Assessing the Effects of Suspended Sediment on Sensitive Aquatic Habitats: A Need for Science-based Solutions

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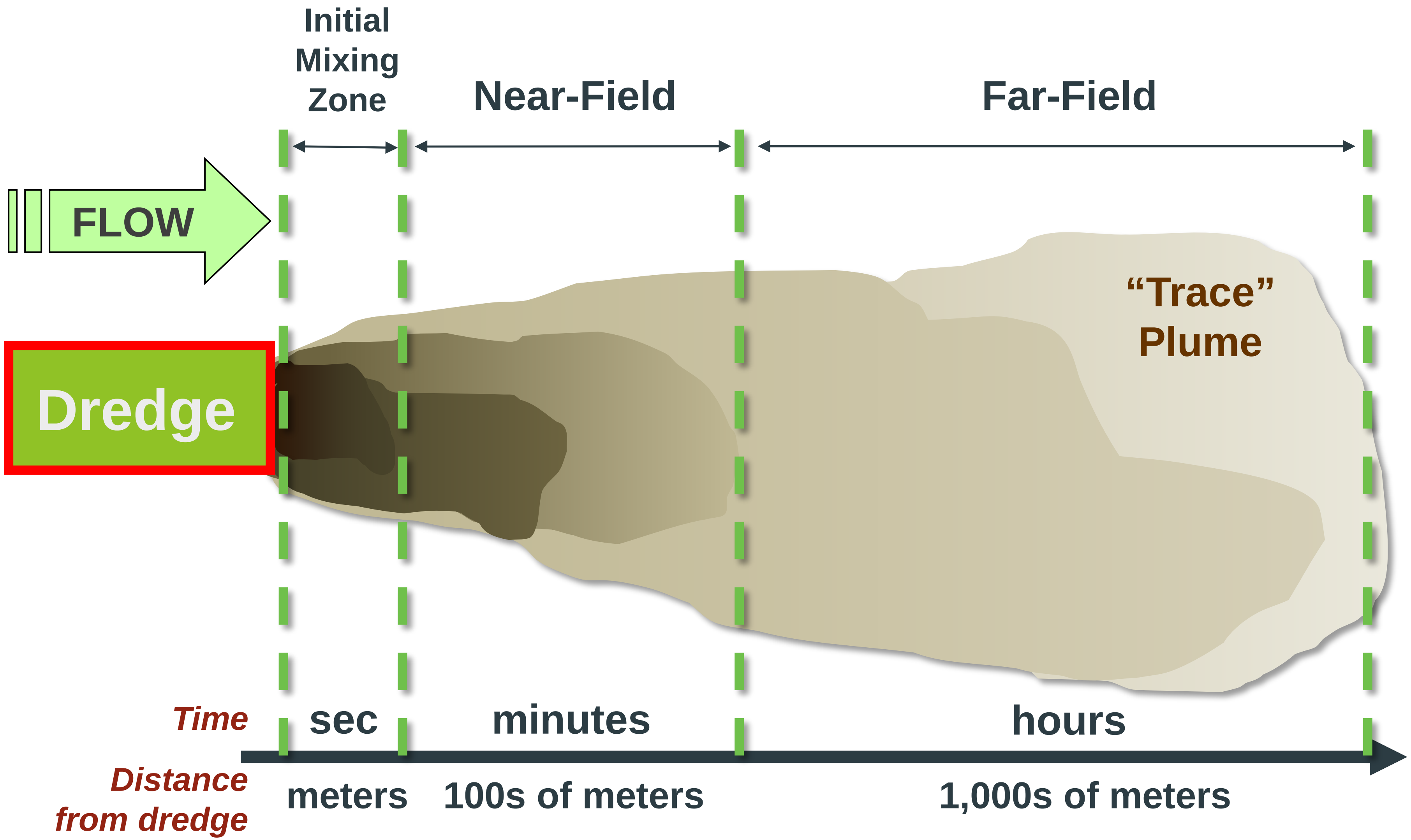
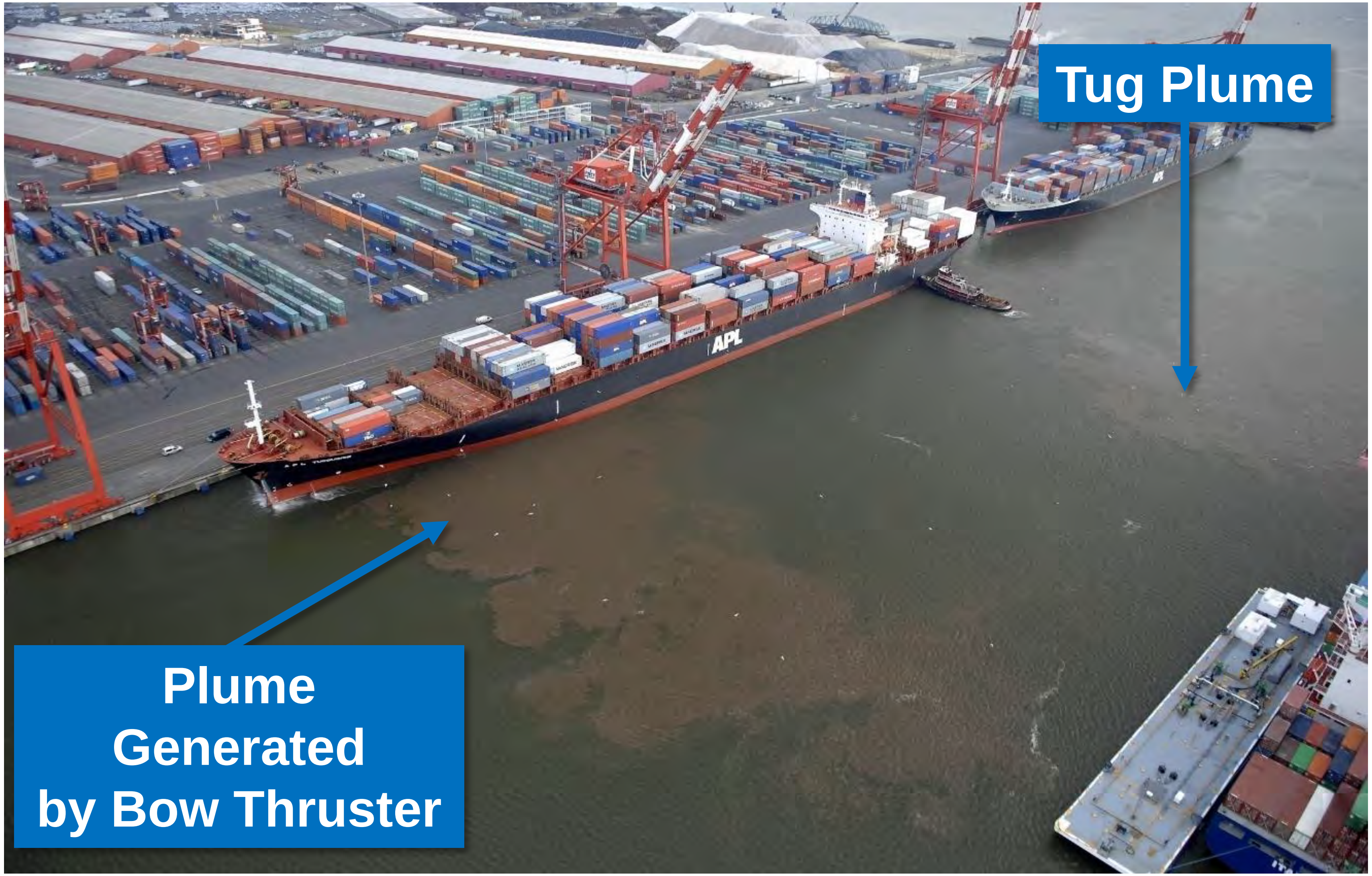
Effects of Suspended Sediments and Sedimentation

