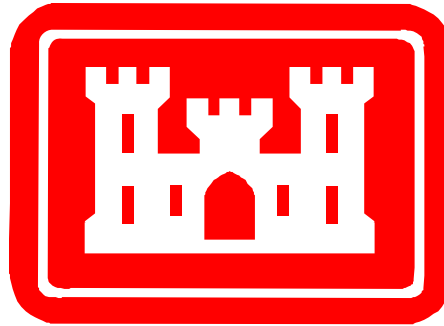


---

# EFFECTS ASSESSMENT



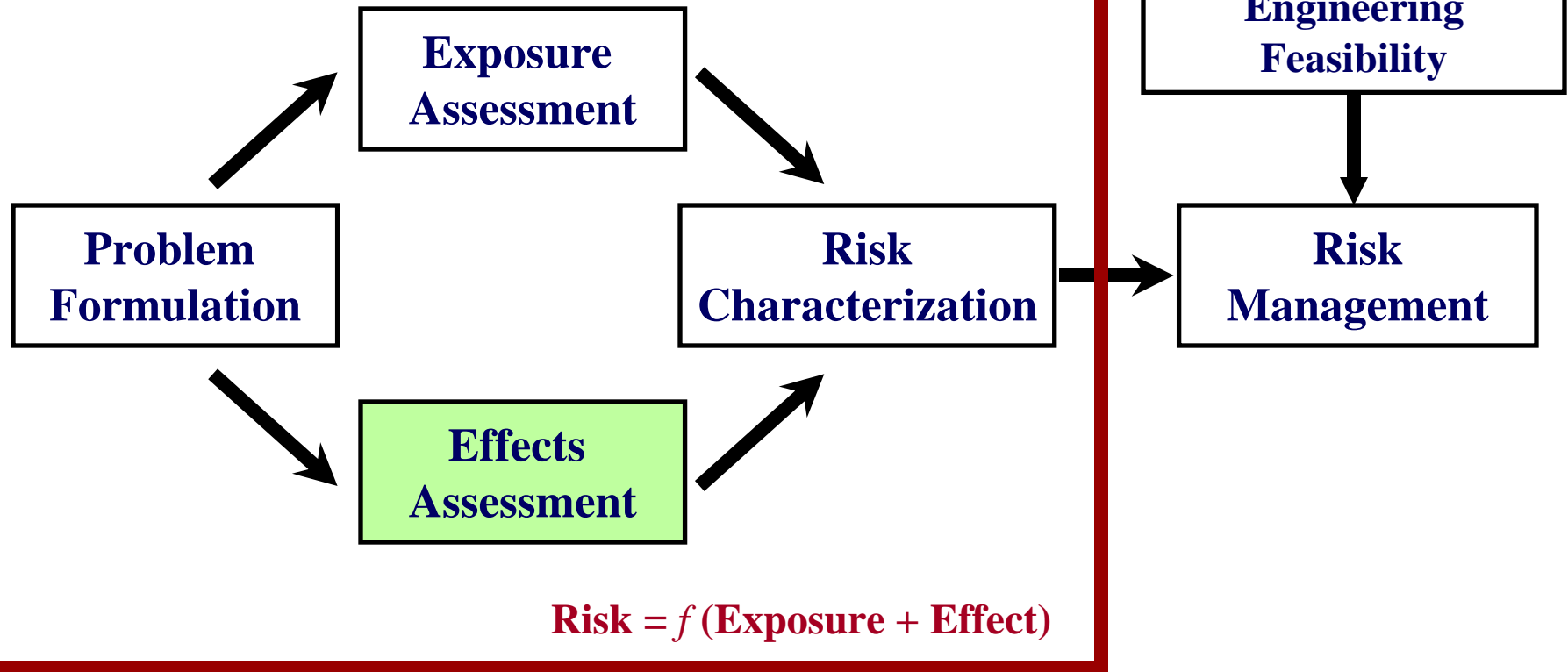
**Doug Clarke**

***Douglas.G.Clarke@usace.army.mil***



# RISK FRAMEWORK

## RISK ASSESSMENT PARADIGM



# Topics

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



# **Ssssome Receptors of Interest**

---

**SUBMERGED AQUATIC VEGETATION**

**SEA TURTLES**

**STRIPED BASS**

**STURGEON**

**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

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



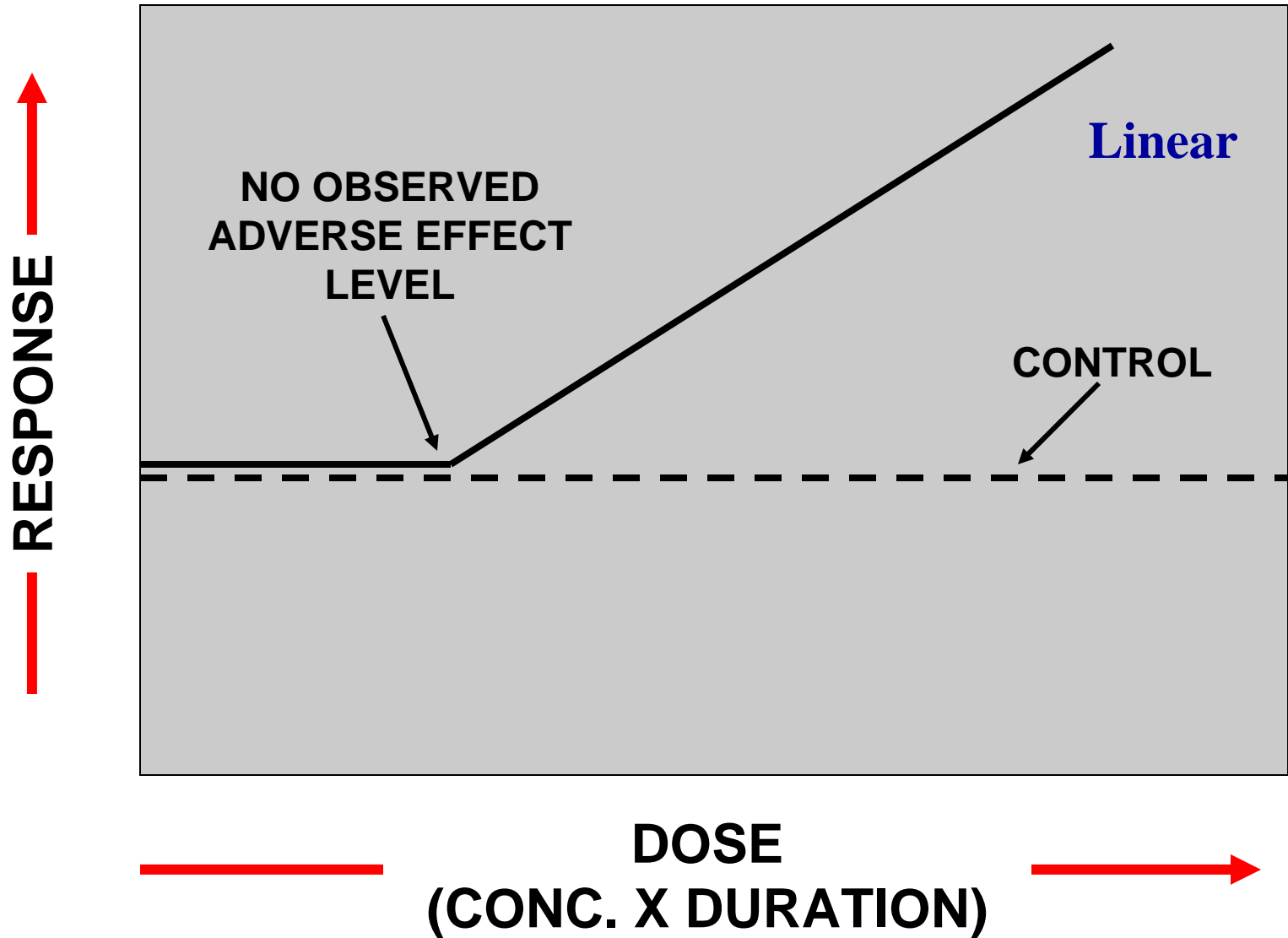
# Factors That Influence Effects

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

