# Assessing the Physical Effects of Dredge Plumes on Aquatic Organisms – A Need for Science-based Solutions

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**USACE-ERDC-EL**
**Vicksburg, MS**

**GLDT Annual Meeting**
**22 May 2018**
**Toledo, OH**

US Army Corps of Engineers
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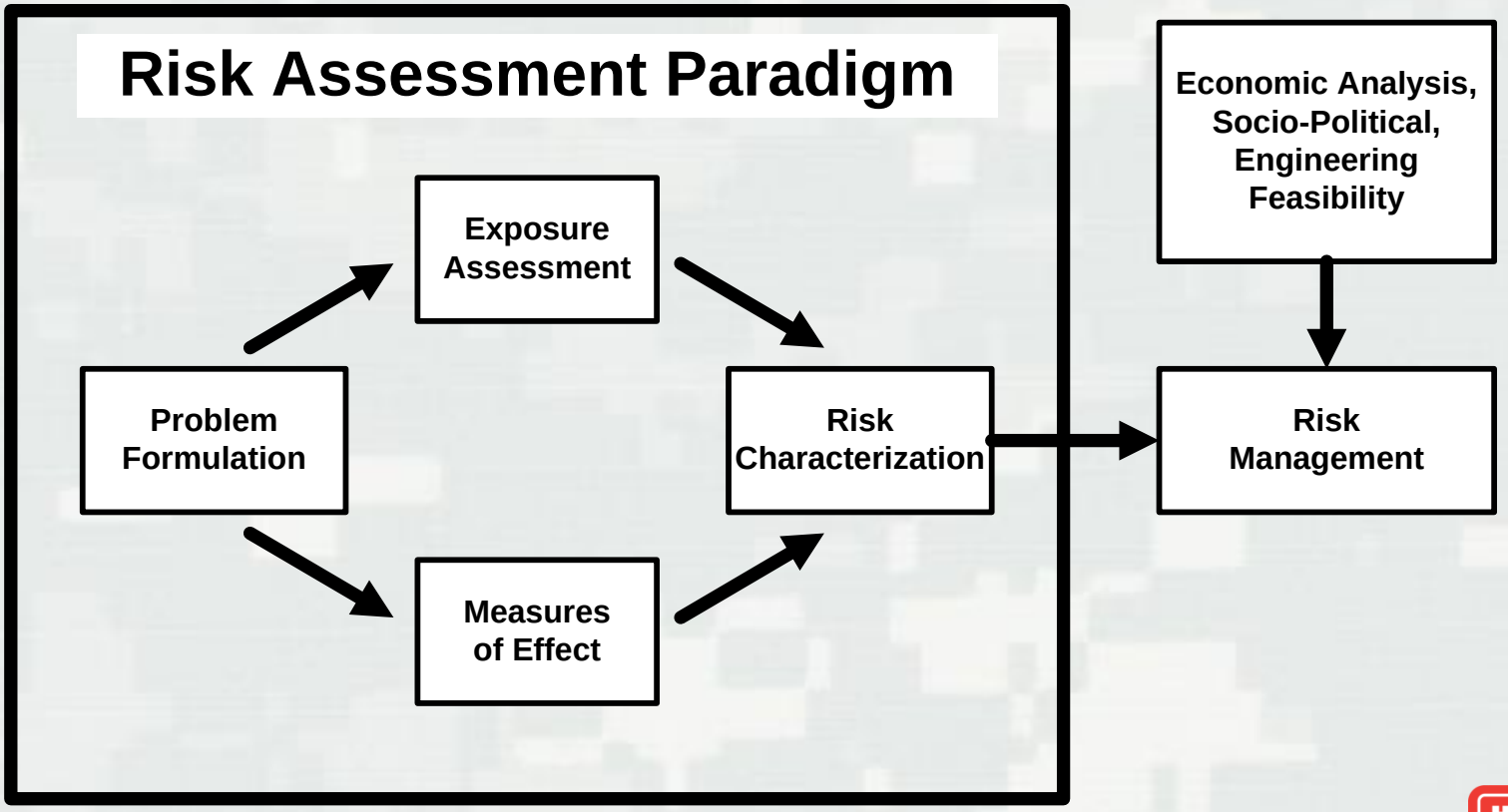
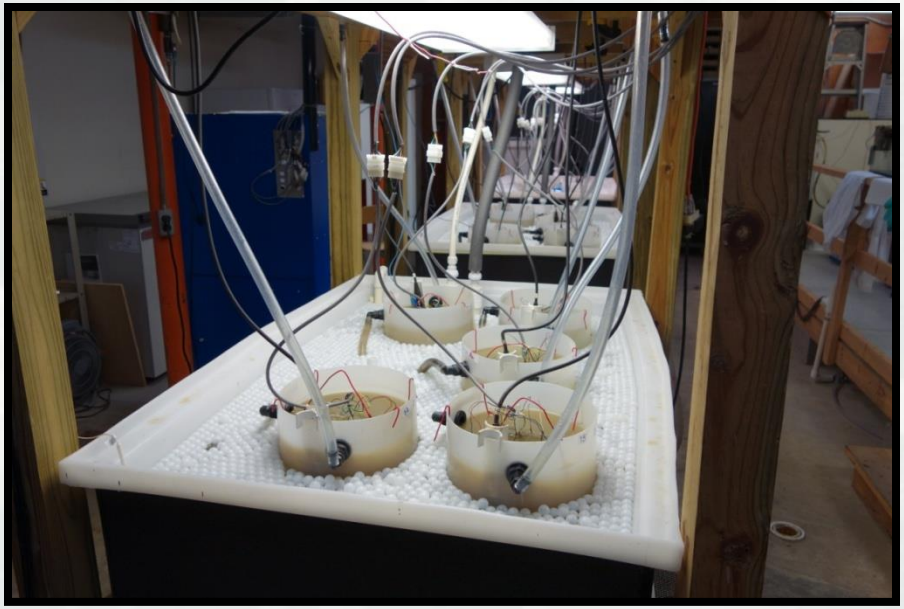
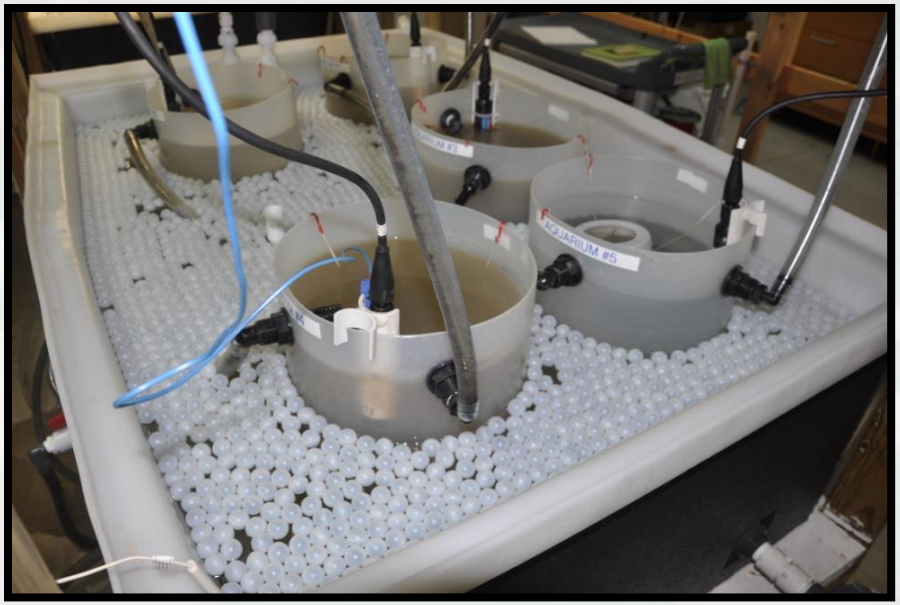
# Applying Risk Assessment Paradigm to Manage Dredging Risk



