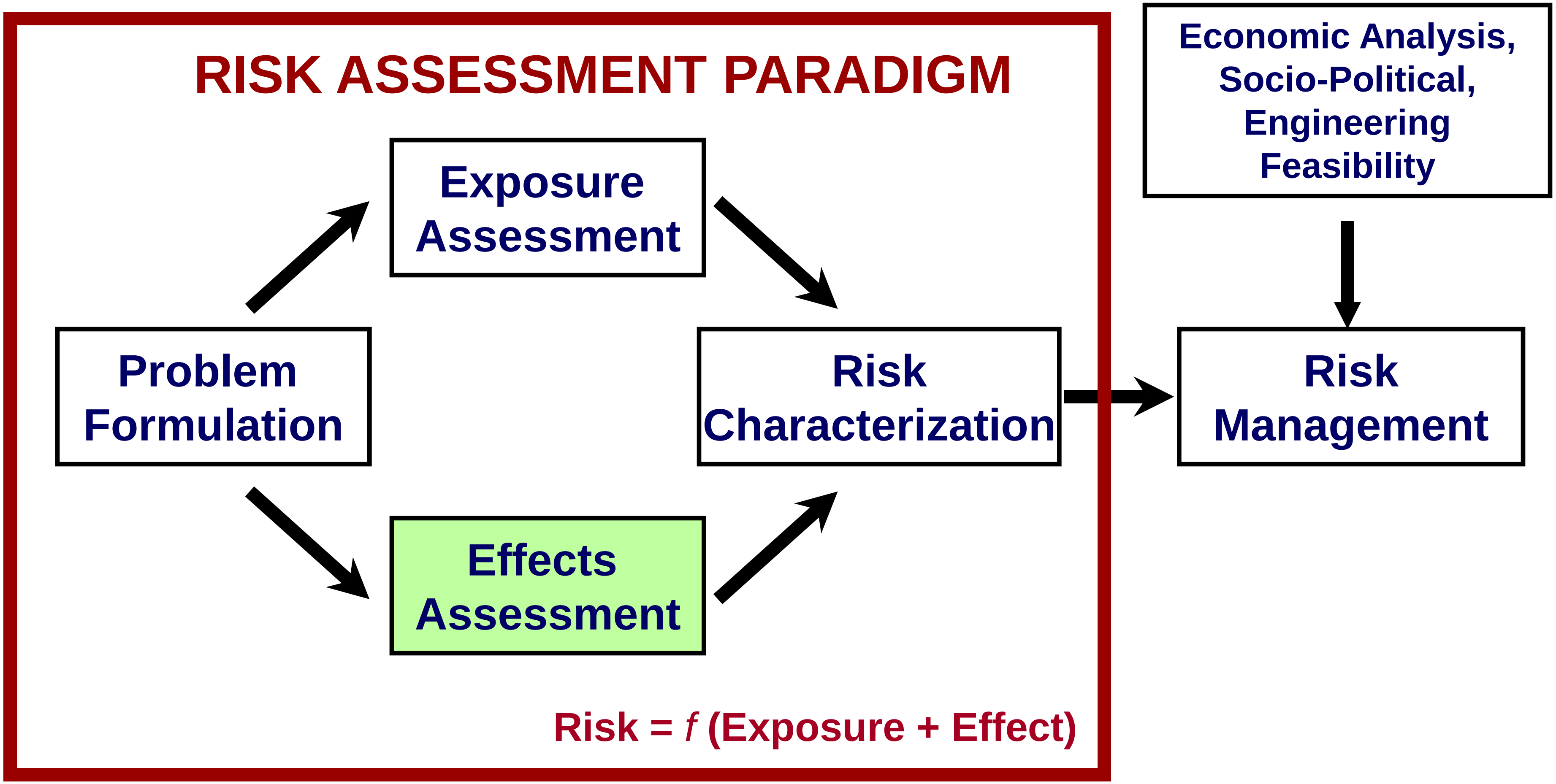
EFFECTS ASSESSMENT

Sandra Brasfield

sandra.m.brasfield@usace.army.mil

RISK FRAMEWORK



Topics

- Typical Receptors
- Modes of impact
- Dose-Response Relationships
- Characteristics of Exposure
- Characteristics of Response
- Hypothetical examples

Sssssome Receptors of Interest

STURGEON

SEA TURTLES

STRIPED BASS

SEAGRASS

SALMON

SHAD

SHELLFISH

SEAGULLS

SPAWNING HABITAT

SENSITIVE LIFE HISTORY STAGES

Some Receptors of Interest

AND DON'T FORGET………

TIGER BEETLES

PIPING PLOVER

MANATEES

OYSTERS

FLOUNDER

WALLEYE

CORAL

FW MUSSELS

LEAST TERN

NURSERY OR FORAGING HABITAT

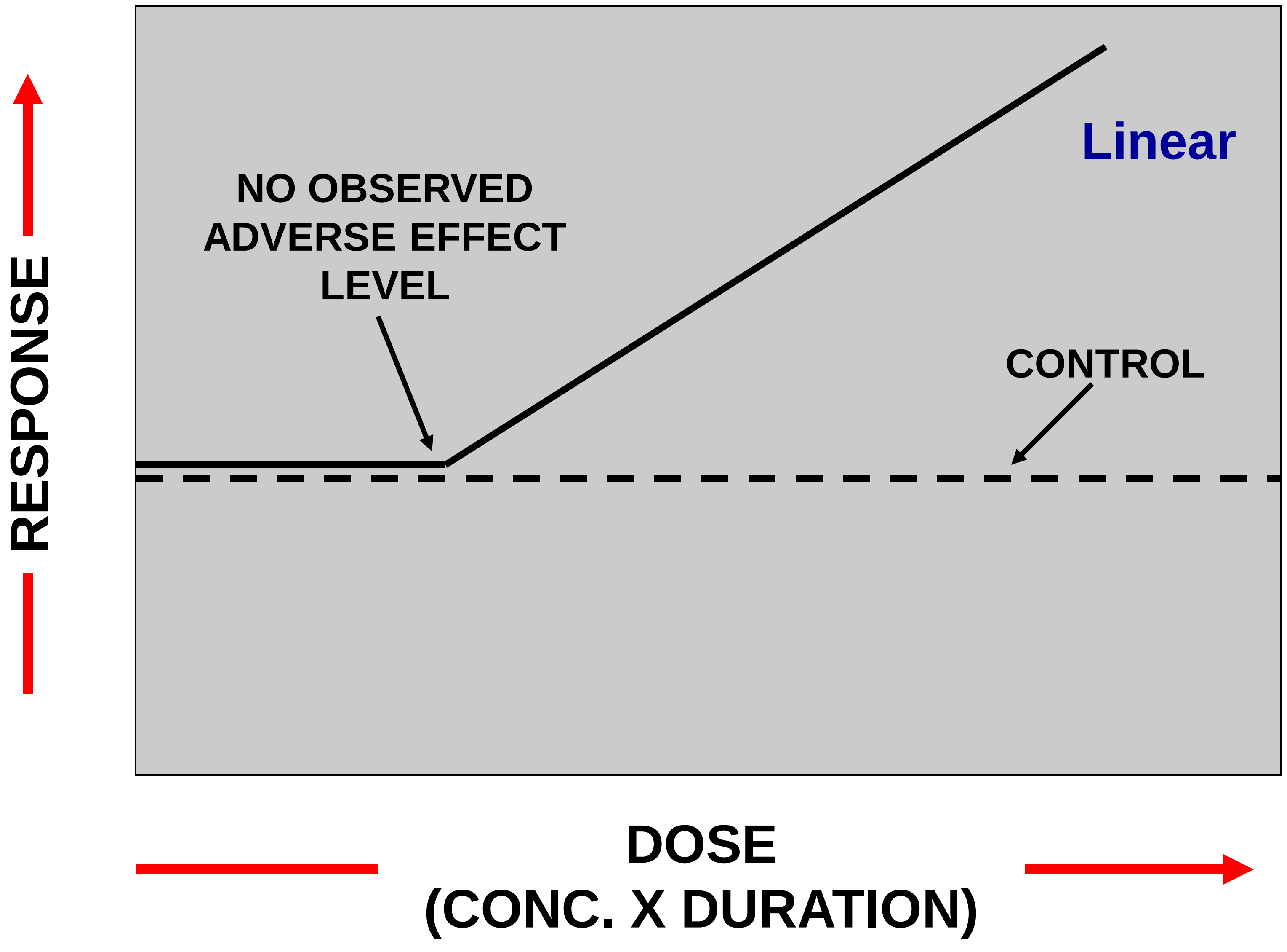
Stressors

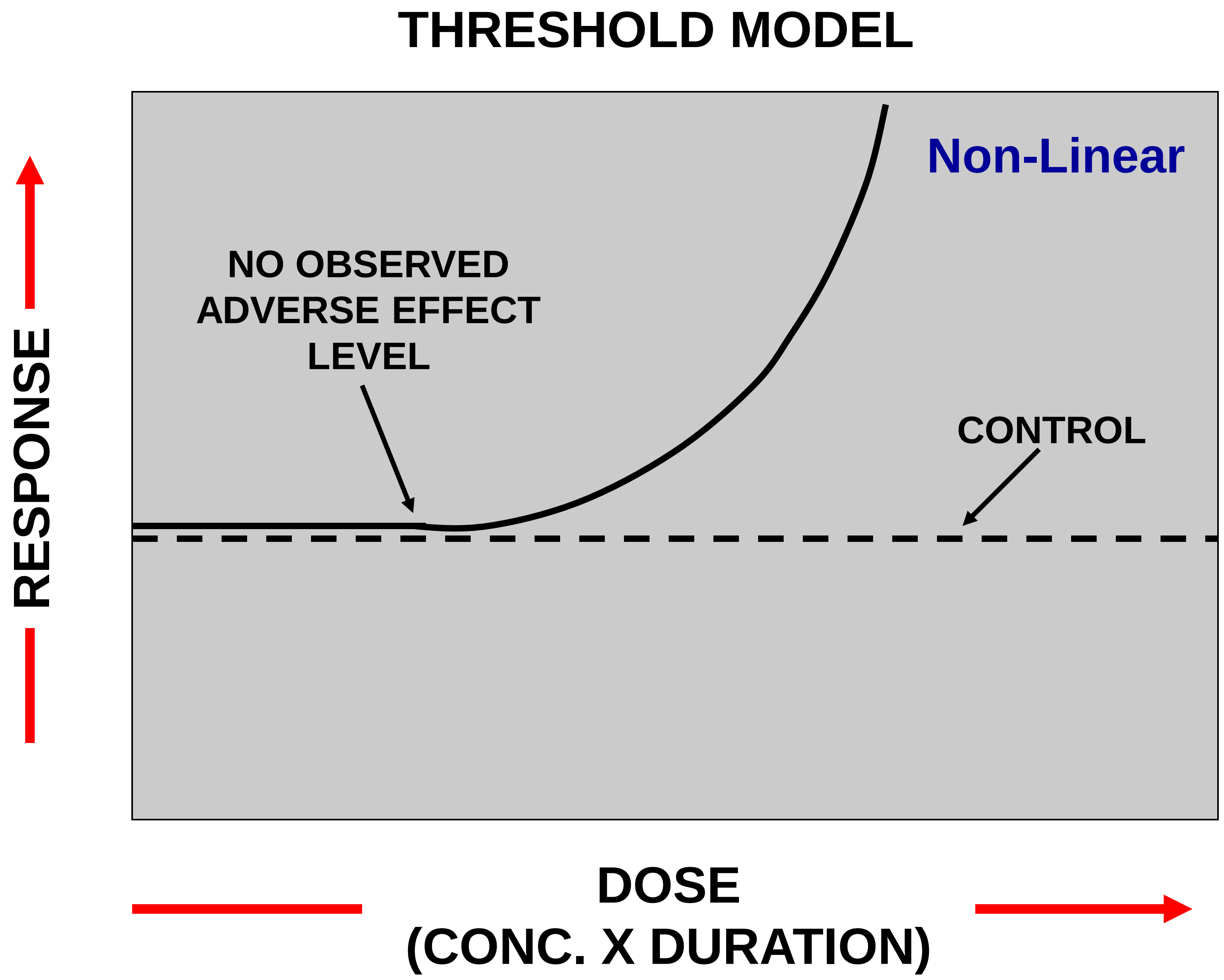
- **Chemical**
  - **Contaminants**
  - **WQ (e.g., ammonia, sulfides, nutrients, DO)**
- **Physical**
  - **TSS**
  - **Light Attenuation**
  - **Deposition**
  - **Altered Habitat**
- **Hydraulic entrainment**
- **Noise**
- **Blasting**