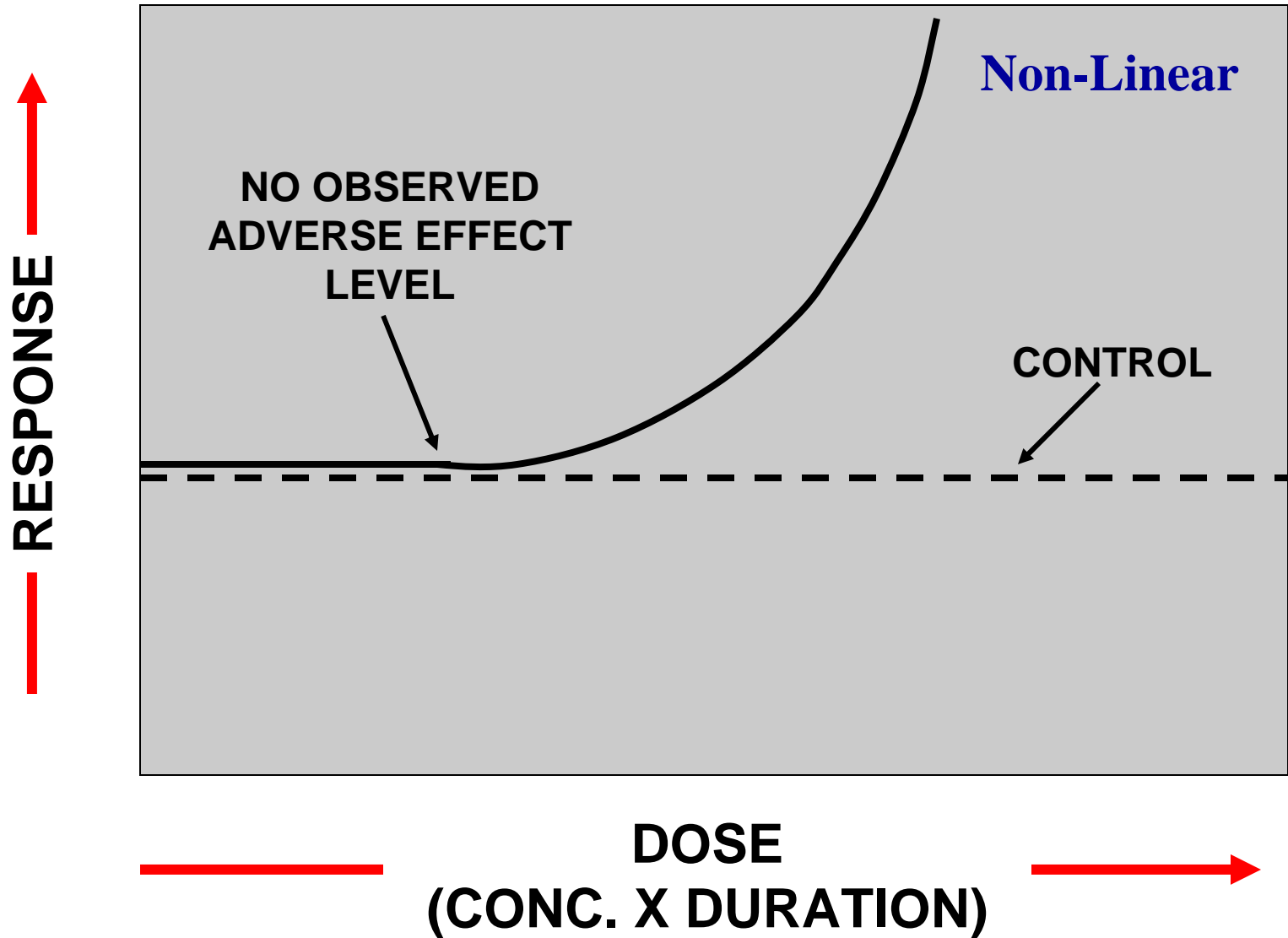


# THRESHOLD MODEL





# THRESHOLD MODEL



# Hypothetical Receptors

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- **Outmigrating juvenile salmon**
- **Adhesive fish eggs at offshore spawning habitat**
- **Endangered freshwater mussels**



# LAKE IMPERIAL

Spawning Habitat

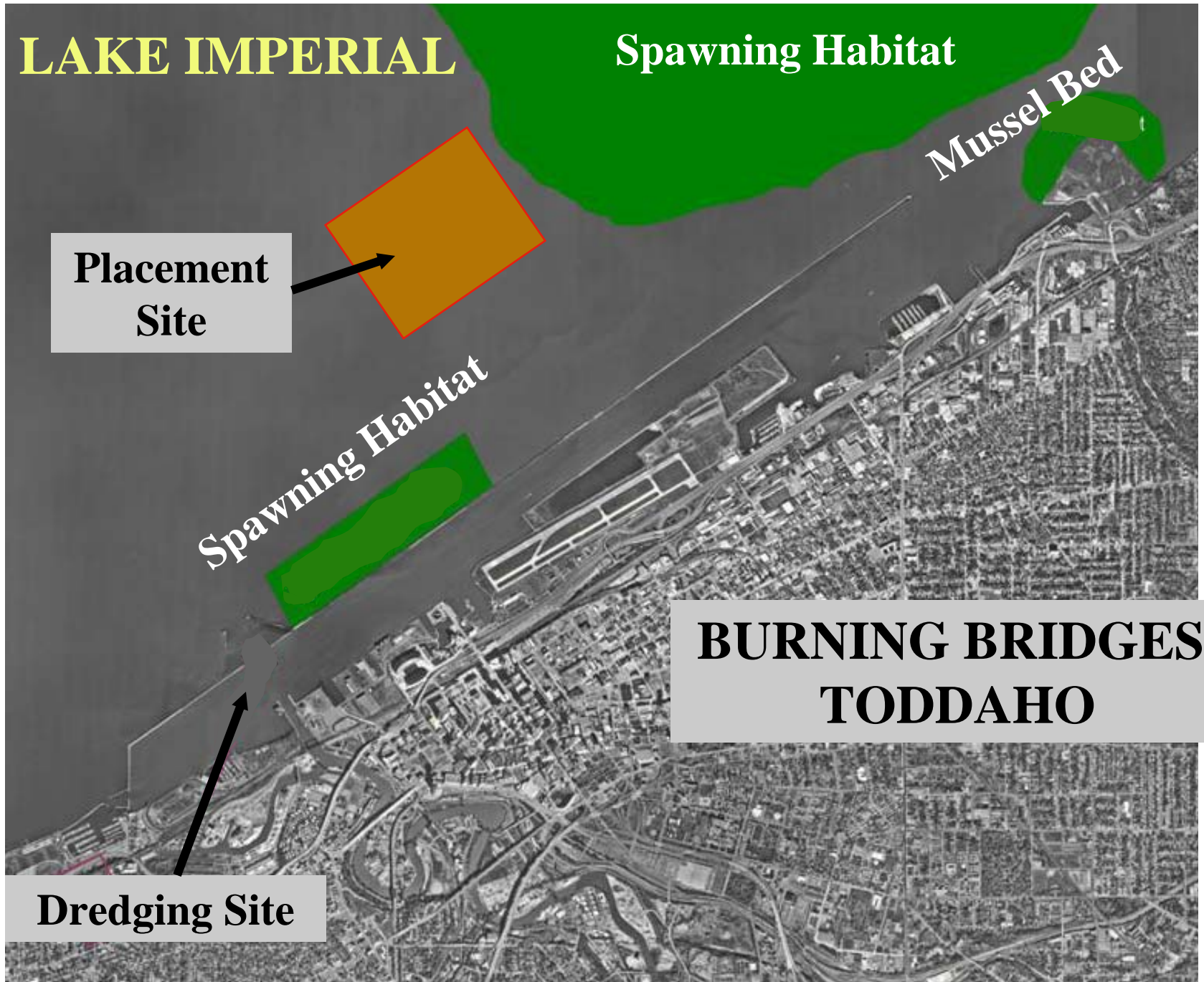
Mussel Bed

Placement  
Site

Spawning Habitat

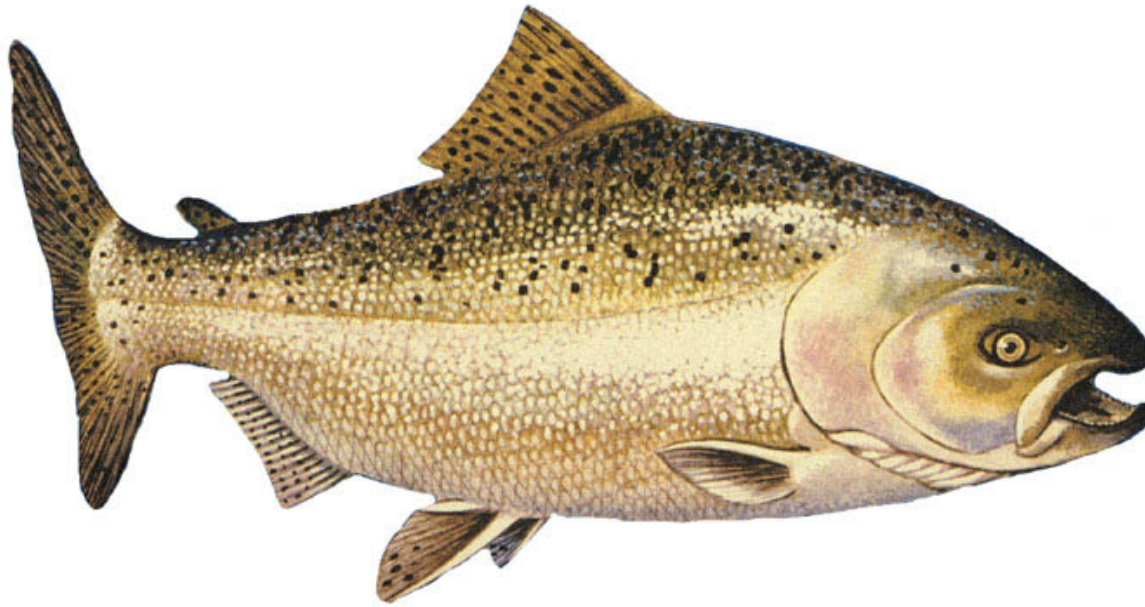
**BURNING BRIDGES,  
TODDAHO**

Dredging Site



# ***Hypothetical Fish Receptor***

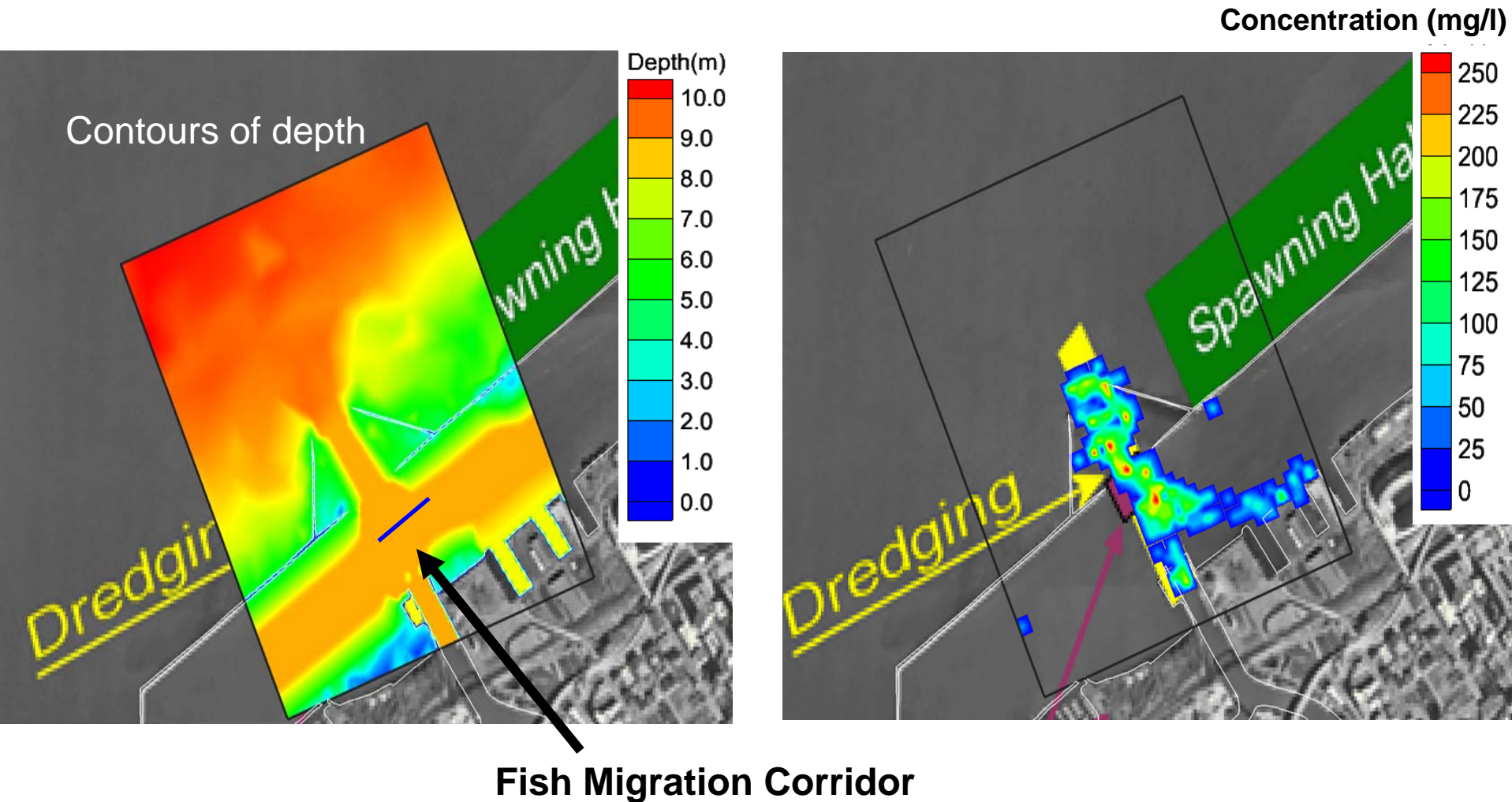
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**Ironhead Salmon**  
***(Oncorhynchus whopperi)***