# Fish Larvae and Egg Exposure System (FLEES)

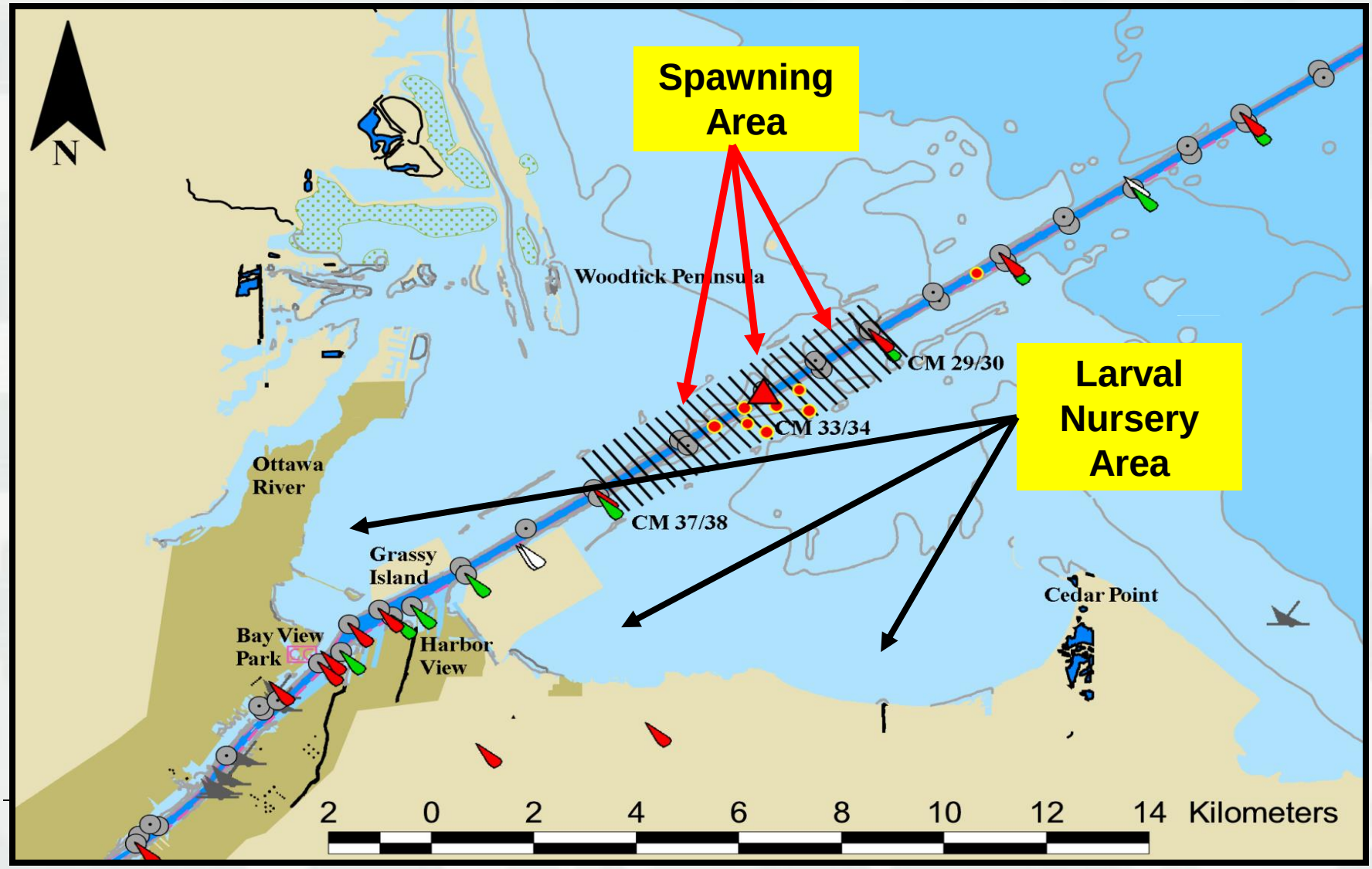




# FLEES Features

- Three (3) modules
- Three (3) 500 L water baths
- 15 total aquaria
- 20 L polyethylene aquaria
- Modules insulated for temperature control
- Each aquarium utilizes pump to suspend sediment
- Pump recirculates water and suspended sediment into aquaria
- Sediment mixed with water and stored in 375 L tank via double diaphragm pump
- Slurry routed through FLEES
- Sediment concentrations monitored using OBS

# Case Study: Walleye EW
# Maumee Bay, OH



# Walleye Case Study, Ohio

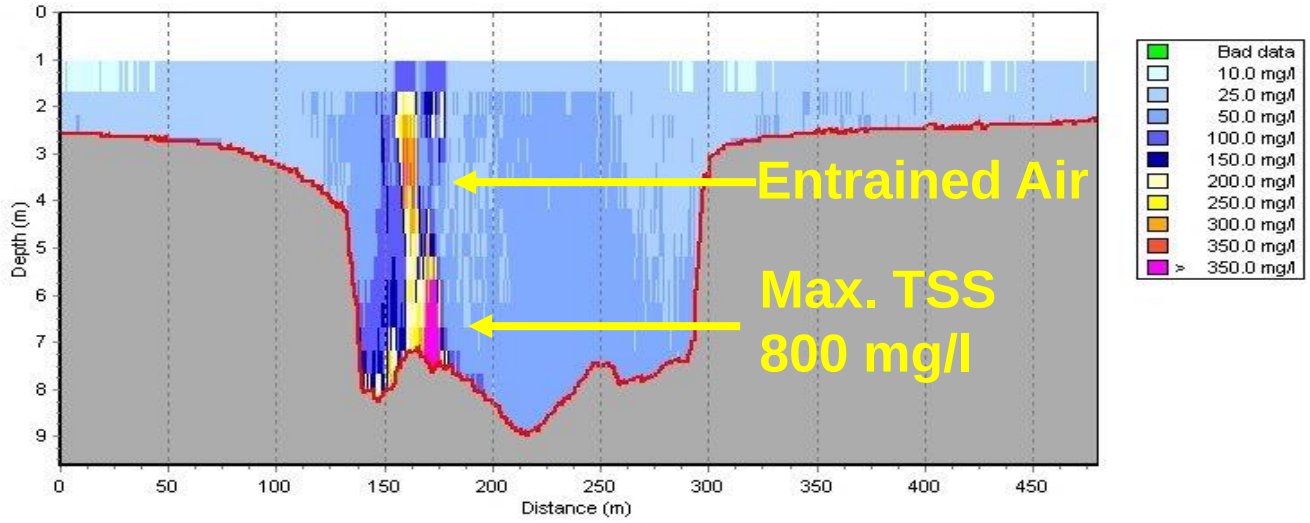
## Problem

- EW in Maumee Bay, OH in western Lake Erie is restricting dredging operations
- Suspended sediment threshold data are lacking for walleye relevant to dredging
- Effects data are essential for conducting risk assessments and managing dredging risks

