# Ecological Impacts of Hydrokinetic Energy: In-stream Tidal Energy

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nnmrec.oregonstate.edu (OSU - Wave)
depts.washington.edu/nnmrec (UW - Tidal)

→ • **In-stream Tidal Energy Overview**

• **Ecological Impacts**

• **Center Activities**

# Tidal Energy Overview

**Advantages**

- Predictable resource
- No $CO_2$ emissions
- No visual pollution
- Often located near load centers

**Challenges**

- Intermittent resource
- Not invisible to aquatic species
- Potential to place additional stress on estuaries

# Approaches to Tidal Energy

**Barrage**

- Comparable to hydroelectric
- Very high cost and environmental footprint

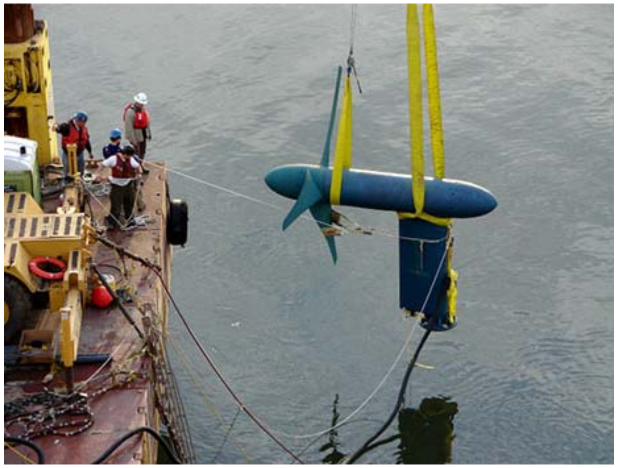
**Hydrokinetic**

- Comparable to wind
- Potentially lower cost and environmental footprint

# General Device Specifications

- **Deployment currents: > 3 m/s peak**
- **Deployment depth: 20-80 m**
- **Rotor size: 5-20 m diameter**
- **Maximum tip velocity limited by cavitation**
  - **Rule of thumb: 12 m/s**
  - **Utility-scale device limited to 10-15 rpm**
- **Power output in proportion to velocity *cubed***
  - **Small changes in velocity = large changes in power**