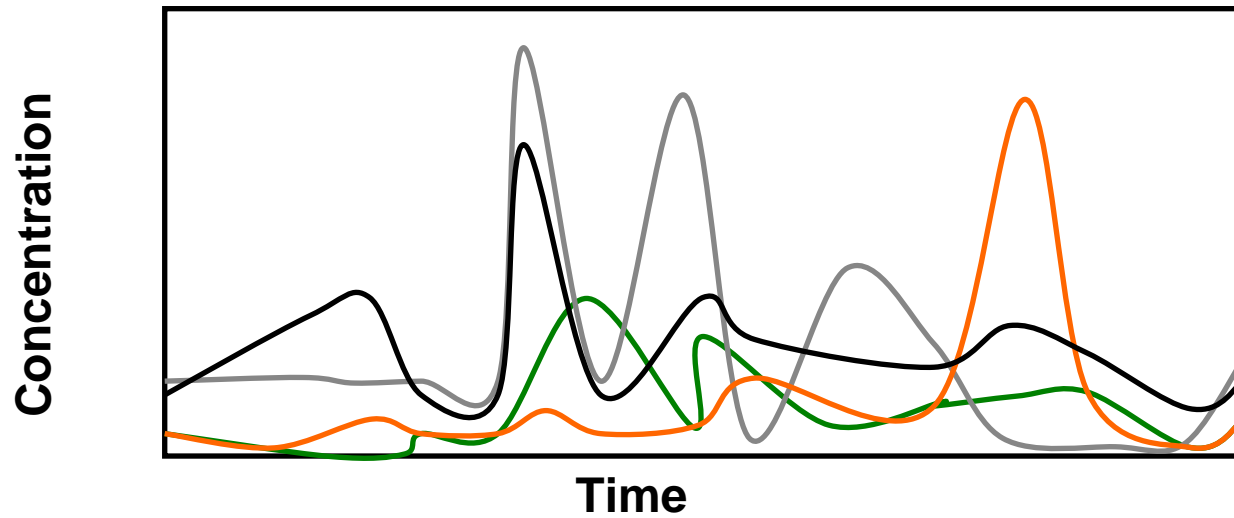
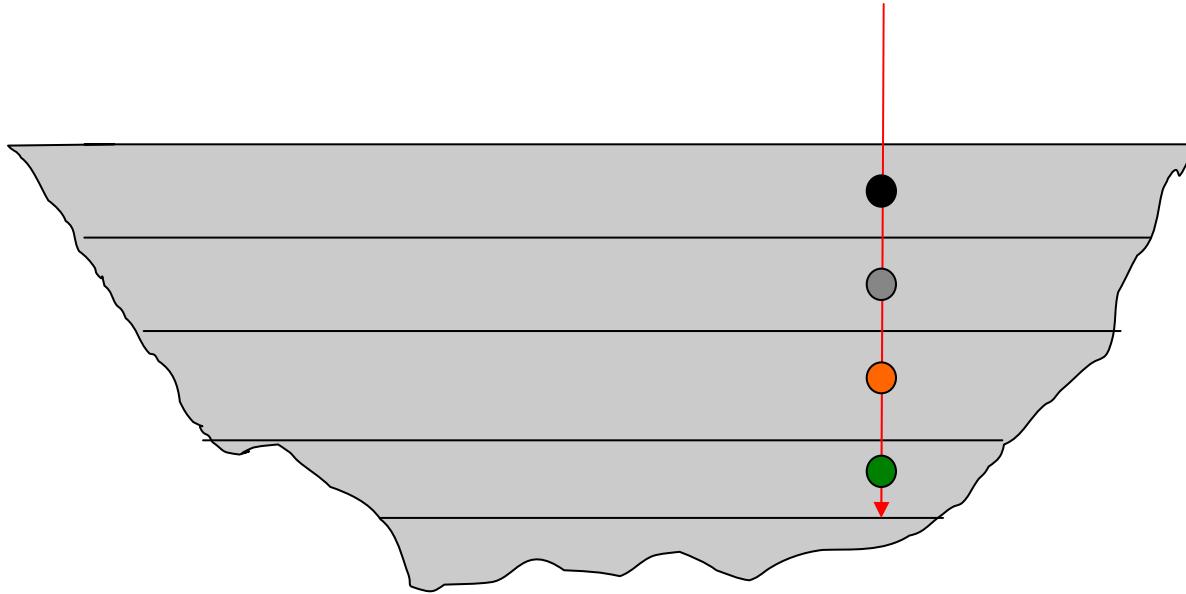