## Objectives

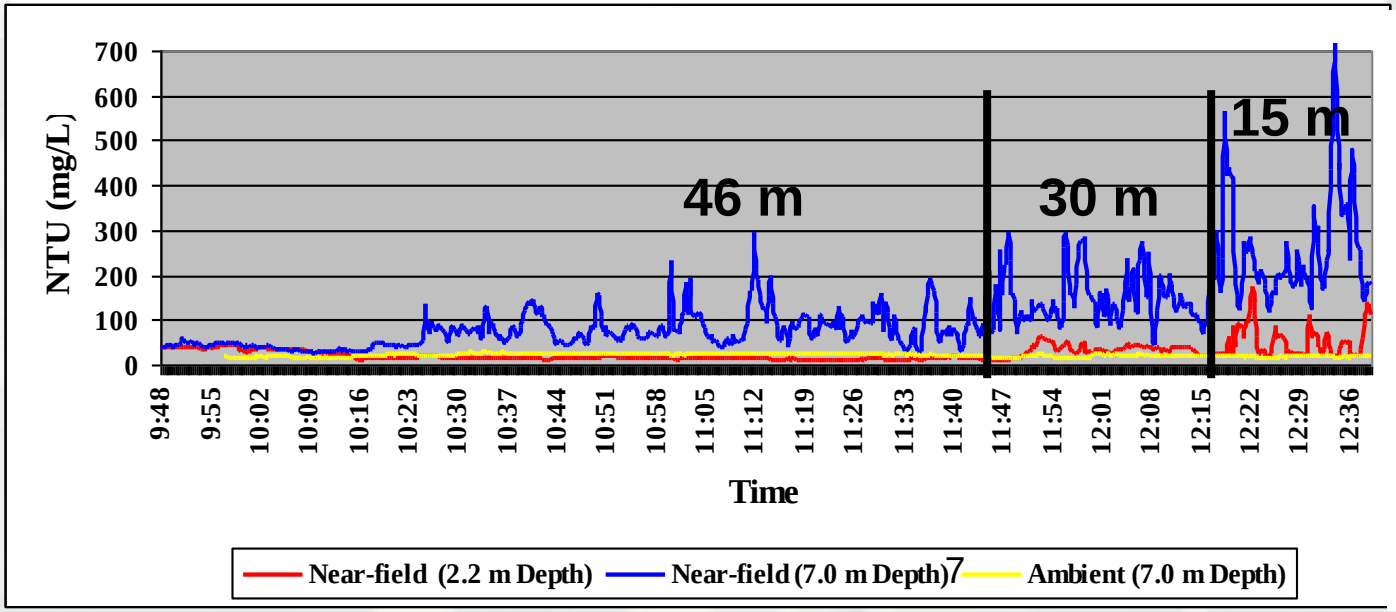
- Develop suspended sediment effects data for walleye early life stages to reduce uncertainty about effects
- Better inform the setting of the EW

# Near-field Plume Conditions
# Maumee Bay, OH Study Area




**Distance from Dredge: 3m**

**Plume Width: 50 m**

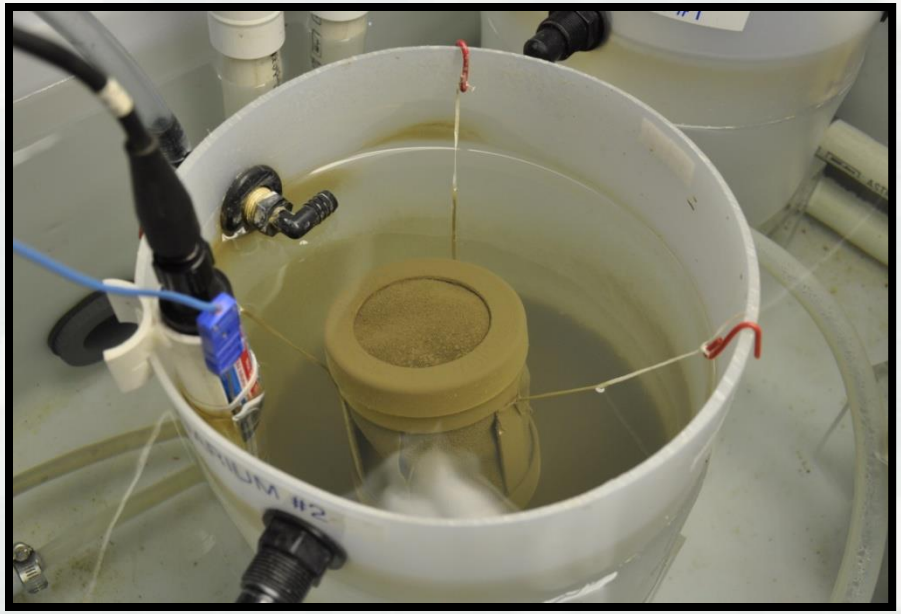



**<u>LWC Max. Turb</u>.**
**700 NTU (15 m)**
**< 300 NTU (30m)**

**<u>UWC Max. Turb</u>.**
**175 NTU (15 m)**
**50 NTU (30m)**
**Ambient < 50 m**

# Materials and Methods

- Walleye (*Sander vitreus*)
- Four experiments: northern and southern strain eggs (newly spawned) and fingerlings (45-60 days)
- Sediment: Maumee Bay, Ohio (Lake Erie)
- Concentrations: 0, 100, 250, 500 mg/L TSS
- Duration: 3 days (72 h)
- Temp: 10 - 13°C eggs; 14 - 17°C fingerlings
- PVC cups for containment

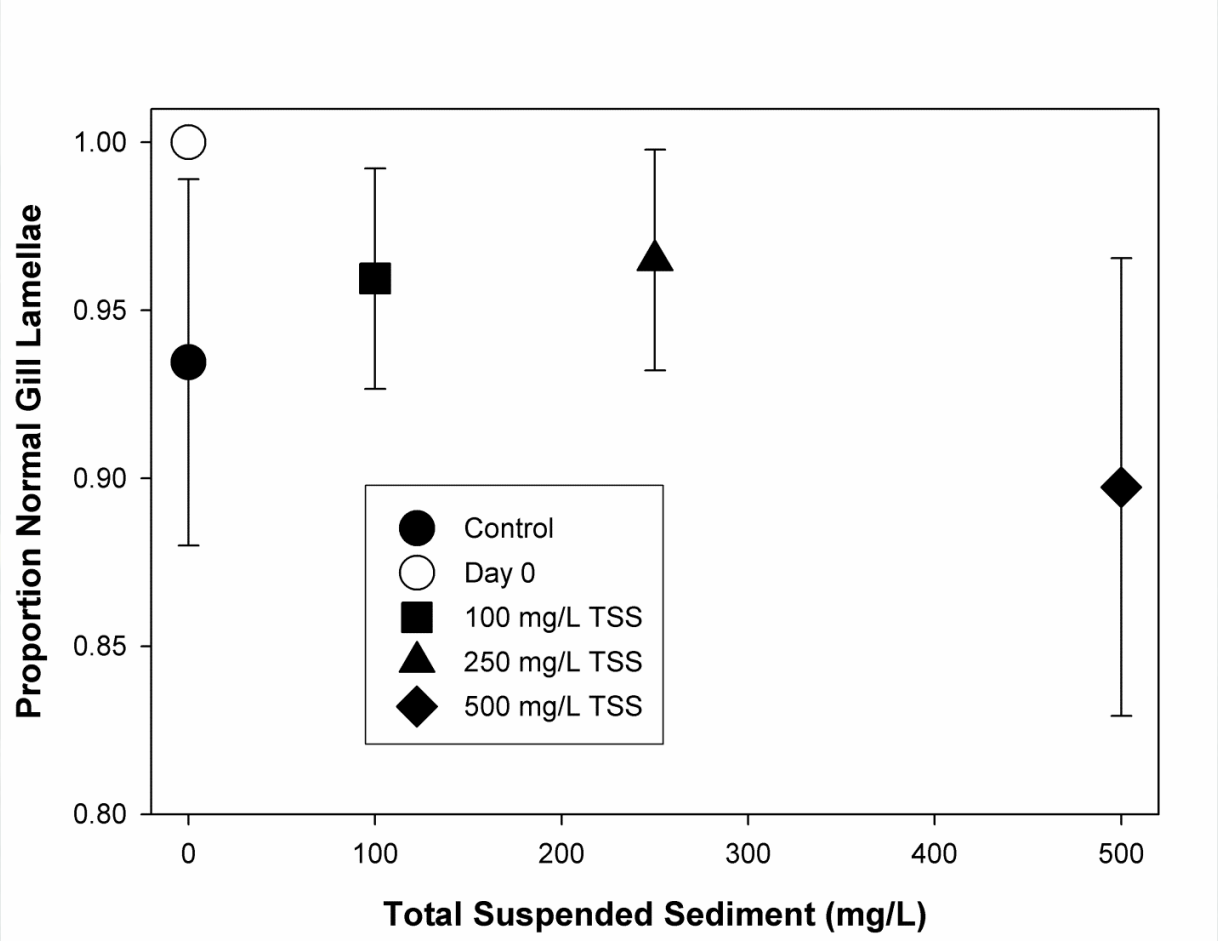


# Walleye Endpoints

- Northern & Southern Strains
  - Fingerlings: survival, coiling, scoliosis, lordosis/kyphosis, gill integrity
  - Eggs: viability and hatchability, wet and dry mass