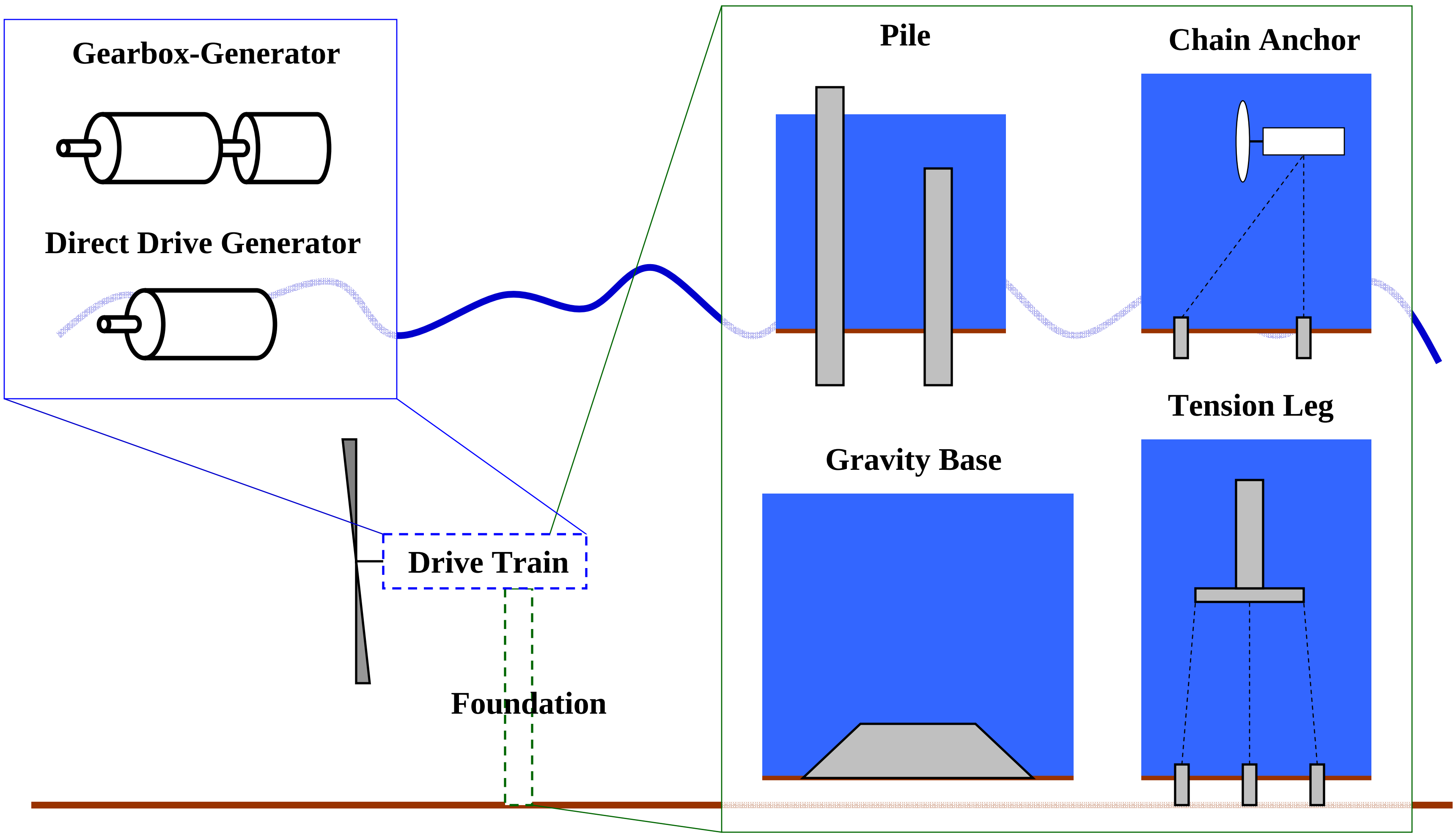
# Hydrokinetic Devices




*(clockwise from left)*

- **Verdant Power**
- **Clean Current**
- **Marine Current Turbines**
- **Open Hydro**


# Common Elements



# Site Characteristics

**Ideal**

- Uniform, flat-bottomed channel
- Smooth, bi-directional currents
- 30-40 m water depth
- Electrical infrastructure to the shoreline
- No existing users
- Biological desert

**Real**

- Variable width and depth
- Variable, turbulent currents with ebb/flood asymmetry
- 15-100 m water depth
- Electrical infrastructure inland
- Many existing users
- Biologically vibrant

- In-stream Tidal Energy Overview
- → Ecological Impacts
- Center Activities

# Ecological Impacts Overview

- **Different concerns at each stage of a project**
  - **Pre-installation**
  - **Installation**
  - **Operation**
  - **Decommissioning**
- **Low level of understanding**
  - **Unknowns or very broad range of potential effects**
  - **Most test data remains proprietary to developers**
  - **Challenging environment to make measurements**
- **Difficult to perform a cost-benefit analysis**

# Pre-installation Studies

- Establish environmental background
  - Often not well-characterized
- Many possible studies
  - Aquatic species use and abundance
  - Water quality
  - Currents
  - Substrate
- How to best structure for "before and after" comparison?

# Installation

- **Disturbances to sea bed**
  - —**Device foundation**
  - —**Sub sea cabling (offshore and nearshore)**
- **Disturbances on surface**
  - —**Ship traffic**
  - —**Lights**
  - —**Noise**
- **Potential to mitigate some impacts?**
  - —**Small foundation footprint**
  - —**Horizontal directional drilling under the nearshore**

# Operation

- **Rotating machinery**
  - —**Strike, collision, or entanglement danger**
- **Noise**
  - —**Avoidance behavior**
- **Hard substrates**
  - —**Colonization leading to aggregation behavior**
- **EMF**
  - —**Generator and cable**
- **Hydraulic fluid and mineral lubricants**

# Operation (cont)

- Changes to local flow field (near-field effects)
  - Sedimentation, mixing
- Changes to regional tidal regime (far-field effects)
  - Currents, mixing, tidal range, transport
- Cumulative effects of large arrays
  - Can effects be extrapolated from a single device?
- Toxicity of anti-fouling coatings
- …

# Decommissioning

- Removal of infrastructure
  - Cables
  - Foundation
  - Device
- Should everything be removed? Would it be less disruptive to leave foundation? Should the cables remain in place for observations?
- Who pays for removal of a failed project?

