

# **CEL Hybrid Model**

## **2-D Application**

*Simulate the Movement Behavior of Blueback  
Herring (*Alosa Aestivalis*) in Response to  
Physicochemical Stimuli in  
J. Strom Thurmond Lake*

# Simulating Mobile Populations in Aquatic Systems Using a Coupled Eulerian-Lagrangian Hybrid Model

## *CEL Hybrid Models & the Numerical Fish Surrogate*

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# Objective

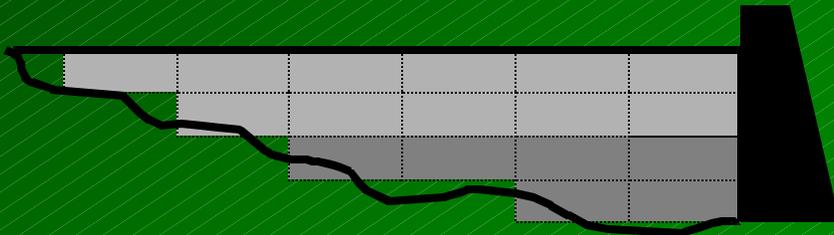
*Develop a Robust Modeling Framework for the  
Improved Simulation of  
Biological Population Processes  
(e.g., movement behavior)  
in Aquatic Ecosystems*

# Comparison of Modeling Framework Attributes

## Eulerian-Based Models

*Often Used by Engineers*

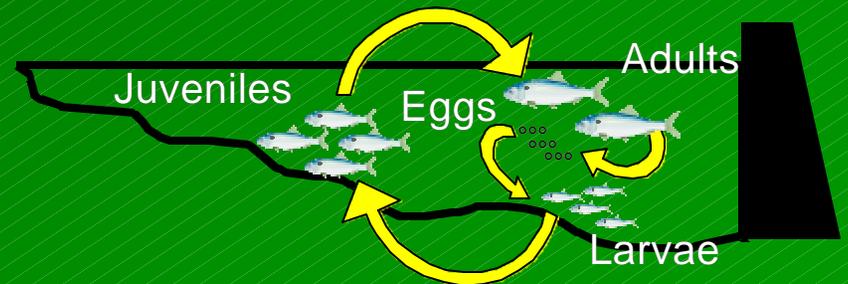
- Often Used to Solve Mass-Balance Physicochemical Equations
- Centered on a Point Fixed in Space
- Discontinuous Spatial Information  
(Information Averaged by Compartment)
- Shorter Time Steps Often Needed



## Lagrangian-Based Models

*Often Used by Biologists*

- Preferred for Simulating Animal Movement
- Centered on the Individual
- Continuous Spatial Information
- Longer Time Steps Possible



# Eulerian - Lagrangian Framework Couple:

## *Numerical Fish Surrogate*

*The Translation Mechanism that Mediates between  
Sensory Inputs from the Eulerian-based Model*

*(e.g., the physicochemical regime)*

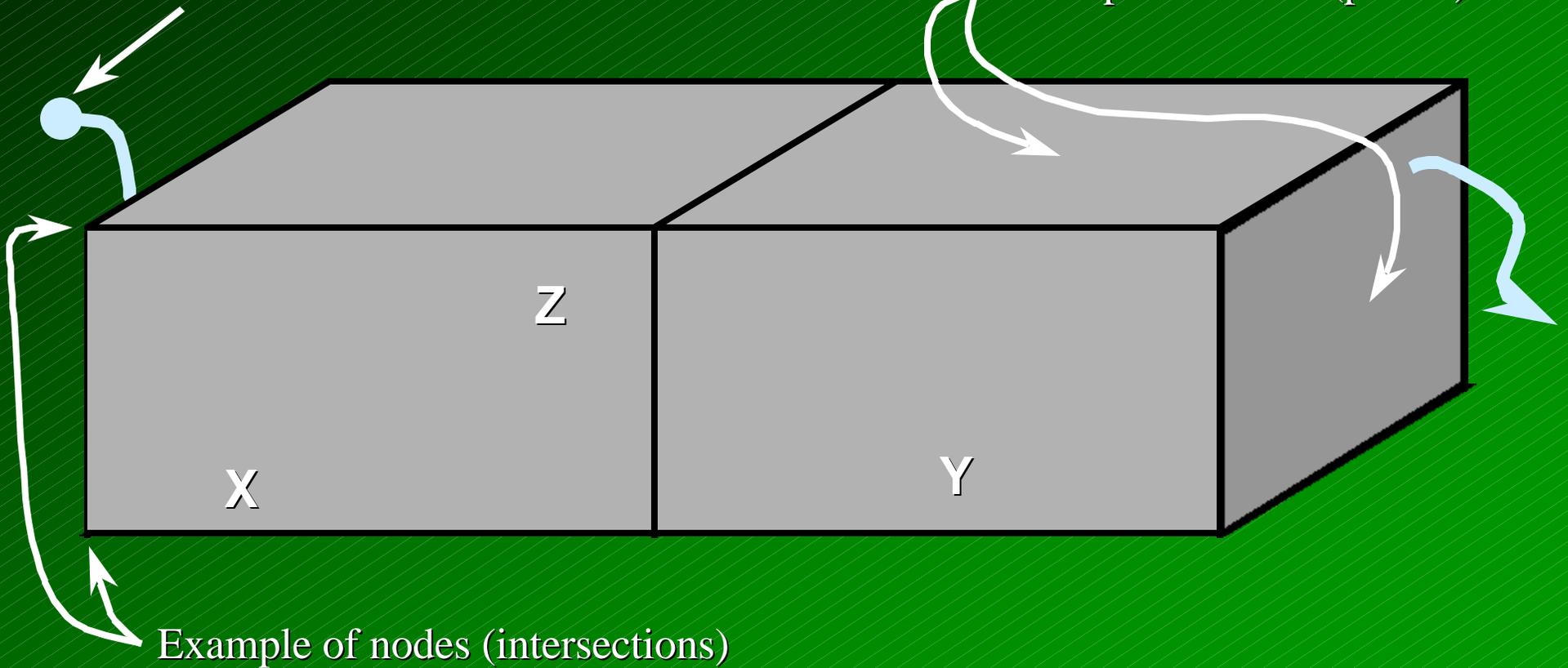
*and*

*Emergent Behavior*

# Particle-Tracking Algorithm

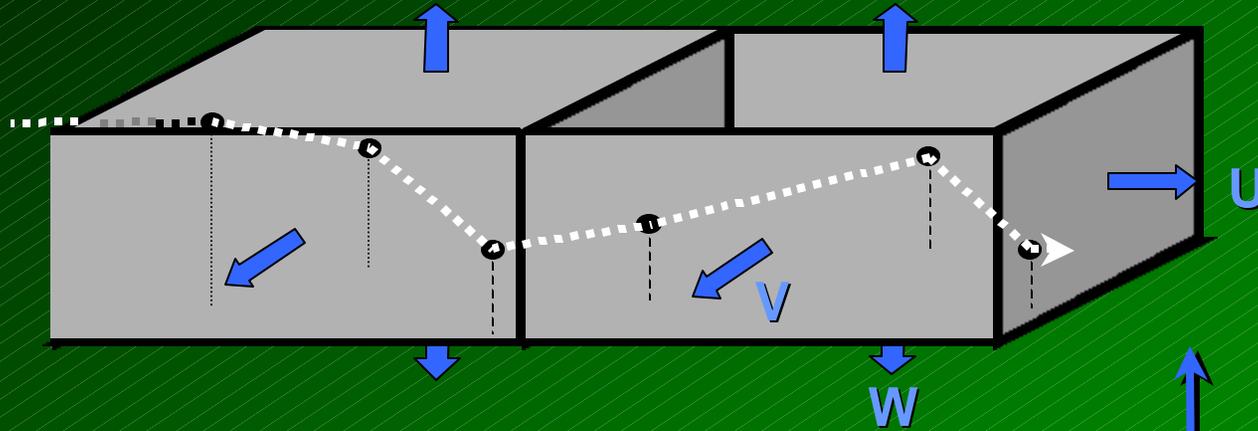
Discontinuous Hydraulic Field Represented as  
2 cells (cubes), 11 faces (planes), or 12 nodes (intersections)