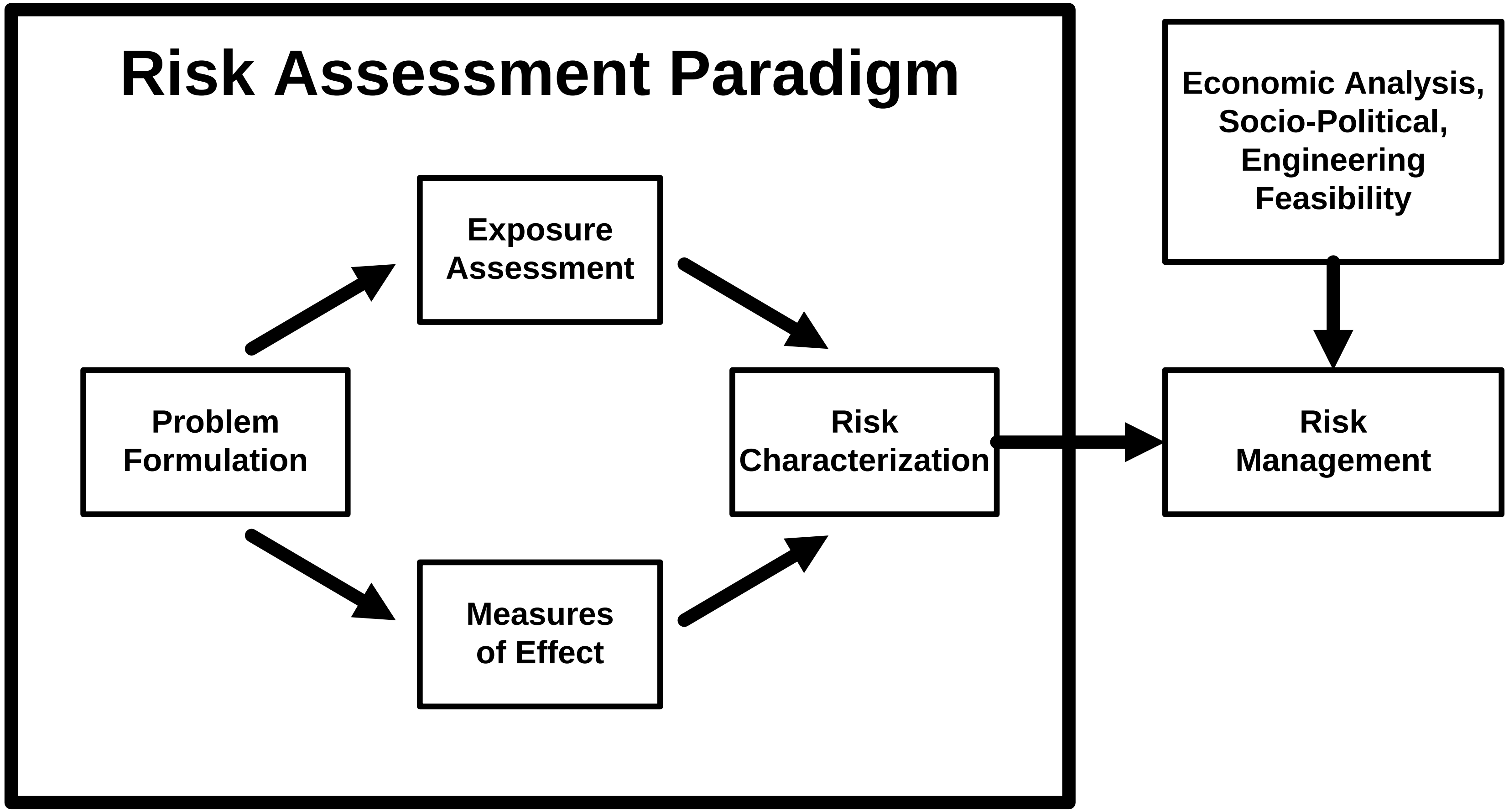
Dredge Plume Spatial/Temporal Scales



Other Sources of Resuspension

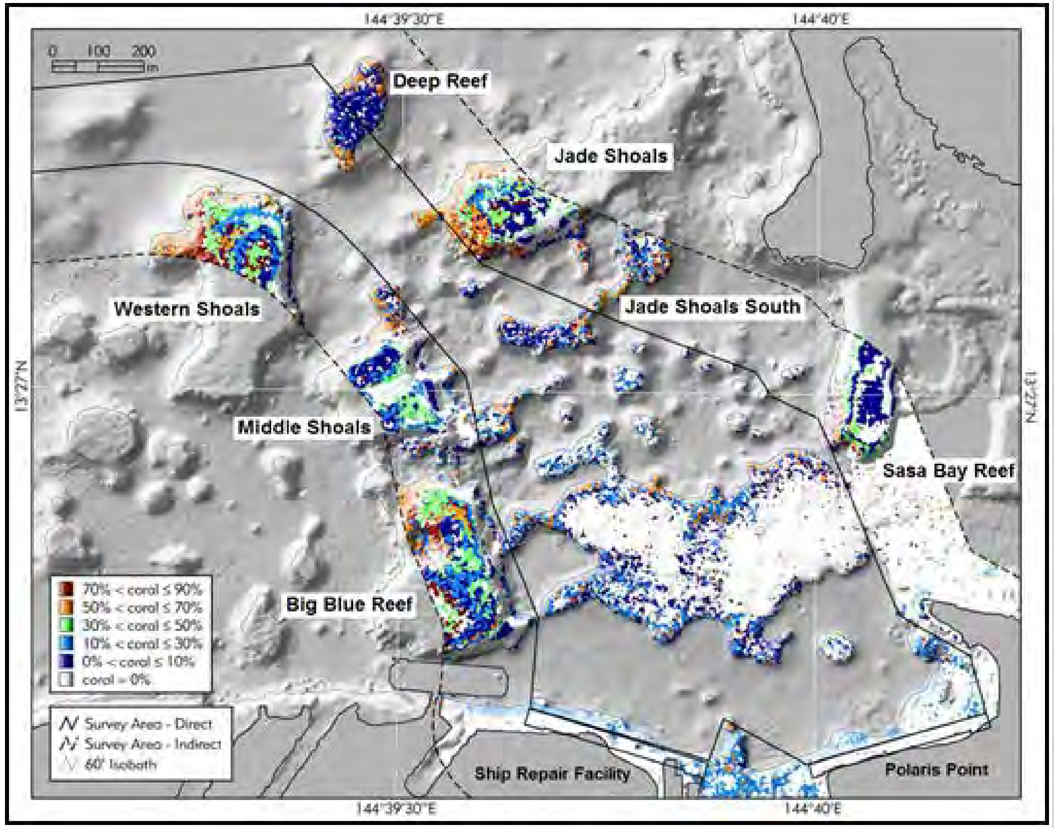


Applying Risk Assessment Paradigm to Manage Risk



Apra Harbor Case Study
Problem Formulation

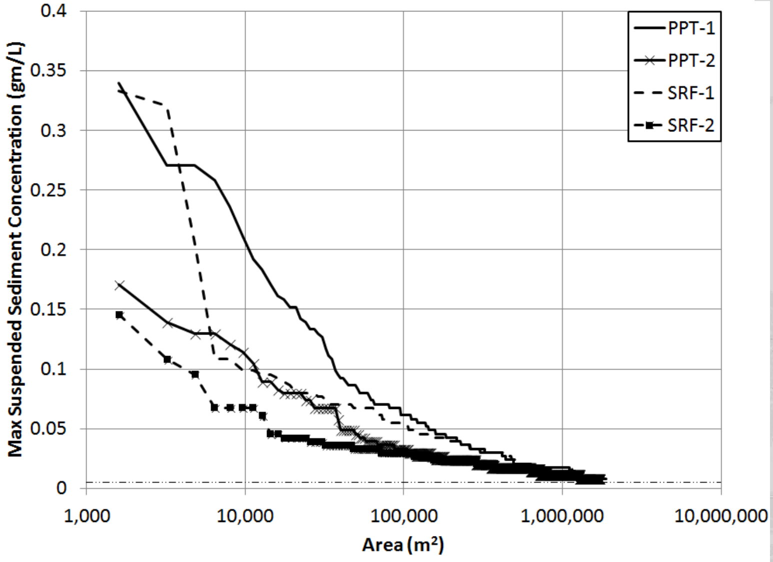
- Identify receptors (coral)
- Identify/map coral density/diversity
- Identify sources of exposure
  - Dredging as source of released sediment
  - Background suspended solids are near zero and there are no outfalls or other land-based sediment sources to Apra Harbor
- Identify exposure mechanisms
  - Total sedimentation from dredging project
  - Maximum sedimentation rate over any 24 hour period
  - Light attenuation (represented by suspended solids time history)



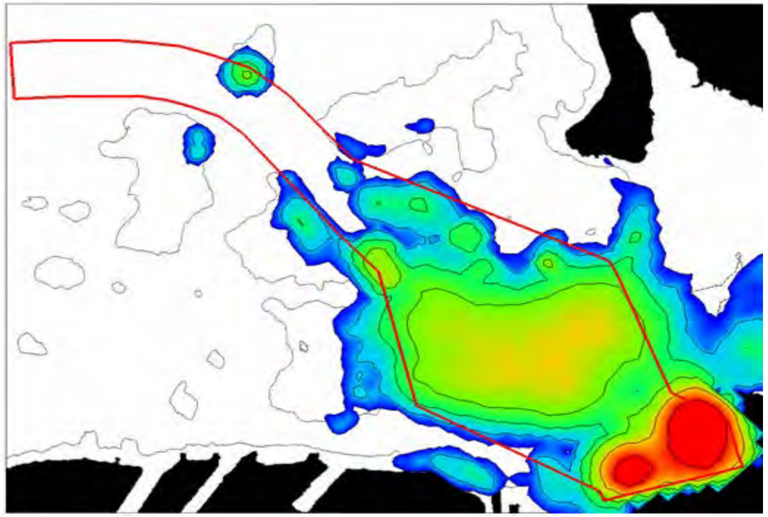
Quantifying Exposure

- Quantify exposure from each risk pathway for each species in areas of concern
- Characterize risks to coral in Apra Harbor from 18 month dredging operation
- Quantify exposure:
  - Simulate sediment transport and sedimentation over coral habitat – 100 scenarios modeled to bracket potential exposure

Peak 24-hr TSS over coral



Total sedimentation for dredge cycle



Combining Exposure and Effects to Characterize Risk

1. Estimate effects via literature review of risk to coral from sediment
2. Green/Yellow/Red light indicator created for coral species using exposure and effects estimates
   - Green – minimal damage
   - Yellow – some damage, recovery expected
   - Red – Significant die-off
3. Exposure thresholds mapped from sediment transport and sedimentation model