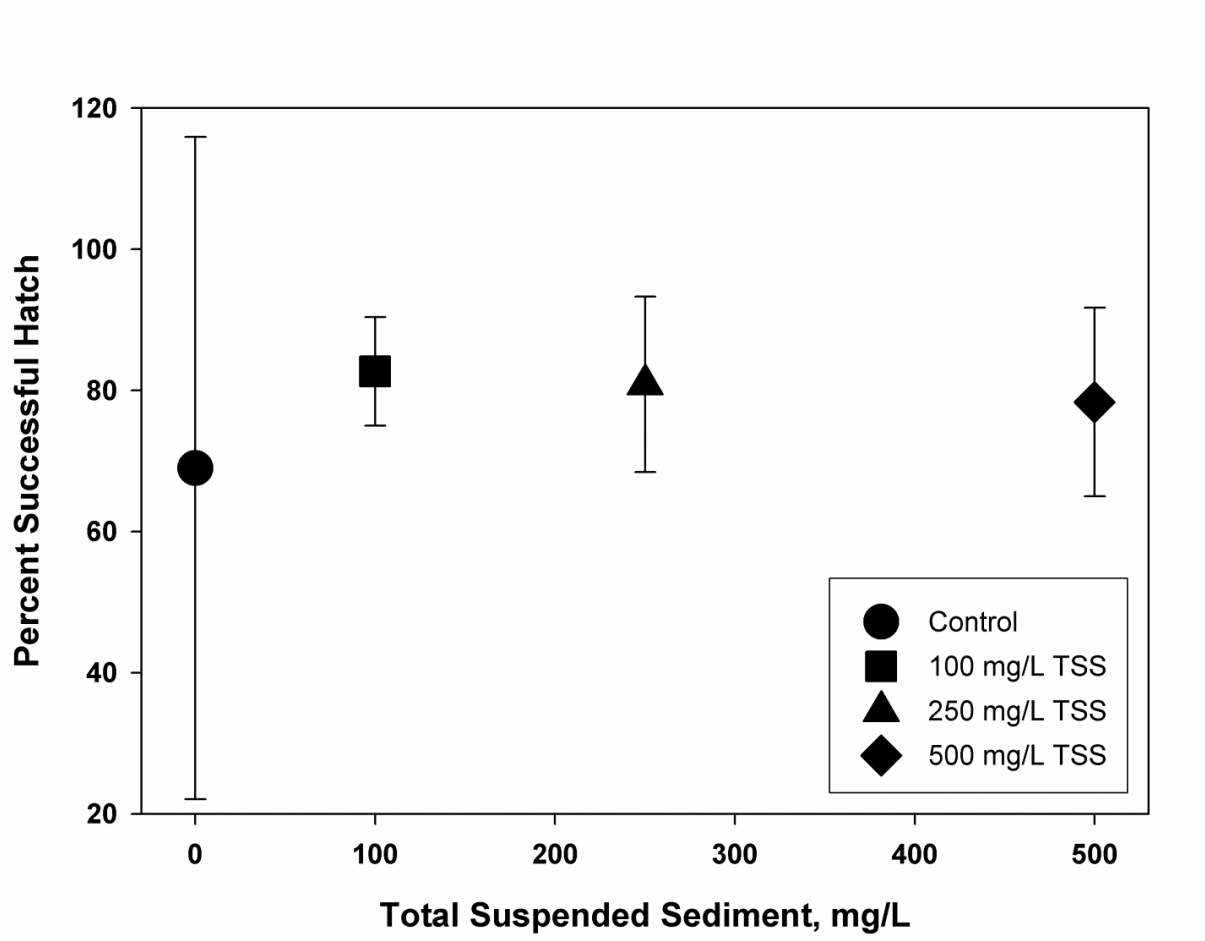
# Northern Strain Fingerling Gill Lamellae

Fingerling gill lamellae did not differ significantly among TSS treatments



# Percent Hatch of Northern Strain Eggs

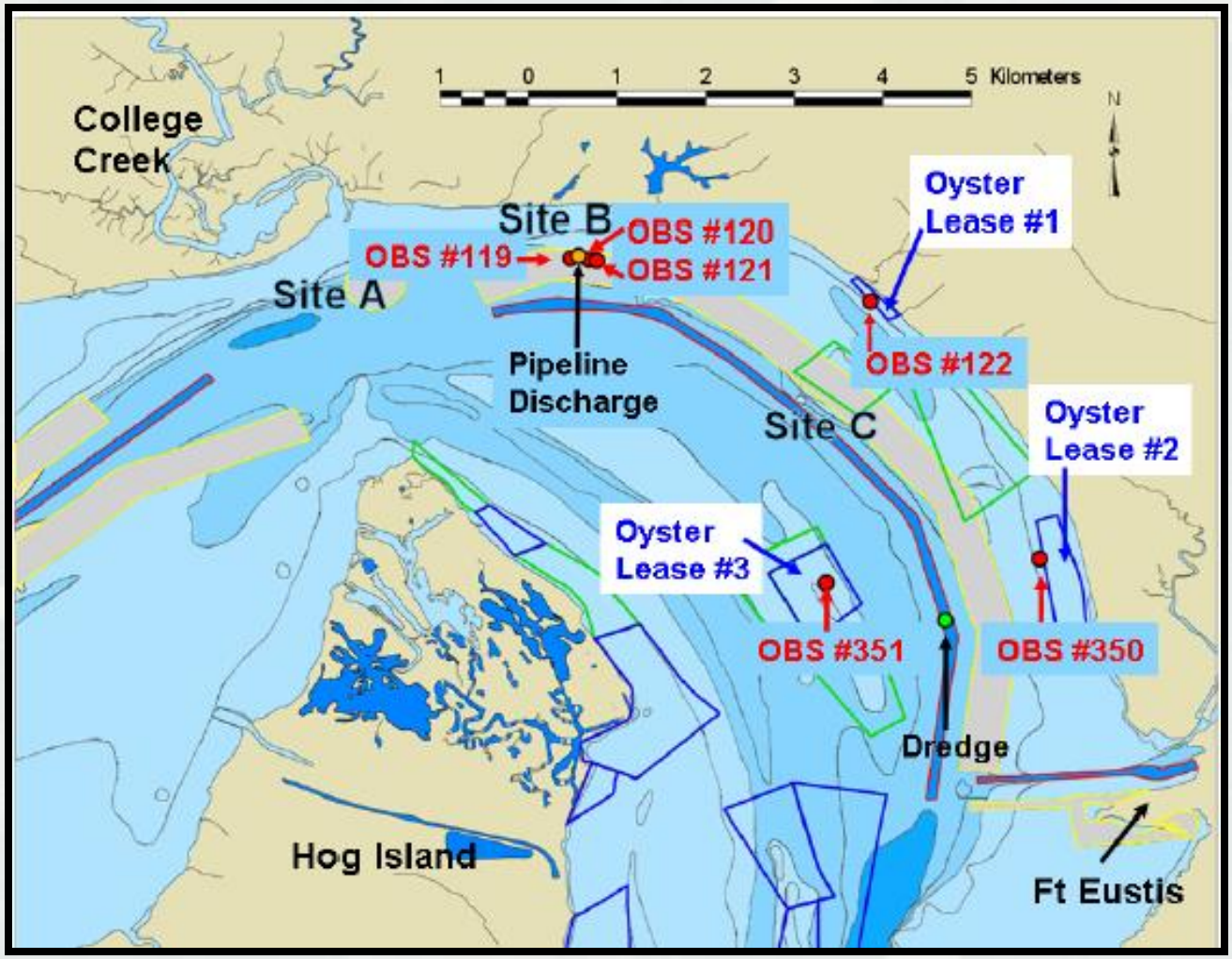
No significant differences among treatments were observed for percent hatch (Anova, F=1.15, P=0.386)



# Walleye: EW Study Status

- Generating effects data
- Published results
- How have these data affected the discussion on the EW for walleye?