Continuous Movement of a  
Particle in a Simulated  
Hydraulic Field

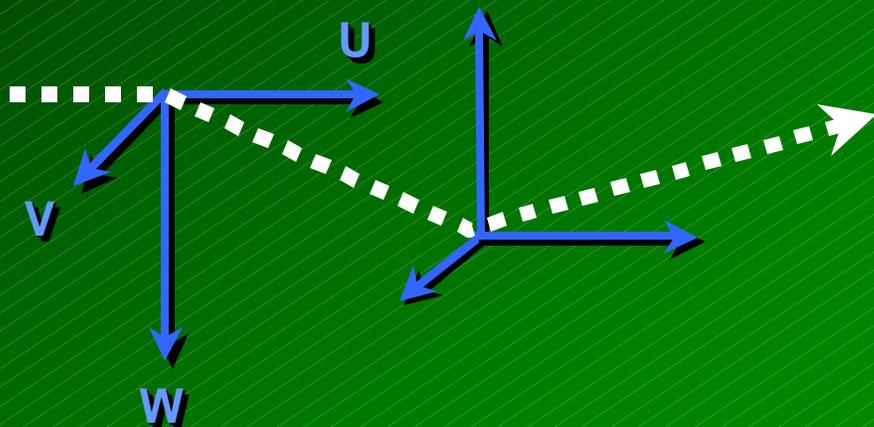


# Particle-Tracking Algorithm

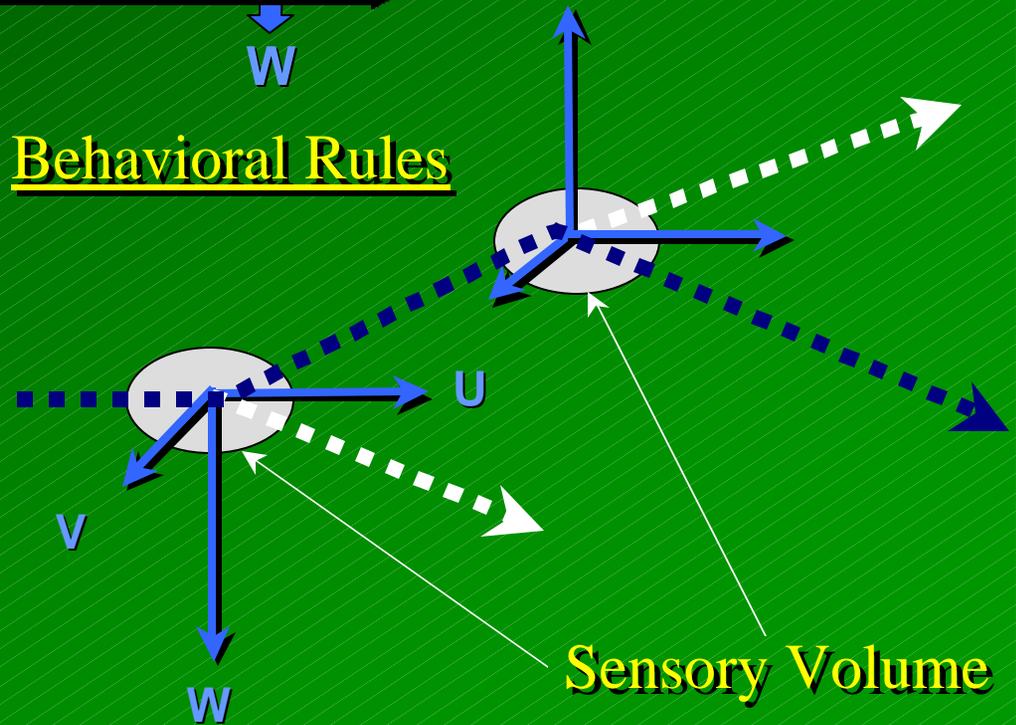
With and Without Behavioral Rules



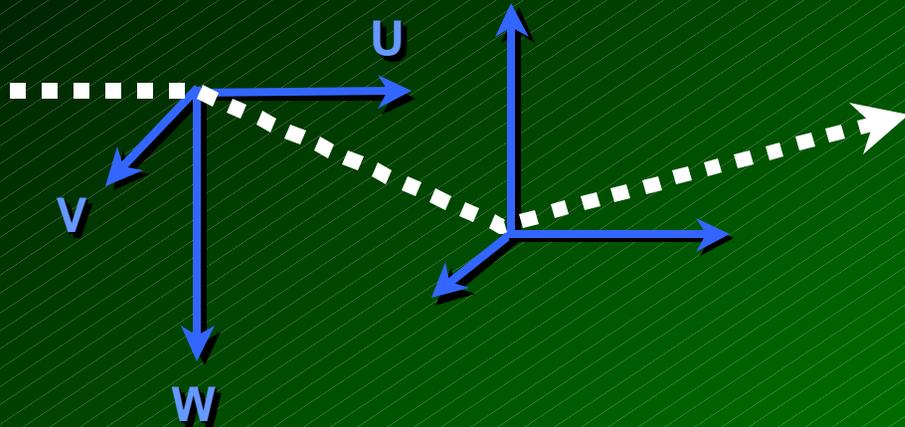
No Behavioral Rules



Behavioral Rules



# Mathematical Description of Movement

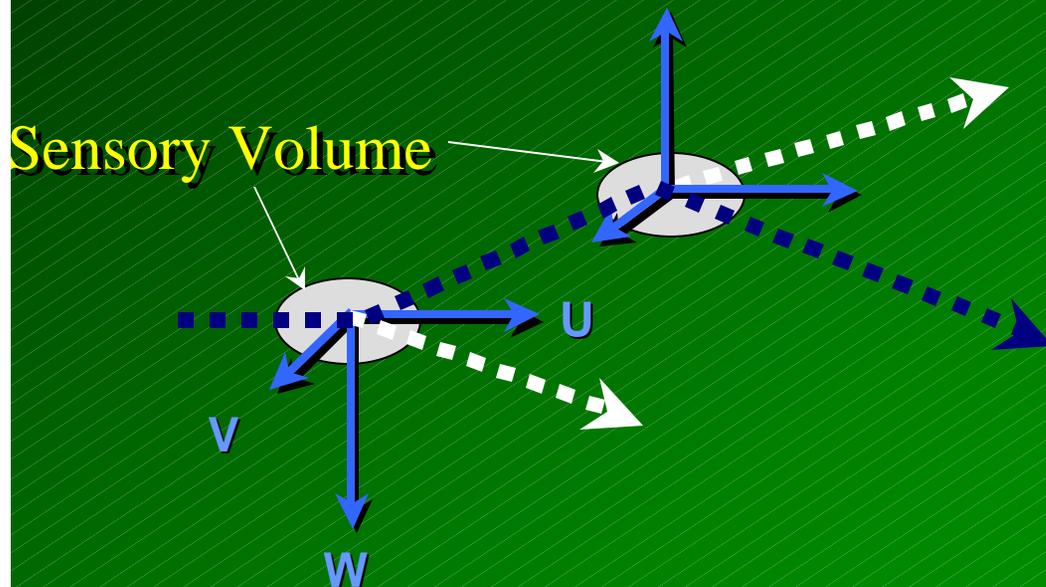


## Passive Particle

$$X_{t+1} = X_t + U * Dt$$

$$Y_{t+1} = Y_t + V * Dt$$