1) Coral thresholds evaluated from literature

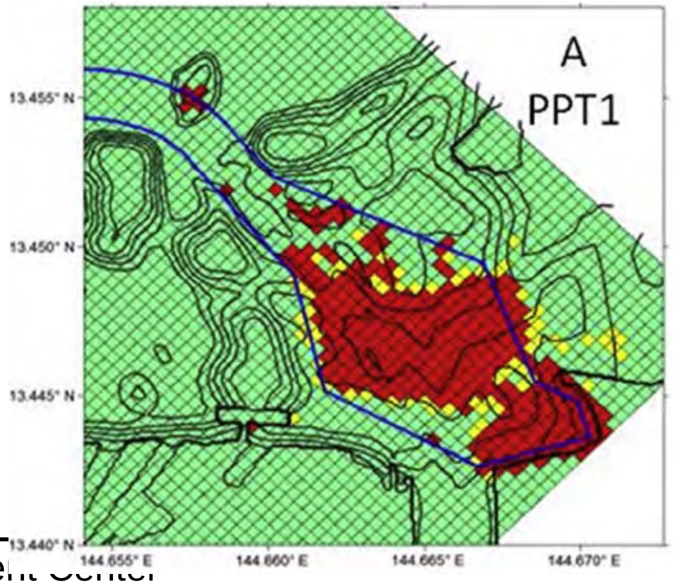
Table 2
Basis for selection of sediment deposition, deposition rate, and turbidity thresholds applied in the modeling exercise to establish stoplight indicator criteria

Effect level	Location or species	Exposure	Description	Reference
Sediment deposition (cm)				
Lethal	*Porites astreoides*	>1 cm	Full or partial colony mortality	Bak, 1978
Sublethal	Curacao	>1 cm	All corals except *P. astreoides* able to reject dredged sediment accumulations	Bak, 1978
	Porites sp.	Burial 20 h	Discoloration and bleaching with full recovery after 1 month	Wesseling et al., 1999
	8 massive species	Burial at 200 mg cm^{-2} for 5 wks	All removed at least 50% of sand within 1000 min	Riegl, 1995
No effect	*Porites* sp.	Burial 6 h	No effect	Wesseling et al., 1999
Sedimentation rate (mg cm^{-2} d^{-1})				
Lethal	Guam	160e200	Low coral cover (2%) and <10 species	Randall and Birkeland 1978
	Acropora millepora	83	Full colony mortality at 12 weeks. Partial mortality began at 4 weeks	Flores et al., 2012
	Worldwide	>50	Severe to catastrophic	Pastorok and Bilyard, 1985
Sublethal	Indonesia	57.5	Dead coral cover ¼ 21%. Mortality index ¼ 0.43	Edinger et al., 1998
	Palau, Micronesia	40 (>2 wks)	Mucus production, partial bleaching	Fabricius et al., 2007
	Worldwide	10e50	Moderate to severe	Pastorok and Bilyard, 1985
	Guam	5e32	>100 coral species	Randall and Birkeland 1978
	Worldwide	>10	Chronic exposure considered "high"	Rogers, 1990
Minimal or no effect	*Siderastrea siderea*	10	No effect	Torres and Morelock, 2002
	Worldwide	1e10	Natural reefs not subject to stress	Rogers, 1990
	Worldwide	1e10	Slight to moderate	Pastorok and Bilyard, 1985

2) Coral thresholds identified

Stoplight indicator	Direct dredging damage	Total depth of sediment deposition (SDD)	Sedimentation rate (SR)[a] (mean over any 30 d running window)
Coral mortality (Red)	Dredging occurred anywhere within grid cell	> 1.0 cm	>25 mg/cm^2/d
Moderate stress (Yellow)	Not defined	>0.5 cm < 1.0 cm	>10 mg/cm^2/d < 25 mg/cm^2/d
Minimal stress (Green)	No dredging occurred within the grid cell	<0.5 cm	<10 mg/cm^2/d

3) Estimated coral effects for one scenario



Fish Larvae and Egg Exposure System (FLEES)

FISH LARVAE AND EGG EXPOSURE SYSTEM (FLEES)

Developed to expose early life history stages of fish, shellfish, and other species to specified concentrations and durations of suspended sediment or sedimentation in a controlled laboratory environment.

01

Capability

SUSPENDED SEDIMENT

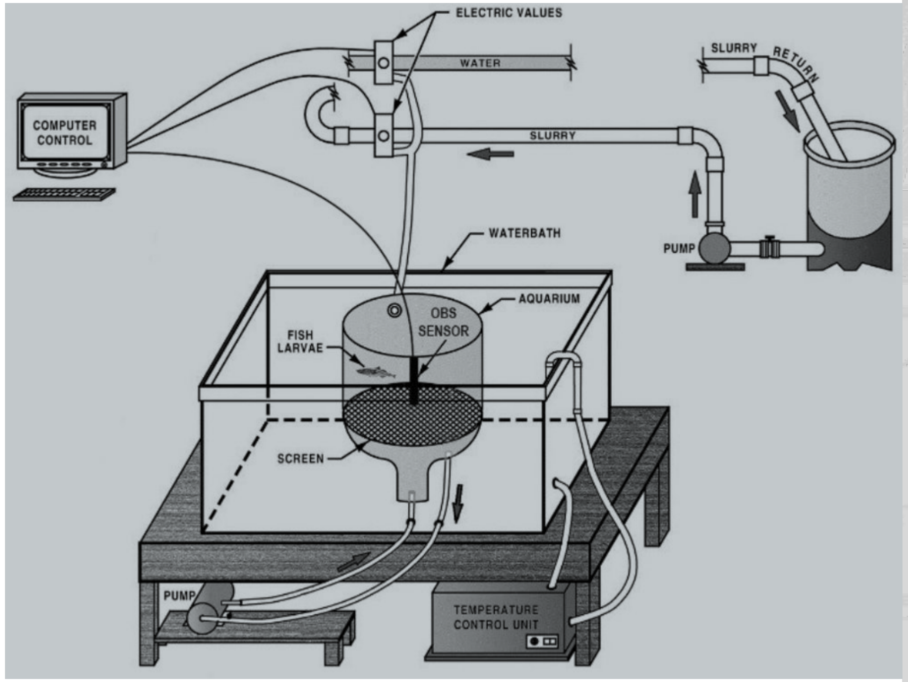
FLEES allows for the design of experiments that simulate resuspension of sediment as a result of dredging operations or other factors such as vessel traffic, freshets, or storms.