- **In-stream Tidal Energy Overview**
- **Ecological Impacts**
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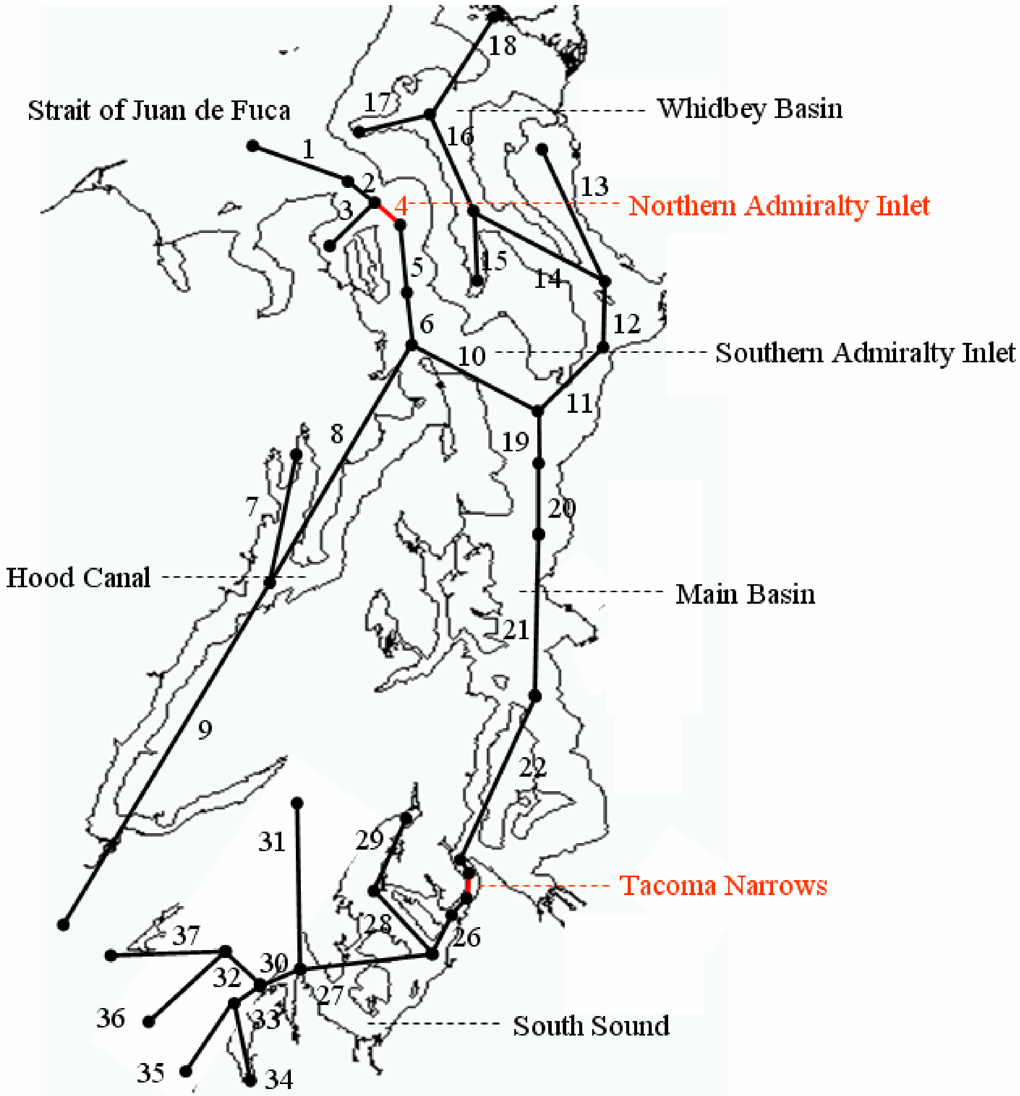
# NNMREC Tidal Research Areas