Factors That Influence Effects

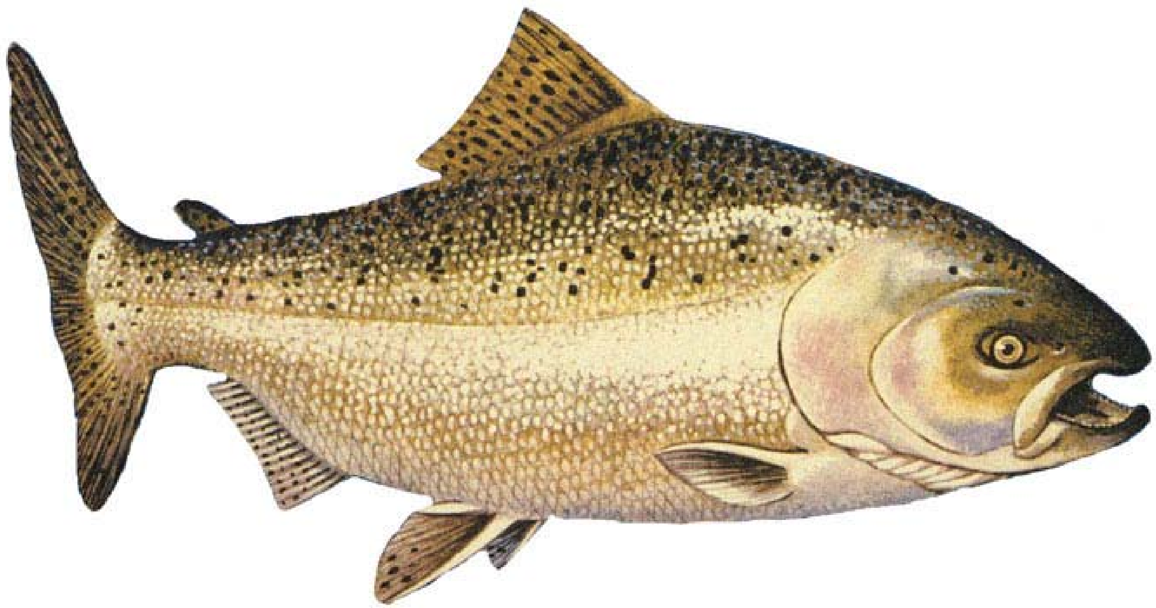
- Ambient conditions
- Static versus dynamic dose
- Duration of exposure
- Intensity of exposure
- Life history stage
  - Egg
  - Larval
  - Juvenile
  - Adult
- Species-specific behavior

THRESHOLD MODEL

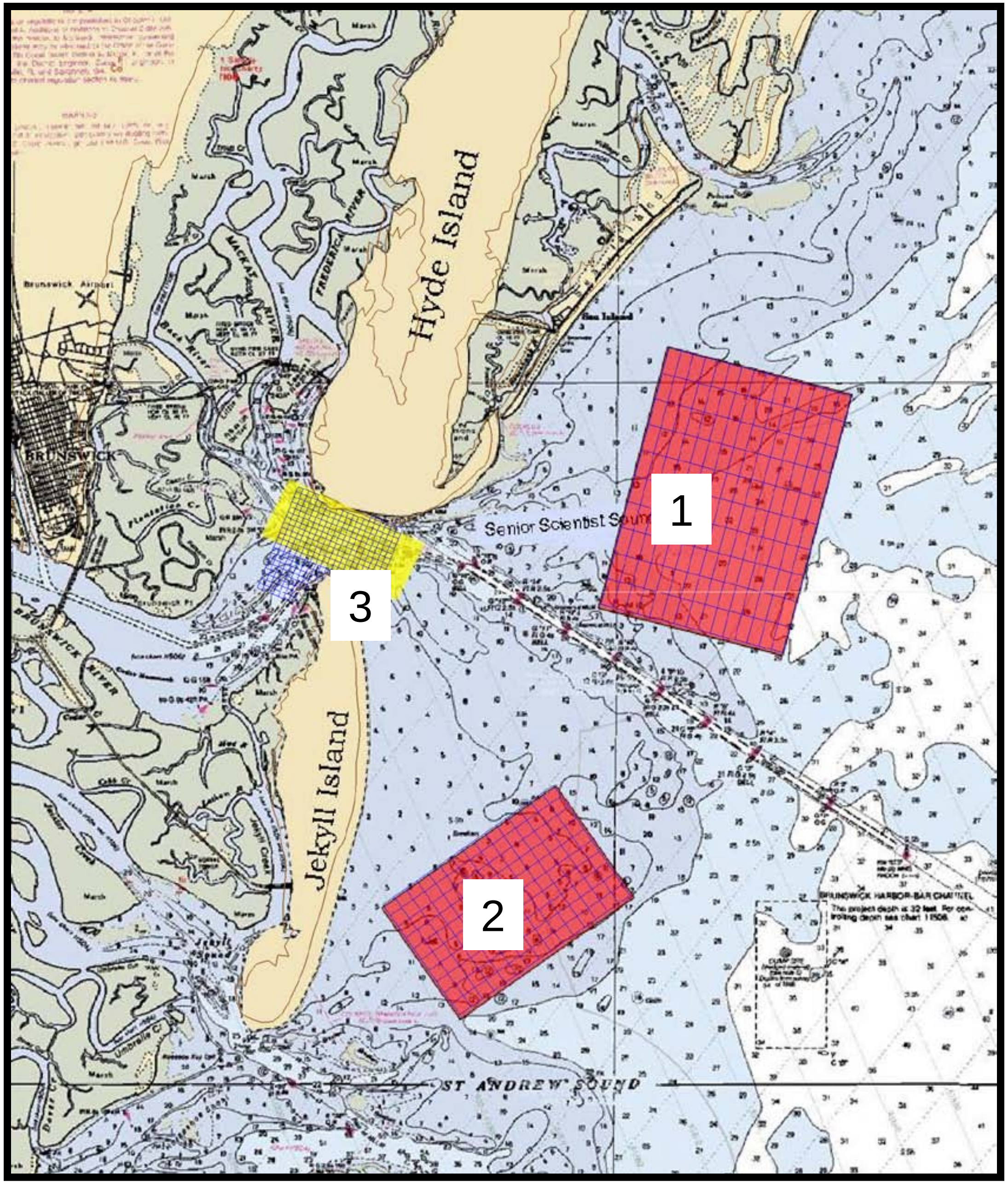



THRESHOLD MODEL
Non-Linear
NO OBSERVED
ADVERSE EFFECT
LEVEL
CONTROL
RESPONSE
DOSE
(CONC. X DURATION)

Hypothetical Fish Receptor



Tropical Salmon (*Oncorhynchus whopperi*)