$$Z_{t+1} = Z_t + W * Dt$$

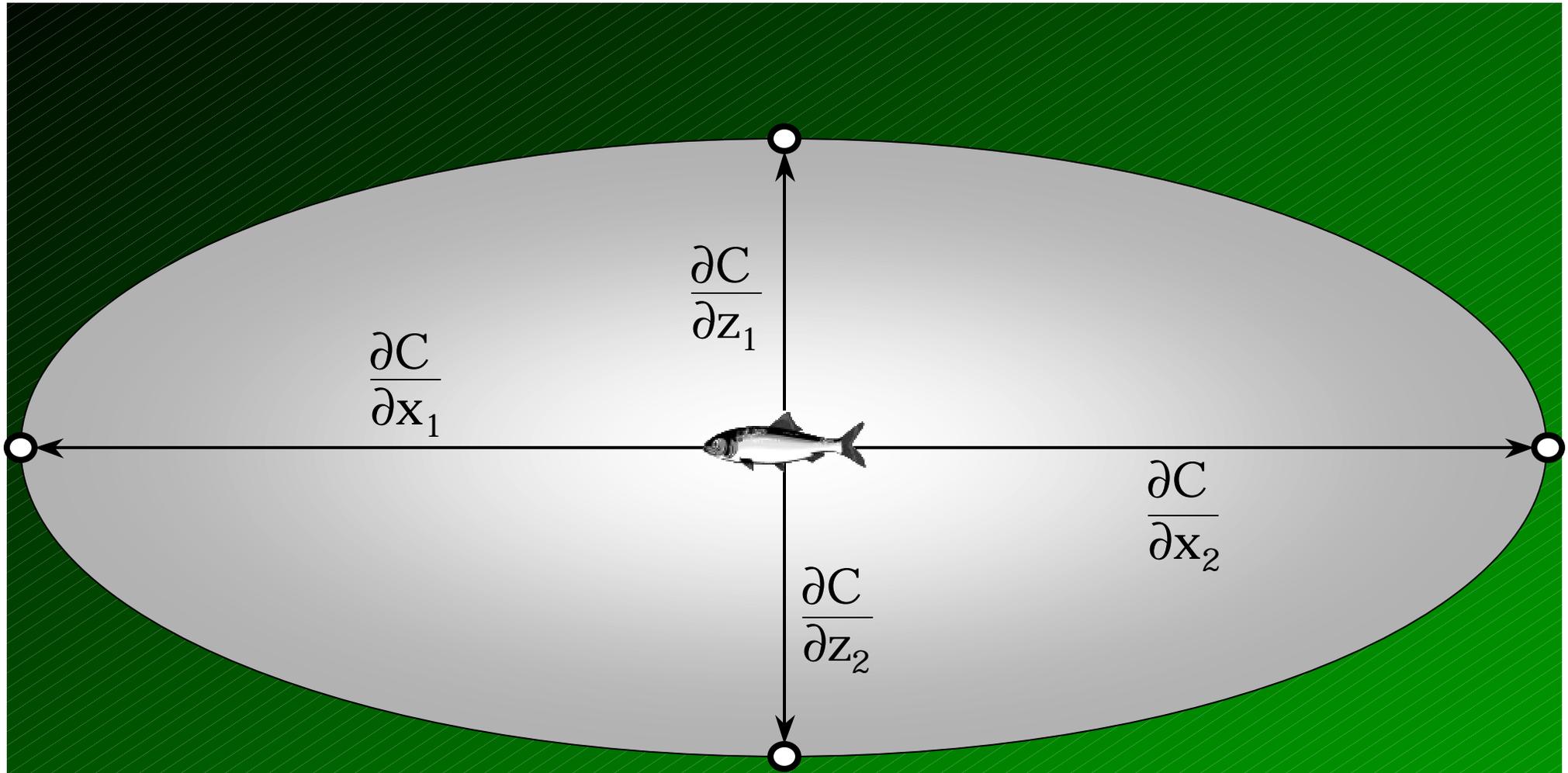


## Active 'Particle'

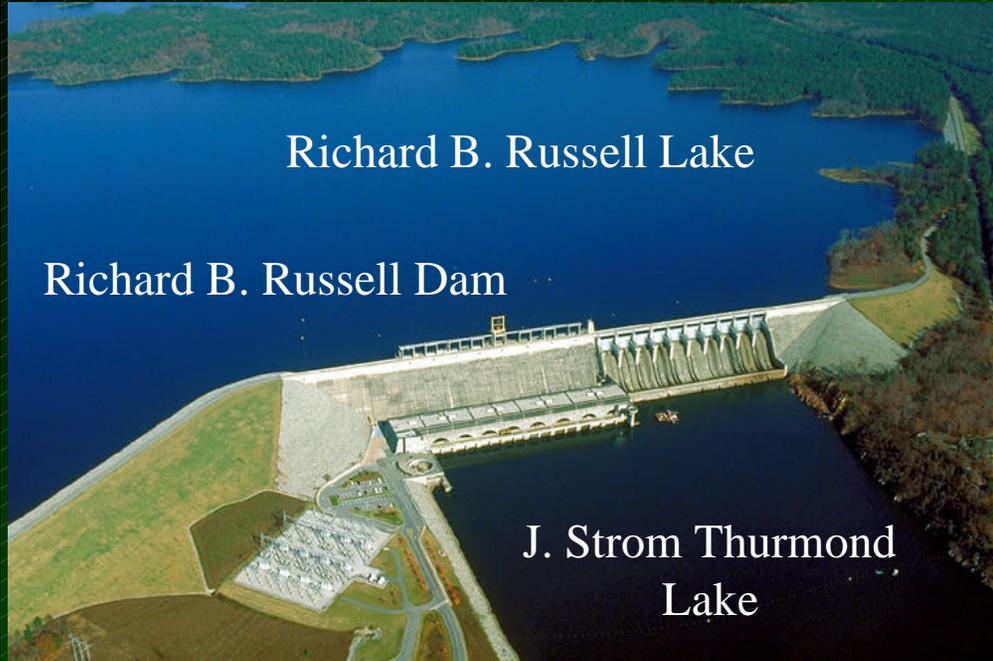
$$X_{t+1} = X_t + (U + U_{\text{fish}}) * Dt$$

$$Y_{t+1} = Y_t + (V + V_{\text{fish}}) * Dt$$

$$Z_{t+1} = Z_t + (W + W_{\text{fish}}) * Dt$$



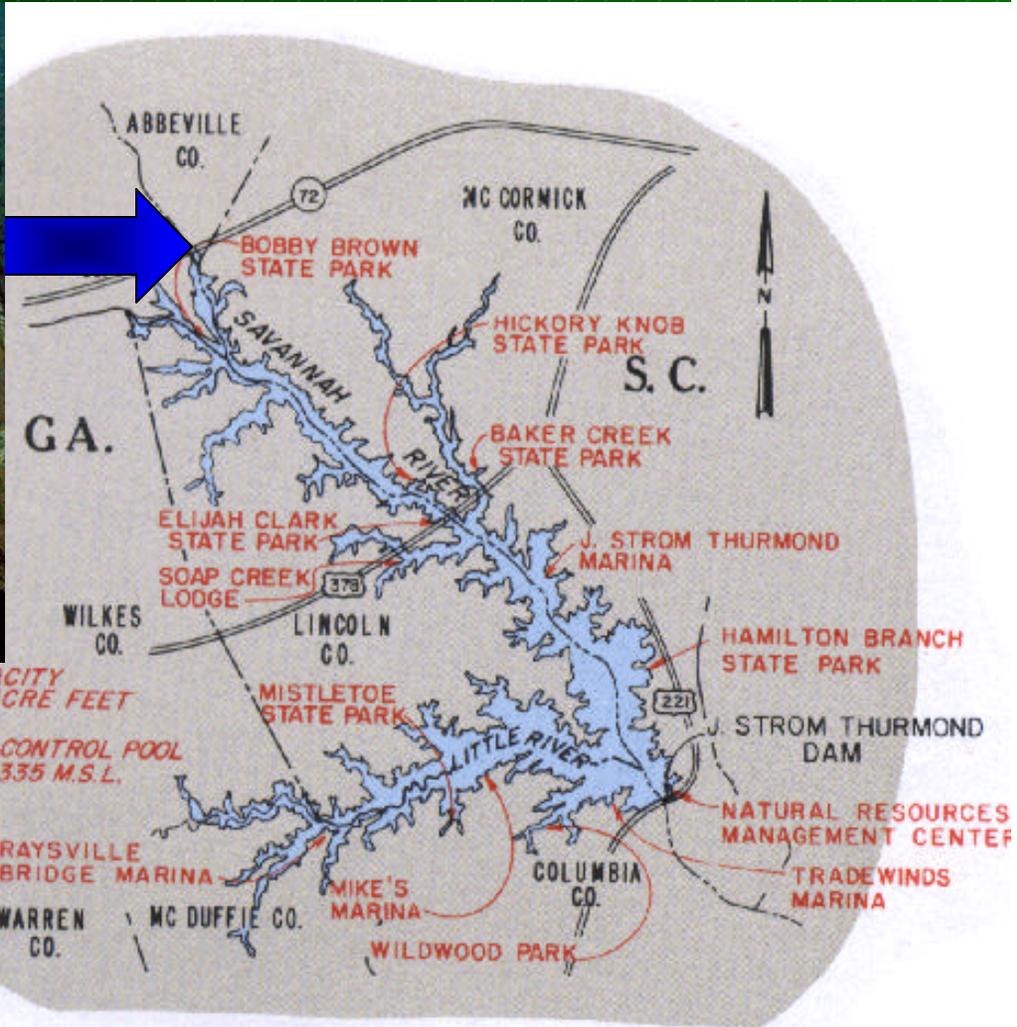
$C = \{ \text{e.g., velocity and/or acceleration vectors, temperature, dissolved oxygen, turbulent kinetic energy, turbulent length scales, pressure, etc.} \}$



