

Dynamics of Willapa Bay, Washington
Links to the Coastal Ocean, Tidal Dispersion, and Oyster Carrying Capacity

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Abstract

Dynamics of Willapa Bay, Washington:
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Willapa Bay is a shallow, macrotidal, coastal-plain estuary where Pacific oysters (*Crassostrea gigas*) are intensively cultivated. The bay's river and ocean end members are both highly variable. Fluctuating ocean conditions—alternations between wind-driven upwelling and downwelling, and intrusions of the buoyant Columbia River plume—force huge changes in input of nutrients, phytoplankton biomass, and temperature and salt on the event (2-10 day) scale, as well as seasonally.

To infer the bay-wide salt balance from salinity time series, an effective horizontal diffusivity parameterizing all up-estuary salt flux is calculated as a function of riverflow. Results show that the overall rate of ocean-estuary exchange is relatively inflexible across seasons, buffered by strong horizontal tidal stirring, increasing only threefold from summer to winter while riverflow rises thirtyfold. A high-resolution numerical model of the bay, an implementation of GETM (General Estuarine Transport Model), is used to map this tidal exchange process in detail. A Lagrangian particle-tracking method reveals coherent lateral exchange flows interwoven with discontinuous, small-scale dispersion, as well as tidal-residual currents that in some

locations sharpen rather than smooth gradients between water masses.

Five years of chlorophyll, productivity, and nutrient measurements are used to establish that in summer, the predominant source of non-regenerated primary production in Willapa is direct import of oceanic phytoplankton blooms. Phytoplankton biomass declines up-estuary, faster than dilution by tidal dispersion could explain. Results from a version of the tidal model modified to include a non-conservative, phytoplankton-like tracer suggest that oysters and other intertidal benthic grazers may be sufficient by themselves to explain the net loss of phytoplankton within the estuary in summer. These grazers appear to be close to carrying capacity: as bay-total filtration capacity increases, the chlorophyll intrusion shortens and food intake per individual grazer declines. This occurs despite the fact that only 10-15% of the net tidal supply of oceanic phytoplankton is consumed within the estuary. Even in this well-flushed system, the small-scale structure of the tidal circulation, rather than total oceanic supply, controls overall food availability for the benthos.

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PREFACE

This dissertation is adapted from four articles originally prepared for independent publication. Chapter 1 is excerpted from the summary paper by Hickey and Banas (2003). Chapter 2 is equivalent to Banas et al. (2004). Chapter 3 is the “submitted” paper by Banas and Hickey (2005). At the time of writing, Chapter 4 is an article in preparation by N.S. Banas, B.M. Hickey, J.A. Newton, and J. Ruesink. Because of these origins, there is some repetition among the Introductions in the four chapters. This repetition has been retained because the four articles are highly sequential: it is in the progressive accumulation of ideas in these Introductions that the synthesis of our physical observations, biological observations, and modeling work on Willapa Bay can be found.

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