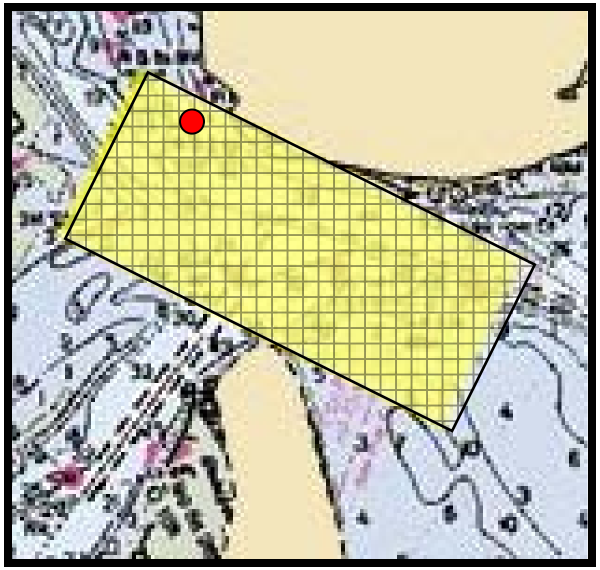


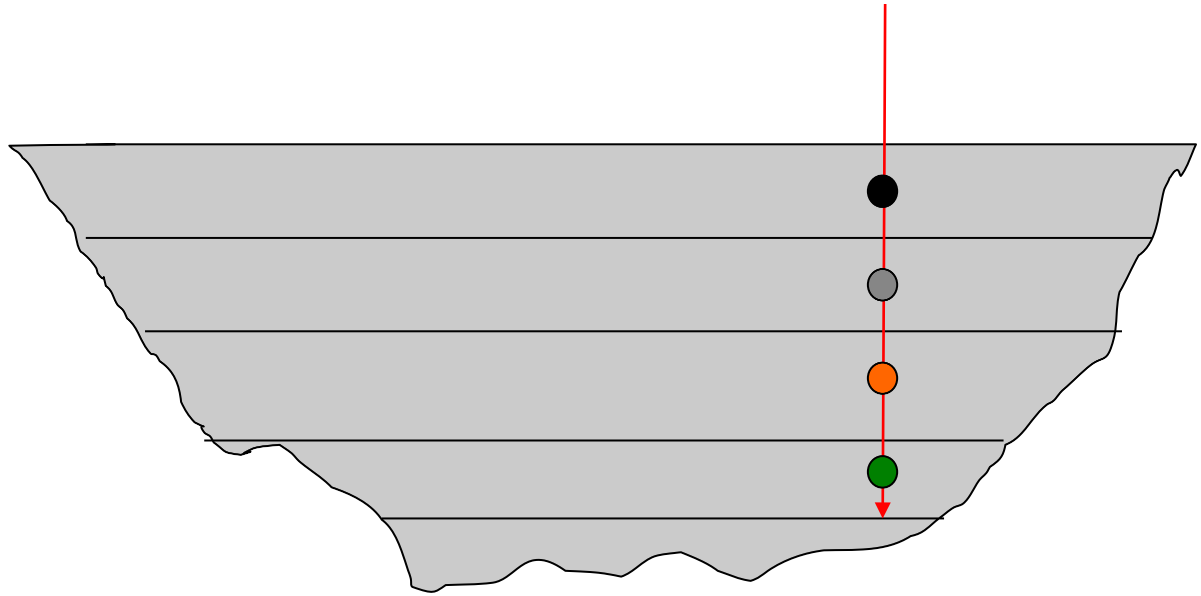
Region 1: Location of SAV bed

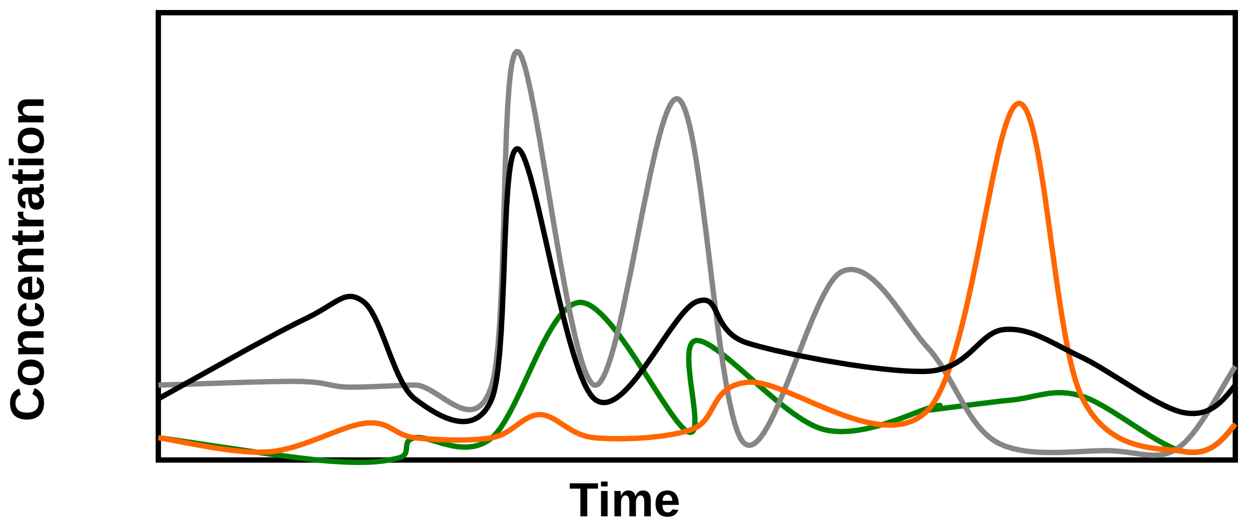
Region 2: Location of coral reef

Region 3: Migratory corridor of juvenile salmon

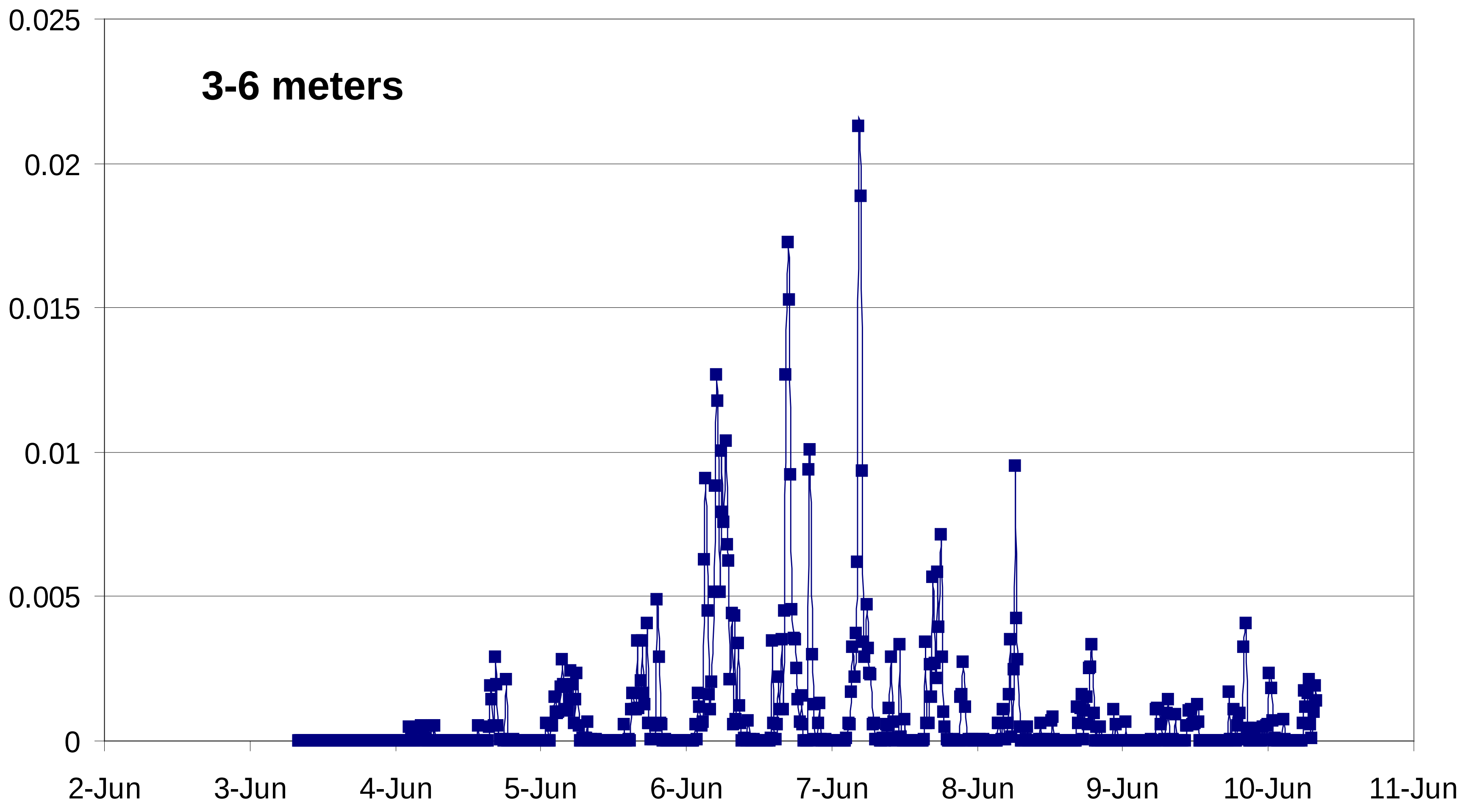
Dynamic Dose

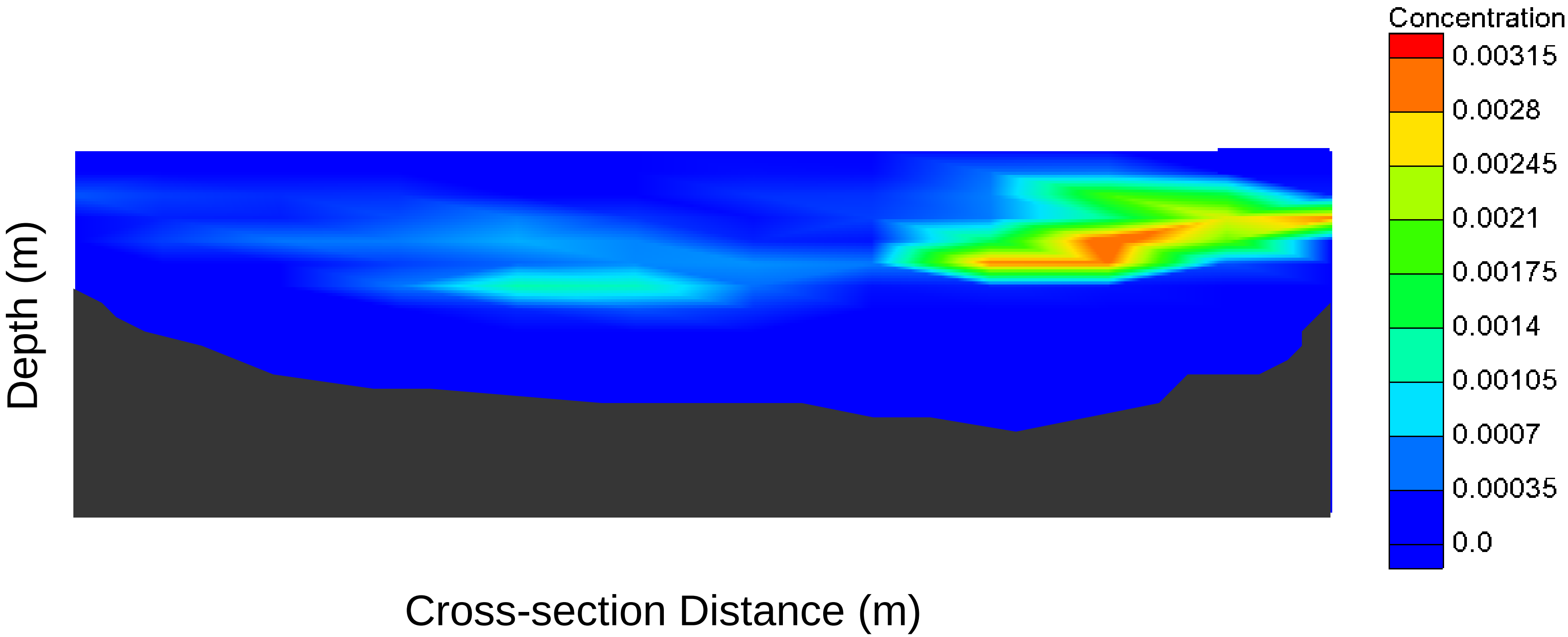






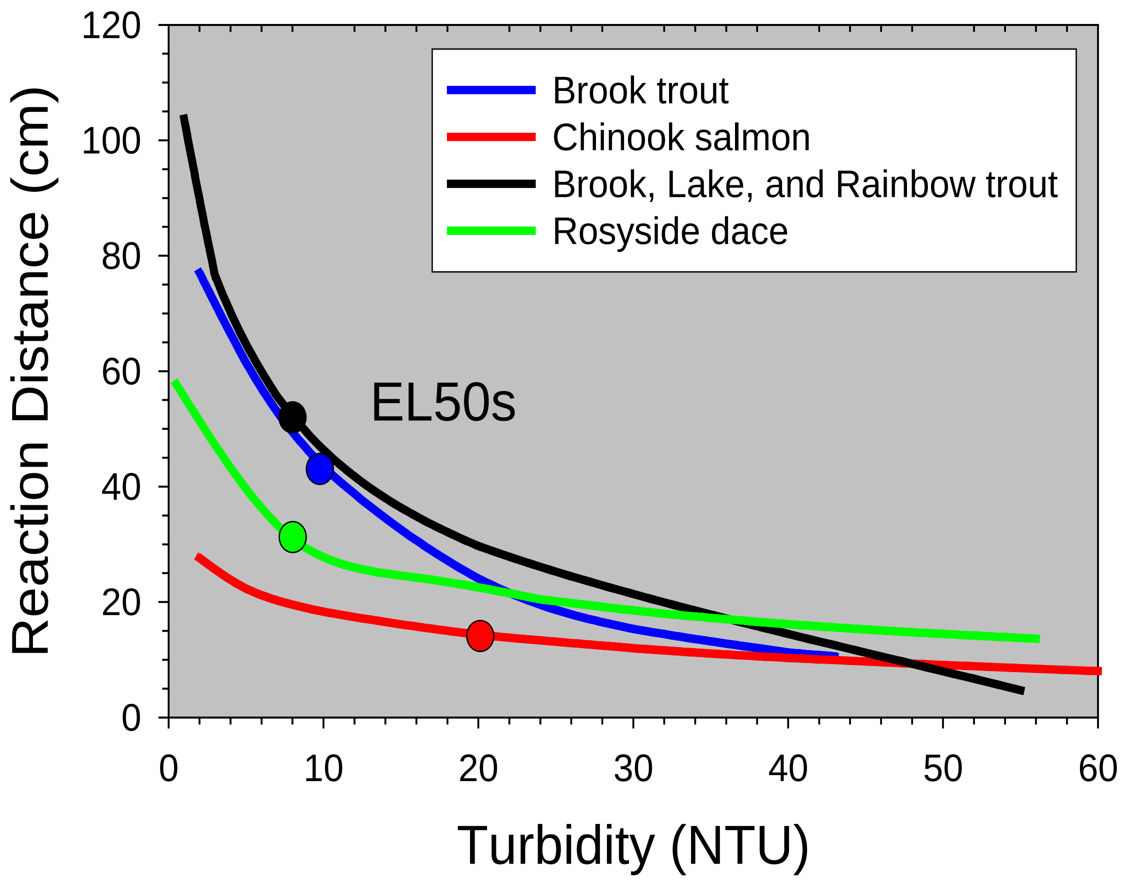
Concentration (kg/m^3)
(30 minute overflow)




Concentration
0.00315
0.0028
0.00245
0.0021
0.00175
0.0014
0.00105
0.0007
0.00035
0.0
Depth (m)
Cross-section Distance (m)

Response Characteristics

- **Severity of effect**
  - **Behavioral**
  - **Sublethal**
  - **Lethal**



Severity of Effect

- **General dose-based model based on meta-analysis of responses of aquatic organisms, including "fishes" (Newcombe & MacDonald 1993)**

$$\mathbf{SEV = 0.738\ log_e\ (concentration\ x\ duration) + 2.179}$$

$$\mathbf{r^2 = 0.64}$$

Severity of Effect

- Refined dose-based model by taxonomic groups: salmonid juveniles, salmonid adults, all fish eggs & larvae, adult estaurine fishes, adult freshwater fishes (Newcombe and Jenson 1996)