02

Capability

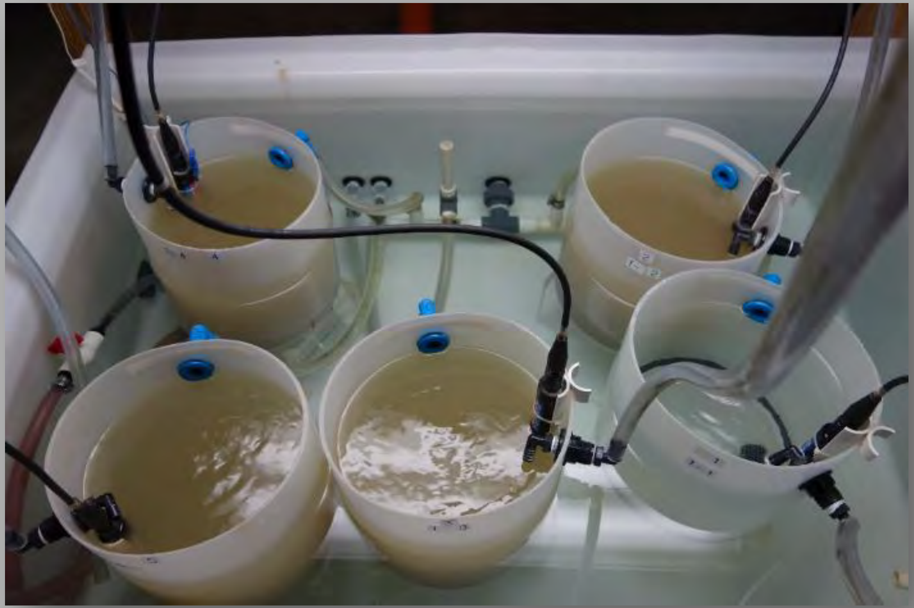
SEDIMENTATION

FLEES can be quickly retrofitted to accommodate the design of experiments that simulate sedimentation.



WHY **FLEES** WORKS AND

SUSPENDED SEDIMENT



A data acquisition device and LabVIEW software is used to integrate turbidity sensors with solenoid valves to build a computer application that both continuously monitors and records turbidity in each aquarium while introducing sediment from the slurry tank to maintain specific NTUs.

WORST CASE SCENARIO

Individuals contained for a prolonged periods, with no escape from exposure to field-collected sediment of varying concentrations.

EW Case study:
Atlantic sturgeon Savannah River and Harbor, GA

Problem

- Suspended sediment effects on sturgeon are restricting dredging operations
- Effects based data needed to characterize and manage risk