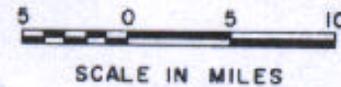
Richard B. Russell Lake

Richard B. Russell Dam

J. Strom Thurmond Lake



J. STROM THURMOND LAKE  
SHOWING MAJOR RECREATIONAL AREAS

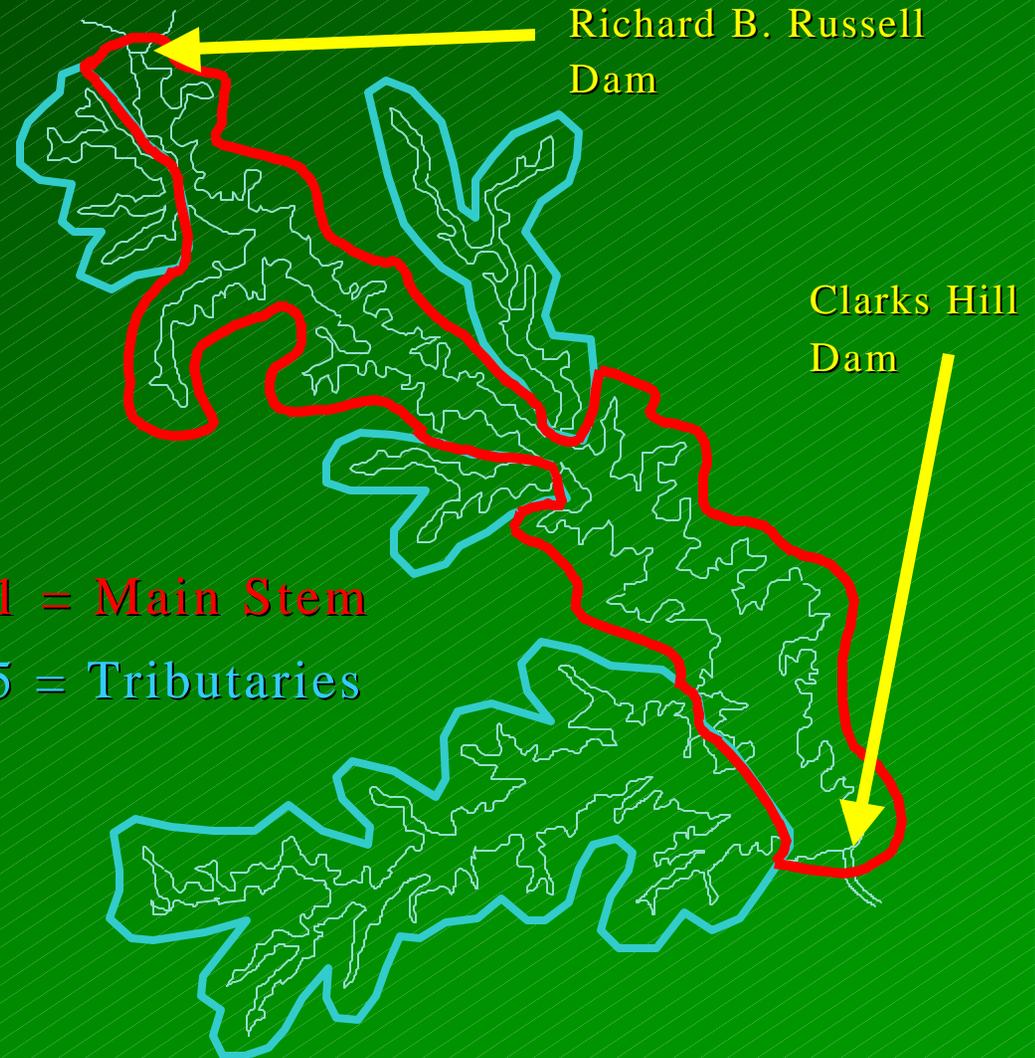


# Site of CEL Hybrid Model Application

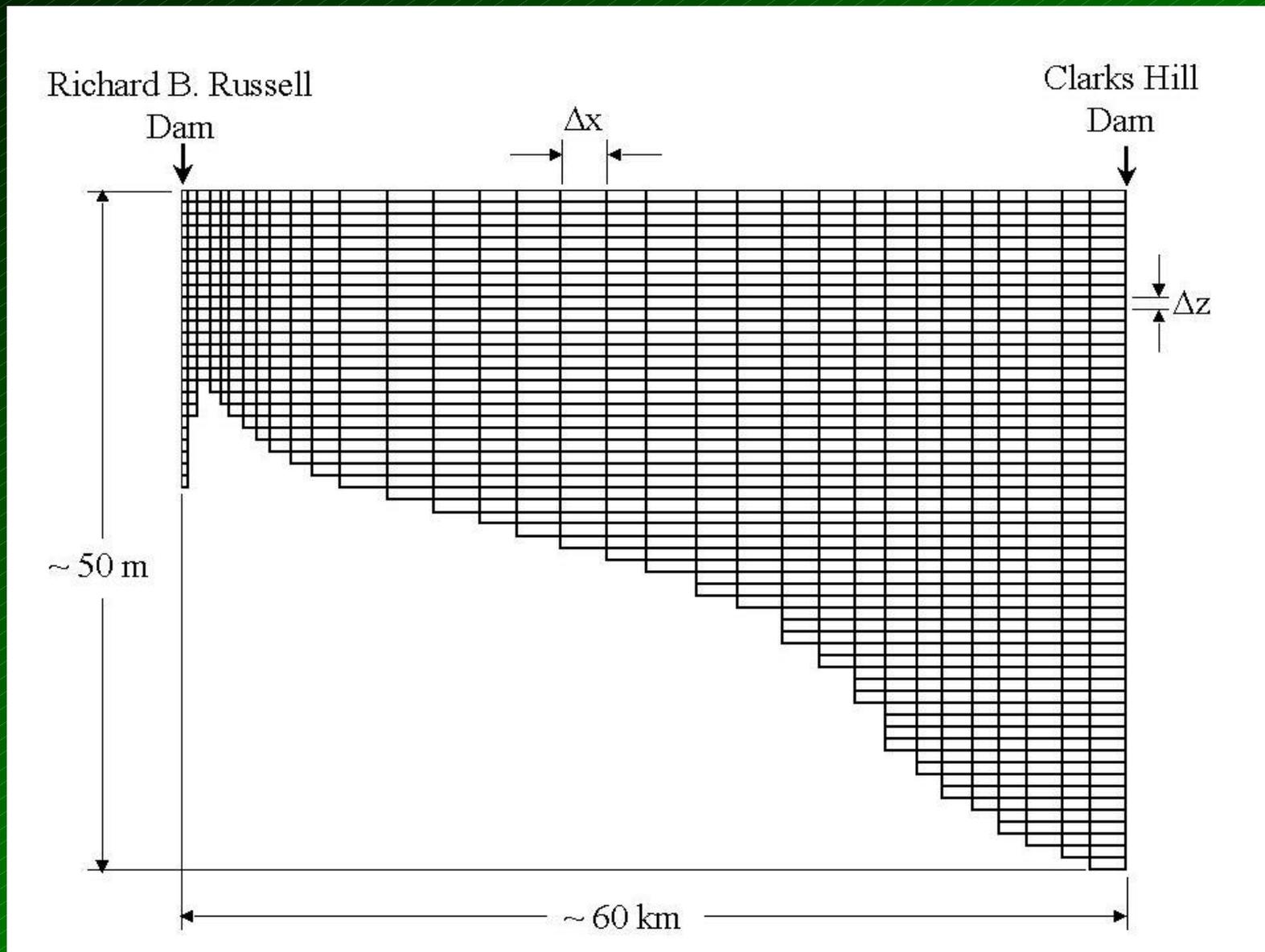
## J. Strom Thurmond Lake

- Located on South Carolina - Georgia Border
  - Surface Area = 28,320 ha
  - Total Length = 61 km
  - JST Represented as:
    - 5 Branches
    - 61 Segments
    - 59 Layers
- in CE-QUAL-W2  
Hydrodynamic &  
Water Quality Model

