

The Influence of Sediment Quality and Dissolved Oxygen on Benthic Invertebrate Communities in Hood Canal

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A Retrospective Data Analysis

As part of the Hood Canal Dissolved Oxygen Program, sediment quality, water-column dissolved oxygen (DO), and sediment-dwelling invertebrate (benthic infauna) data from Hood Canal studies from 1932 to 2005 were gathered.

These data were examined to (1) determine their characteristics in Hood Canal, (2) evaluate their relationship to each other, and (3) determine how low DO may affect benthic infauna in Hood Canal.

Sediments in Hood Canal – What’s It Like at the Bottom?

Measures of depth, sediment texture (percent fines), and total organic carbon (TOC) content of Hood Canal sediments are depicted in Figure 1.

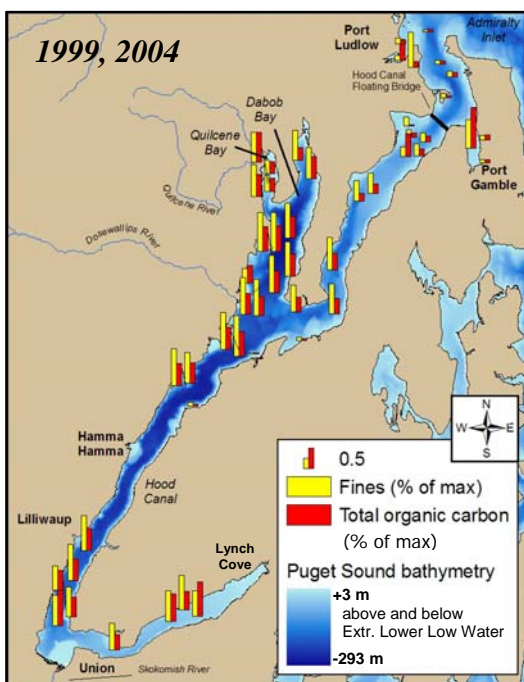


Figure 1. Depth, percent fines, and percent TOC in Hood Canal sediments.

Relatively coarse sands with low TOC were found in shallower northern Hood Canal and along shorelines.

Fine-grained sediments with higher TOC occurred in the embayments, in the deep middle and southern reaches of the central axis, in deep central Dabob Bay, and in Lynch Cove.

Sediment chemical contamination and toxicity were low in Hood Canal, rarely exceeding Washington State Sediment Quality Standards or other criteria. Highest levels occurred primarily in Port Ludlow, Port Gamble, and Dabob Bay (Figure 2).

Summary of Findings

- ❖ Unique benthic invertebrate communities were distinguished for nine sub-regions of Hood Canal, adapted to the sediment and DO characteristics found in each sub-region.
- ❖ The number and variety of benthic invertebrates declined, and stress-tolerant species become dominant as (1) sediment texture became finer, (2) near-bottom DO levels decreased, (3) sediment organic carbon content increased, and (4) station depth increased.
- ❖ Dissolved oxygen ranges of >3 to 6 mg/L and <1 mg/L may be critical thresholds for benthic invertebrates in Hood Canal.