# Fish Exposure to Plumes

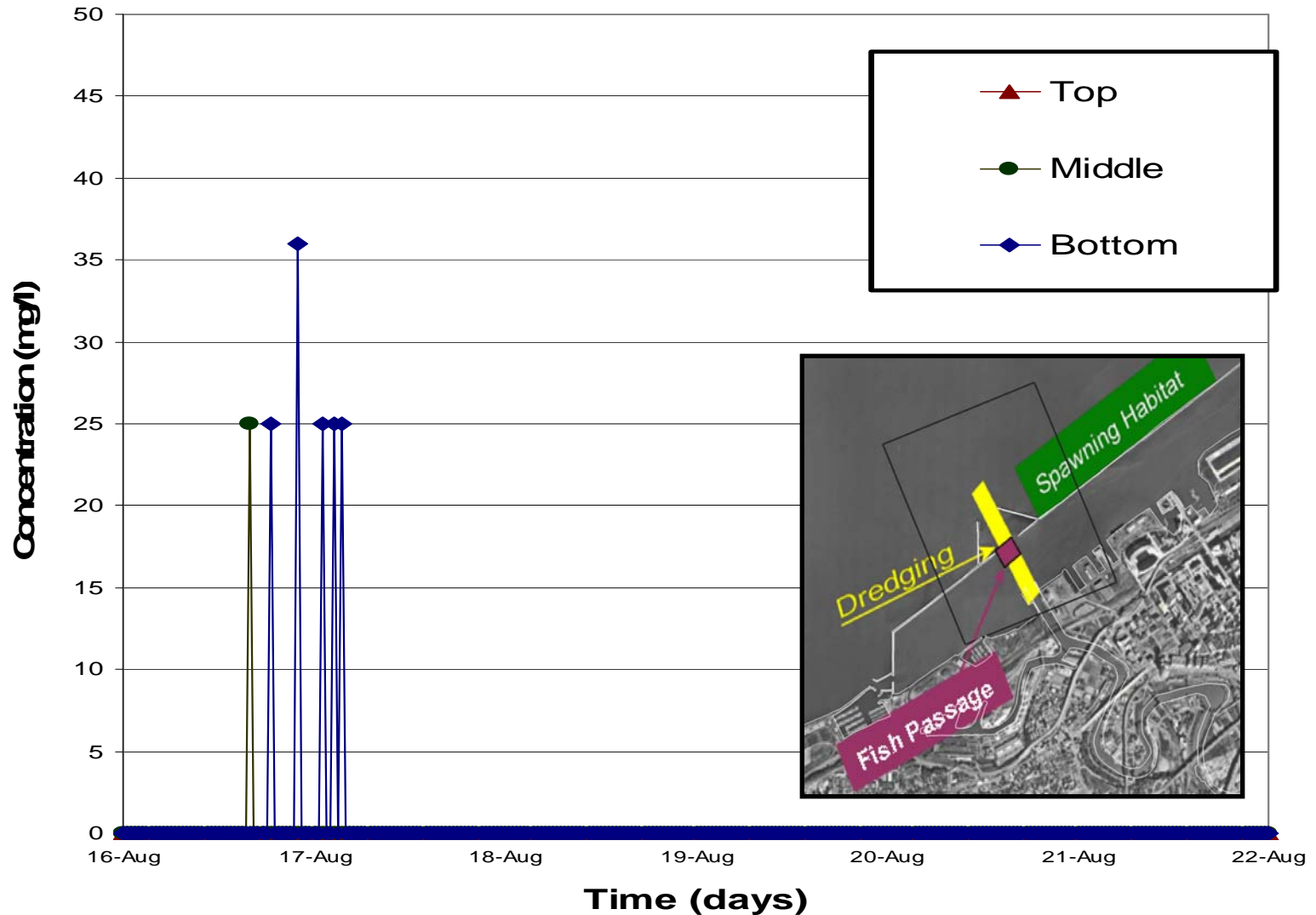




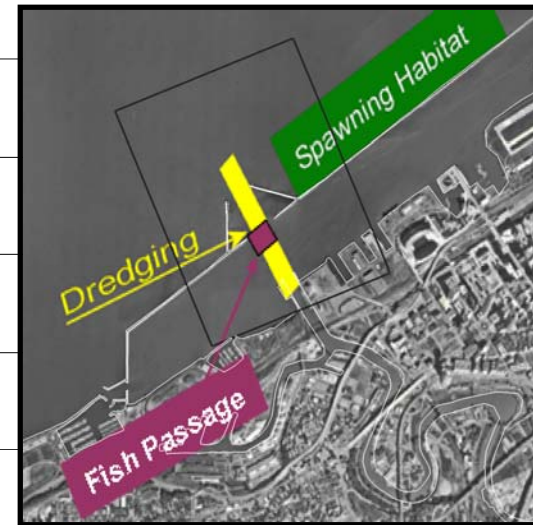
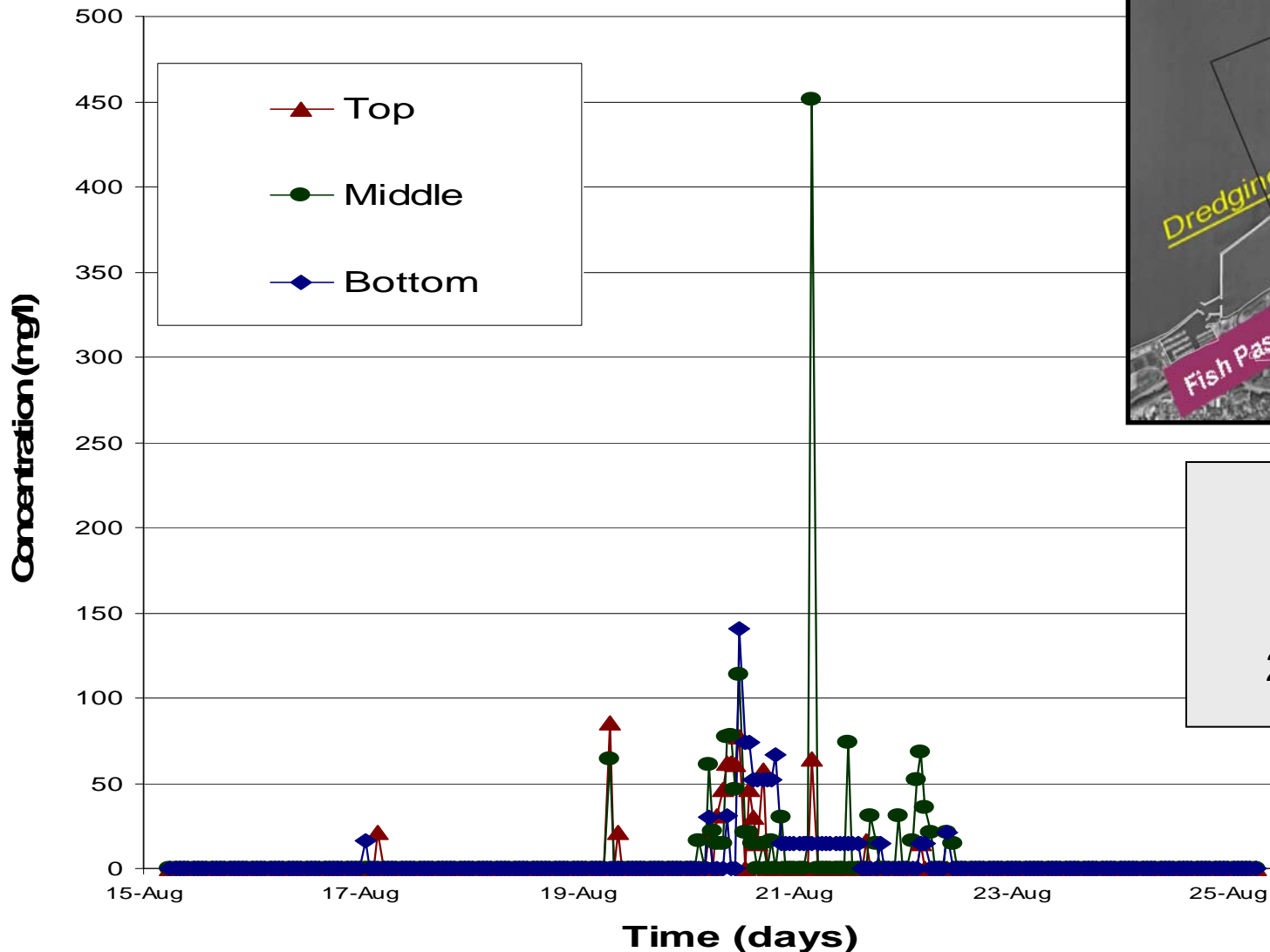
# Dynamic Dose



# Hopper Dredge TSS Time Series



# Bucket Dredge TSS Time Series



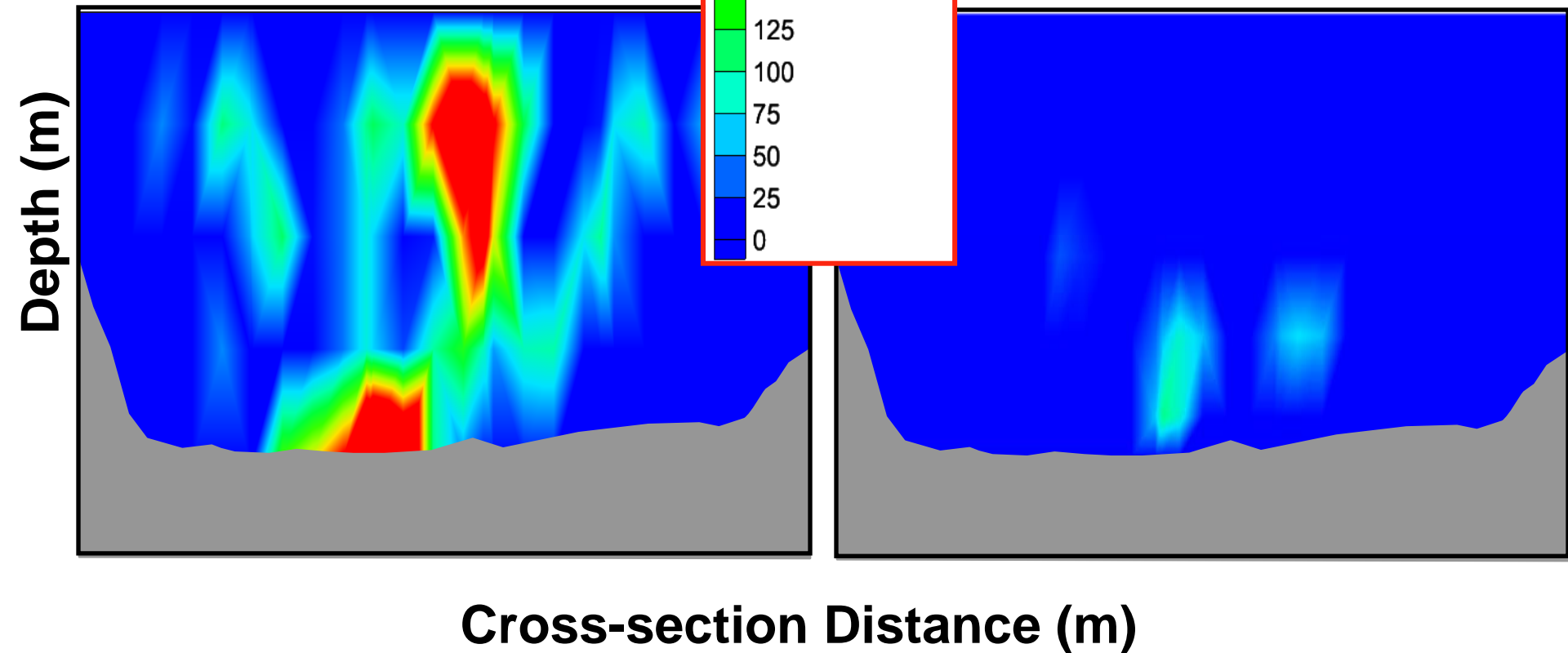
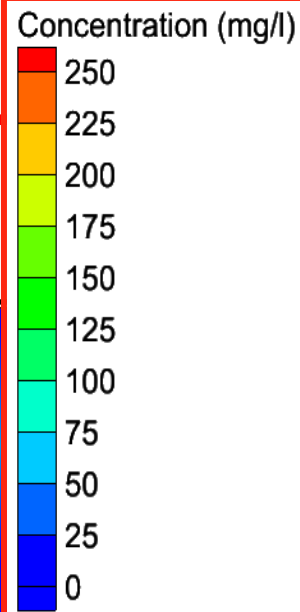
$$D = \int C dt$$