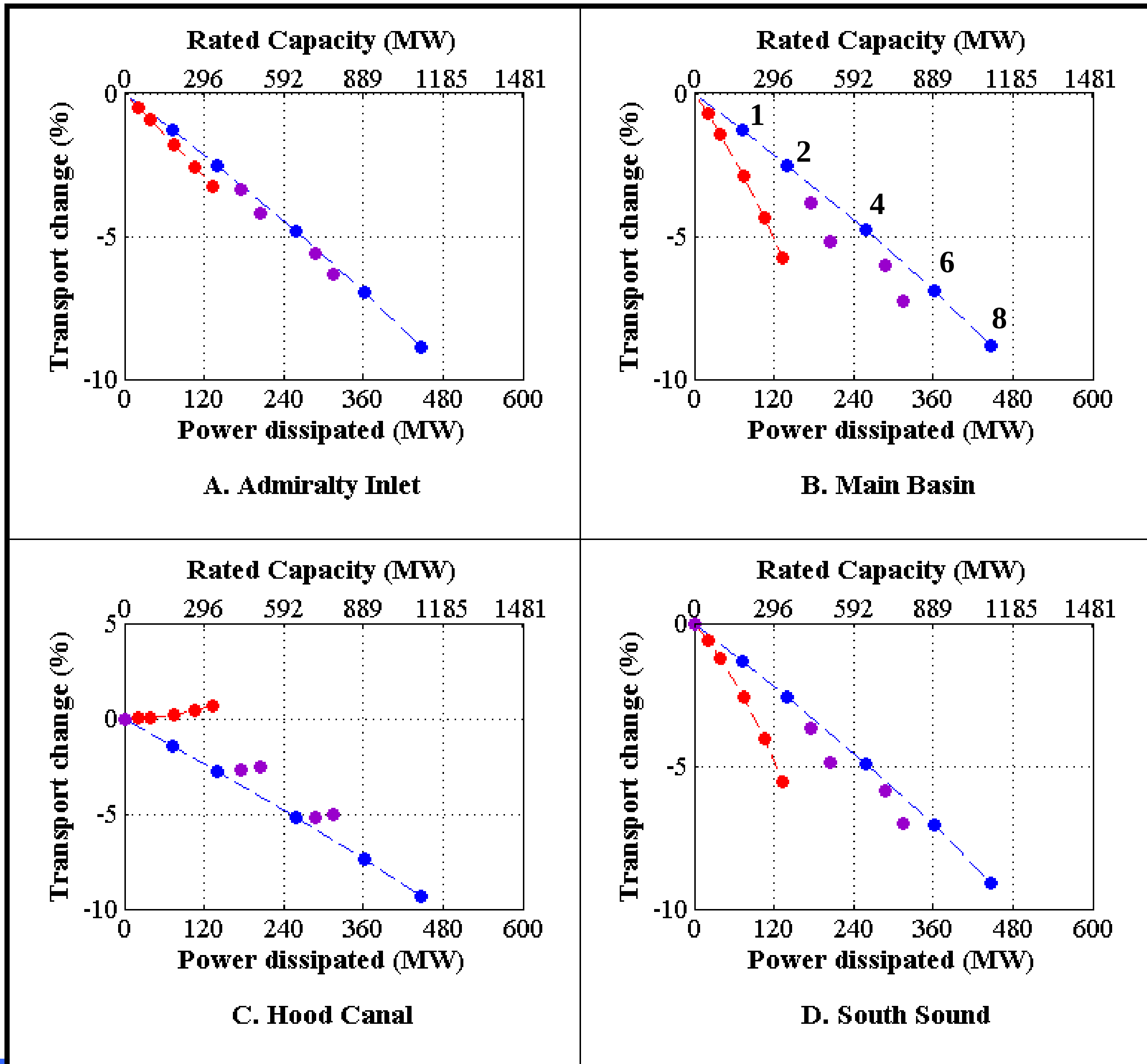
- **Area #1: Environmental effects**
- **Area #2: Site and device characterization (mobile testing)**
- **Area #3: Array optimization**
- **Area #4: Advanced materials for survivability and reliability**