Branch 1 = Main Stem  
Branches 2-5 = Tributaries

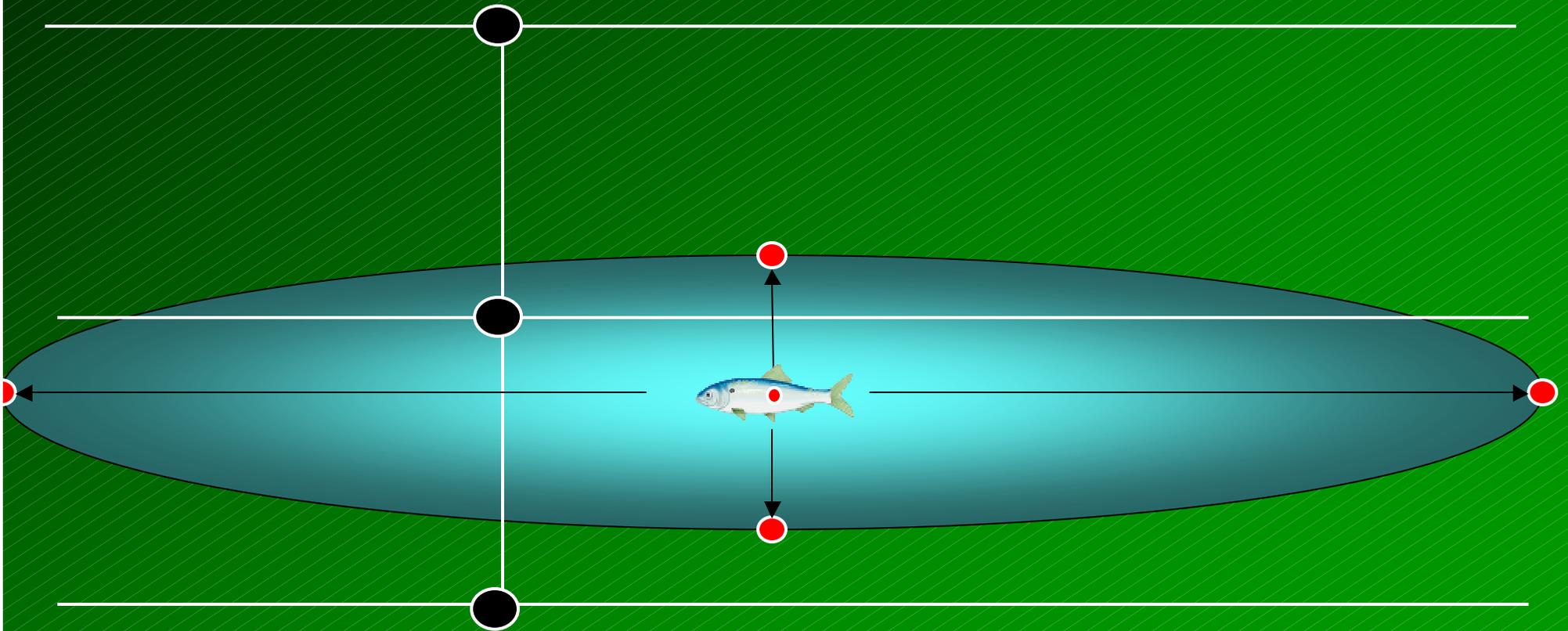


# CE-QUAL-W2 Representation of Main Stem of J. Strom Thurmond Lake



# Sensory Volume in CE-QUAL-W2

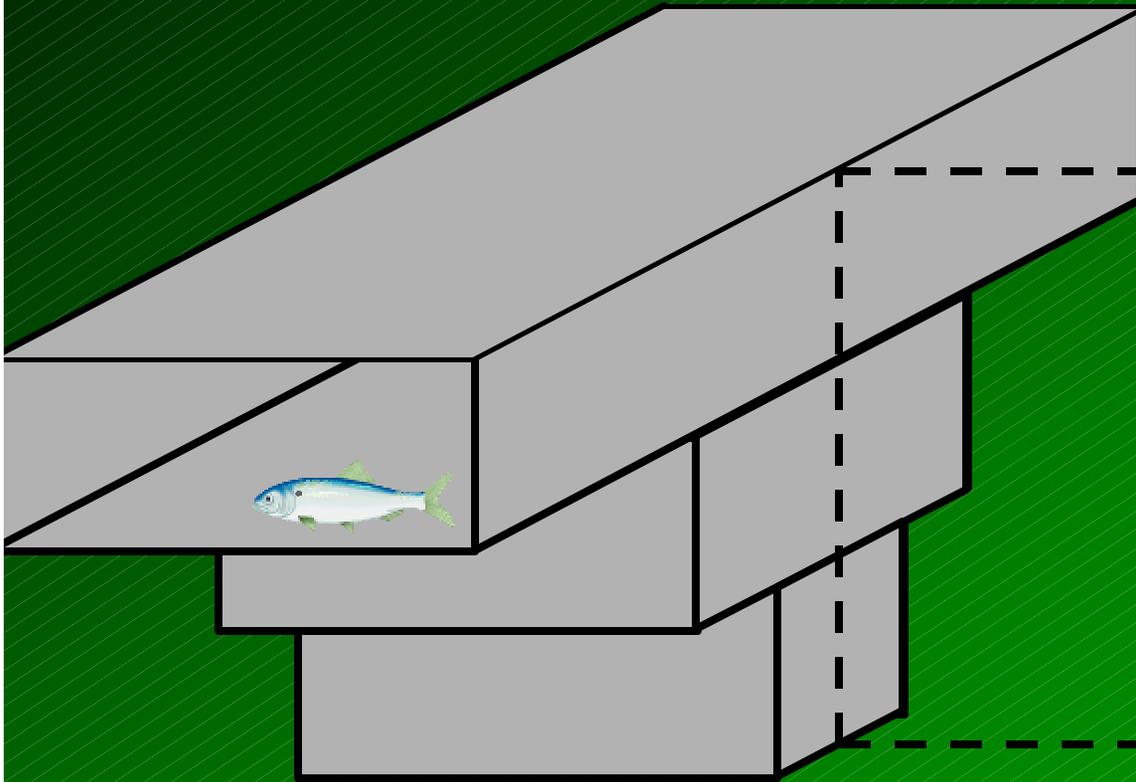
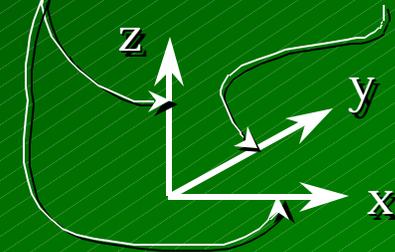
- Hydraulic Variables, Temperature, and Dissolved Oxygen
- Size and Shape of Sensory Volume Based on:
  - Fish Size, Species, NFS Time Step, and Other Factors