$$2.2 \text{ kg} \cdot \text{hr} / \text{m}^3$$



## Bucket Dredge Plume

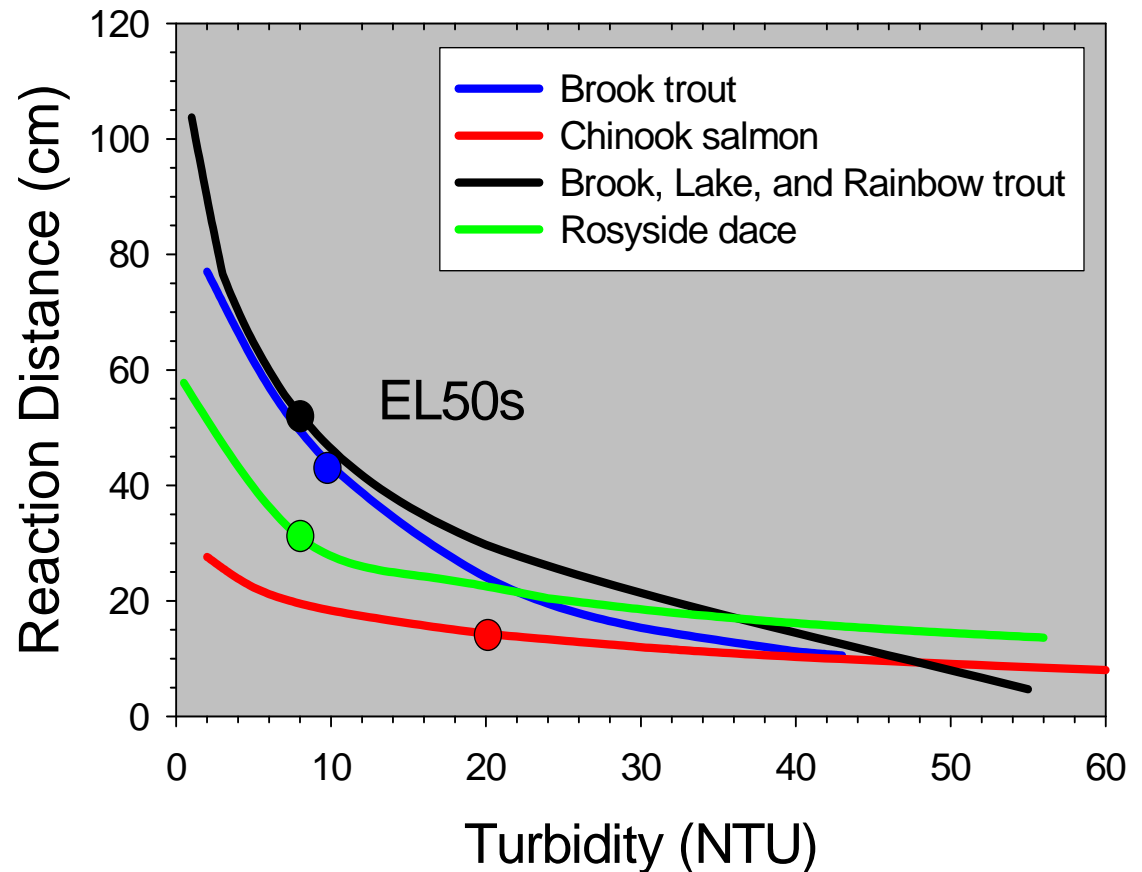
## Hopper Dredge Plume



# Response Characteristics

- **Severity of effect**

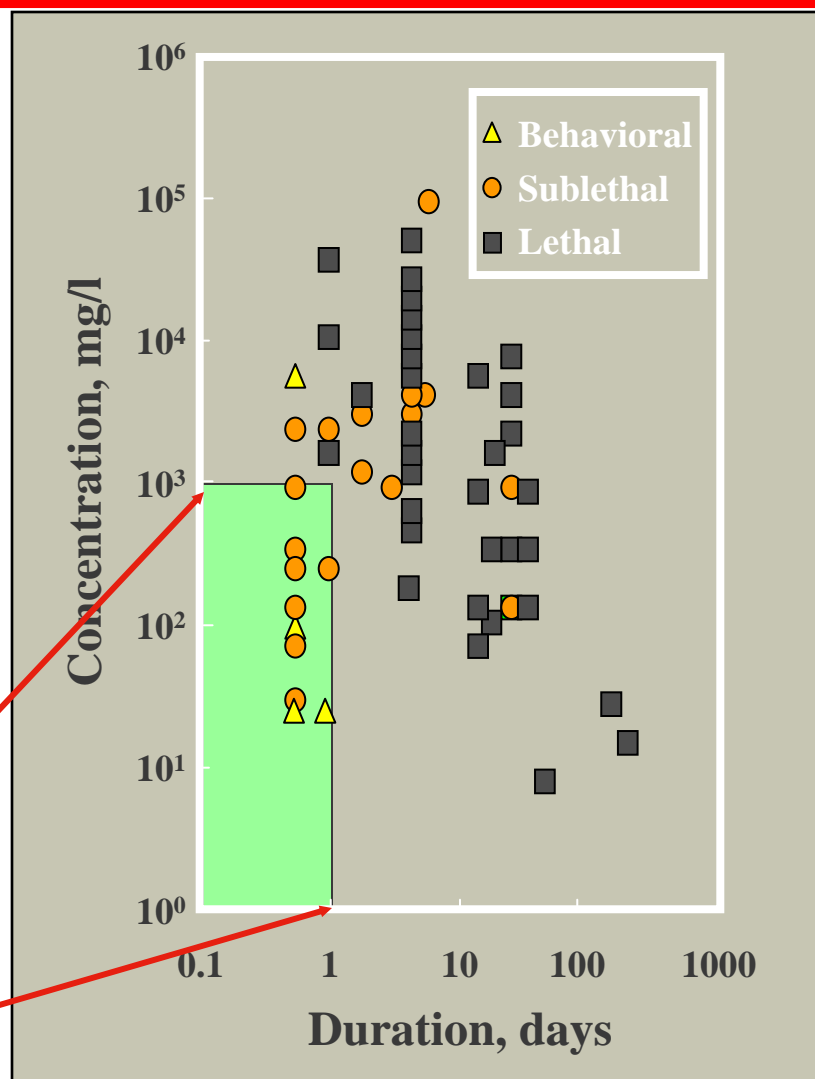
- **Behavioral**
- **Sublethal**
- **Lethal**



