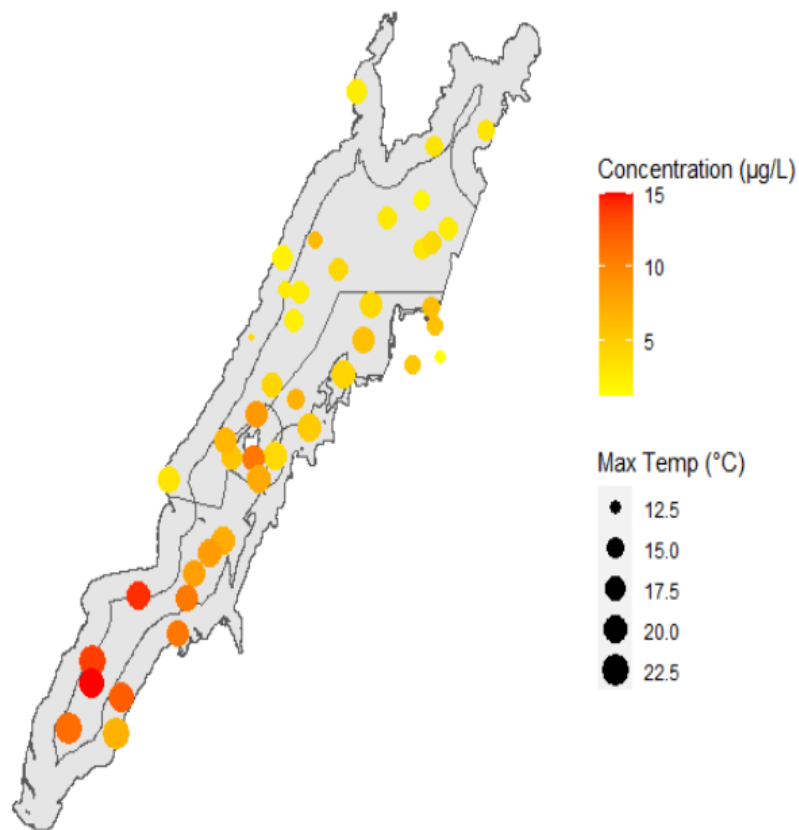
- Cost-effective
 - 4,210 km² assessed from only 55 sites
- Public-informing
 - Assigns real data to a colloquial condition
 - Simple metric, easy to understand
- Management-relevant
 - Helps to identify degraded or reference areas
- Tracking
 - Repeated surveys allows for a spatiotemporal assessment of ecological conditions in the Great Lakes and their embayments
- Data can be used to support other research needs
 - Not limited to GFP categorical estimates