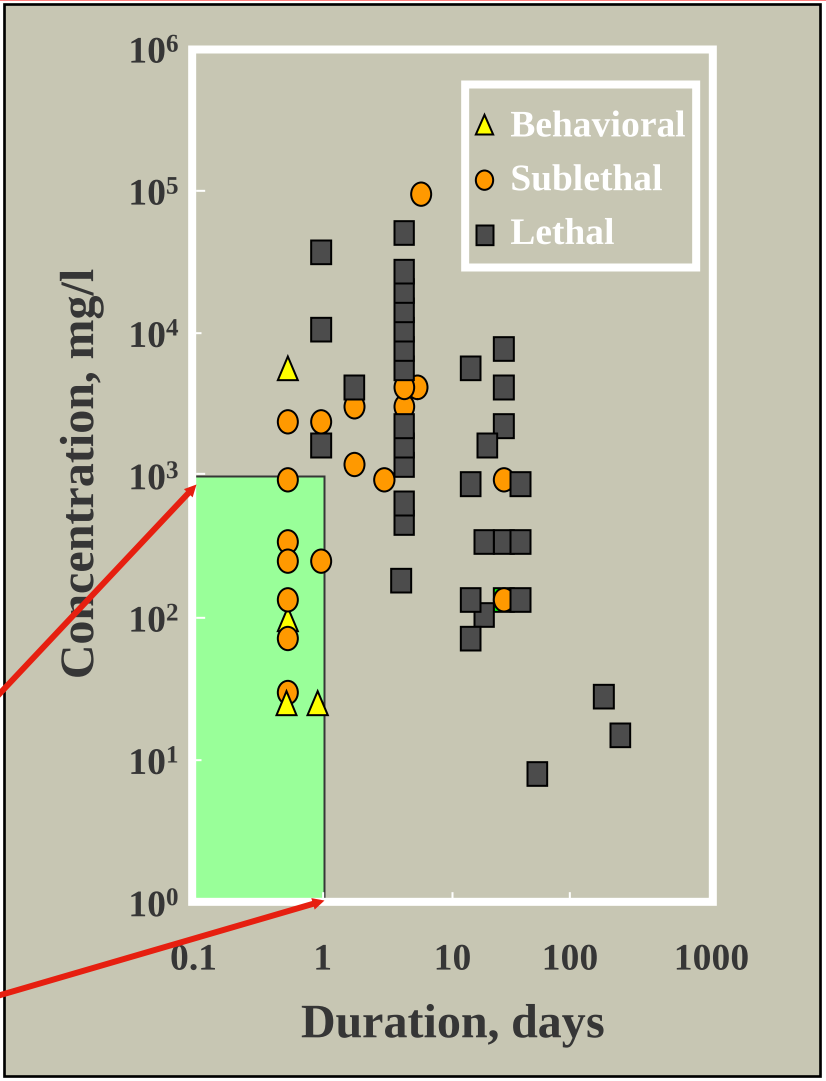
$$SEV = a + b\,(\log_e \text{duration}) = c\,(\log_e \text{concentration})$$

  - Salmonid juveniles - $r^2 = 0.60$
  - Salmonid adults - $r^2 = 0.62$
  - All fish eggs & larvae - $r^2 = 0.55$
  - Adult estuarine fishes - $r^2 = 0.62$
  - Adult freshwater fishes - $r^2 = 0.70$

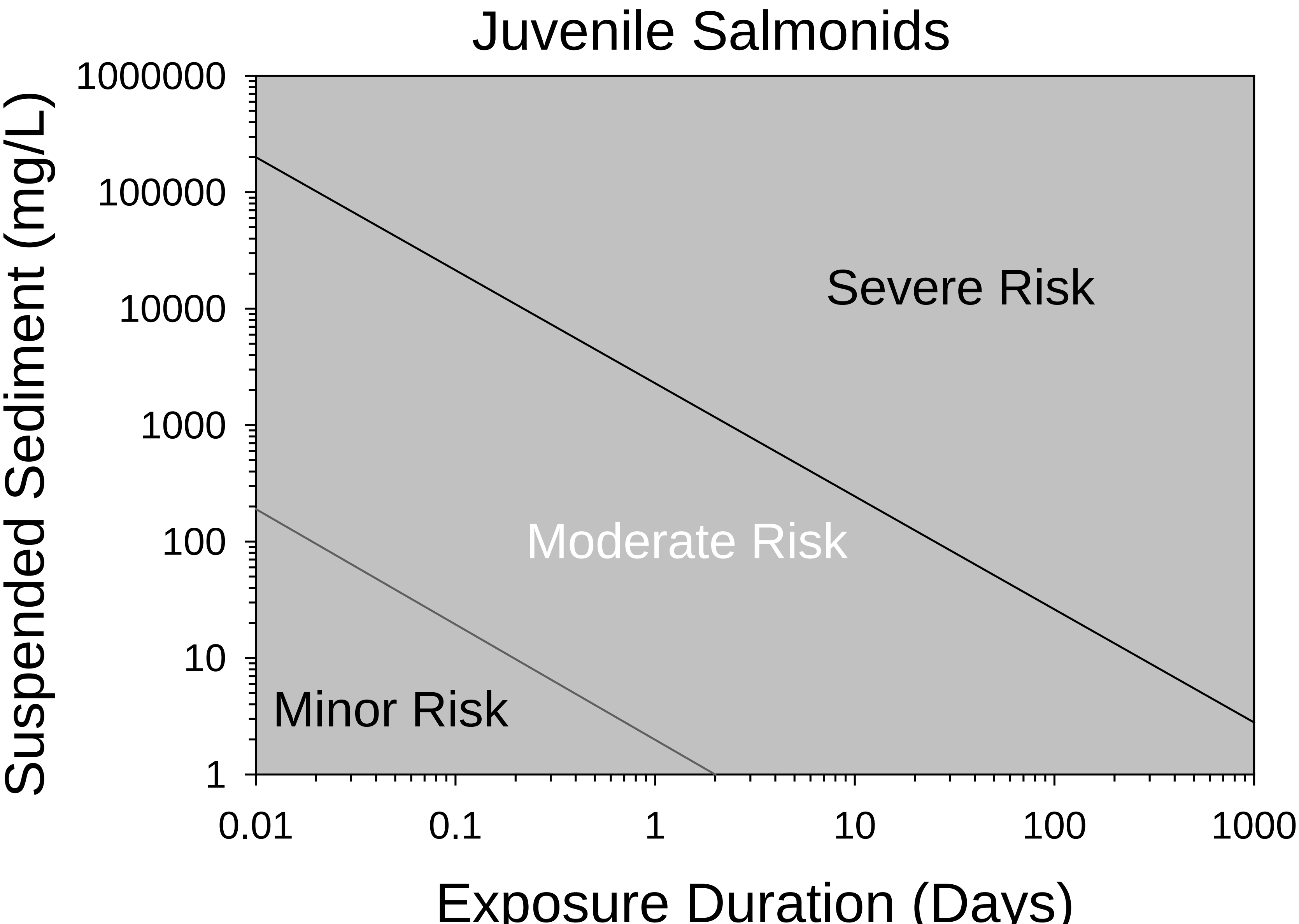
SEV	EFFECT
0	No effects
1	Alarm reaction
2	Abandonment of cover
3	Avoidance response
4	Short-term reduction of feeding rate or success
5	Minor physiological stress; coughing or increased respiration rate
6	Moderate physiological stress
7	Moderate habitat degradation or impaired homing
8	Major physiological stress; long-term reduction in feeding rate or success
9	Reduced growth rate; delayed hatching; reduced fish density
10	0-20% mortality; increased predation; severe habitat degradtion
11	>20-40% mortality
12	>40-60% mortality
13	>60-80% mortality
14	>80-100% mortality