# Case Study: Oyster EW
# James River, VA



# Eastern Oyster Case Study- VA

## Problem

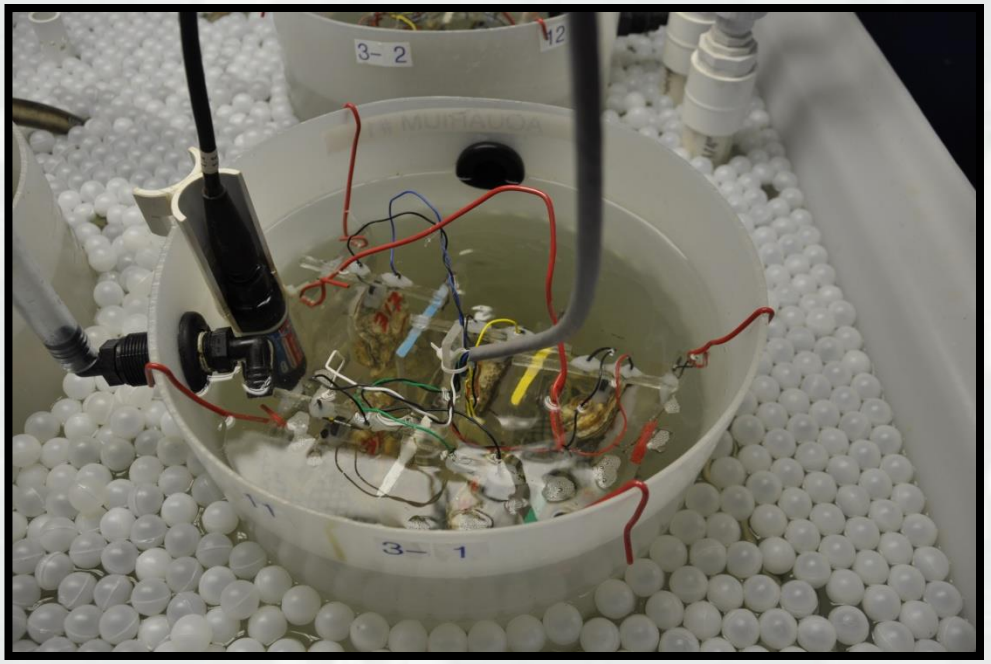
- Suspended sediment effects are driving EWs in the Tribell Shoal area of the James River, VA
- Suspended sediment threshold data are lacking for oysters relevant to dredging
- Effects data are essential for conducting risk assessments and managing dredging risks

## Objectives

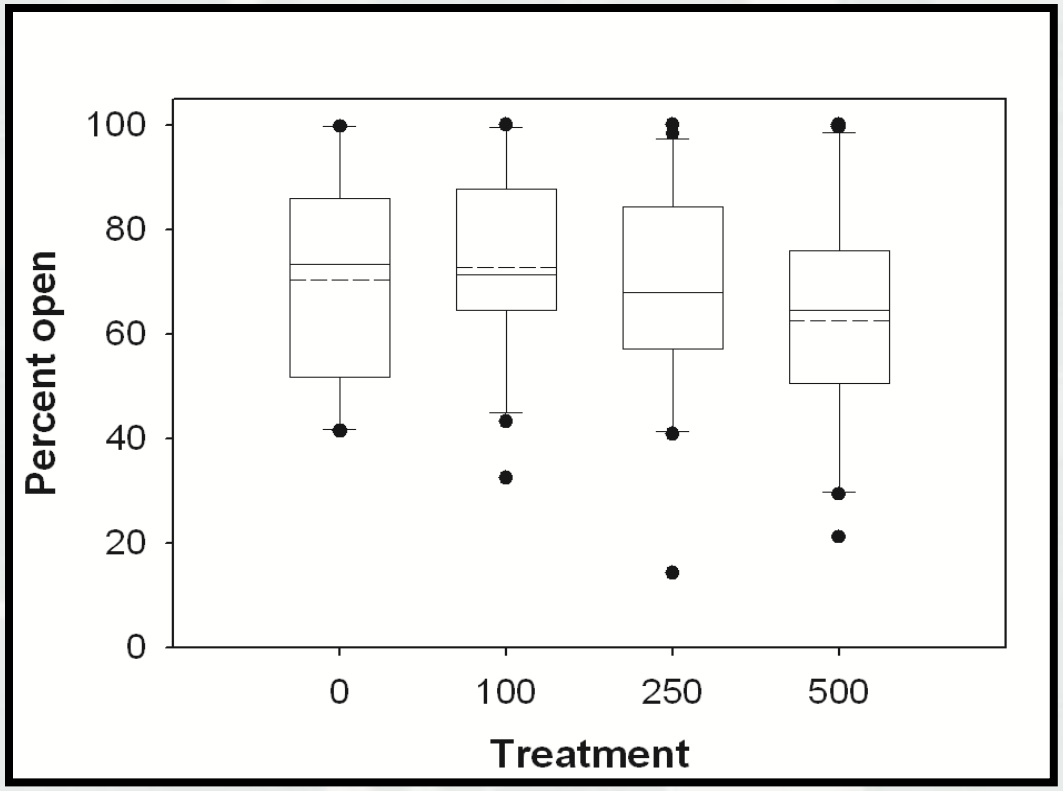
- Develop suspended sediment effects data for the eastern oyster
- Reduce uncertainty about effects to the local oyster fishery

# Oysters: Experimental Parameters

- *Crassostrea virginica*
- 3-inch oysters (legal)
- Test conditions:
  - 7-day exposure
  - 12°C
  - 15 ppt salinity
  - James River sediment
- Continuous monitoring of suspended sediment and oyster feeding (5 min intervals)



# Oysters: Shell Opening Data




- No statistically significant difference between treated and control for any MEs (shell opening, length, weight, condition after grow out at VIMS)

# Atlantic Sturgeon EW Case Study
# Savannah River and Harbor, GA

# Atlantic Sturgeon Case Study - GA

## Problem

- Suspended sediment effects on sturgeon are restricting dredging operations (via EWs)
- Suspended sediment threshold data are lacking
- Effects based data needed to characterize and manage risk