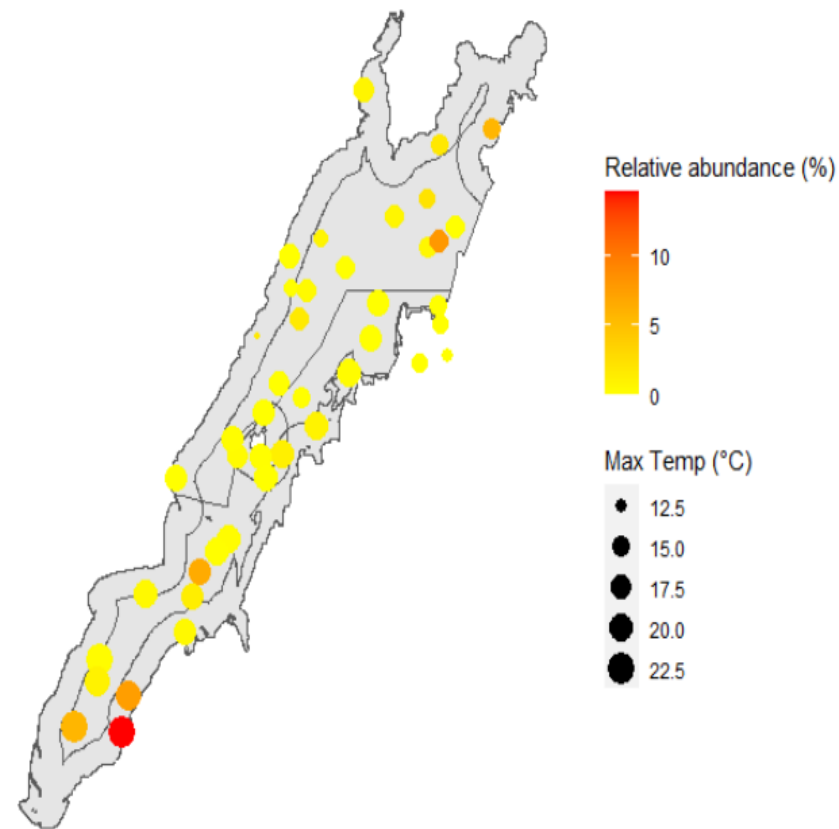
FOR EXAMPLE

Algal Concentrations

Mean Total Algal Concentrations ($\mu\text{g/L}$)



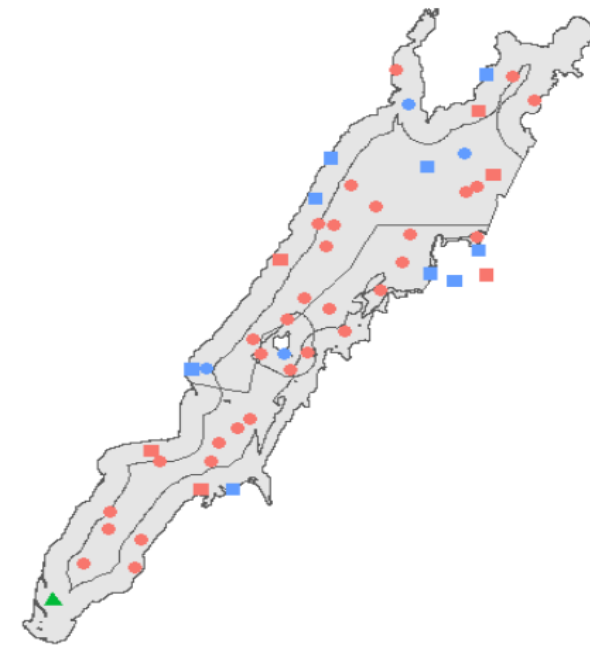
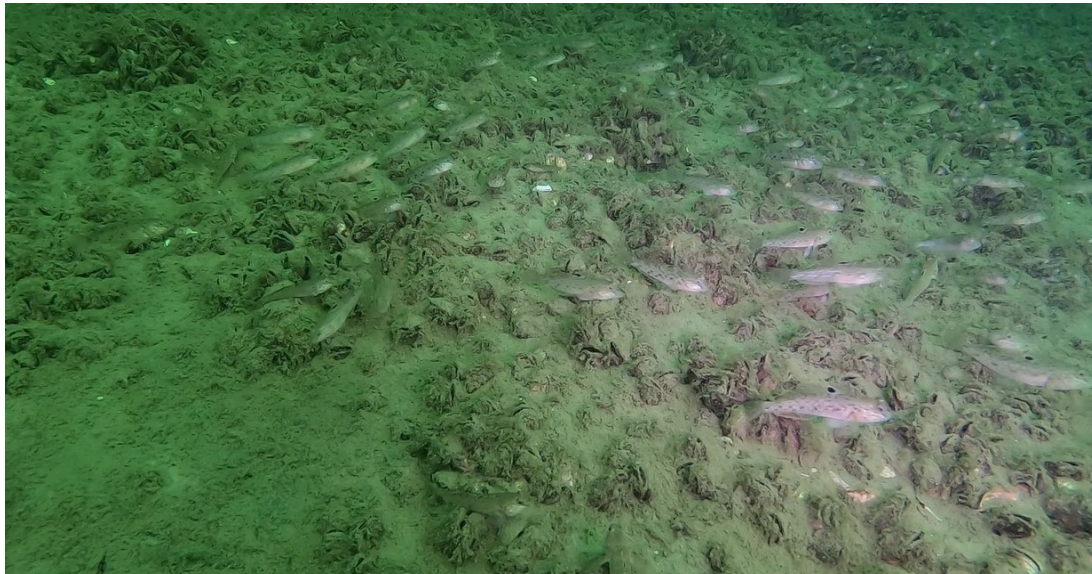
Relative Blue-Green Algae Abundance (%)