# Modeling Extraction in Puget Sound




- Concerns that tidal energy extraction could exacerbate existing stresses (hypoxia)
- Modeling goals:
  - In-stream power potential for Puget Sound
  - Optimal siting of arrays
- Assumptions:
  - Flow dominantly 1D
  - Neglect salinity effects
  - Neglect small-scale features

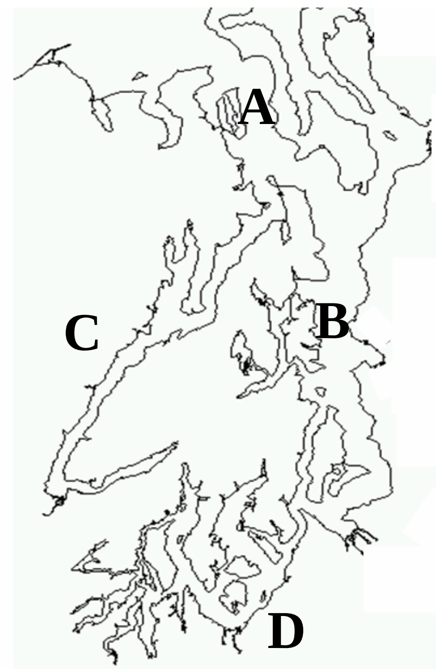
# Effect of Extraction on Transport




Extraction from Admiralty Inlet

Extraction from Tacoma Narrows

Extraction from Both Sites



# Cost-Benefit Evaluation

**Changes to tidal regime**
(transport, range, mixing)

↓ ?

**Changes to physical environment**
(sedimentation, dissolved oxygen)

↓ ?

**Species impact**
(fish, marine mammals)

# Site and Device Characterization

R/V Jack Roberston
University of Washington, Applied Physics Lab

Students preparing Sea Spider for deployment

**Field measurements to inform all parties**

- Site developers – resource and site characteristics
- Device developers – device performance and effects
- Regulators – existing environmental and effects