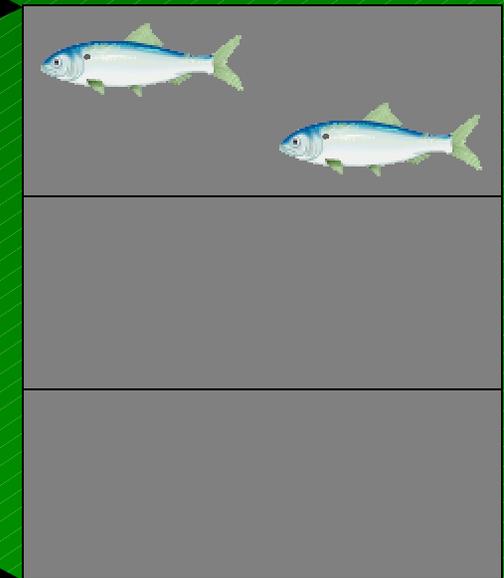
# CE-QUAL-W2

Approximates Bathymetry of System in 3-D  
Conserves Mass and Momentum in 2-D

Mass & Momentum  
*Conserved*   *Not Conserved*

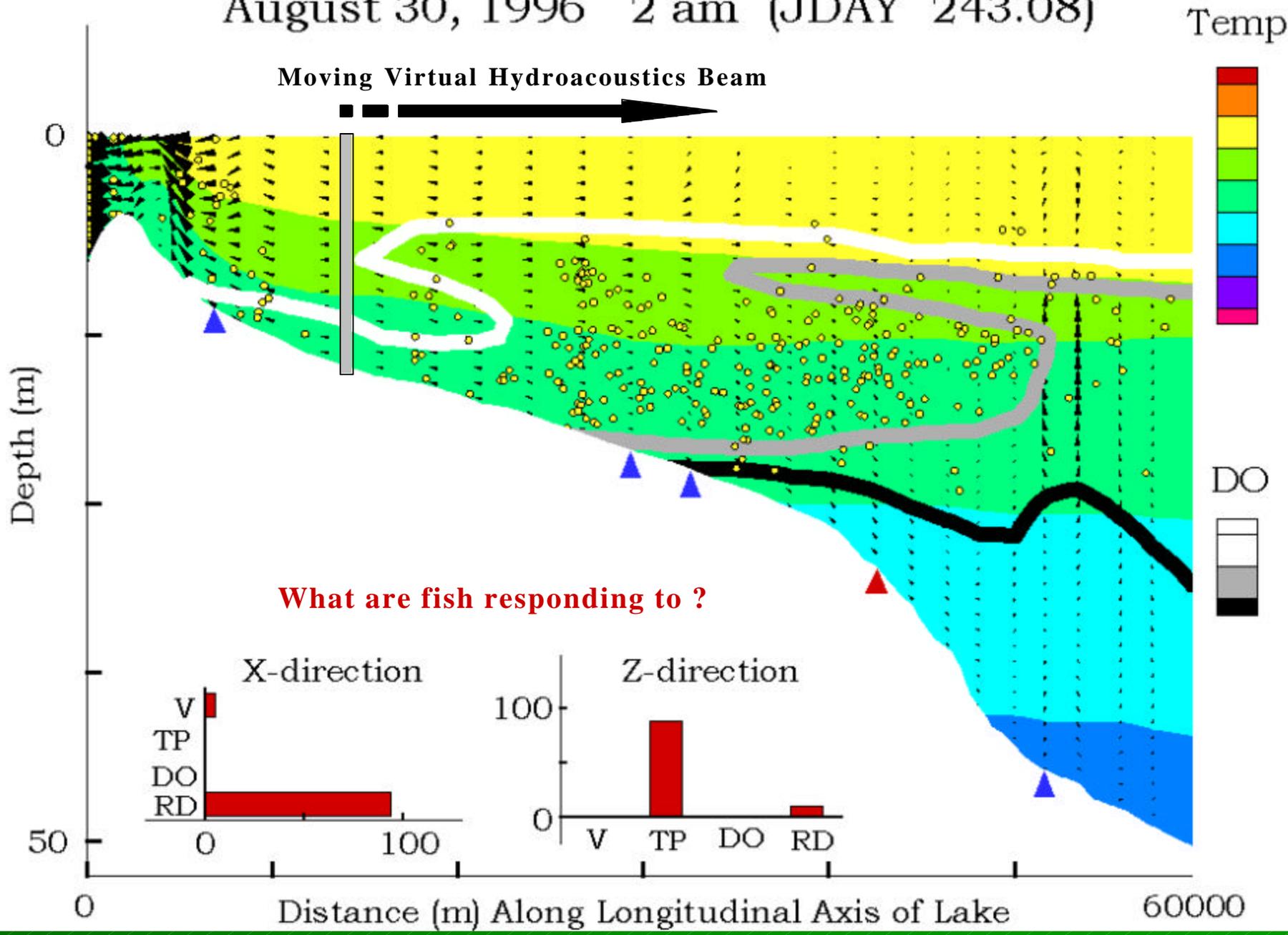


Fish "Swim" in 3-D

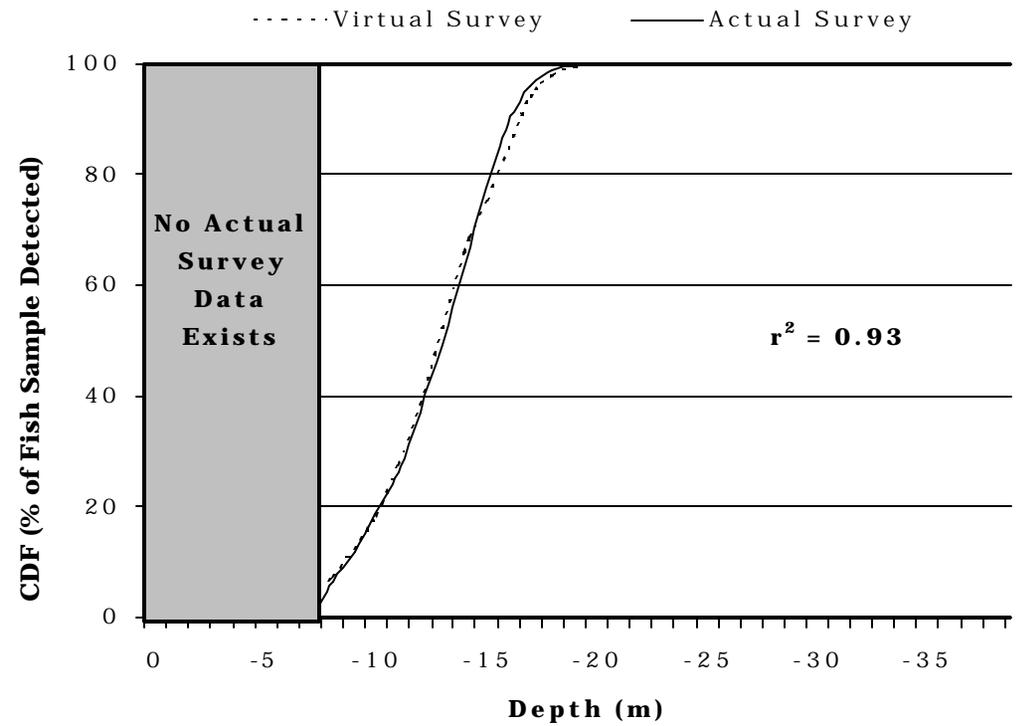
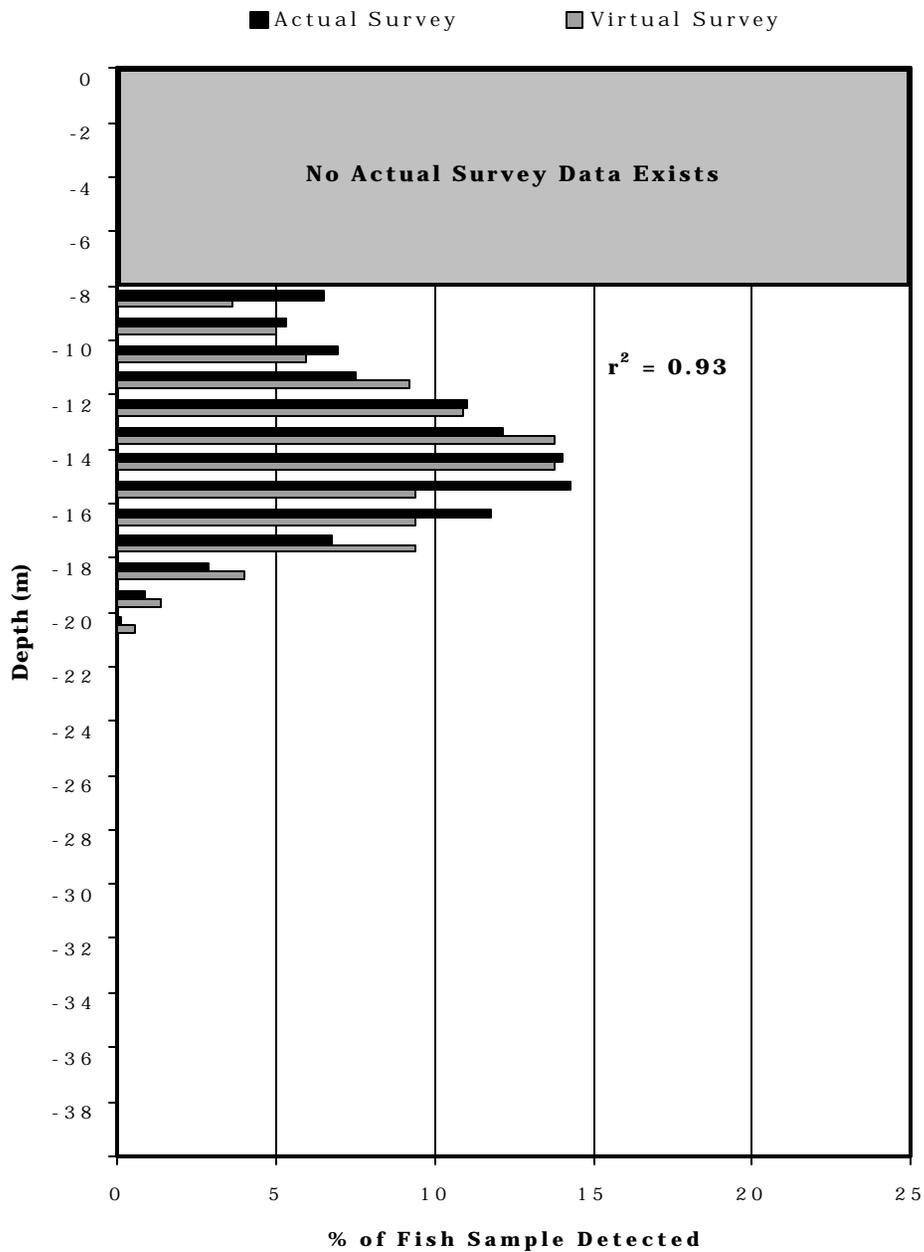


Fish Visualized in 2-D

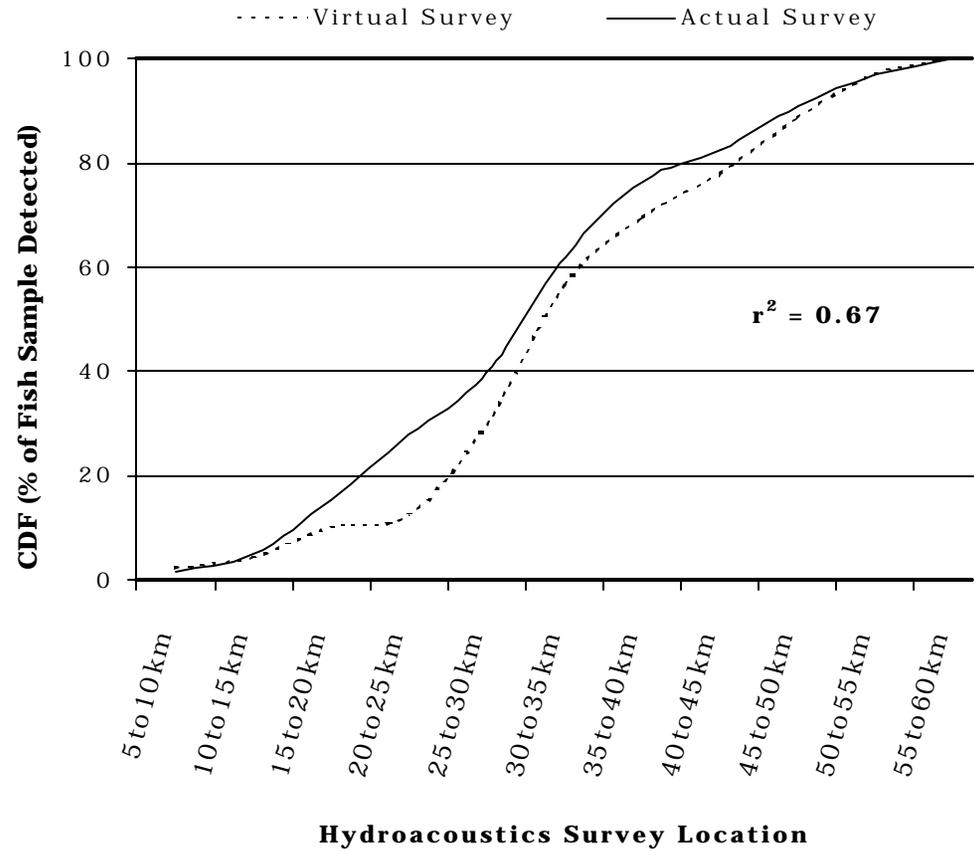
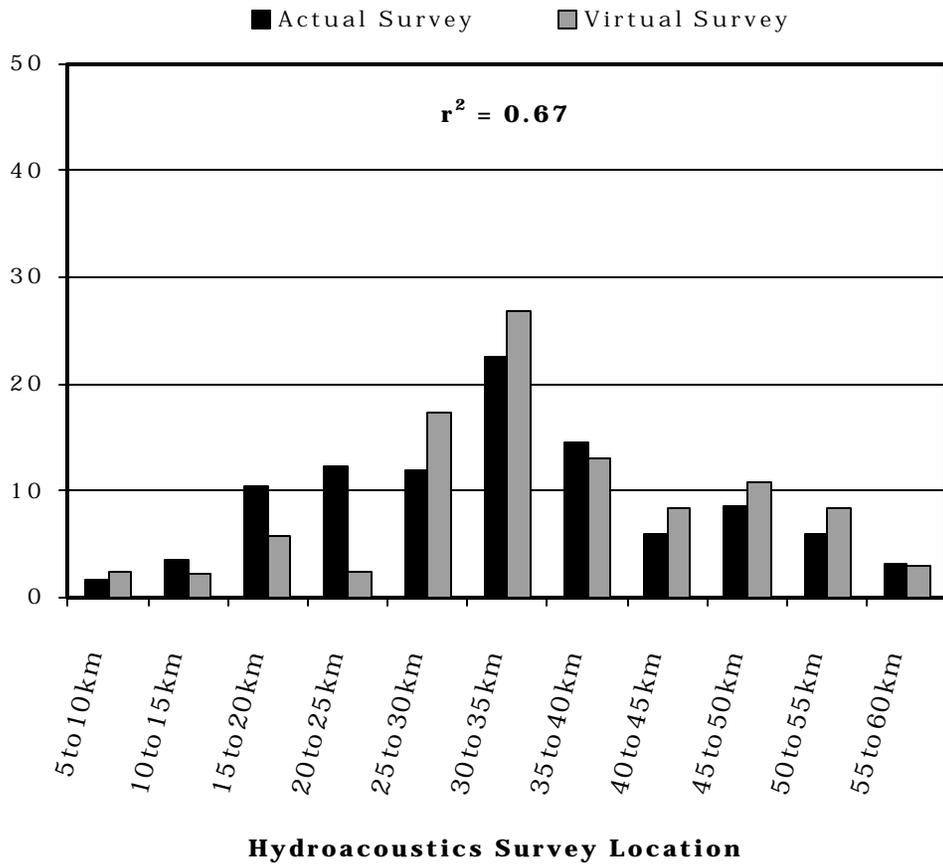
Simulated Conditions on:  
August 30, 1996 2 am (JDAY 243.08)