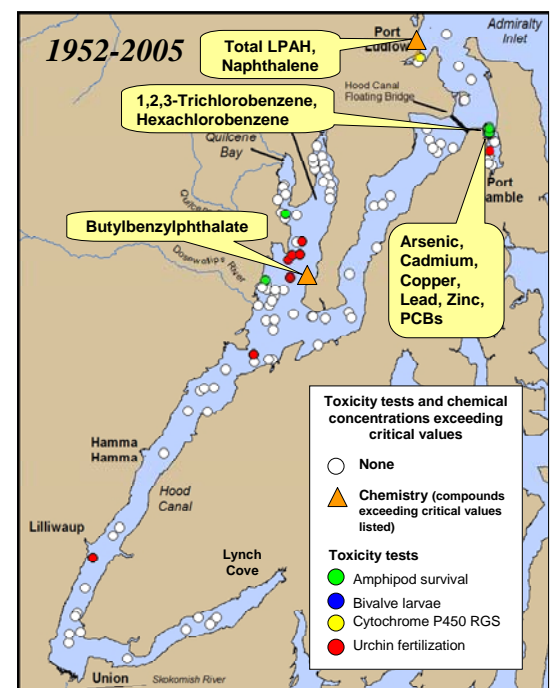


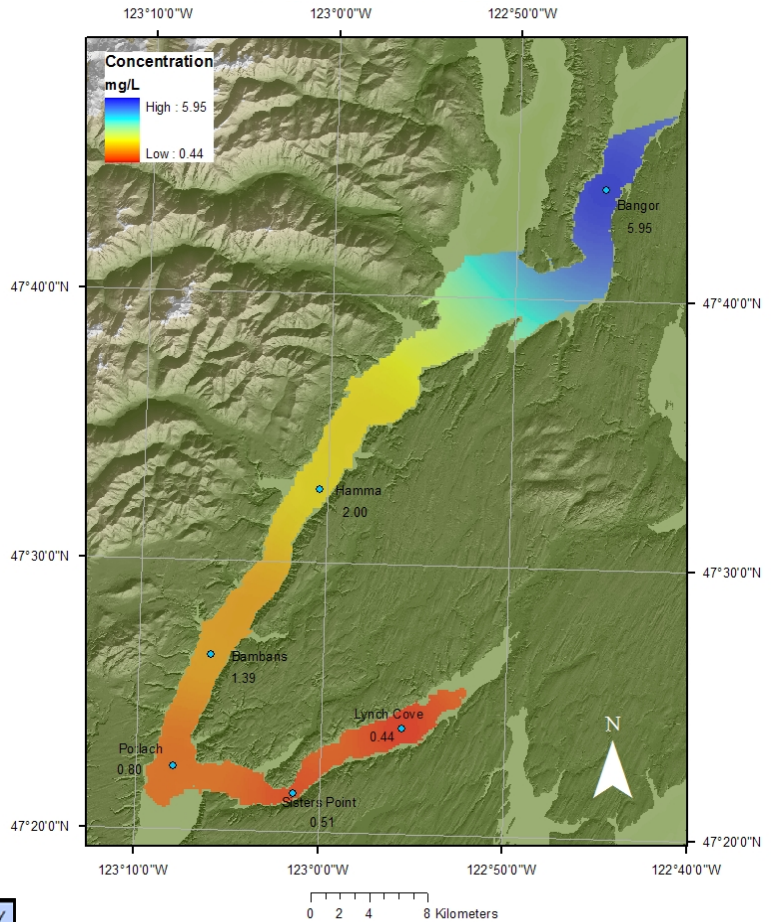
Figure 2. Chemical contaminants and toxicity in Hood Canal sediments.

Dissolved Oxygen in Hood Canal Waters – How Low Does It Go?

Dissolved oxygen (DO) levels varied throughout Hood Canal due to bathymetry, water circulation, and wind patterns. Levels varied seasonally and with water depth. DO was generally highest in the canal entrance, over the shallow entrance sill, and along the shorelines. Lowest concentrations were usually found southward and in deep locations in the late summer and early fall (Figure 3).

Lowest DO concentrations measured since 1932 have steadily decreased over time. Since the late 1990s, DO levels have periodically fallen below critical levels thought to protect bottom-dwelling biota (< 5 mg/L to < 1 mg/L) in most southern stations and at an increasing number of central and northern stations.

Figure 3. Measures and estimated levels of dissolved oxygen in Hood Canal (example - August 2002). Source: www.hoodcanal.washington.edu/observations/hypoxia.jsp.



Sediment-dwelling Invertebrates – Who Lives Where in Hood Canal?

Total numbers and types of sediment-dwelling invertebrates generally decreased from north to south along Hood Canal's main axis, with increasing percent fines and total organic carbon, decreasing DO concentrations, and from shallow to deep waters (Figure 4).

Relatively well-defined invertebrate communities were distinguished for three regions and nine sub-regions (Figure 5).

Northern Hood Canal sub-region sediments, with relatively low percent fines and TOC, supported the most diverse communities, with a well-balanced mix of annelids (worms), arthropods (crabs and shrimp), and bivalves (clams).