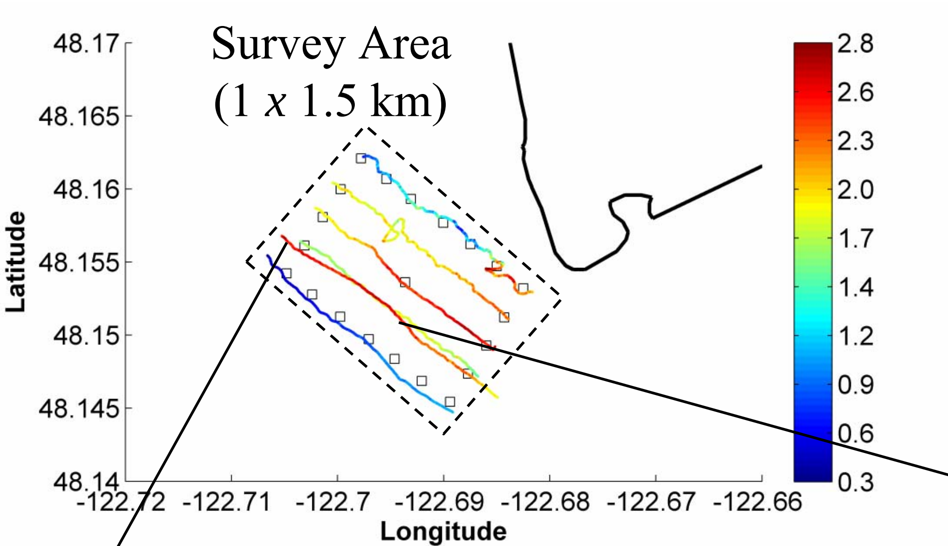
# Shipboard Survey

**Research Question**

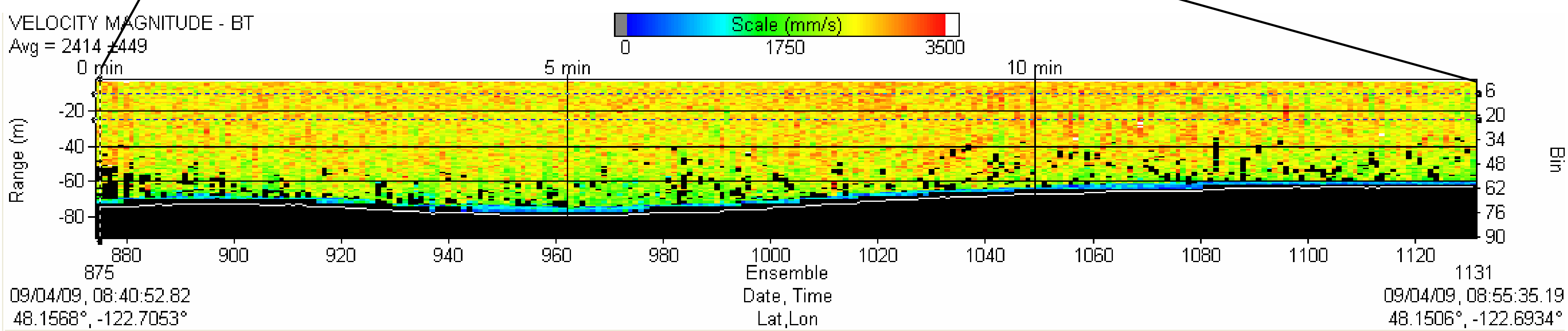
**What is the most efficient way to survey a tidal energy site?**

| Survey | Equipment |
| --- | --- |
| Currents | ADCP (RDI Workhorse - 300 kHz) |
| Water Quality | CTD + $O_2$ (SeaBird), Bottle Rosette |
| Fish Abundance | Echosounder (BioSonics) |
| Seabed | Bottom grab, ROV (SeaBotix) |
| Ambient Noise | Hydrophone (Cetacean Research) |

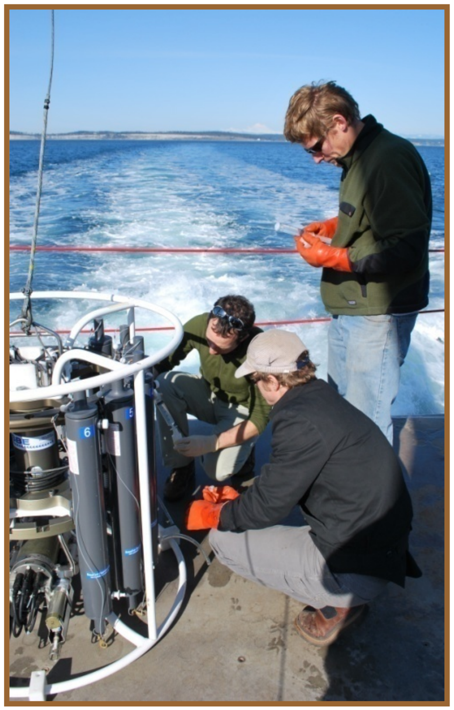
# Currents

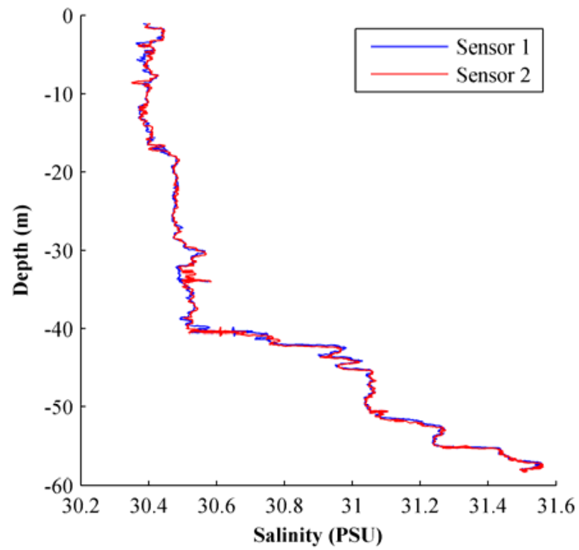



- **Currents exceeding 3m/s**
- **“Slack water” for 10-20 minutes (currents less than 1 knot)**
- **Significant spatial and temporal variability**