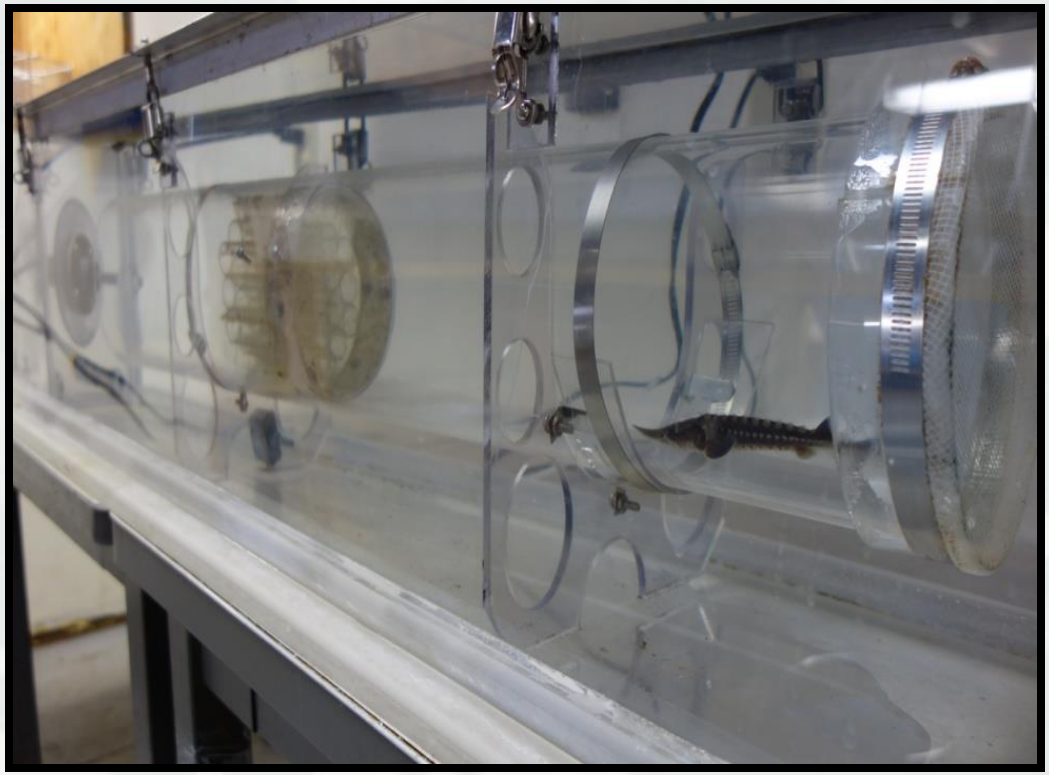
## Objective

- Develop suspended sediment effects data
- Reduce uncertainty about effects
- Support or revise the EW

# Sturgeon: Endpoints

*Acipenser oxyrinchus*

- **Survival**
- **Growth**
  - Total length (mm)
  - Standard length (mm)
  - Weight (g)
- **Swim performance**
  - Rheotaxis
  - Endurance
  - Swim speed

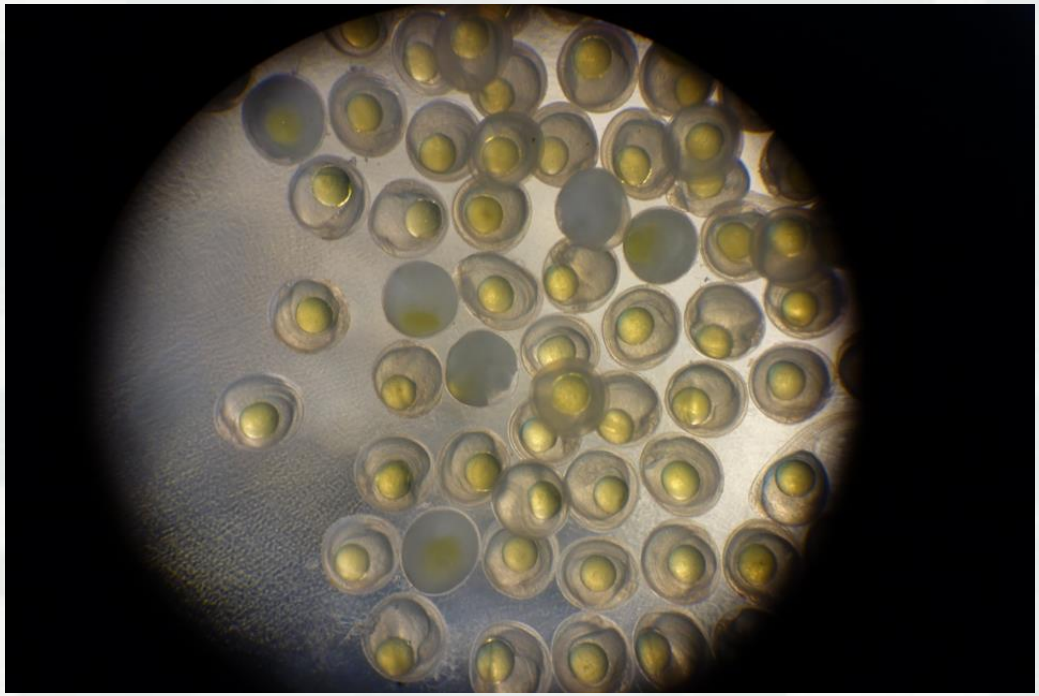


# Sturgeon Results

| Response of Atlantic sturgeon to 3-day sediment exposures. Values are means. Means for any variable were not significantly different from those of other treatments based on ANOVA ( p > 0.05). | | | | | |
|---|---|---|---|---|---|
| Treatment (TSS) | 0 | 100 | 250 | 500 | ANOVA PR > F |
| Survivorship during exposure (% of all fish tested) | 100% | 100% | 96% | 92% | n/a |
| Post-exposure survival time (mean proportion of 14 day monitoring period) | 0.89 | 0.78 | 0.76 | 0.71 | 0.3285 |
| $Ucrit_{ABS}$ (cm/s) | 21.0 | 23.3 | 31.3 | 29.6 | 0.4874 |
| $Ucrit_{REL}$ (BL/s) | 1.24 | 1.62 | 1.84 | 1.74 | 0.5819 |

**No significant effects observed for endpoints measured.**

# Smallmouth Bass (*Micropterus dolomieu*) EW Case Study



# Dredging Effects on Smallmouth Bass

## Problem

- Environmental windows in multiple Great Lakes harbors restricting dredging operations
- Smallmouth bass spawning along waterway shoals
- Suspended sediment threshold data lacking for smallmouth bass relevant to dredging
- Effects data essential for conducting risk assessments and managing dredging risks

## Objective

- Develop suspended sediment effects data for smallmouth bass early life stages to reduce uncertainty about adverse dredging impacts

# Materials and Methods

- Experiments: Texas and Illinois eggs (newly spawned) and swim-up fry
- Sediment: Fairport Harbor (Lake Erie); Grand Haven Harbor (Lake Michigan)
- Concentrations: 0, 100, 250, 500 mg/L TSS
- Duration: 3 days (72 h)
- Temp: 16.1 – 18.8°C
- D.O.: 7.2-7.6 mg/L
- Water volume exchange: 1-2; 4-6 (grow-out)

# Experimental Endpoints

**Eggs→Larvae**

- Survival immediately post-hatch

**Swim-up fry**

- Survival, growth, and swimming performance
- Survival and growth of swim-up fry grown out after exposure

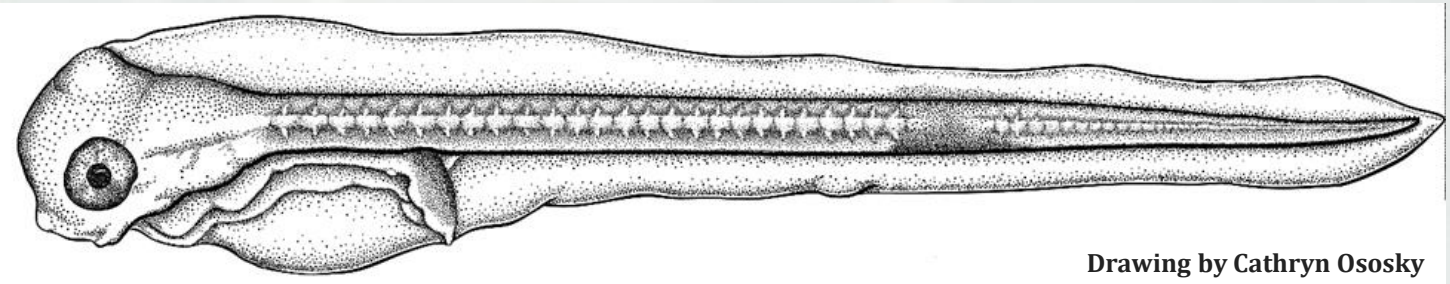
# Survival and growth of smallmouth bass fry exposed to suspended sediment for 3 days

