



# Using Ferries for Marine Water Quality Monitoring in the Salish Sea



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## INTRODUCTION

To better understand and predict water quality throughout Puget Sound, the Washington State Department of Ecology (Ecology) has sought creative approaches to collecting monitoring data. Ecology has partnered with Clipper Navigations and Washington State Ferries to collect oceanographic data. The resulting data sets are necessary to quantify the exchange of water masses and therefore to manage water quality (e.g., nutrient enrichment, low

dissolved oxygen conditions, the transport of toxic chemicals, harmful algal blooms, and ocean acidification), improve our water quality assessment decisions (303(d) listings under the federal Clean Water Act), and improve the performance of numerical models in Puget Sound.

Scientists expect that data collected by ferries continuously over many seasons and years will increase understanding of how water quality in the Salish Sea is modulated by oceanic and large-scale climate patterns.

## VICTORIA CLIPPER FERRY MONITORING

In 2009, Ecology partnered with Clipper Navigations, Inc. and installed oceanographic sensors on the *Victoria Clipper IV* ferry vessel. The twice-daily runs between Seattle and Victoria, B.C. provide phytoplankton concentration and temperature data to help understand spatial gradients, variability, and dynamics of water masses, river plumes, and algal blooms (Figure 1a).

These data can also be used for daily calibration of satellite images, thus enabling Ecology to stitch together the long-term data from our marine flight program with Clipper and satellite data (Figure 1b, 1c).

### Figure 1a. Ferry Monitoring – Clipper Navigations, Inc.

Collaboration started in May 2010 on *MV Victoria Clipper IV*

- Fluorometer with three optical lenses
- Travels between Seattle and Victoria, BC
- Added salinity in Apr 2012, Thermosalinograph
- Cost-effective data collection
  - 100-m spatial resolution (5 sec)
  - 4-hr temporal resolution
- Regular schedules, reliable
  - 80-mile long transect at 35 mph
  - 1-2 times daily year-round
- Daily data pickup



MV Victoria Clipper IV

### Figure 1b. Sea Plane Sampling

- Monthly flights since 1973
  - Four flights per month
  - Core and rotating stations
- Vertical profile sampling from a seaplane

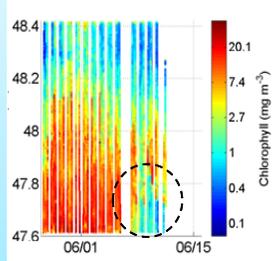


CTD being deployed through belly of sea plane.

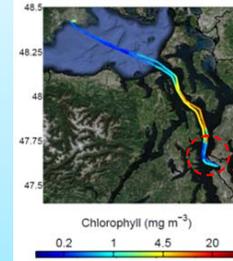
### Figure 1c. The grazing effect from a large-scale *Noctiluca* bloom observed from a marine flight is evident as low chlorophyll in the *Victoria Clipper IV* data (dashed circle).



*Noctiluca* surface aggregations looking west into Eagle Harbor (Bainbridge Island) June 12, 2012, 8: 39 AM



Temporal and latitudinal fluorescence measurements from *Victoria Clipper IV* on same day



Spatial view of fluorescence measurements from *Victoria Clipper IV* on same day



Ferry routes for the *Victoria Clipper IV* (VC; regular route shown) and Washington State Ferry (WSF)

### Parameters measured by each monitoring method

Parameter	Satellite	Sea Plane Sampling	Ferry Monitoring
Water color (true color, RGB composites)	✓		
Temperature	✓	✓	✓ VC
Salinity		✓	✓ VC
Transmissivity		✓	
Turbidity	✓	✓	✓ VC
River water		✓	
Fluorescence (chlorophyll a)	✓	✓	✓ VC
pH		✓	
Dissolved oxygen		✓	
Nutrients		✓	
Colored dissolved organic matter			✓ VC
Photosynthetically active radiation		✓	
Current velocity			✓ WSF

## WASHINGTON STATE FERRY MONITORING

In 2013, Ecology partnered with the Applied Physics Laboratory at the University of Washington (APL-UW) to install instruments on Washington State Ferries (WSF) to provide surface-to-bottom measurements of current velocities across Admiralty Reach. This is where water exchange (intrusions of ocean water) occurs between the Strait of Juan de Fuca and Puget Sound.

Direct observations of exchange velocities have been shown to correlate well with surface signals from the Clipper measurements (Figure 2c from Deppe, 2013), and thus Clipper data can be combined with WSF data to give a comprehensive description of the exchange through Admiralty Reach.

### Figure 2a. Ferry Monitoring – Washington State Ferries

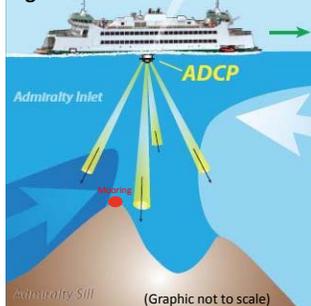
New collaboration with APL-UW and WSF

- Install ADCP on *MV Salish* (Apr 2014) and *MV Kennewick* (Oct 2014)
- Ferry transits on Port Townsend-Keystone route many times daily
- Route crosses Admiralty Sill which is the gateway separating the Strait of Juan de Fuca and greater Puget Sound
- Admiralty Reach is where circulation and exchange between the basins happens
- Collect data to calculate speed and direction (velocity) of water flowing under the ferry



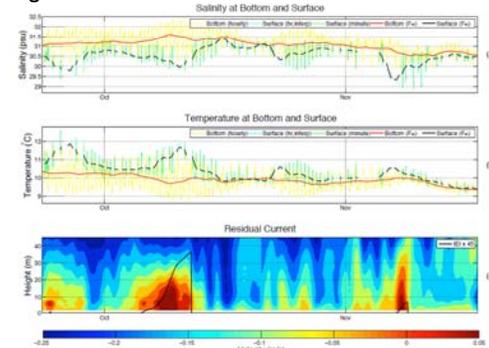
MV Kennewick (shown) and MV Salish

### Figure 2b.



Sensors called Acoustic Doppler Current Profilers, or ADCPs, will be installed on the hulls. ADCPs send sound waves (pings) down through the water column beneath the ferry as it is under way. The time it takes for the echoes to return to the ADCP is used to calculate the speed and direction (velocity) of the water flowing under the ferry.

### Figure 2c.



Time series presentation of salinity and temperature signals at the bottom and surface of Admiralty Inlet in relation to residual currents. (a) Salinity signals at the bottom from the mooring and at the surface from the *Victoria Clipper IV*. (b) Temperature signals at the bottom from mooring and at the surface from the *Victoria Clipper IV*. (c) Low-pass filtered, residual currents (m/s), height measured from the sea floor, overlaid with magnified Intrusion Event Index values to demonstrate oceanic water intrusion activity.



Staff involved with ferry monitoring and collaboration.

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### Reference

Deppe, R. Walt. 2013. Hypoxic Intrusions to Puget Sound from the Pacific Ocean. Final Report to the Washington State Department of Ecology. University of Washington, Seattle, WA.