(based on Newcombe and Jensen 1996)

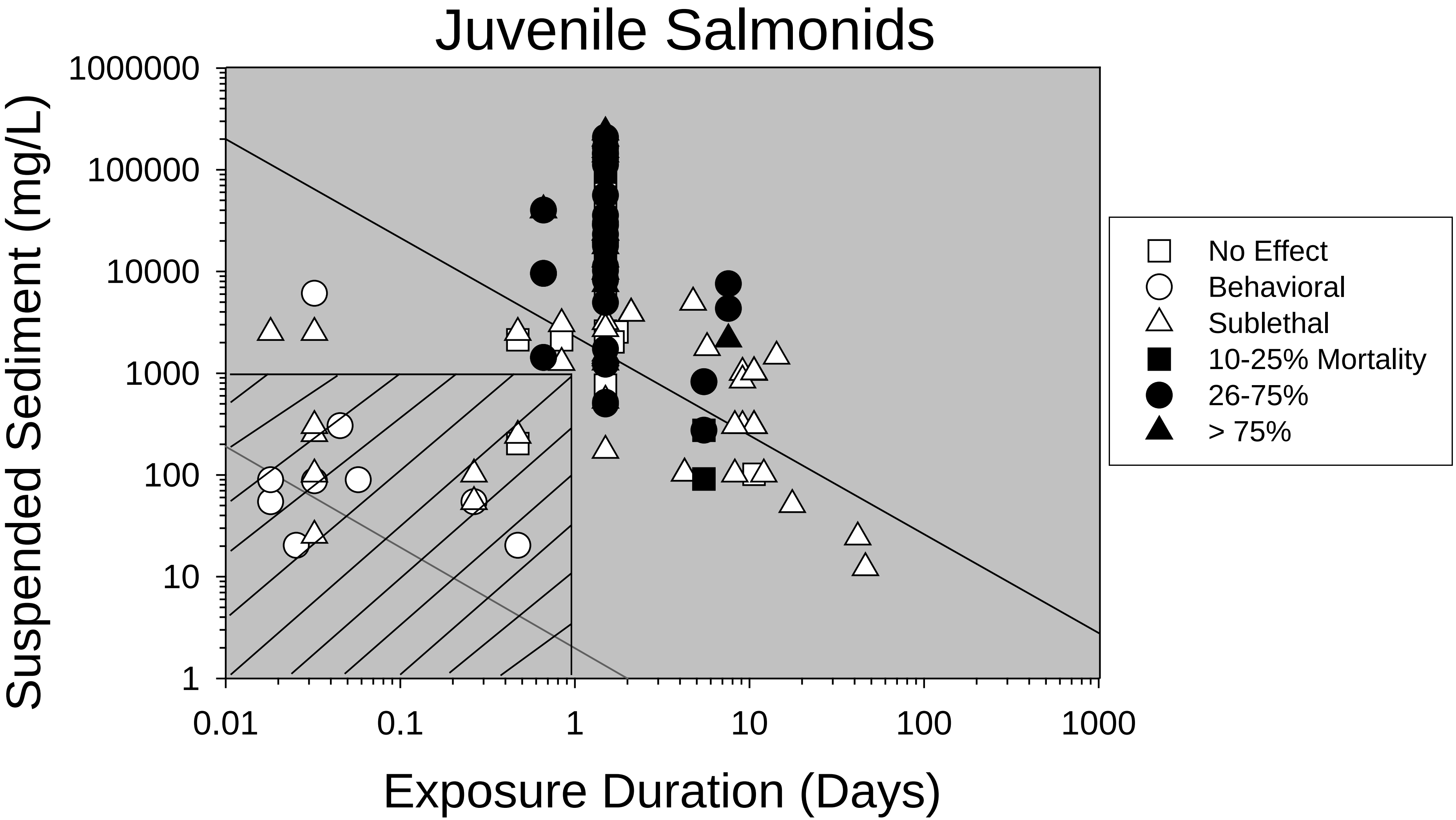
Juvenile Salmonids



Limits of Probable Exposure to Dredge Plumes



Juvenile Salmonids
1000000
100000
10000
1000
100
10
1
Suspended Sediment (mg/L)
Severe Risk
Moderate Risk
Minor Risk
0.01
0.1
1
10
100
1000
Exposure Duration (Days)



Juvenile Salmonids
Suspended Sediment (mg/L)
1000000
100000
10000
1000
100
10
1
0.01
0.1
1
10
100
1000
Exposure Duration (Days)
No Effect
Behavioral
Sublethal
10-25% Mortality
26-75%
> 75%

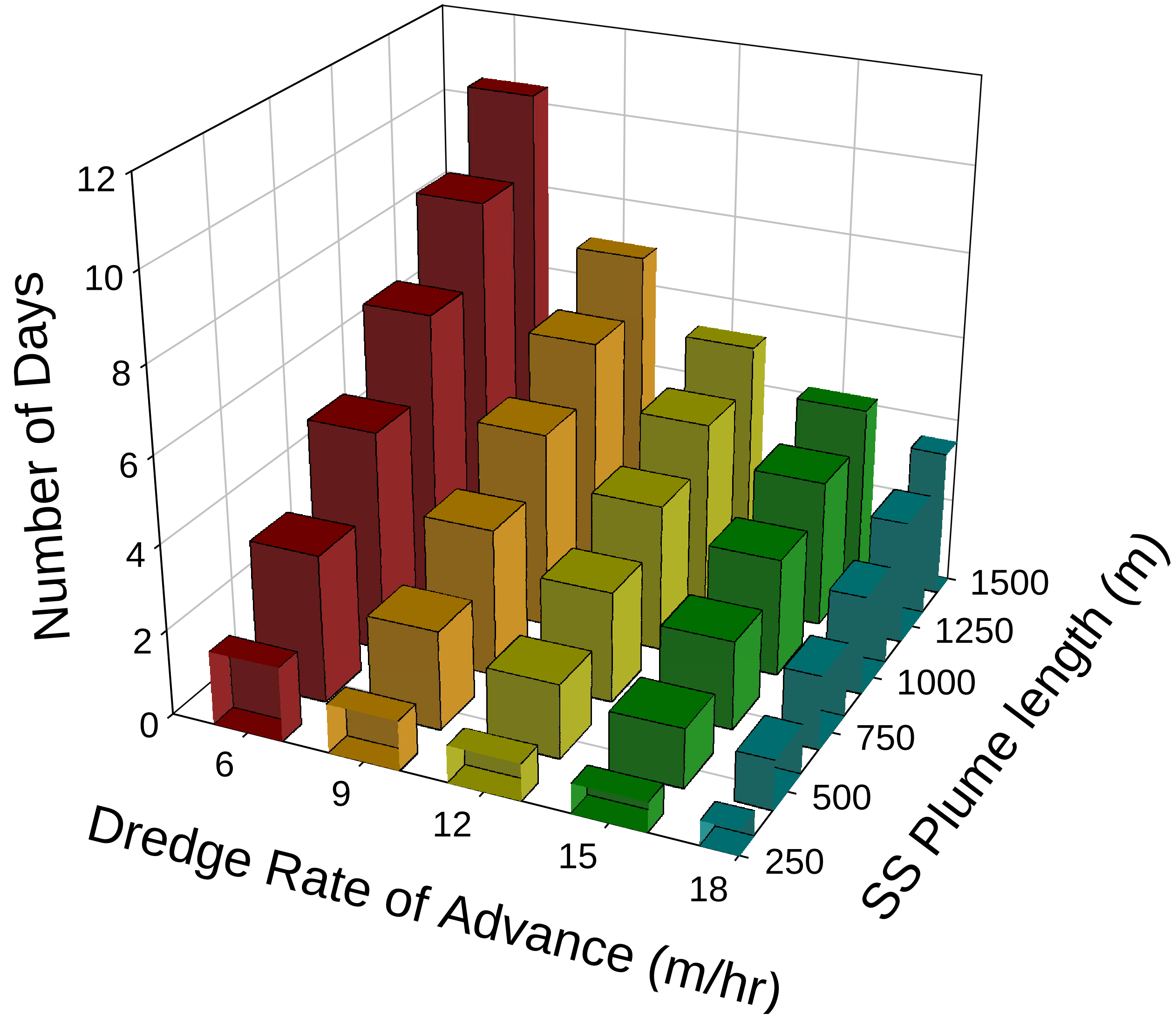
Fish Receptor Response Characteristics

- **Aspects of response relevant to risk management**
  - **Seasonality**
  - **Migration rate affects duration of exposure**
    - **species specific (e.g., 0.75 – 1.5 miles/hr)**
  - **Threshold with respect to maximum exposure**
  - **Threshold with respect to duration**

- **Reliance on lab versus field-derived data**
  - **Behavioral effects based on few observations**
  - **Sublethal effects based on indirect measures (e.g., levels of stress hormones in blood)**
  - **Lethal effects based entirely on lab data using static dose**