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

*(based on Newcombe and Jensen 1996)*

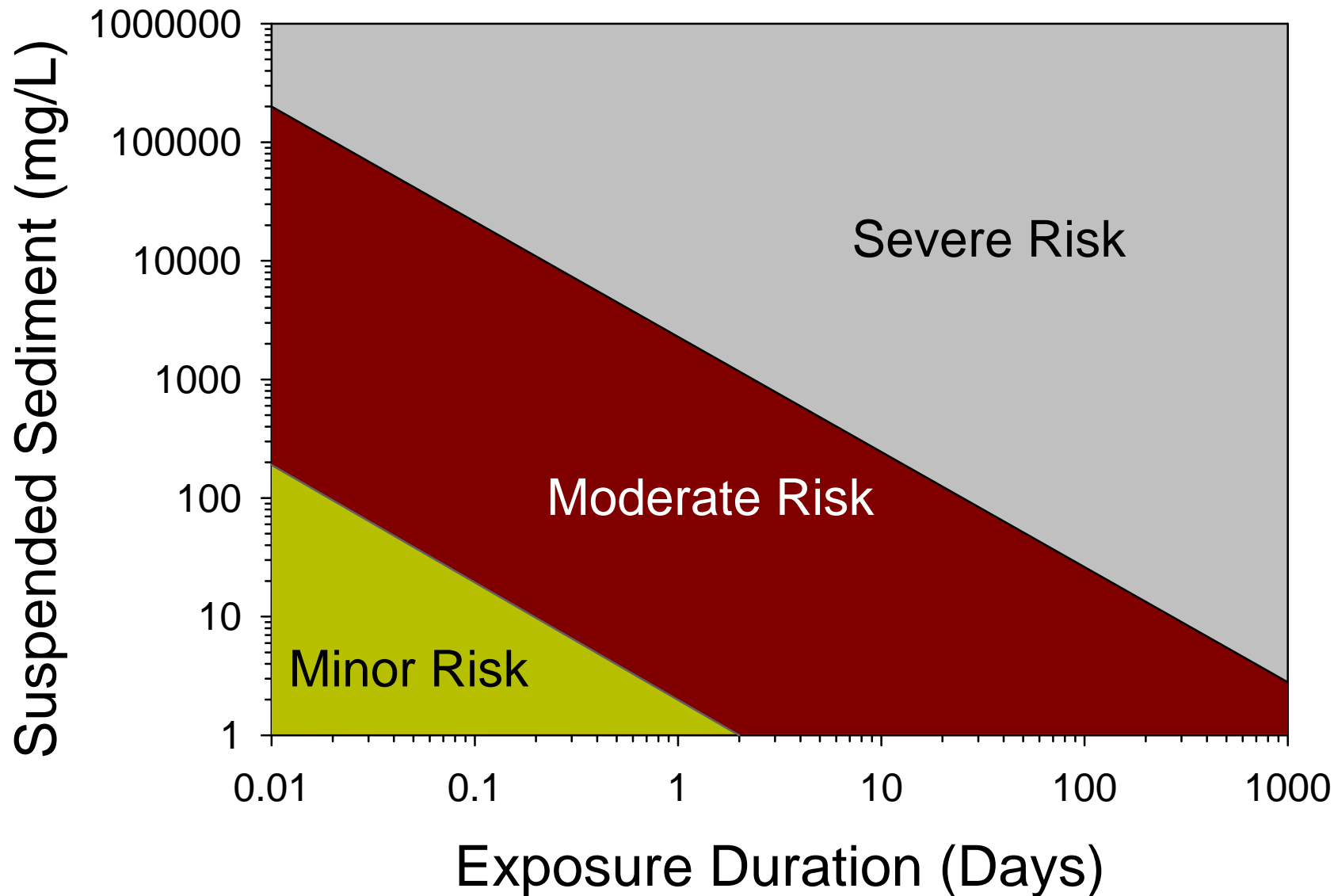
# Juvenile Salmonids



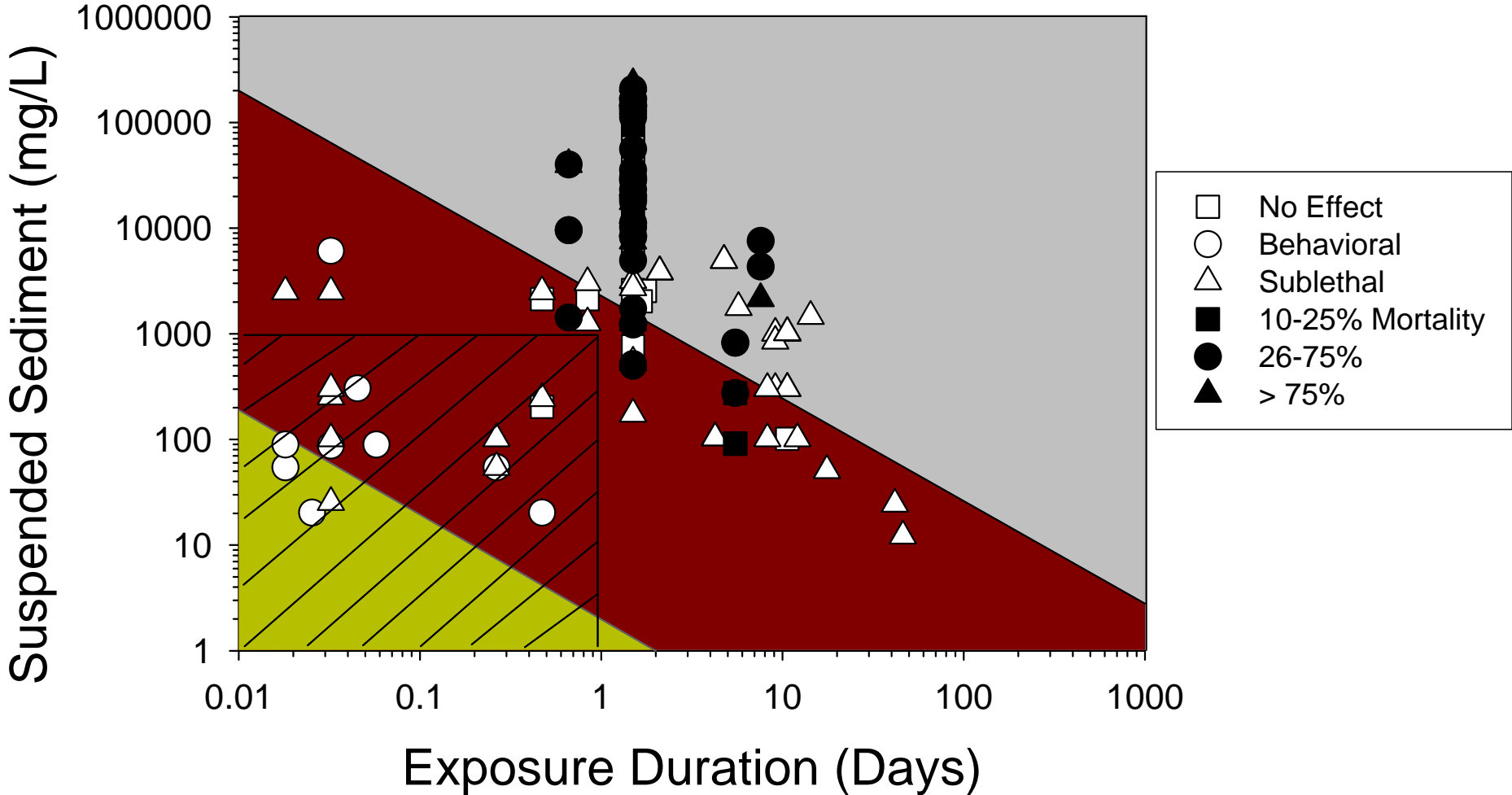
**Limits of  
Probable  
Exposure to  
Dredge Plumes**



# Juvenile Salmonids



# Juvenile Salmonids



# Fish Receptor Response Characteristics

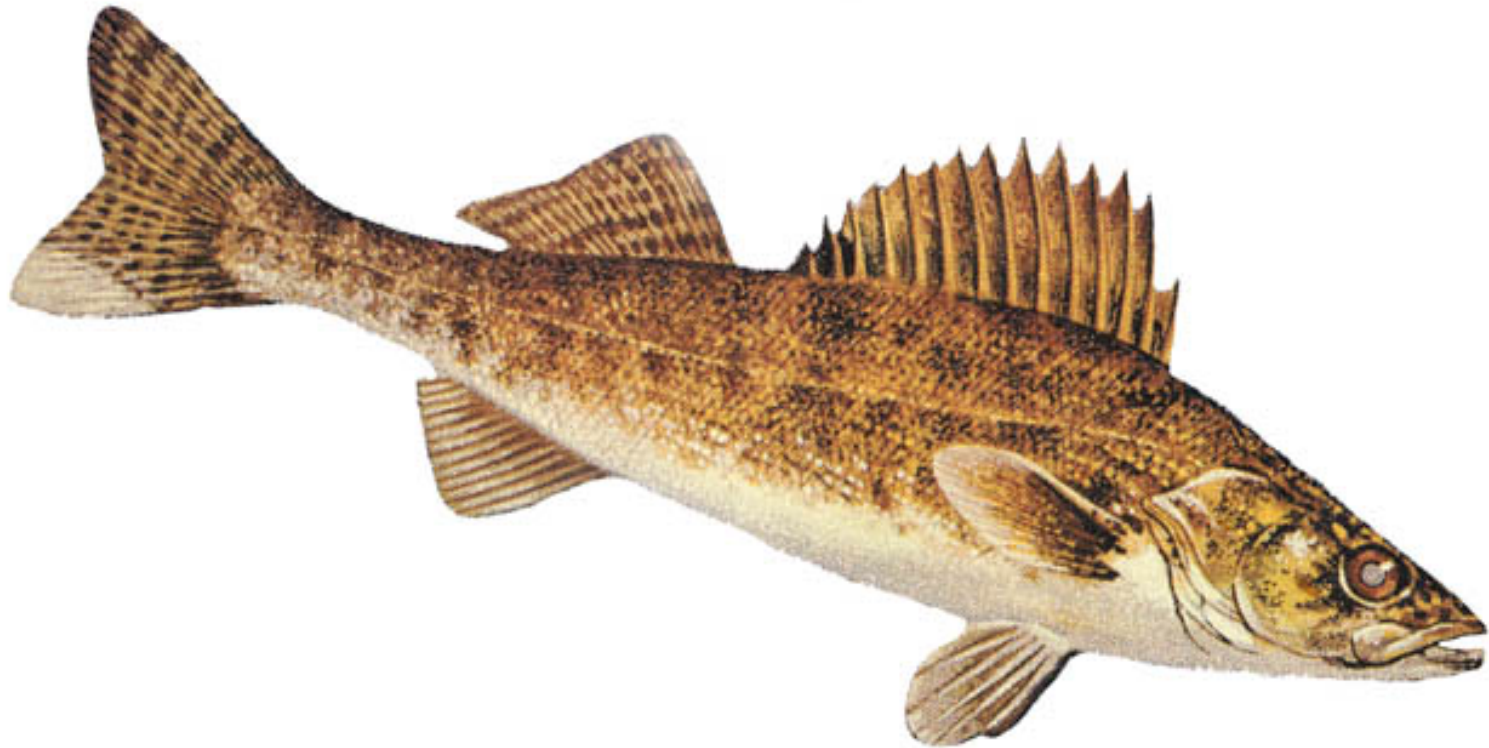
---

- **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 a static dose**



# *Hypothetical Fish Egg Receptor*

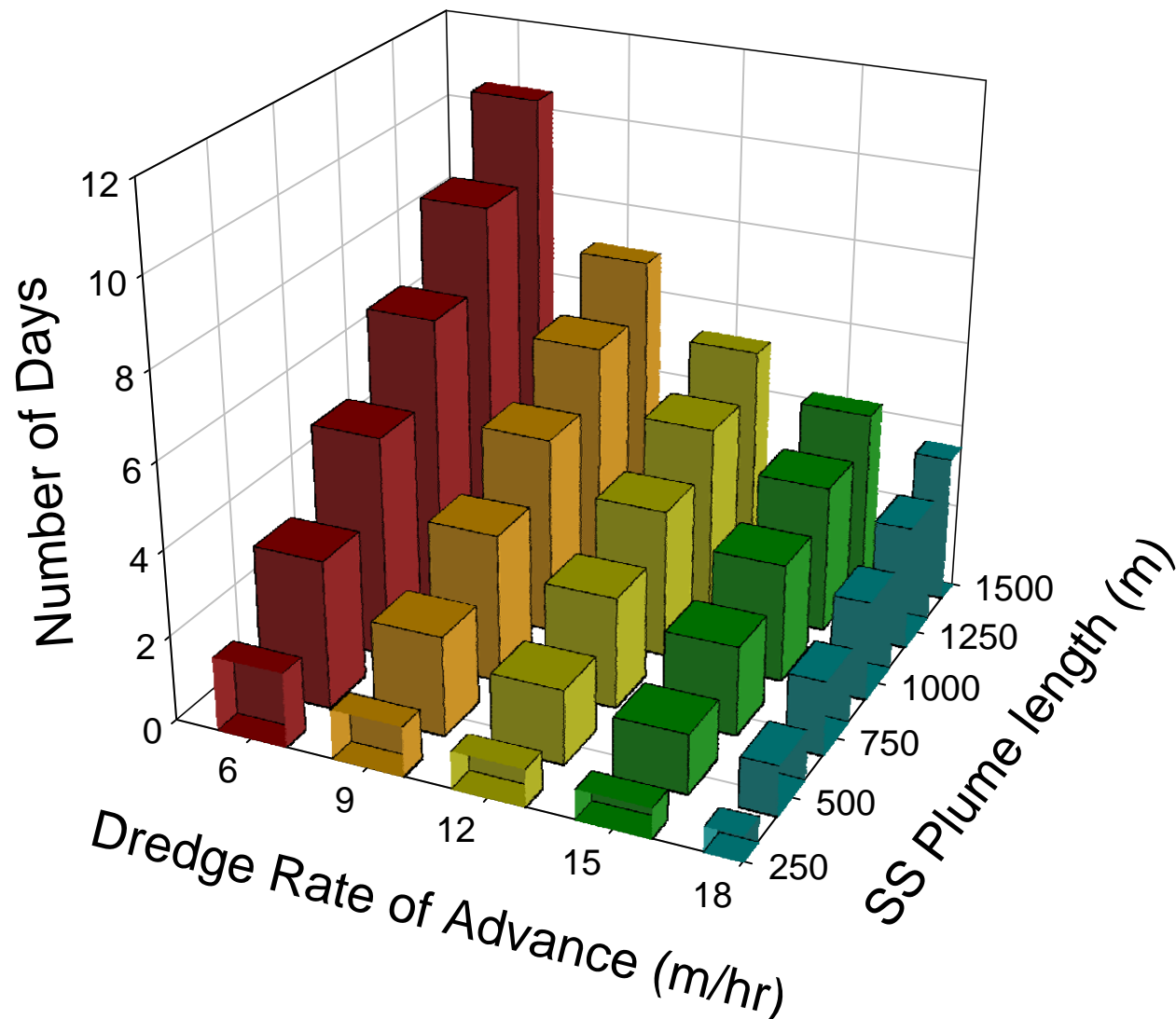
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**Fallguy (*Sander toddahoensis*)**