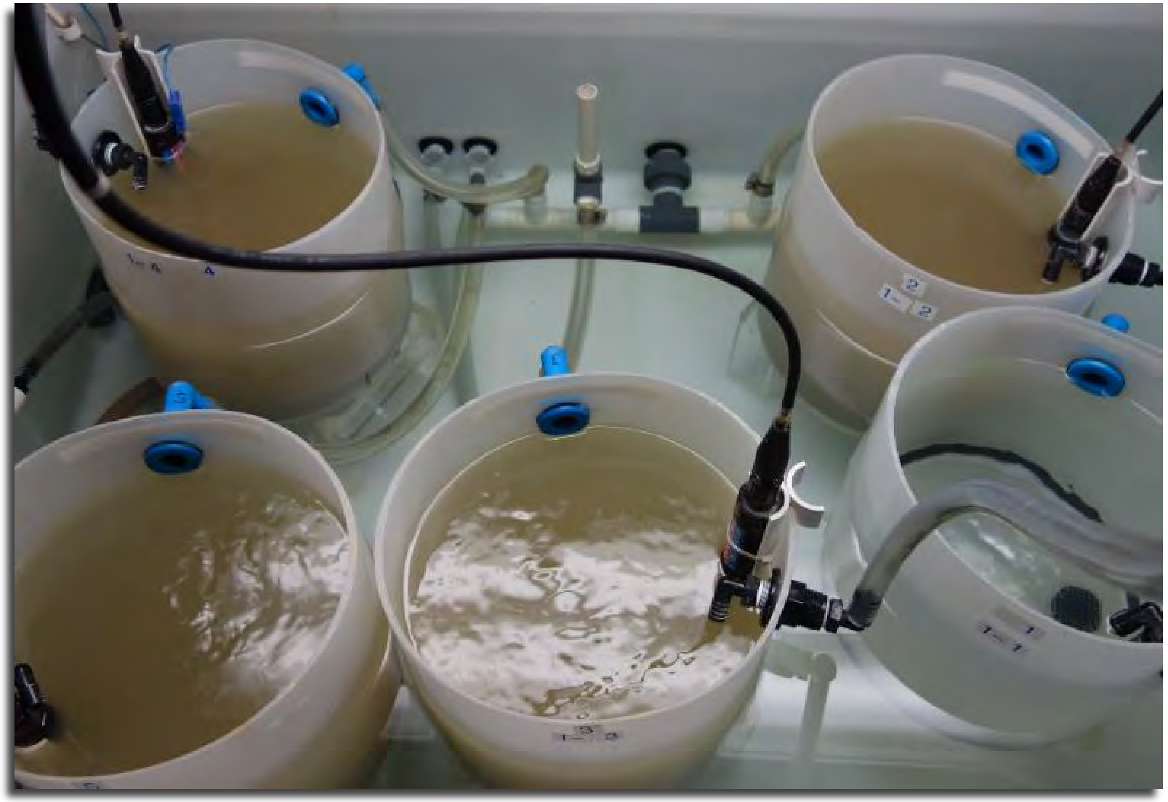
Objective

- To investigate the survival and swimming performance of juvenile sturgeon after exposure to varying concentrations of suspended sediment in FLEES

Methods

EXPOSURE

- Fish exposed to three concentrations of TSS (100, 250, 500 mg/L) plus controls (0 mg/L) for 72 h (16 h light: 8 h dark)
- Three control replicates and four replicates of each TSS were arranged randomly using three fish per aquarium (N = 45 fish)
- **FLEES Response metric:** short-term survival

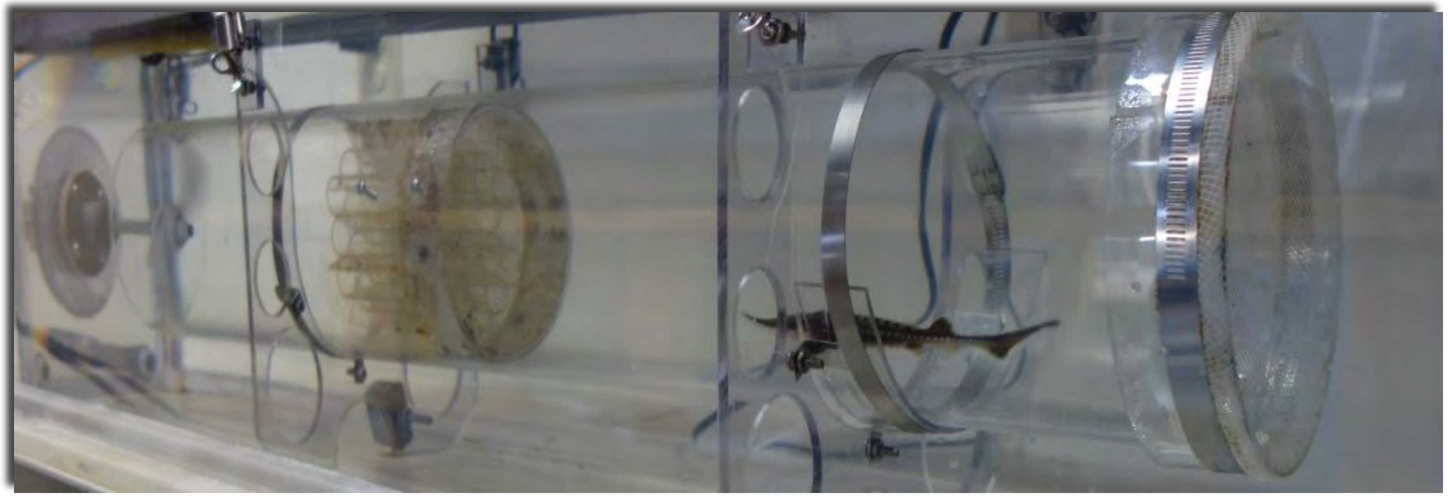


Methods

SWIM TUNNEL

Swimming performance was tested for one fish selected randomly from each concentration replicate. It was placed immediately after the 72-h exposure period into the test section of a Blazka swim tunnel.

Response metrics: (i) positive rheotaxis head first orientation into the direction of water flow; (ii) critical swim speed – endurance at successively higher water velocities; and (iii) station-holding behavior – proportion of time spent in various modes of locomotion.