Hypothetical SAV Receptor

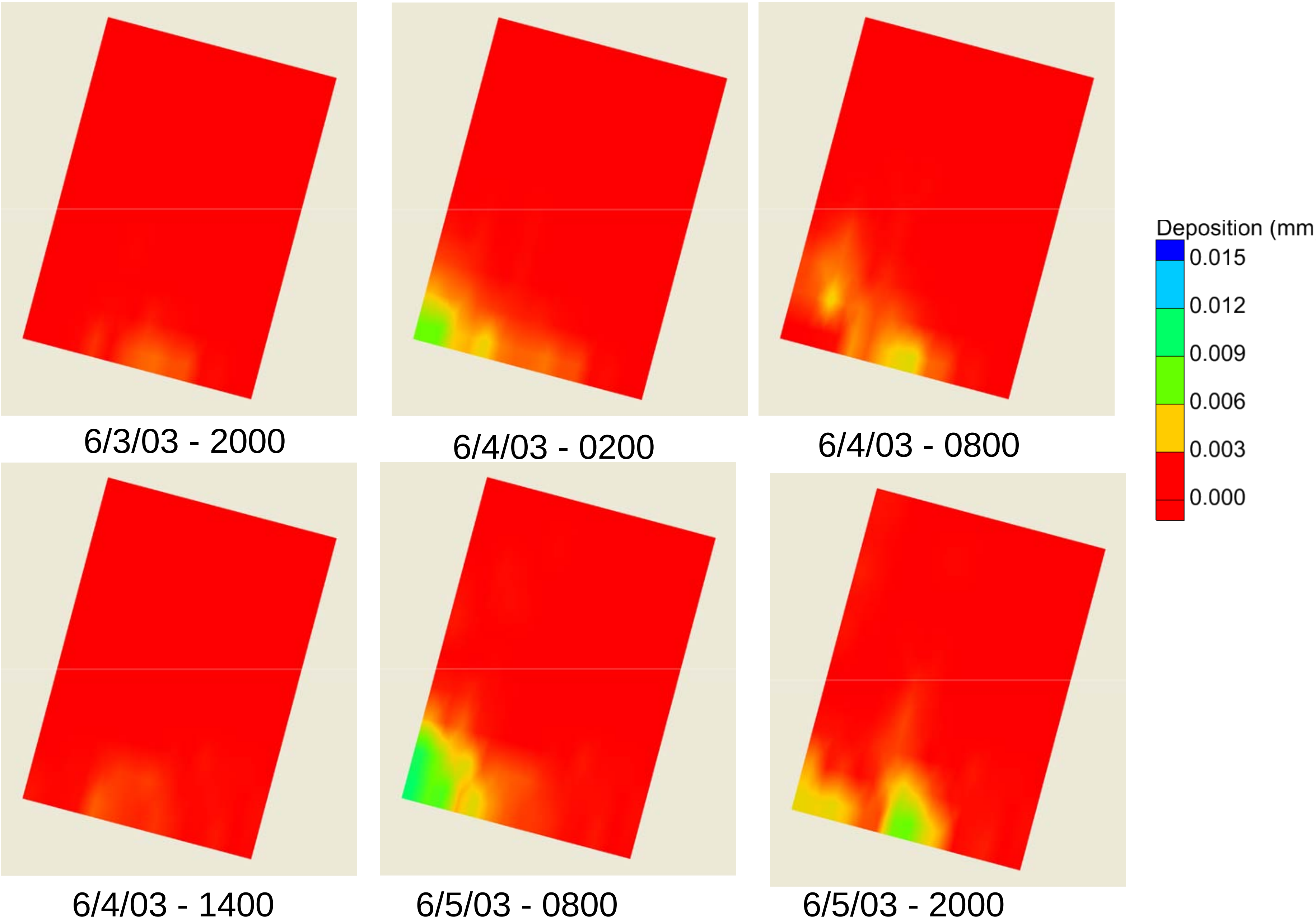
Fuzzy Grass (*Zostera toddistaniensis*)



Duration of exposure for a *sessile receptor* such as SAV or coral will depend on plume dimensions and dynamics in relation to the rate at which the dredge moves through the project site.

(from Wilber and Clarke 2001)

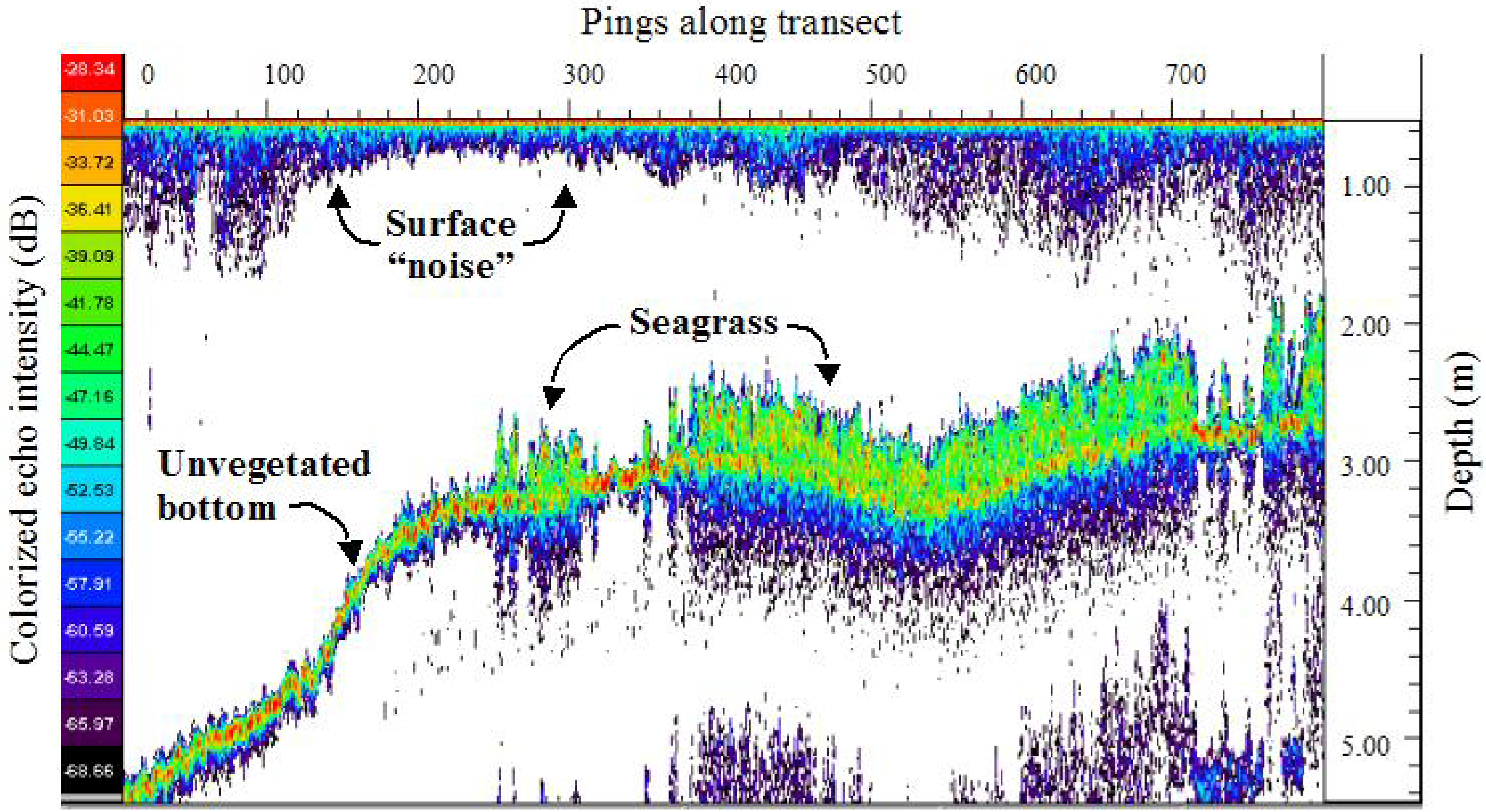
Deposition – 30min overflow



Potential Seagrass Responses

- **Induced by sedimentation**
  - **Differ based on depth of burial and life history**
    - **Modified growth**
    - **Shoot mortality**
- **Induced by shading**
  - **Differ based on duration, presence of ephiphytes, and life history**
  - **Depth distribution**
    - **Altered plant architecture**
    - **Biomass partitioning**
    - **Lateral shoot development**
    - **Flowering intensity**

Effects of light deprivation generally first observed along deep fringes of beds, or by deeper-dwelling species

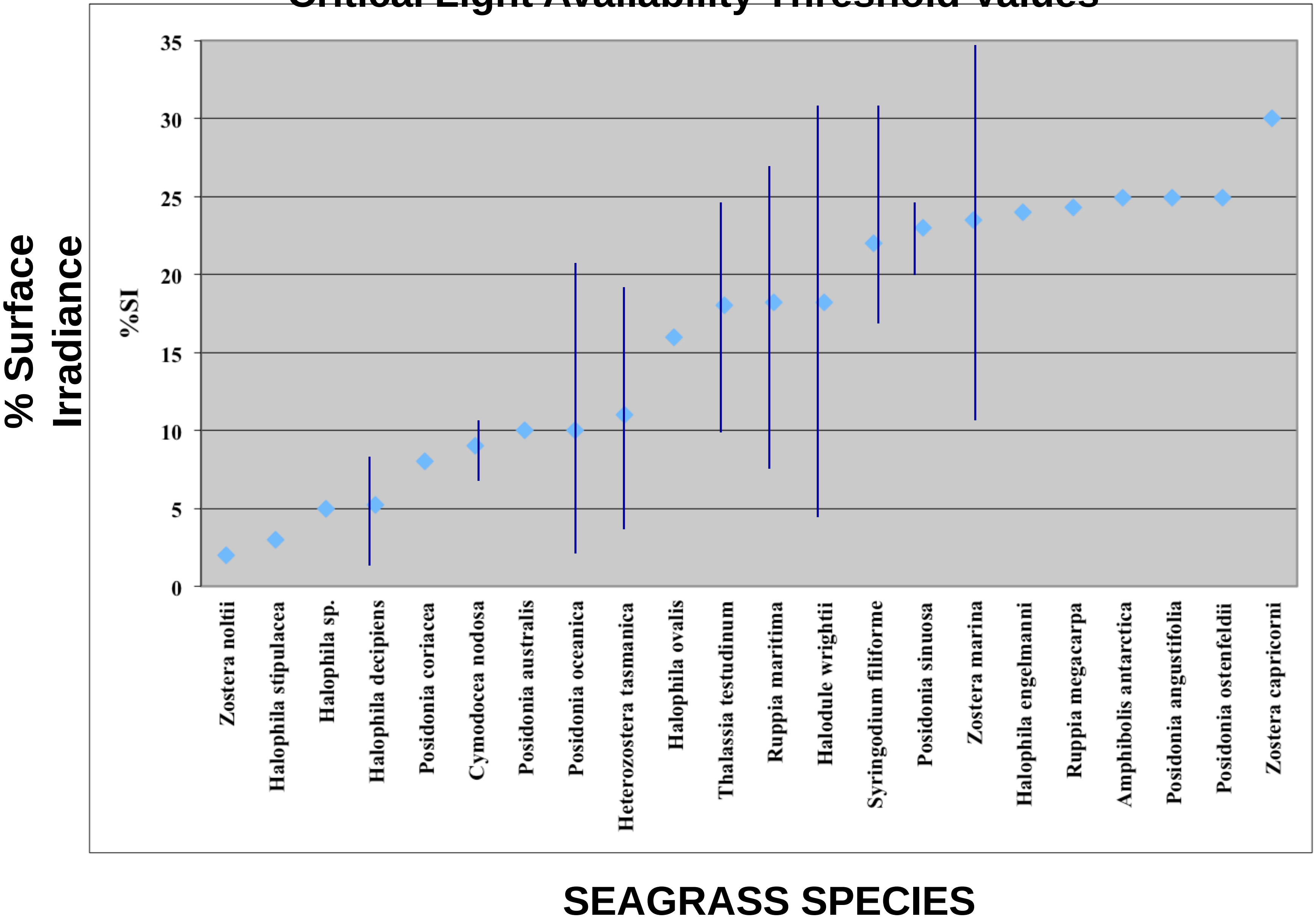


Shading Effects

- **Difficult to relate effects to conventional measurements of turbidity (e.g., NTUs)**