Underwater Video

Round gobies eat invasive mussels² and macrophytes¹

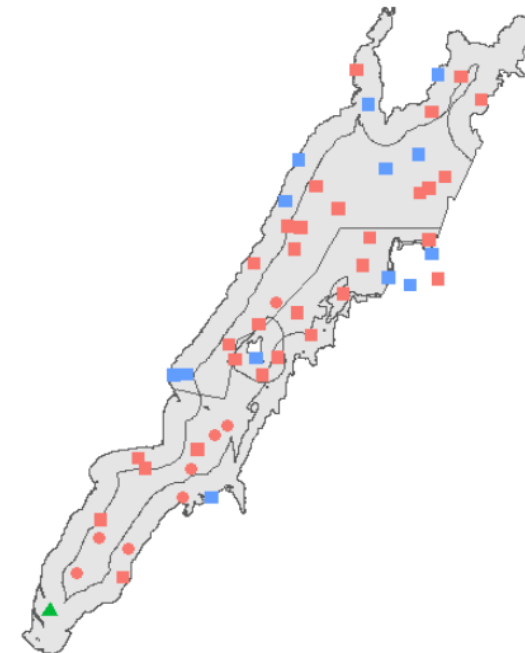


VEGETATION

- No
- ▲ No Data
- Yes

GOBIES

- No
- No Data
- Yes



GOBIES

- No
- No Data
- Yes

MUSSELS

- No
- ▲ No Data
- Yes





Discussion: Limitations

- PBE will likely change seasonally
 - Conditions may be worse in late summer
- Green Bay sampling delayed
 - Lake Michigan was sampled a year earlier and later in the season
 - However, t-test found no significant difference ($p = 0.1$) in the sample means between the two studies



Future Analysis

- Compare phytoplankton community assemblages between select sites
- PBE of TP and Chl a
- Analysis of benthic macroinvertebrates and sediment conditions
- Analysis of water quality and algal toxins
- Comprehensive report/journal article on Green Bay water and sediment quality anticipated 2023





Conclusions

- Green Bay is in mostly Good condition for BDO and mostly Poor condition for Secchi depth.
- LGB was in poorer condition than UGB
- Compared to Lake Michigan's nearshore, Green Bay's nearshore has a higher percentage of waters rated poor
- Population-based estimates are a spatially unbiased method of assessing water quality conditions based on reference lake thresholds
- NCCA methods can be used as a cost-effective, public-informing, and management-relevant approach to assessing any area of interest



References

1. Bauer, C. R., Bobeldyk, A. M., & Lamberti, G. A. (2007). Predicting habitat use and trophic interactions of Eurasian ruffe, round gobies, and zebra mussels in nearshore areas of the Great Lakes. *Biological invasions*, 9(6), 667-678.
2. Ray, W. J., & Corkum, L. D. (1997). Predation of zebra mussels by round gobies, *Neogobius melanostomus*. *Environmental Biology of Fishes*, 50(3), 267-273.
3. USEPA, 2019. A Special Report for the Great Lakes: 2015 National Coastal Condition Assessment (NCCA) and 2014-2018 Connecting River System Pilot Assessments (unpublished). EPA. 600-R-19-097.
4. USEPA, 2016. National coastal condition assessment 2010. EPA. 841-R-15-006. Washington, DC. 46 pp. https://www.epa.gov/sites/default/files/2016-01/documents/ncca_2010_report.pdf
5. USEPA, 2020. National coastal condition assessment: field operations manual. EPA 841-F-19-005. https://www.epa.gov/system/files/documents/2021-09/ncca_2020_fom_version_1.2.pdf
6. USEPA, 2020. National coastal condition assessment: laboratory operations manual. EPA 841-F-19-004. https://www.epa.gov/system/files/documents/2021-09/ncca_2020_lom_version_1.2.pdf