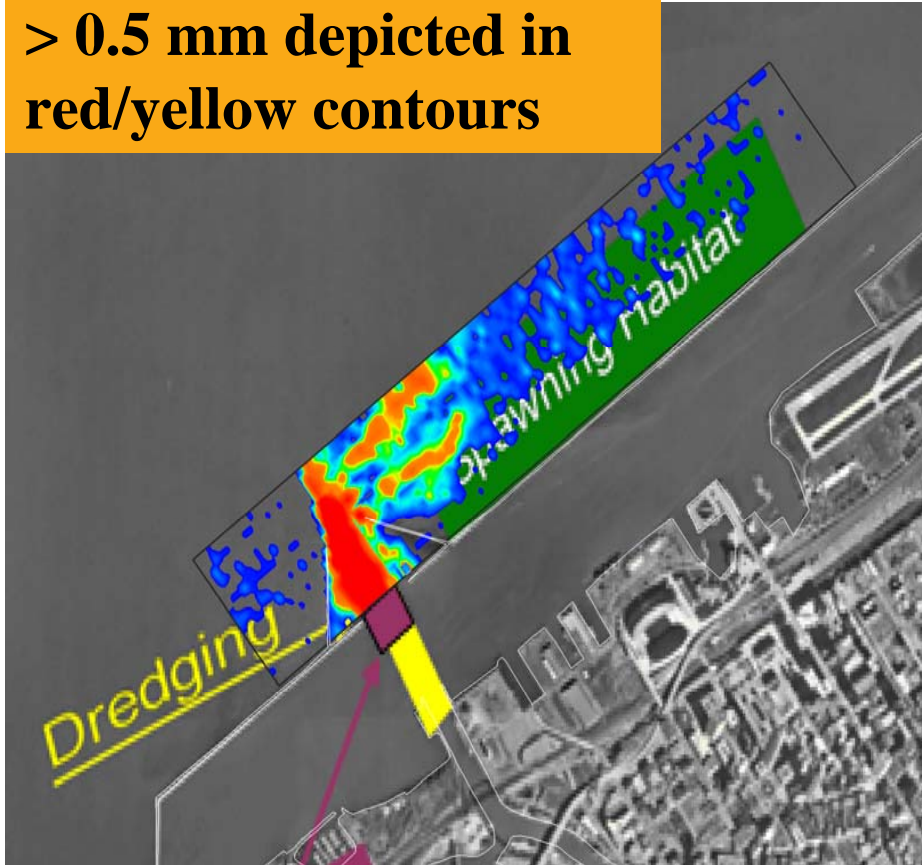


Duration of exposure for a *sessile receptor* such as adhesive fish eggs, bivalve mollusks, or SAV will depend on plume dimensions and dynamics in relation to the rate at which the dredge moves through the project site.

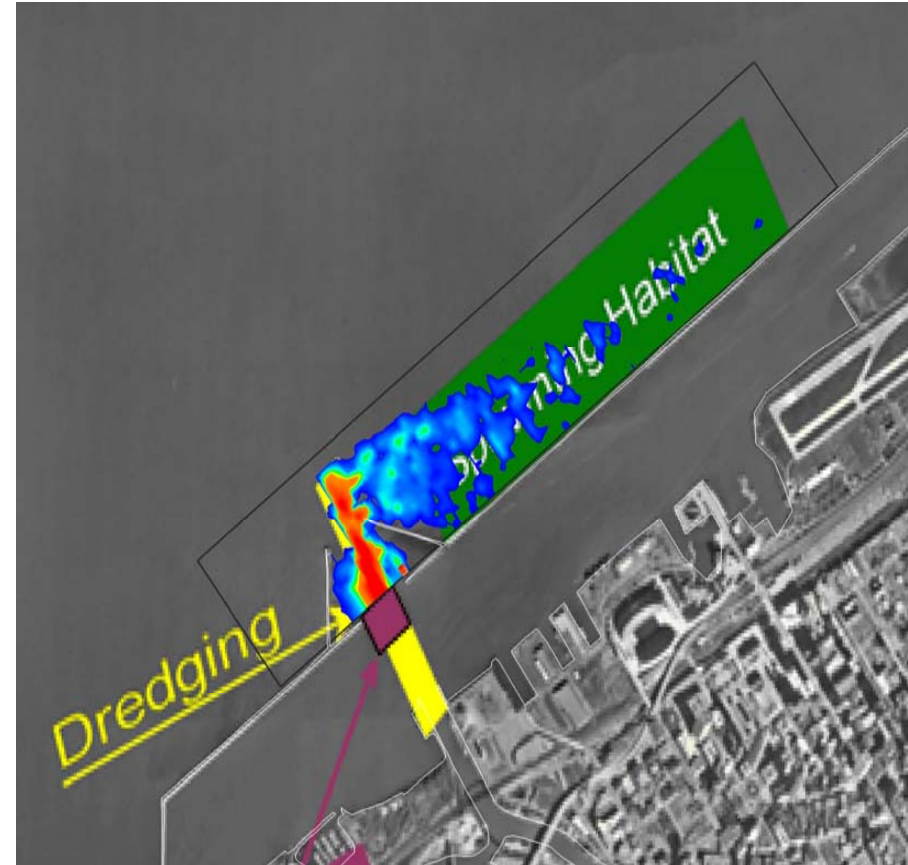
(from Wilber and Clarke 2001)