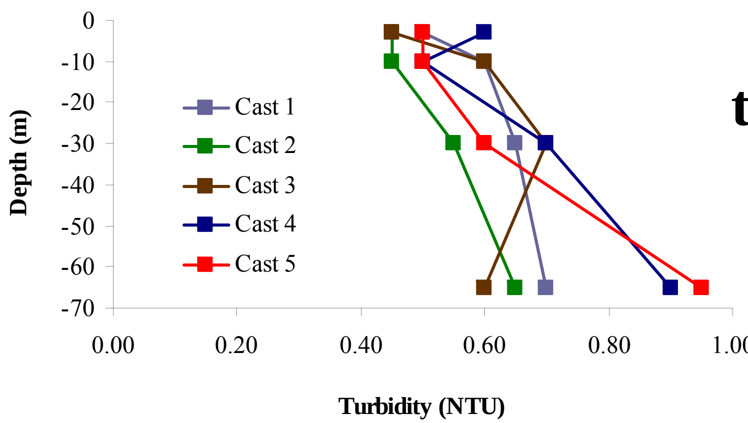


# Water Quality



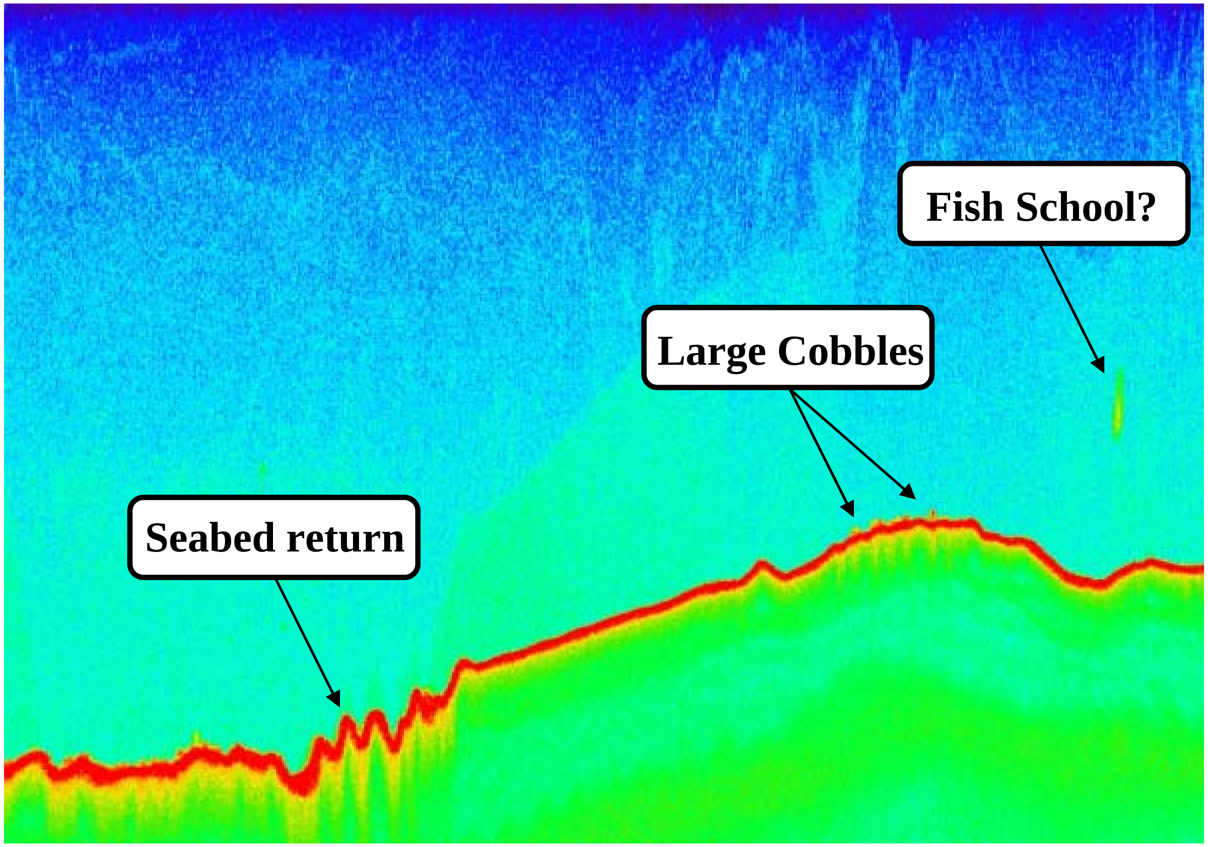



***In-situ* measurements show slight halocline and thermocline (*for this cast*)**



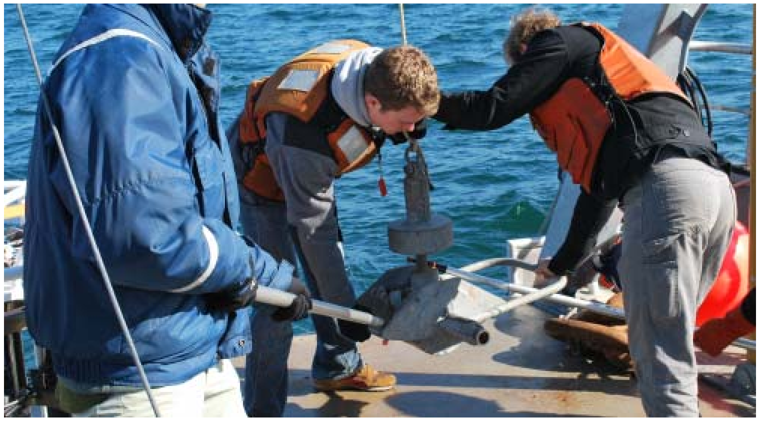

**Lab results indicate low turbidity (*for this season*) (WHO drinking water guidelines: < 1 NTU)**

# Hydroacoustics for Fish Abundance




- BioSonics echosounder (Center partner)
- Significant cross-talk between echosounder, ADCP, and depth finder

# Grab Samples



- Shipec grab (spring loaded)
  - — Attempt #1: 3 pebbles
  - — Attempt #2: nothing
- Van Veen grab (not deployed)
- Consistent with scoured seabed

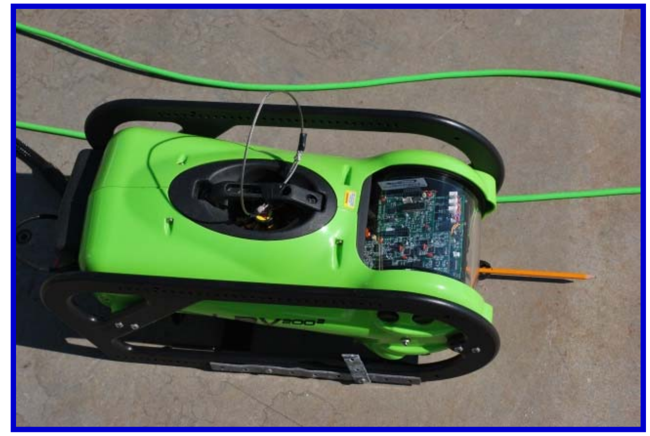
# Background Noise


Natural noise from strong currents
Many anthropogenic sources

# ROV Survey


- Scoured seabed
- Relatively flat
- Cobbles and gravel
- Sponges
- Barnacles

- Consistent with high currents and grab samples



# Equipment Package for Stationary Survey

**Acoustic release**
(redundant recovery)

**300 kHz ADCP**
(velocity)

**Hydrophone**
(background noise)

**Mini-CTD**
(salinity and temperature)

**Sea Spider**
(heavy duty fiberglass frame)

**Lead Weight**
(600 lbs)

**Programmed for 4 month deployment**

# Next Steps in these Areas

- **Modeling changes to physical environment**
  - 3D numerical modeling, including baroclinic effects
  - Partnership with Pacific Northwest National Labs (PNNL) to evaluate changes to physical environment
- **Additional shipboard surveys**
  - Every four months for next 8-20 months
  - Begin to establish seasonal variability
- **Additional instrumentation for stationary survey**
  - Fish tag hydrophone (May)
  - Upgraded storage and power for ADCP (May)
  - Echolocation hydrophone (August)

# Questions?

Northwest National Marine Renewable Energy Center

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