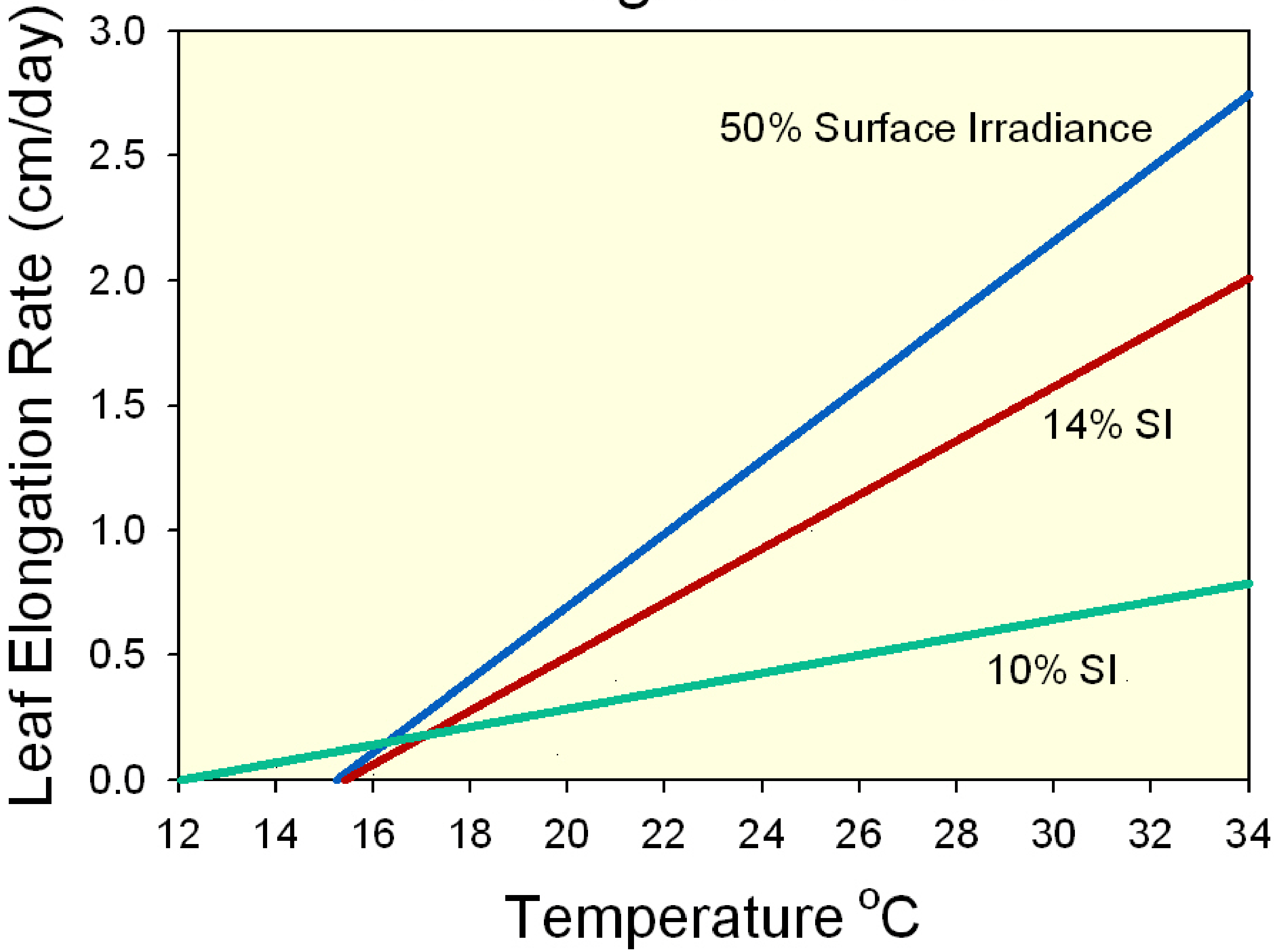
- **Most effective monitoring studies measure light attenuation as a function of Surface Irradiance (SI), or as photosynthetically available radiation (PAR)**

Critical Light Availability Threshold Values



(from Erftemeijer and Short 2006)

Reduced Light Effects on Seagrass Growth

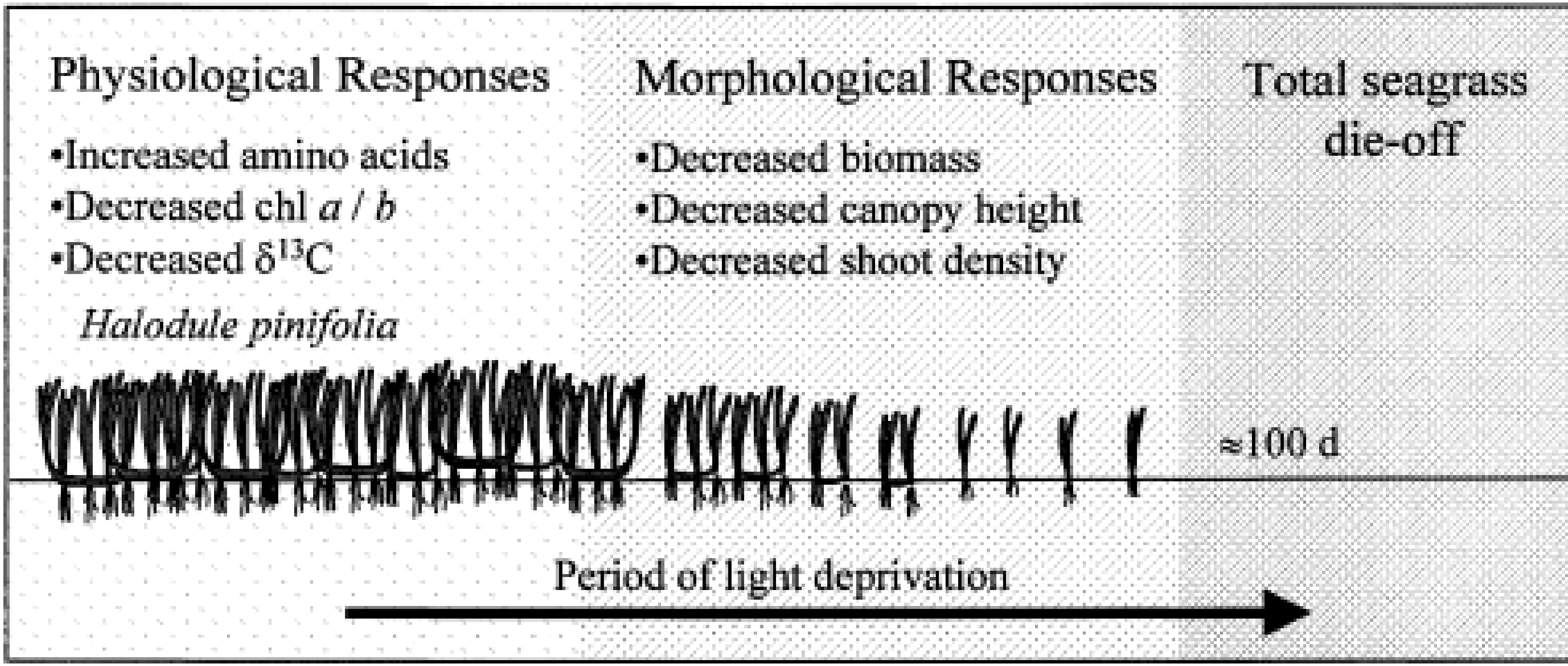


(from *Czerny and Dunton 1995*)

Seagrass Species	Light Availability	Survival (Month)
Halodule pinifolia	0	3-4
Halodule wrightii	13-15% SI	9
Halophila ovalis	0	1
Heterozostera tasmanica	9% SI	10
Heterozostera tasmanica	2% SI	2-4
Posidonia sinuosa	12% Ambient	24
Thalassia testudinum	10% SI	11
Zostera capricorni	5% SI	1
Zostera noltii	<2% SI	0.5

(from Erftemeijer and Short 2006)

Effects of Turbidity on Seagrasses



(*from Longstaff and Denston 1999*)

Effects of Turbidity on Seagrasses

Physiological Stress	Increased amino acid content Decreased Chl a/b ratios Decreased ^{13}C values Decreased carbohydrate content of rhizomes Decreased tissue nutrient contents
Morphological Changes	Reduced shoot density Reduced lateral shoot formation Reduced leaf density Reduced leaf length Reduced below-ground biomass Reduced canopy height
Lethal	Mortality largely dependent on duration of light deficit (e.g., 50% after 200 days of SI from 46% to 14%)

Seagrass Response Summary

- **Short-term burial events can produce severe effects, but recovery can be relatively rapid**
- **Chronic reduced light availability generally produces substantial damage with low probability of full recovery**

Seagrass Species	Critical Threshold for Sedimentation (cm/yr)
Cymodocea nodosa	5
Cymodocea rotundata	1.5
Cymodocea serrulata	13
Enhalus acroides	10
Halophila ovalis	2
Posidonia oceanica	5
Zostera noltii	2

(from Erftemeijer and Short 2006)

Effects of Sedimentation on Seagrasses

Sublethal

- Interference with photosynthesis
- Decline in shoot density
- Decline in species richness if silt/clay content exceeds 15%
- Modification of vertical growth to relocate meristems
- Physical removal during dredging process
- Mortality associated with partial or total burial