Less stress-tolerant arthropods, echinoderms (brittle stars and sea urchins), and other species generally became rare or absent progressing southward, with increasing percent fines and TOC, and in the deepest locations and terminal inlets. The more stress-tolerant annelids and several bivalves became dominant in these southern locations.

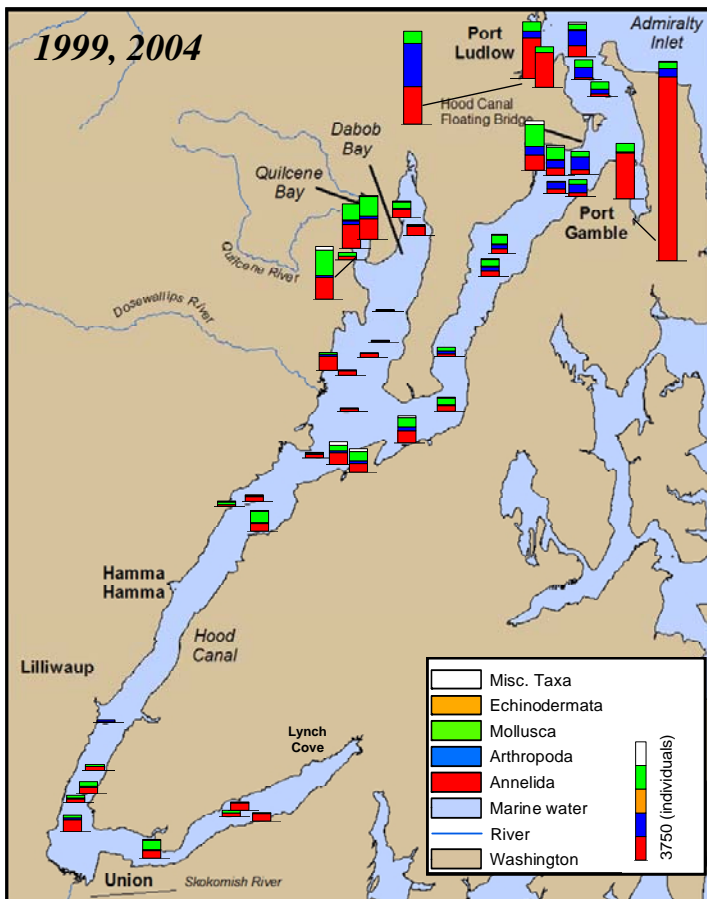


Figure 4. Total and major species abundance measured in Hood Canal sediment-dwelling invertebrate communities.

In general, Hood Canal benthic communities were less abundant and diverse than elsewhere in Puget Sound. Seventy-two (72) percent of the 58 stations sampled in Hood Canal from 1989 through 2005 had communities with benthic indicators lower than median indicator values generated Puget Sound-wide.

Relationships between Sediments, Dissolved Oxygen, and Benthic Invertebrates

Relationships between sediment quality, near-bottom DO levels, and benthic infaunal community characteristics measured simultaneously for 30 samples were examined using various statistical techniques.

Analyses suggested that measures of percent fines, near-bottom DO, TOC, and depth (in this order) were strongly related to each other and to the total numbers and species of benthic invertebrates. It is possible that all of these variables jointly influenced benthic invertebrate community structure in Hood Canal.

Community characteristics changed as near-bottom DO levels decreased. When samples were grouped into five declining DO ranges, differing patterns of declining abundance were observed for various species (Figure 6). Nine indicators used to characterize benthic communities also generally declined, especially at DO ranges of >3 to 6 mg/L and ≤1 mg/L (Figure 7). These two ranges may be critical levels for many benthic species in Hood Canal.

Further analysis of long-term data indicated that changes in benthic communities in the vicinity of the Great Bend (southern Hood Canal) were consistent with declining DO.