| Sediment | Measured TSS (mg/L) | Survival (%) | Dry weight (mg) | Total Length (mm) | Standard length (mm) | Swim bladder length (mm) |
|---|---|---|---|---|---|---|
| Fairport Harbor | 0 ± 4 | 99 ± 1 | 3.0 ± 0.1 | 11.47 ± 0.13 | 10.04 ± 0.06 | 1.53 ± 0.06 |
| | 91 ± 11 | 100 ± 1 | 3.1 ± 0.2 | 11.67 ± 0.07 | 10.03 ± 0.08 | 1.58 ± 0.02 |
| | 221 ± 17 | 100 ± 0 | 2.9 ± 0.7 | 11.16 ± 0.71 | 9.55 ± 0.58 | 1.46 ± 0.16 |
| | 452 ± 39 | 90 ± 17 | 2.2 ± 0.2* | 10.97 ± 0.33 | 9.32 ± 0.27* | 1.38 ± 0.13 |
| Grand Haven Harbor | 0 ± 3 | 100 ± 0 | 2.6 ± 0.2 | 11.14 ± 0.20 | 9.74 ± 0.08 | 1.37 ± 0.08 |
| | 110 ± 17 | 100 ± 0 | 2.4 ± 0.1 | 11.24 ± 0.12 | 9.67 ± 0.12 | 1.43 ± 0.04 |
| | 263 ± 37 | 100 ± 0 | 2.0 ± 0.2* | 10.85 ± 0.06* | 9.30 ± 0.06* | 1.32 ± 0.08 |
| | 528 ± 40 | 95 ± 6 | 1.7 ± 0.0* | 10.64 ± 0.12* | 9.10 ± 0.09* | 1.29 ± 0.05 |

# Research Findings

- Exposed eggs hatched normally but newly hatched larvae are more vulnerable to the effects of suspended sediment
- Egg experiments indicated reduced survival of larvae when exposed to suspended sediments (≥ 100 mg/L TSS)
- Swim-up fry survival was not reduced (≥ 90%) even at the highest exposure concentration
- Sublethal effects were observed in growth of fish in swim-up fry experiments
- Swimming behavior of fry not affected
- Sublethal growth effects were observed in fish in grow-out fry experiments: FPH (26-d): NOEC=221 mg/L; GHH (7-d): NOEC=91 mg/L
- Worst case exposure scenario that can be conservatively extrapolated to the field for protecting the smallmouth bass fishery in Great Lakes harbors
- Publication in JGLR

# Case Study: Effects of Sedimentation on Winter Flounder Eggs

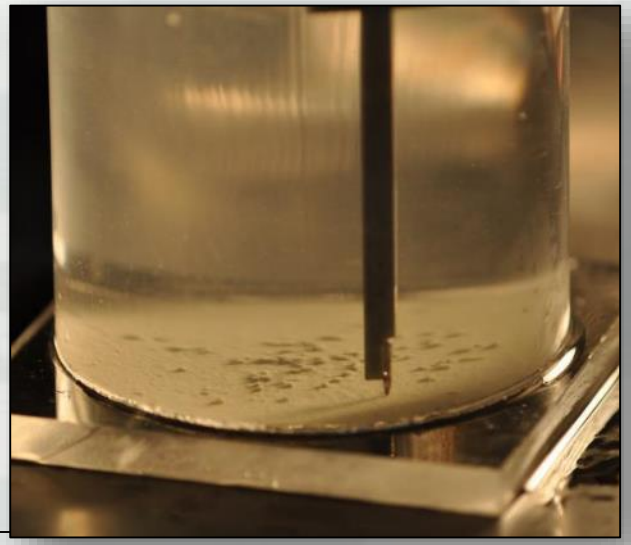


Drawing by Cathryn Ososky

# Problem Statement and Objectives

**Problem:** Overlap of WFL spawning areas and dredging operations

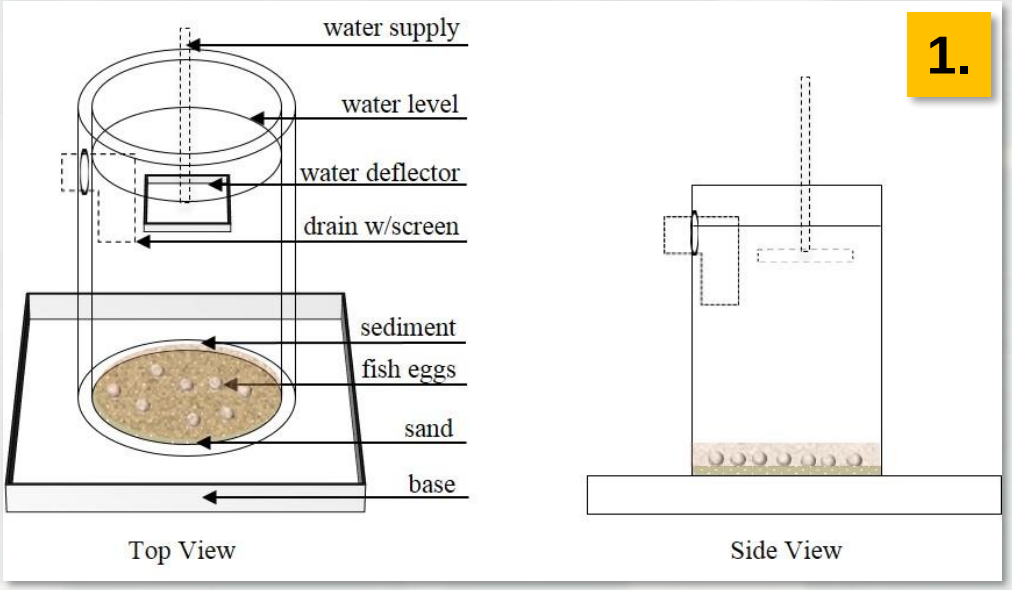
**Objective:** Determine relationship of sedimentation to performance of WFL eggs under laboratory conditions

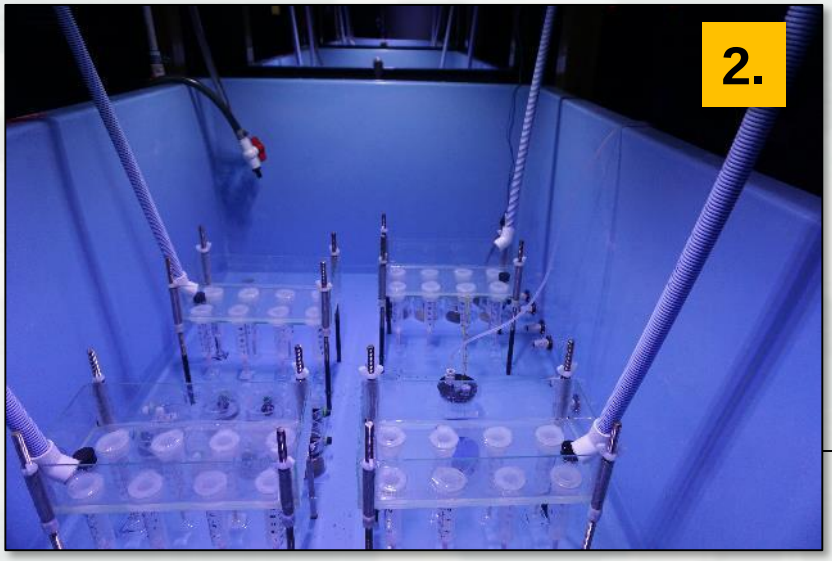


**Key Questions:**

- What depth results in unacceptable mortality?
- Is there a difference across three sediments?

