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## **Strait of Juan de Fuca, Offshore Finfish Mariculture: Final Report**

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*PREPARED FOR:*

National Marine Fisheries Service  
National Sea Grant College Program,  
Office of Oceanic and Atmospheric Research  
Washington D.C.

*DATED:*

1 August 2005

*WITH A GRANT TO:*

Washington Fish Growers Association  
10420 173rd Ave. SW  
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NOAA Award # NA16RG1592

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## **Acknowledgements**

We thank the following organizations and individuals for their support or services.

Our co-authors and cooperators:

Dr. Dale Kiefer, University of Southern California, Los Angeles  
Dr. Dana Woodruff, Battelle Marine Laboratory, Sequim, Washington  
Mr. Nathan Evans, Battelle Marine Laboratory, Sequim, Washington

Others involved in various phases of this work:

Mr. Pete Granger, for assistance in some of the initial field work and grant writing.  
Dr. Rita Horner, for taxonomy and advice regarding phytoplankton  
Mr. Joe Schmidt, assistance with boats and field sampling  
Makah Tribal Nation, assistance with boats and field sampling  
Cypress Island Inc., for D.O. monitoring and growth factors for spreadsheet analysis  
University of Washington Routine Chemistry Laboratory, sample analyses  
Marnie Jo Zirbel, Shannon Point Marine Laboratory, for fieldwork assistance.

This report was prepared with funds provided by NOAA, Office of Oceanic and Atmospheric Research, grant # NA16RG1592.  
Federal Program Officer Dr. James McVey

This report should be cited as:

Rensel, J.E. and J.R.M. Forster. 2005. Strait of Juan de Fuca, offshore finfish mariculture: Final Report. Prepared for National Oceanic and Atmospheric Administration by Rensel Associates, Arlington, Washington.

## Executive Summary

This study addressed the Strait of Juan de Fuca in Washington State as a possible offshore fish mariculture location. A few highlights of the work are mentioned here, the reader may refer to our website line <http://www.wfga.net/sjdf/index.html> to obtain details, annual reports, a publication and other materials associated with this work. The site will be maintained until at least May 2007. After that point, information should be available from the NOAA Aquaculture Page on line or from the primary author.

### Accomplishments and findings:

- Described circulation patterns at possible candidate mariculture sites in the western, central and eastern Strait. Flows were typically alongshore, although a previously not described subsurface and very large scale gyre was detected just east of Port Angeles Harbor near our Western Strait study site.
- Conducted acoustic Doppler current profiler studies at all three candidate sites to describe surface to near-bottom velocity and directional components of the currents. Differences among sites were observed, re-studied in some cases, and described.
- Conducted two-month current and wave height study in the Western Strait near Neah Bay and found relatively modest significant wave height in the winter storm season. Mean current velocity at western and central Strait sites was near 30 cm/s with rare peak flows near 100 cm/s.
- Studied phytoplankton assemblages including harmful algae throughout the Strait in summer and early fall and compared to nearby bays. Phytoplankton biomass is relatively low in the Strait compared to the nearby bays and Puget Sound. Harmful algae were observed, but only infrequently at low concentrations.
- Collected salinity, temperature, pH, dissolved oxygen, *in vivo* chlorophyll a and turbidity vertical profiles in 2001 and 2002 at candidate sites during short time periods. As previously known, water temperatures are moderate and ideal for marine fish and salmonid culture.
- Compared spot surveys of dissolved oxygen profiles to those at an existing fish farm in North Puget Sound and found similar conditions during concurrent observations. However, much more oxygen flux is available in pens in the Strait as periods of slack tide are very minimal compared to inshore locations in Puget Sound. Lack of slack tide is a positive aspect for fish health, but will potentially make facility maintenance more difficult. Some marine fish species are adapted to low dissolved conditions, but their performance in higher current regimes is not known.
- Demonstrated that dissolved oxygen concentrations increased at the existing fish farm site during neap tides, ostensibly because the surface layer warms, becomes more stratified and allows increased oxygen production from phytoplankton. Fish farmers routinely observe increased phytoplankton biomass at this time, so the hypothesis is likely true.