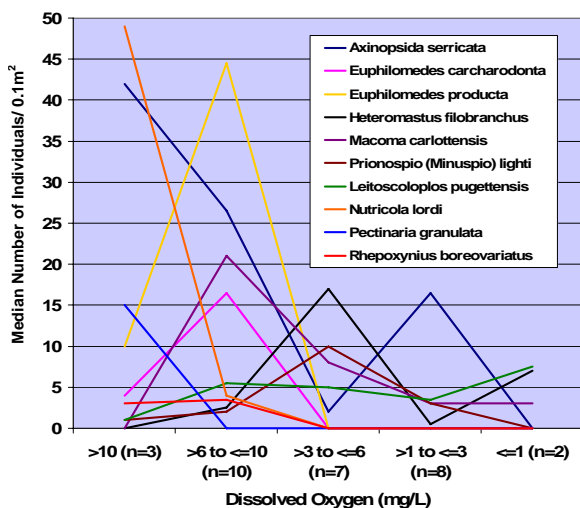


Figure 6. Changes in abundance for 10 benthic species from 30 Hood Canal samples grouped into five DO ranges.

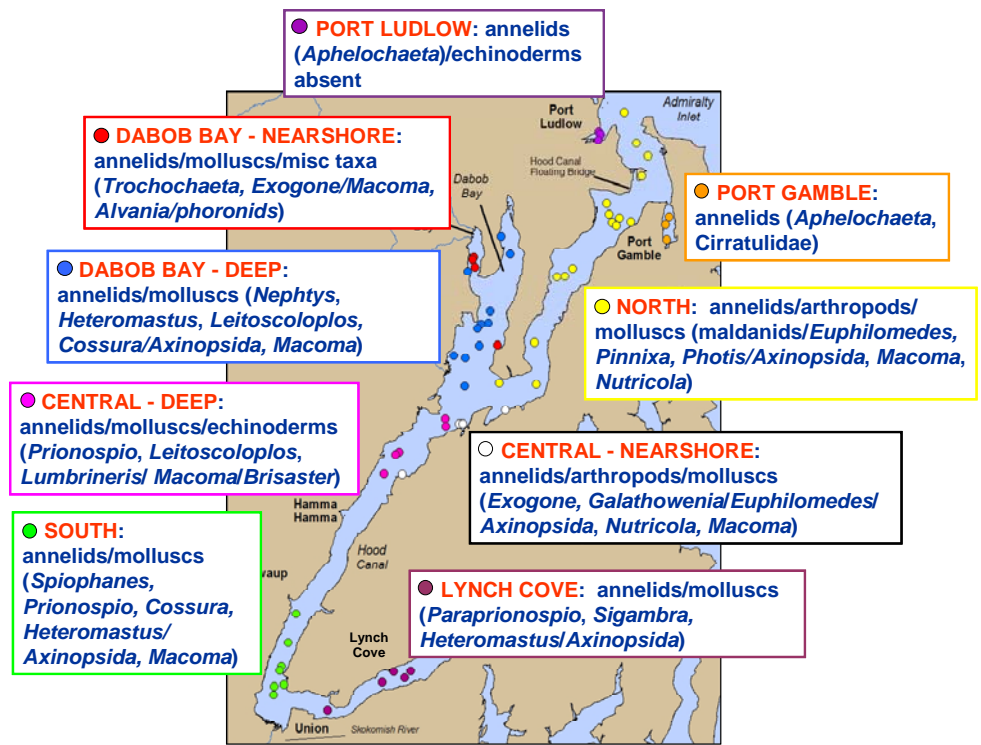


Figure 5. Invertebrate communities from 1989-2005 Hood Canal sediment stations fall into nine distinct sub-regions. Dominant organisms are listed.