# JST Lake Blueback Herring Population as Detected by Virtual and Actual Hydroacoustic Surveys

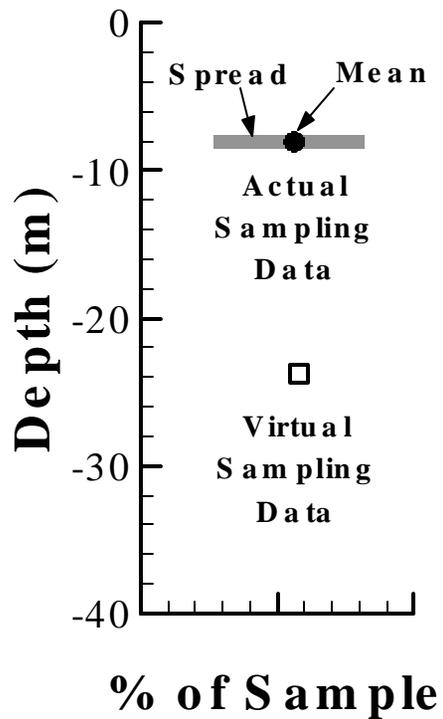


# JST Lake Blueback Herring Population as Detected by Virtual and Actual Hydroacoustic Surveys

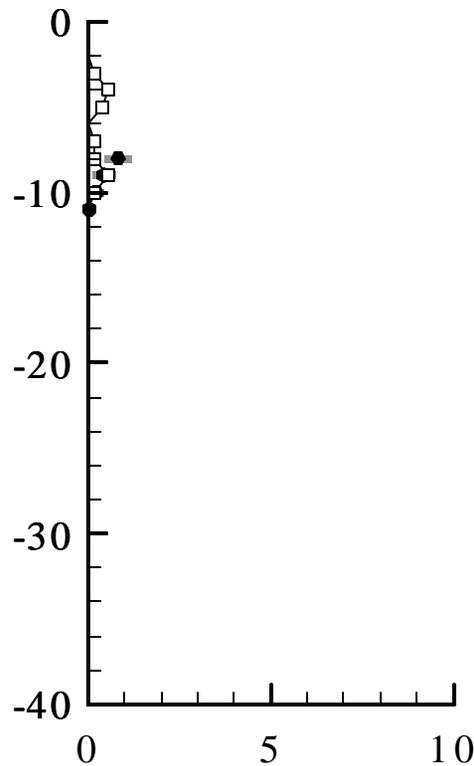


# JST Lake Blueback Herring Population as Detected by Virtual and Actual Hydroacoustic Surveys

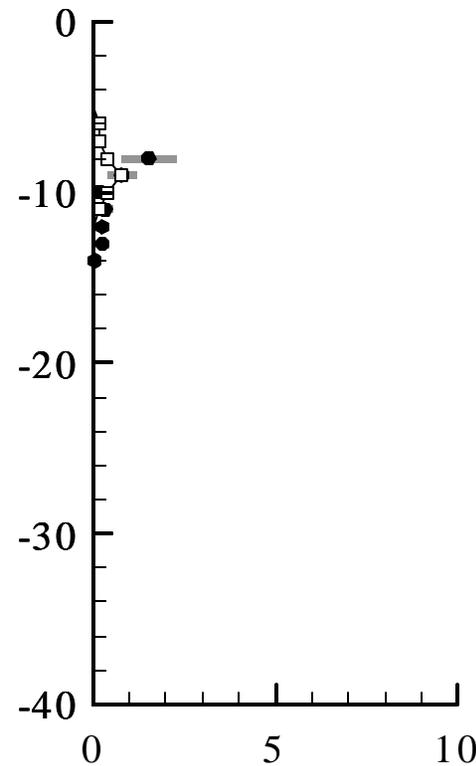
Survey Location  
Downstream of  
RBR Dam