# Methods- Exposure Design

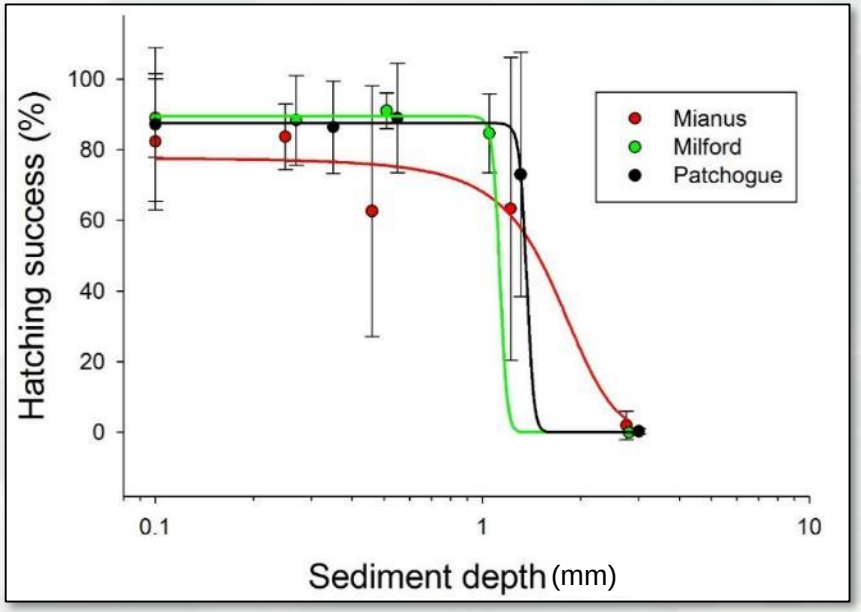



# Results- Hatching Success

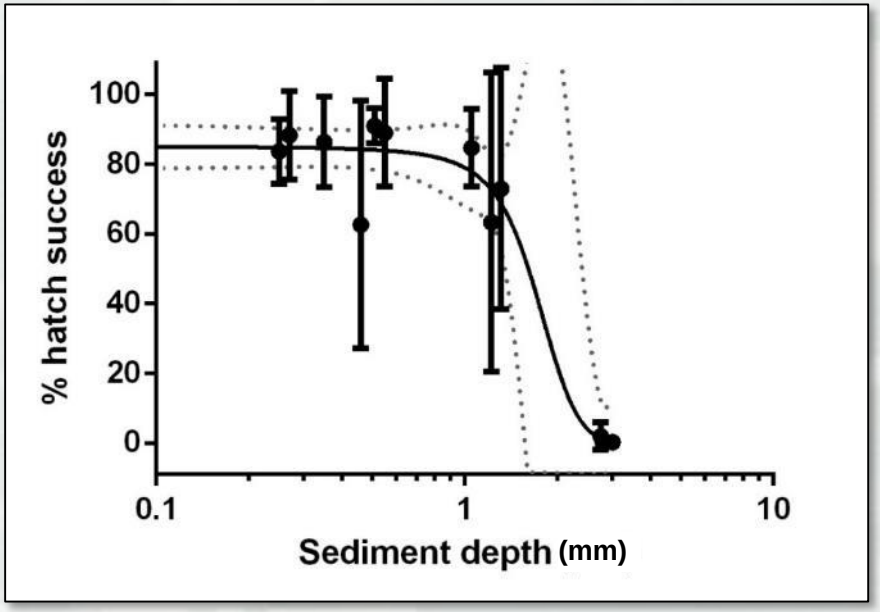
Three test sediments plotted individually

A




Three sediments combined

B




*Mean +/- one standard deviation around the mean. Dotted line represents 95% confidence interval.*

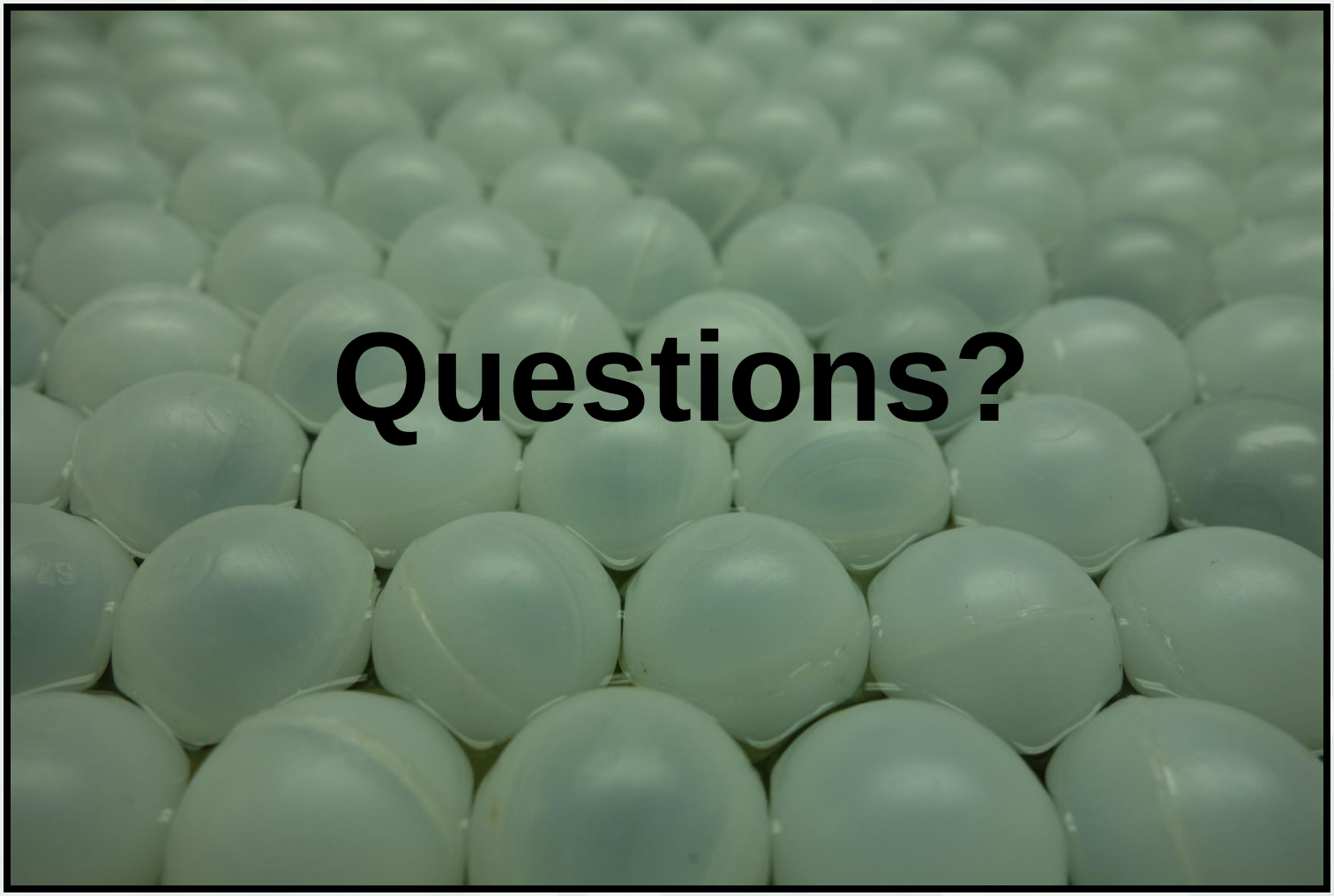
# Cumulative Findings

- Results indicate that detailed, site-specific knowledge of the dredge project, sediment type, organism life history and exposure can better support decisions regarding the development of adequately protective EW risk management practices.

- Effects-based experimental data can be used with dredge plume exposure data to assess risk to aquatic species driving EWs

- Effects-based data can reduce uncertainty in assessing risk associated with perturbations due to dredging

- Risk-based approach using newly available data should be used to inform the setting and revision of EWs


Questions?