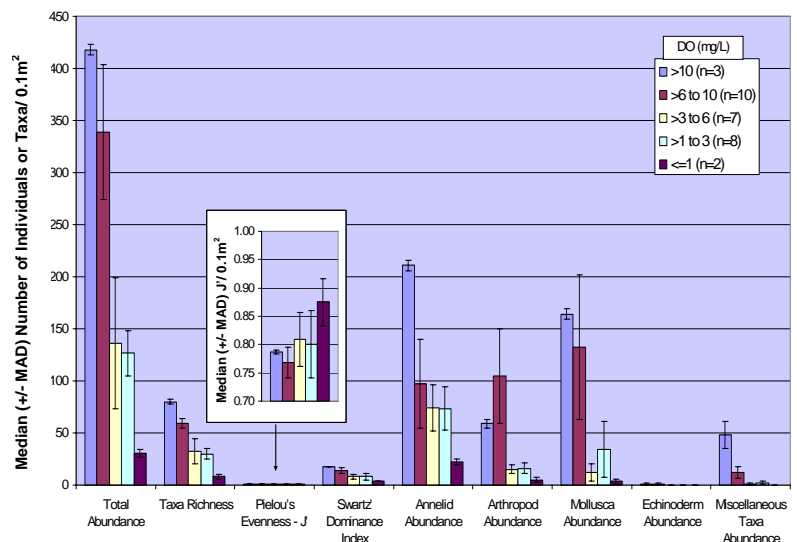


Figure 7. Median (± mean absolute deviation) benthic index values from 30 Hood Canal samples grouped into five DO ranges.

Why Do We Care About the Benthos in Hood Canal?



Pinnixa spp

Positioned near the bottom of the food chain, benthic infauna (benthos) include a wide variety of invertebrates that live on or in marine sediments. They cycle nutrients through the sediments and serve as an important food source for bottom-dwelling fish, larger surface-dwelling invertebrates, and many marine birds and mammals (including gray whales).



Macoma spp

Monitoring has indicated that in many locations throughout Puget Sound sediments can support thousands of marine invertebrates and hundreds of species in just a tenth of a square meter of surface area. An abundant and diverse benthic infaunal community is one sign of a healthy ecosystem.



Brisaster latifrons

Seasonal episodes of low DO in the waters of Hood Canal have increased in duration, frequency, and area since scientists first began taking measurements in the 1930s. Recent episodes of low DO have triggered fish and invertebrate kills in southern Hood Canal and have become a focus of concern for scientists and the general public.

While most of the attention has been focused on the effects of low DO on fish and larger invertebrates such as crab, shrimp, squid, and octopus, little has been done to assess the effects of low DO on the lesser-known, benthic infauna.



Pectinaria spp

Photos courtesy of Dr. Jeff Cordell

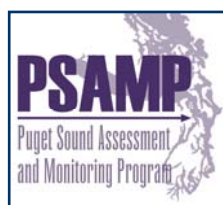
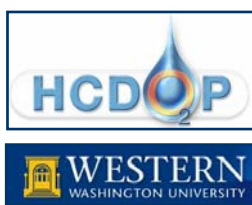
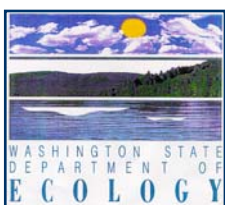
What Does This Study Tell Us?

Benthic infaunal communities in Hood Canal are generally less abundant and diverse than elsewhere in Puget Sound, and differ from one area to another throughout Hood Canal. Existing sediment, DO, and benthos data suggested that the total number and variety of benthic invertebrates declined, and several stress-tolerant species became dominant, from north to south in Hood Canal as (1) sediment texture became finer-grained, (2) DO levels near the bottom decreased, (3) nutrient content (percent TOC) in the sediments increased, and (4) depth increased. Chemical contamination and toxicity in Hood Canal sediments were limited, so had less influence on benthos. Initial steps have been taken to develop critical DO thresholds which can be used to determine when benthic infauna are at risk.

It is clear from the review of existing data that the benthic infauna in Hood Canal are likely to be sensitive to future natural and anthropogenic (human-caused) changes in Hood Canal in any or all of the environmental factors examined in this study.

The existing data set posed some limitations for relating sediment quality, DO, and benthic infauna in Hood Canal. The full report gives recommendations for further work needed to refine our understanding of relationships between parameters, and particularly, how changes in DO may affect the benthos in Hood Canal.

This work was conducted as a partnership between:



This paper is based on the report:

Long, E.R., S. Aasen, M.E. Dutch, K.I. Welch, V.A. Partridge, and D.H. Shull, 2007. *Relationships between the Composition of the Benthos and Sediment and Water Quality Parameters in Hood Canal: Task IV – Hood Canal Dissolved Oxygen Program*. Washington State Department of Ecology and Western Washington University. Ecology Publication No. 07-03-040. www.ecy.wa.gov/biblio/0703040.html

General information and all data generated for this report can be accessed from Ecology's Marine Sediment Monitoring website: www.ecy.wa.gov/programs/eap/psamp/index.htm

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