# Dredging-Induced Deposition

> 0.5 mm depicted in  
red/yellow contours



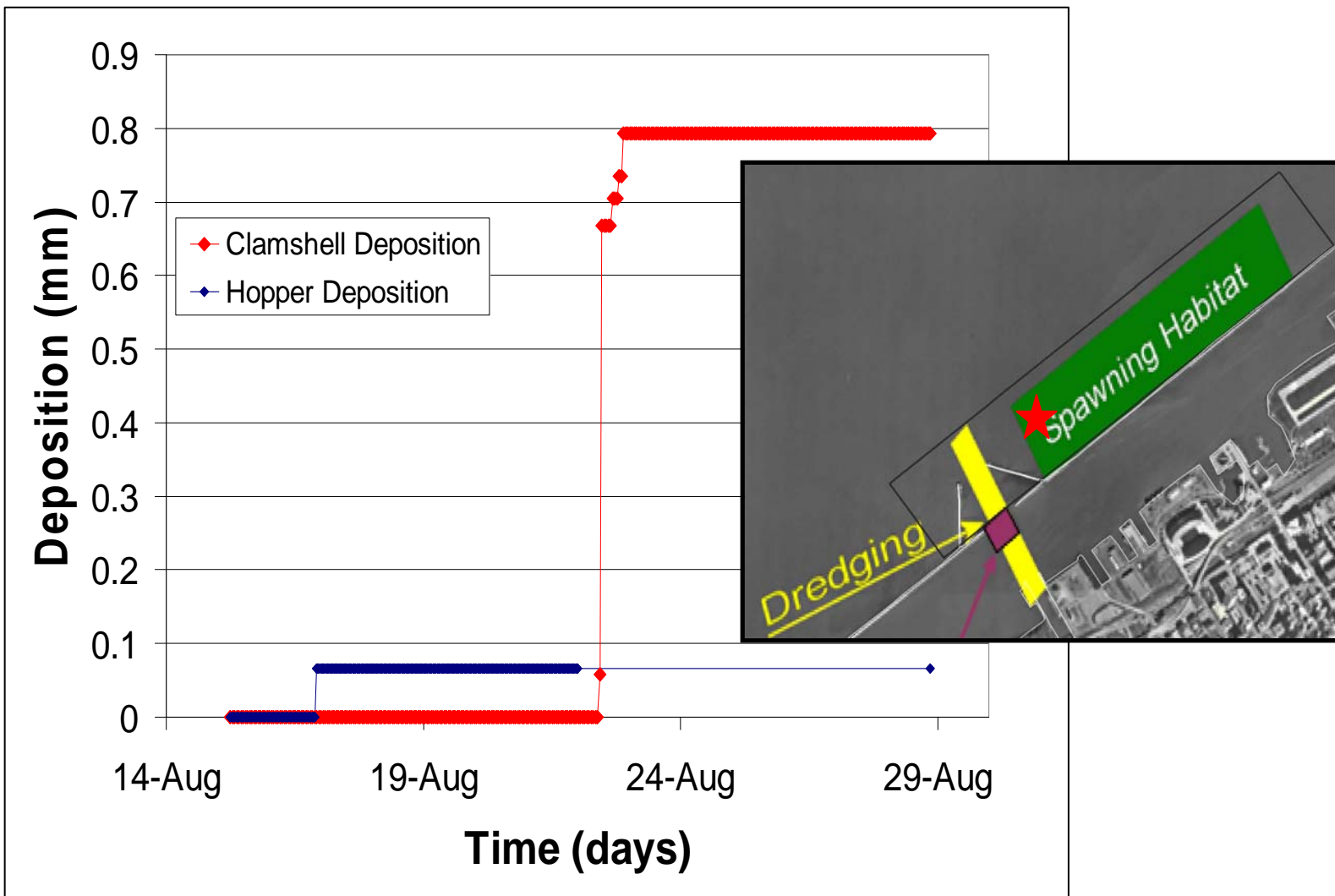
**Bucket Dredge**



**Hopper Dredge**

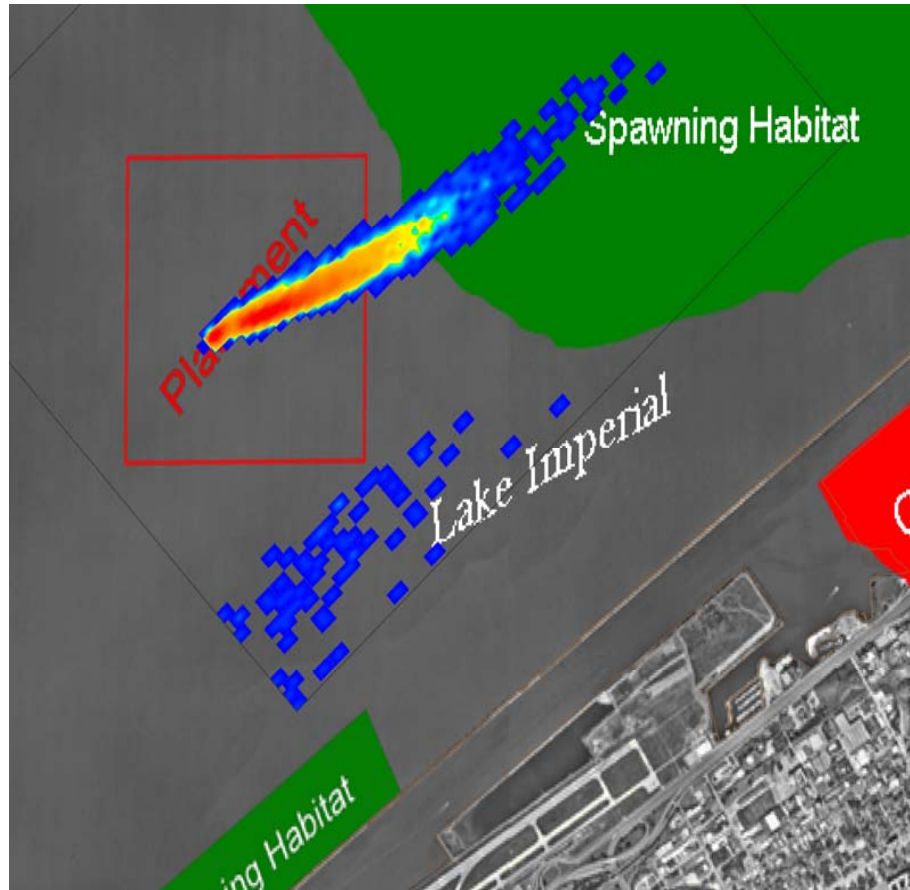


# Time Series of Deposition

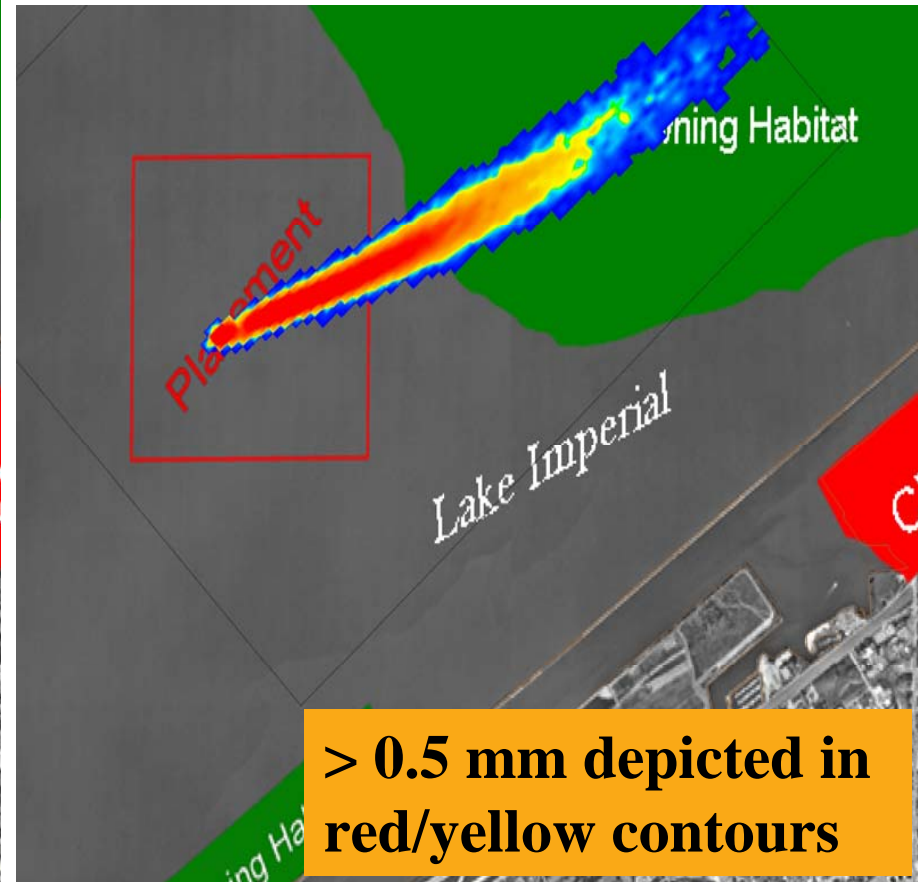


# Deposition at Offshore Placement Site

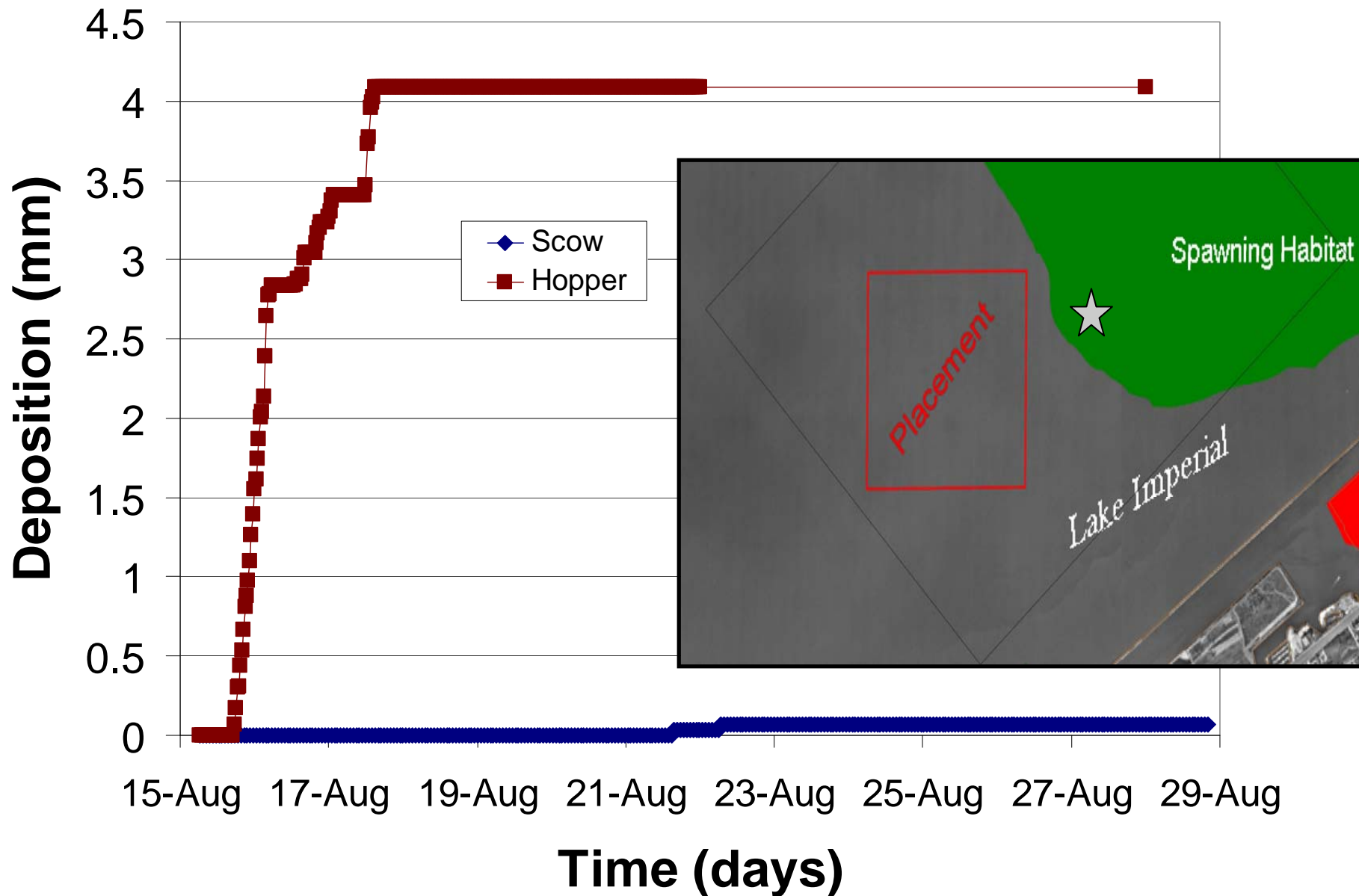
## Barge Placement



## Hopper Dredge Placement



# Time Series of Deposition



# Effects of SS on Fish Eggs

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## **Acute Exposure**

- **Abrasion/occlusion of chorion**
- **Plugging of micropyle**

## **Chronic Exposure**

- **Delayed hatching mediated by physiological response to impaired gas exchange**
- **Accelerated hatching mediated by turbidity-induced change in water temperature regime**



# **Effects of Sedimentation on Fish Eggs**

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## **Sublethal**

- **Interference with fertilization**
- **Abraded surface membranes and impaired gas exchange**
- **Loss of adhesion (for adhesive eggs)**
- **Delayed cell cleavage and differentiation**
- **Interrupted or incomplete development**
- **Delayed hatching and impaired larval development**

## **Lethal**

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

# **Summary of Deposition Effects on Fish Eggs**

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- **Timing of acute exposure could be critical**
- **Once fertilized, most eggs are relatively tolerant of SS**
- **Net deposition of less than half an egg diameter should be tolerated by most species**



# *Hypothetical Mussel Receptor*

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**Brainsplitter (*Unio idontknowicus*)**



# Potential Mussel Exposures

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- **Acute exposures**
  - Smothering and burial
- **Chronic exposures**
  - Elevated sedimentation rates and persistent overburden
  - Elevated TSS



# Effects of Sedimentation on Mussels

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## Behavioral Responses

Use of foot to migrate vertically  
Temporary valve closure

## Physiological Responses

Increased inorganic/organic intake ratio requires greater metabolic expenditure for clearance  
Change in excretion rate/excretion products  
Reduced gonad development and interference with reproductive cycle  
Decreased calcification / growth  
Increased respiration rate  
Greater susceptibility to parasites/pathogens

## Lethal

Suffocation

# Summary of Effects on Mussels

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- Short-term exposures (up to a week) of elevated SS or deposited sediment tolerated well by “clamming up”.
- Thin-shelled lentic species are relatively mobile, capable of migrating upward through overburden
- Long-term deposition (> month of 2 cm) could cause mortality of thick-shelled lotic species. Thin-shelled lentic species are better adapted to depositional conditions.





**The End**

**QUESTIONS?**

# Key References

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- **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 Jensen, J. 1996. Channel suspended sediment and fisheries: A synthesis for quantitative assessment of risk and impact. N. Amer. J. Fish. Management 16:693-727**
- **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**