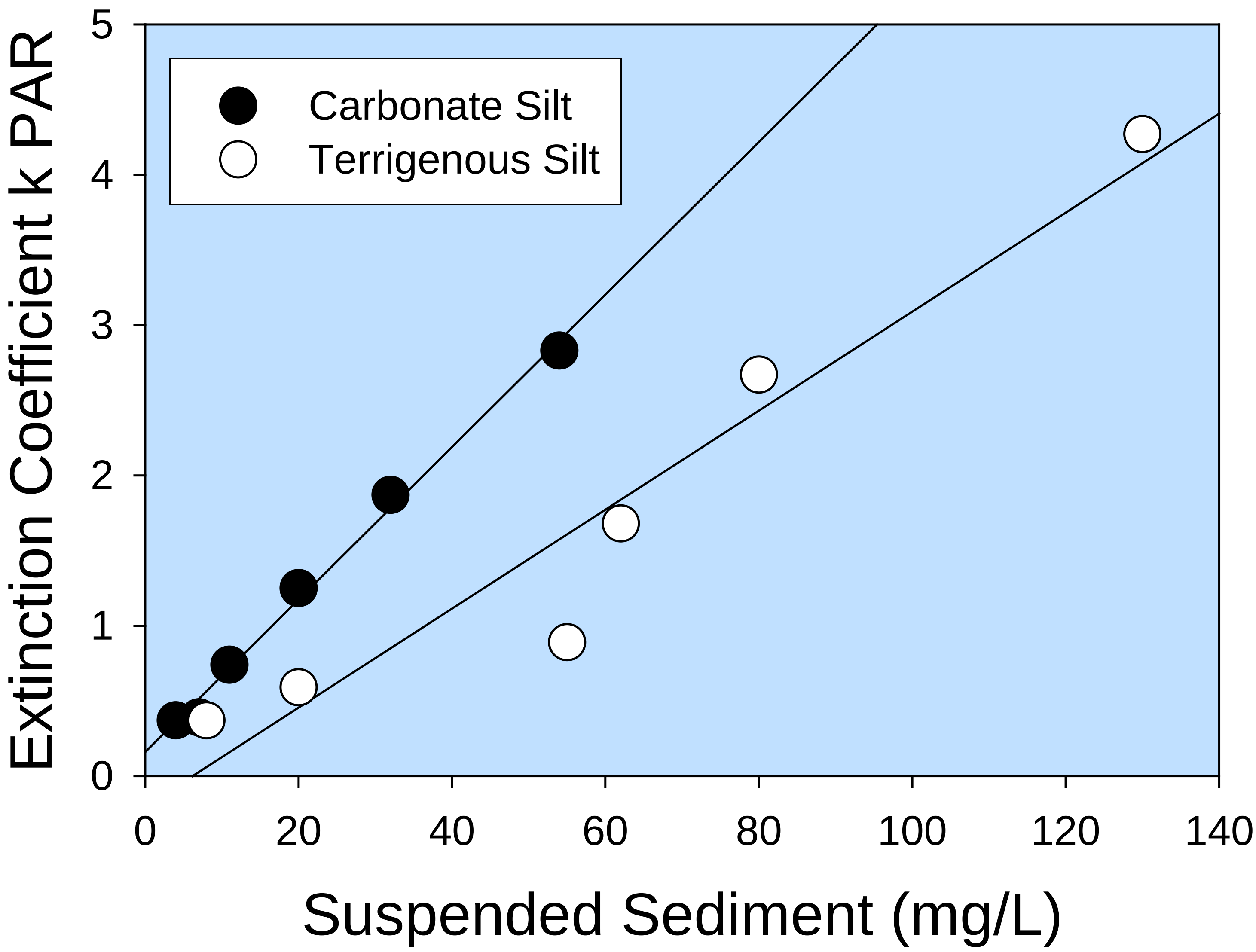
Lethal

- Physical removal during dredging process
- Mortality associated with partial or total burial

Hypothetical Coral Receptor

Brainy Coral (*Dufus idontknowicus*)

Image courtesy of Reef Relief website



Carbonate Silt
Terrigenous Silt
Extinction Coefficient k PAR
Suspended Sediment (mg/L)
0
1
2
3
4
5
0
20
40
60
80
100
120
140

(*from Te 1997*)

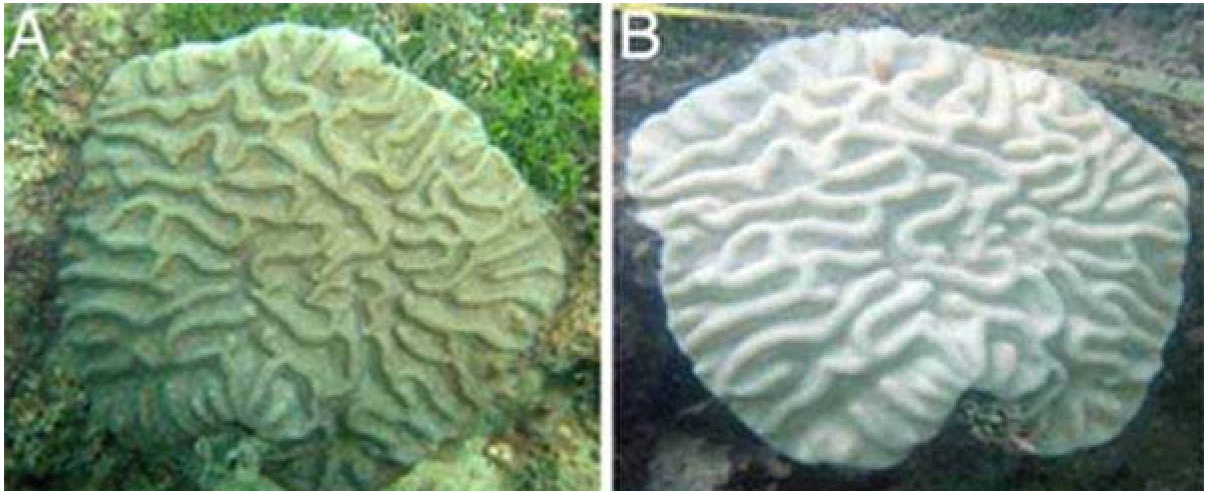
Potential Coral Responses

- **Acute effects**
  - Smothering and burial – most corals can survive burial for less than several hours
- **Chronic effects**
  - Induced by sedimentation and/or turbidity
    - Normal rates generally < 10 $mg/cm^2/day$
  - Reduced net productivity
  - Decreased respiration
  - Decreased growth rate
  - Bleaching and mortality

Image courtesy of Reef Relief website

Effects of Turbidity on Coral Reefs

- **Mucus production**
- **Increased respiration**
- **Decreased photosynthetic production**
- **Lower density of zooxanthellae (“bleaching”)**
- **Lower calcification / growth**
- **Bleaching and mortality**

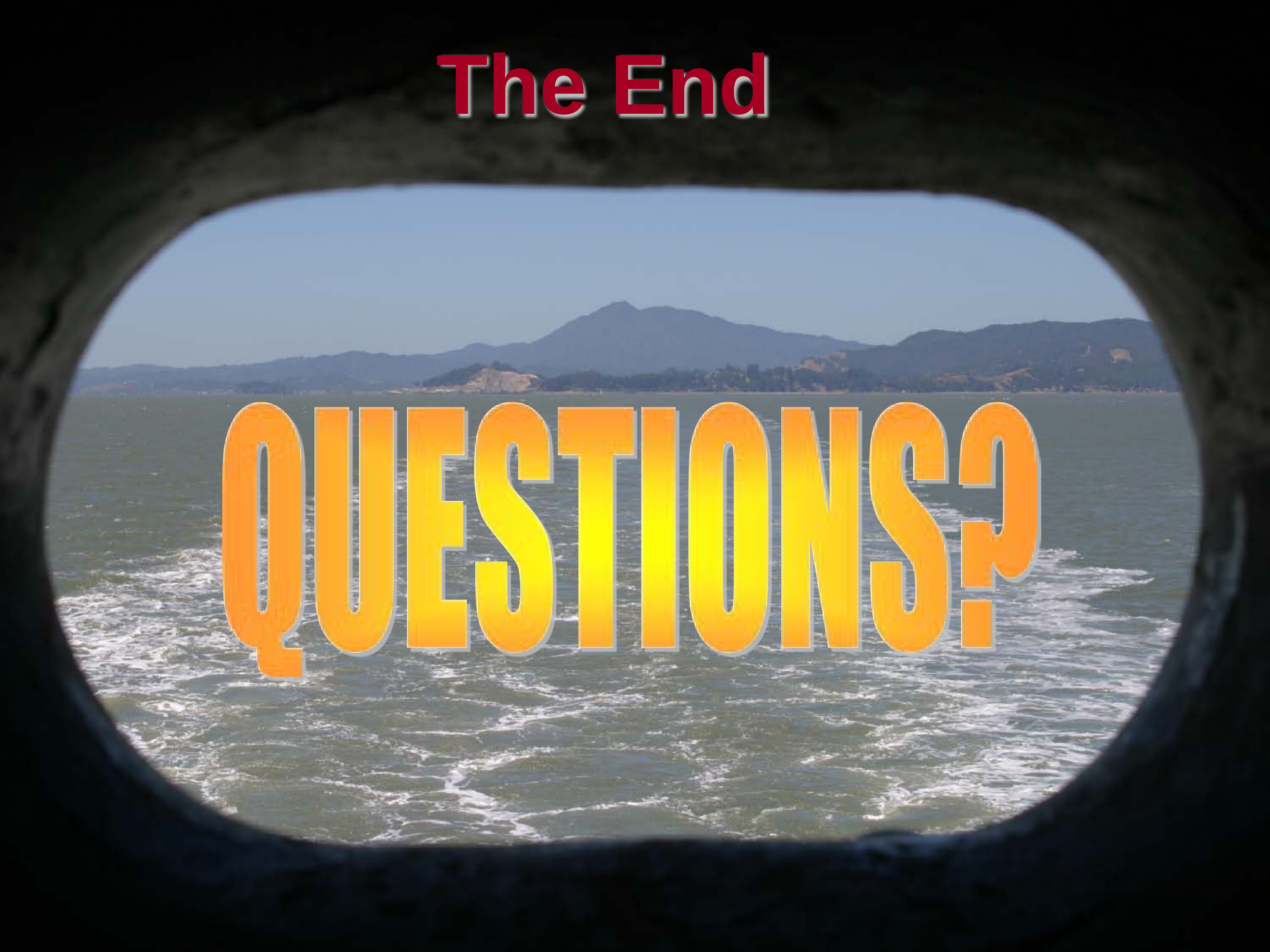


Pre-bleached **Bleached**

Photo credit: http://environment.newscientist.com

Effects of Sedimentation on Coral Reefs

Behavioral Responses	Use of tentacles and cilia to reject particles Stomodeal distension through uptake of water Entanglement of sediments in mucus Feeding response impaired Altered oral openings
Physiological Responses	Lower density of zooxanthellae (bleaching) Oxygen production decreased Nitrate uptake decreased Change in excretion rate/excretion products Reduced gonad development Interferes with recruitment Decreased calcification / growth Decrease in net production Increase in respiration rate Altered morphology Presence of parasites/pathogens
Lethal	Coral tissue smothered


The End
QUESTIONS?

Key References

- Edmunds, M. et al. 2004. Seagrass impact and risk assessment. Ch. 16 in Port Phillip Bay Channel Deepening Project Environmental Effects Statement – Marine Ecology Specialist Studies, Port of Melbourne Corp.
- Erftemeijer, P. and Lewis, R. 2006. Environmental impacts of dredging on seagrasses: A review. Mar. Poll. Bull. 52:1553-1572
- Fleming, S. et al. 2005. Magnitude-duration based ecological risk assessment for turbidity and chronic temperature impacts: Method development and application to Millionaire Creek. British Columbia Ministry of Environment, Surrey.
- Newcombe, C. and Jenson, J. 1996. Channel suspended sediment and fisheries: A synthesis for quantitative assessment of risk and impact. N. Amer. J. Fish. Management 16:693-727
- Rogers, C. 1979. The effect of shading on coral reef structure and function. J. Exp. Mar. Biol. Ecol. 41:269-288
- Rogers, C. 1983. Sublethal and lethal effects of sediments applied to common Caribbean reef corals in the field. Mar. Poll. Bull. 14:378-382
- Rogers, C. 1990. Responses of coral reefs and reef organisms to sedimentation. Mar. Ecol. Prog. Ser. 62:185-202
- Te, F. 1997. Turbidity and its effect on corals: A model using the extinction coefficient (K) or photosynthetic active radiance (PAR). Proc. 8th Intern. Coral Reef Symp. 2:1899-1904
- Wilber, D. and Clarke, D. 2001. Biological effects of suspended sediments: A review of suspended sediment impacts on fish and shellfish with relation to dredging activities in estuaries. N. Amer. J. Fish. Management 21(4):855-875