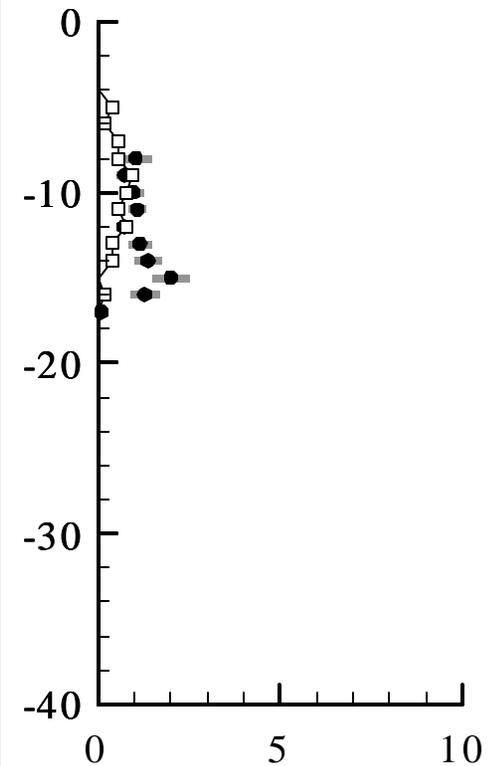
5 to 10 km



10 to 15 km

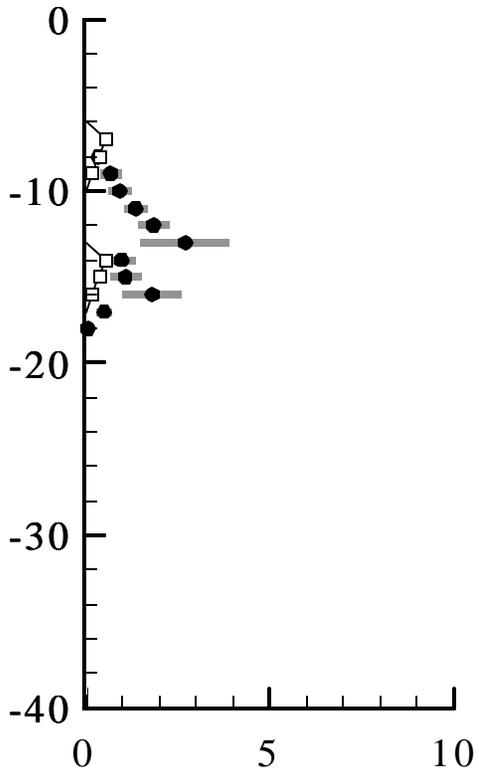


15 to 20 km

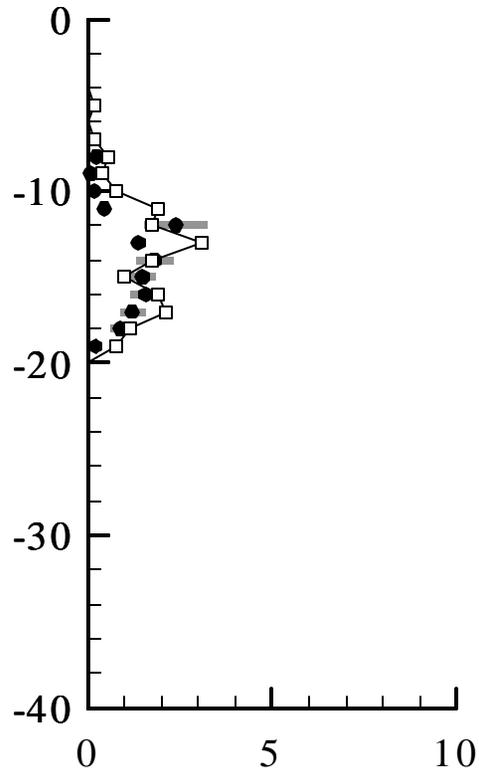


# JST Lake Blueback Herring Population as Detected by Virtual and Actual Hydroacoustic Surveys<sup>(cont.)</sup>

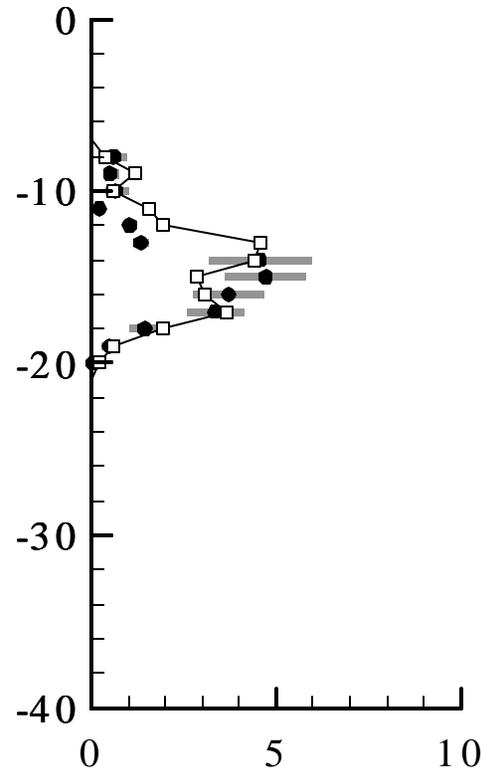
20 to 25 km



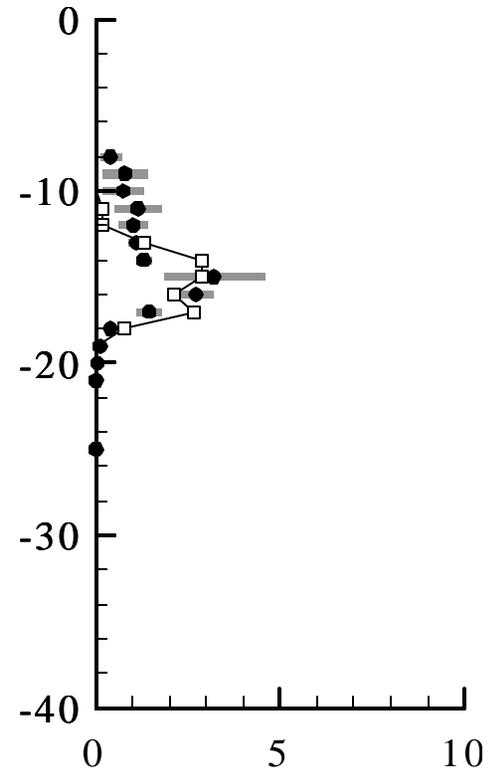
25 to 30 km



30 to 35 km

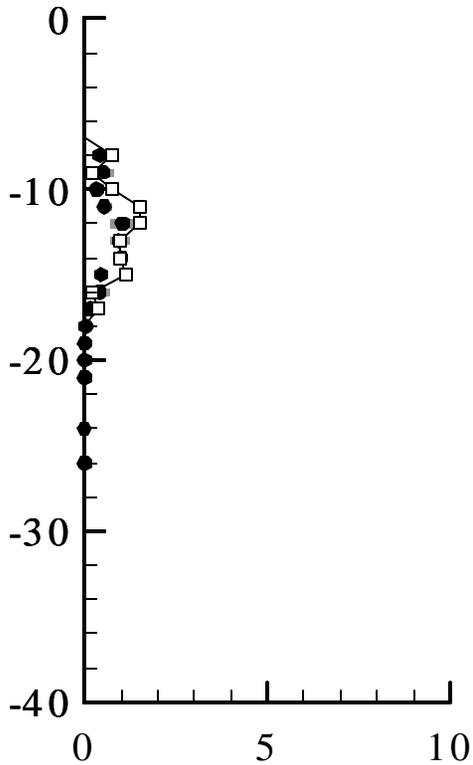


35 to 40 km

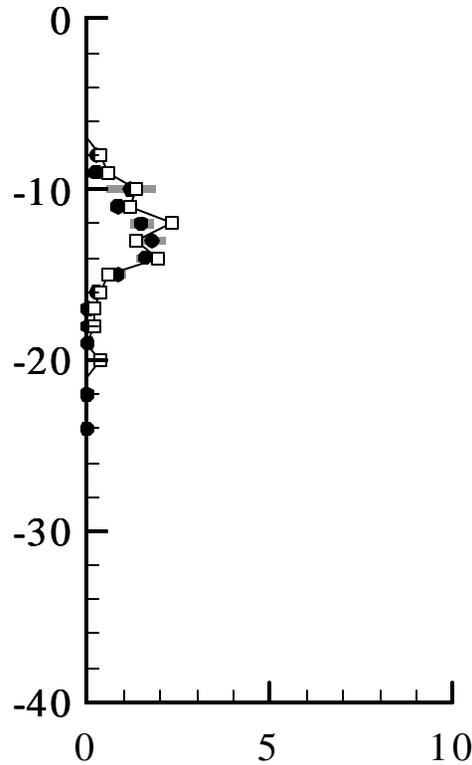


# JST Lake Blueback Herring Population as Detected by Virtual and Actual Hydroacoustic Surveys<sup>(cont.)</sup>

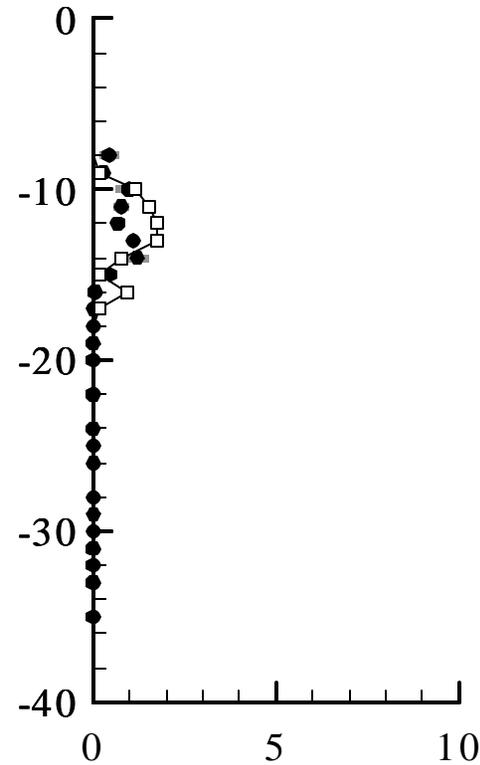
40 to 45 km



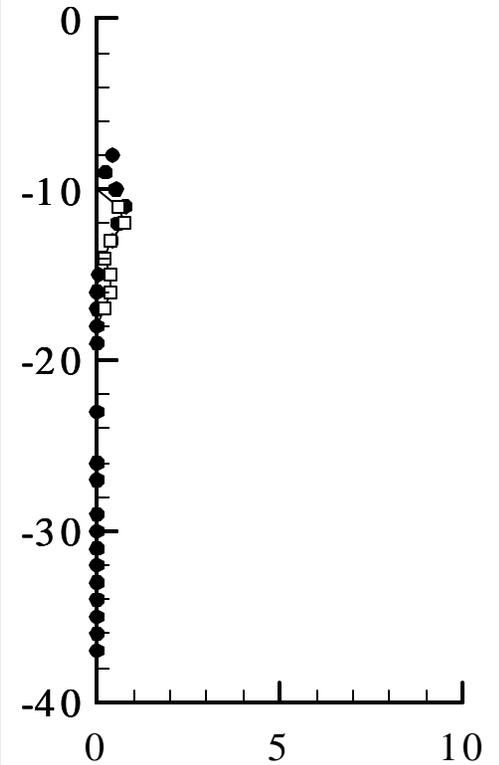
45 to 50 km



50 to 55 km



55 to 60 km



# Cumulative Decision History of Virtual Population

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Physicochemical Stimulus or Randomization	Longitudinal Movement Decisions (%)	Vertical Movement Decisions (%)
Horizontal Velocity	42.7	3.8
Vertical Velocity	0.0	1.1
Temperature	0.0	45.0
Dissolved Oxygen	0.0	6.0
Randomization	57.3	44.2

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