- Demonstrated strong positive water temperature or salinity to dissolved oxygen correlations in the database.
- Assembled extensive sea surface temperature (SST) images from satellite observations during 2001 and 2002 which were drought and normal river discharge years, respectively.
- Detected and quantified a previously undetected cool water temperature anomaly in the central Strait. The anomaly may indicate lower dissolved oxygen content due to the water temperature to DO correlations mentioned above but it may not apply to nearshore areas as SST images do not have close resolution in those areas.
- Designed, constructed and tested a water-column simulation model of fish farm effects on dissolved oxygen, nutrients and plankton. The model runs within a GIS software package that is unique in its inclusion of depth, where normal GIS systems are only 2 dimensional. The resulting software package is Windows-PC based, user friendly and founded on the extensive salmonid physiology literature that we parameterized specifically for this project.

We conclude that low or no impact marine fish mariculture is technically feasible in the Strait. As the area is naturally replete with dissolved nitrogen, waste nitrogen from the fish will not stimulate algal blooms or productivity. Current velocities are sufficient to prevent measurable sea bottom deposition as occurs at some inshore sites. However, the high energy environment and challenging conditions will necessitate revised and novel management techniques and suitable facilities to insure successful operations. Presently there are no known projects or permits involving for salmon or marine fish mariculture in the Strait. Suitable pen designs are available for conditions to be found in the Strait, and other work is proceeding to characterize marine fish physiology and adaptability to higher current velocity conditions.

#### **List of reports and presentations produced to date**

Rensel, J.E. and J.R.M. Forster. 2002. **Strait of Juan de Fuca, offshore finfish mariculture: Literature review and preliminary field results.** Prepared for U.S. National Oceanic and Atmospheric Administration. Office of Oceanic and Atmospheric Research. 87 pp.

Rensel, J.E. and J.R.M. Forster. 2003. **Strait of Juan de Fuca, offshore finfish mariculture: feasibility study, Data report, Year two.** Prepared for U.S. National Oceanic and Atmospheric Administration. Office of Oceanic and Atmospheric Research. 72 pp. (summary prepared for NOAA-OAR web site too).

Rensel, J.E. 2003. **Offshore mariculture in the Strait of Juan de Fuca.** Presentation to NOAA aquaculture oversight group, Conrad Mahnken coordinator. Manchester Washington.

Rensel, J.E. 2003. **Offshore siting study update, fish physiology & modeling**: Jack Rensel 17 Jan 03 Manchester Research Laboratory, Manchester WA. Special meeting held for WFGA and PAC and hosted by Rensel Associates and Forster Consulting.

Rensel, J.E. 2003. **Water quality and sediment impact management of finfish net pens in Washington State (including Strait of Juan de Fuca)**. Conference on Marine Aquaculture: Effects on the West Coast and Alaska Fishing Industry – November 17-19, 2003 – Seattle, Washington Pacific States Fisheries Management Council meeting on aquaculture and fisheries interactions.

Rensel, J.E. and J.R.M. Forster. 2004. **Offshore Mariculture in the Strait of Juan de Fuca: Physicochemical and Biological Considerations**. American Geophysical Union, Annual Meeting, Portland Oregon, February 2004.

Rensel, J.E. and J.R.M. Forster. 2004. **Offshore finfish mariculture in the Strait of Juan de Fuca**. Presentation to the offshore session, World Mariculture Society annual meeting, Honolulu Hawaii.

Rensel, J.E., J.R.M. Forster, D. Woodruff, D. Kiefer. 2004. **Physicochemical and Biological Study, 20 to 40 m Depth Zone, Strait of Juan de Fuca: Spring 2004 Update**. Nearshore Ecology Conference, Port Angeles Washington.

Rensel, J.E. and J.R.M. Forster. 2004. **Strait of Juan de Fuca, offshore finfish mariculture: Year three study report**. Prepared for U.S. National Oceanic and Atmospheric Administration. Office of Oceanic and Atmospheric Research. 42 pp.

Rensel, J.E. 2004. Presentation to the WAC-PAC annual meeting at Neah Bay. **Oceanography of the Strait of Juan de Fuca**. Neah Bay, WA. Sept. 15, 2004.

Rensel, J.E., D.A. Kiefer, J.R.M. Forster, D.L. Woodruff and N.R. Evans. 2004. Zero Impact fish mariculture. Presentation to the .US.-Japan Cooperative Program in Natural Resources, 33rd Annual Meeting. Nagasaki Japan 2004

Rensel, J.E., D.A. Kiefer, J.R.M. Forster, D.L. Woodruff and N.R. Evans. In Press. **Offshore finfish mariculture in the Strait of Juan de Fuca**. U.S.-Japan Cooperative Program in Natural Resources, 33rd Annual Proceedings. Nagasaki Japan 2004. See publication at <http://www.wfga.net/sidf/index.html>