Sturgeon Results

	Suspended Sediment Concentration (mg/L)			
Endpoint	**0**	**100**	**250**	**500**
FLEES				
Survival (%)	100	100	96	88
Swim tunnel				
Rheotaxis (%)	100	100	100	96
U_{crit} (cm/s)	21.02 ± 12.59	23.32 ± 9.38	31.34 ± 14.69	29.58 ± 19.24
U_{crit} (BLS)	1.45 ± 0.72	1.89 ± 0.88	2.15 ± 0.91	2.09 ± 1.29
Contact-based station-holding (%)	81.7 ± 40.1	51.0 ± 51.9	75.7 ± 44.9	69.3 ± 47.5

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 ($p > 0.05$).

Summary

- Results indicate that detailed, site-specific knowledge of the dredge project, sediment type, and species life history can inform risk-based decision making regarding dredging effects on sensitive habitats
- Exposure and effects-based data can reduce uncertainty in assessing risk associated with perturbations due to dredging
- Combination of exposure and effects data can be effectively used to assess risk to species occupying sensitive habitats
- Structured science-based approach can effectively assess risk to sensitive habitats for appropriately managing risk to these species

References

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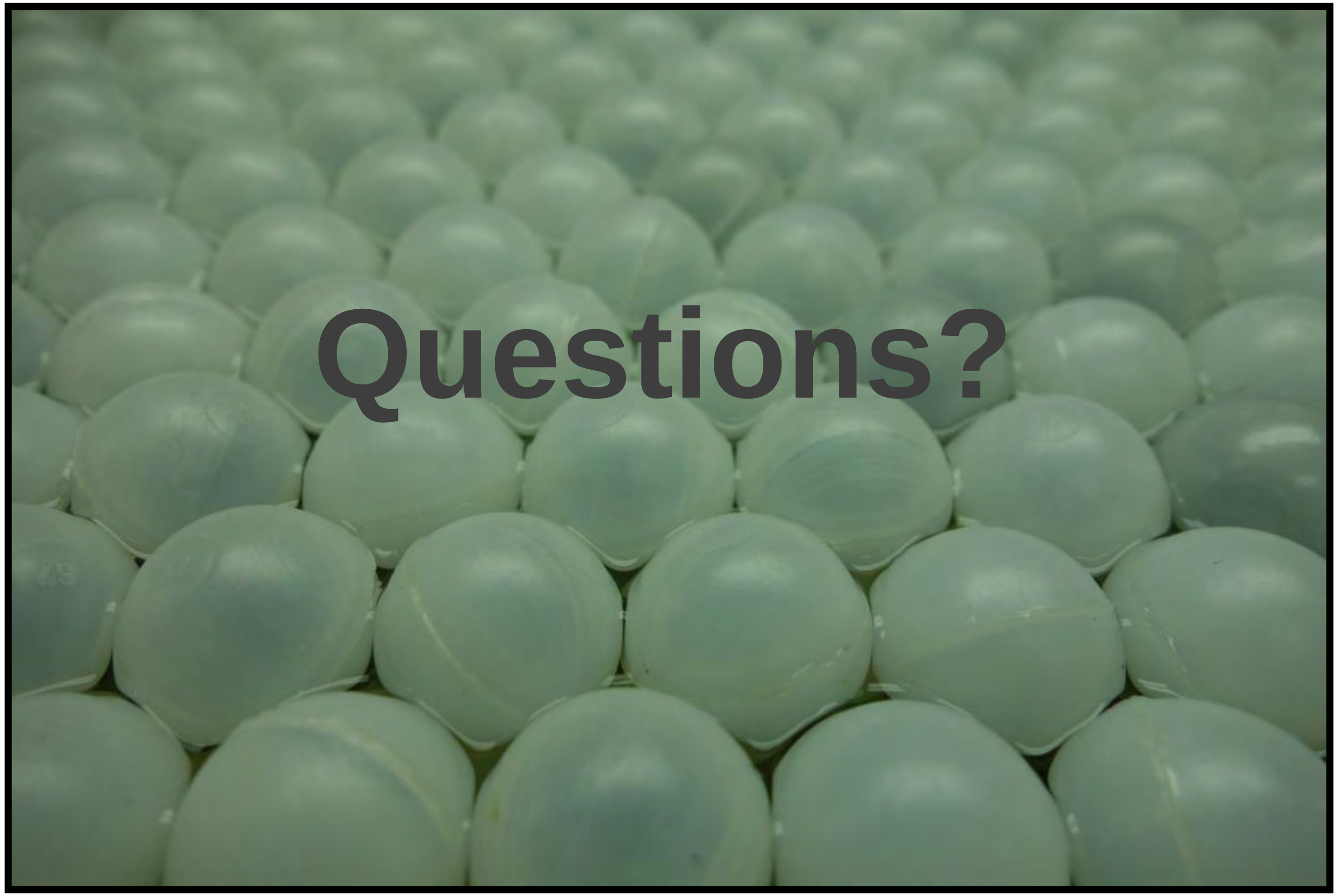
Questions?