Marine Spatial Planning Report: November 1, 2012–June 30, 2013

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Purpose

University of Washington oceanographers have conducted almost four decades of empirical research and data collection on coastal resources relevant to Marine Spatial Planning (MSP) on the open Washington coast and in Washington's coastal estuaries, including those related to the renewable energy, cable installation, and ecosystem habitat evaluation. Recent research has resulted in development of a cutting edge numerical model of currents, water conditions and the ecosystem for the entire region, which also will provide relevant data for MSP. The oceanography team includes scientists and staff that have worked in this region for decades and have both access to and memory of existing datasets, as well as the skill to assemble both the metadata and data for the MSP process.

The University of Washington team is tasked with ensuring that the MSP process for WA State incorporates the latest understanding of both the static features of the ocean and the dynamic, time variable processes that define zones of greatest primary productivity; e.g., critical habitats change with seasons. To that end, the oceanography datasets provide information on the monthly, seasonal and decadal changes that characterize coastal ocean processes as well as the degree of variability that can be expected.

The UW team was tasked with assembling, preparing and delivering data and metadata for existing data sets relevant to the development of the MSP. The team has prepared and submitted a DVD containing datasets, metadata, pdf maps and the final report. In addition, as tasked, oceanography personnel have provided expertise to assist stakeholders in MSP planning efforts.

Methods

a) Measured data archive: Moored array data

Data reports, files and notebooks beginning in 1967 (the earliest reference to current meter deployments on the Washington Shelf) were reviewed for information about existing current meter records acquired on the Washington coast by the UW coastal team.

Specific data sets from the field projects were next identified. Current meter data in digital form was located and evaluated before adding to the database.

Metadata describing the types of instruments, periods sampled and sampling interval along with the current meter data in digital form was also included in the database. Data consists of time series of measured u and v components of velocity and temperature. Data are summarized in Table 1 and included on the DVD. Data is arranged by project. All data for each project along with a "Readme" file with information about the data files is in one folder with the exception of the Columbia River Plume project. For the Columbia River Plume project the main folder is divided into 5 folders arranged by instrument type. Each folder has at least one Readme file describing the data files.

Date	Project Name	Number of Data Files
1967-1969	Shelf Observations near the Columbia River	8
1975	Winter-Spring	14
1977	Cross Shelf Experiment	12
1977-1978	Slope Undercurrent Study	27
1978	Astoria Canyon I	10
1979	Quinault Canyon I	17
1980-1981	Quinault Canyon II	21
1981	UP-I	41
1981-1982	Quinault Canyon III	10
1982	UP-II	22
1983	Astoria Canyon II	21
1990-1991	Columbia River Plume	53

Table 1. Number of current meter time series data files summarized by project.

b) Measured data archive: Water property profiles

The UW archives also include a number of profiles of water properties from several decades beginning in the 1960's. Profiles were collected during comprehensive research cruises focused on the Washington coast. Water properties included temperature, salinity and pressure on all cruises; light transmission and conductivity data are available on selected cruises. As with moored array data, measured water property profiles are used to assess seasonal and multi-year changes in properties.

Because data were recorded in formats not currently used, data recovery involved several steps to make it compatible for MSP use. Accurate metadata has been prepared for each cruise and data set. Data recovered to date are summarized in Table 2, see below, and the data and metadata are included on the DVD.

Cruise Name	Location	Ship	Dates	Number of Stations	Instrument Type	Variables
TT125	Washington Coast	R/V Thompson	January 1978	70	Neil-Brown Mark III CTD	P, T, S
W7904	Washington Coast	R/V Wecoma	April 1979	52	Neil-Brown Mark III CTD, Sea Tech Transmissometer	P, T, S, Light trans.
TT140	Washington Coast	R/V Thompson	July 1979	10	Neil-Brown Mark III CTD, Sea Tech Transmissometer	P, T, S, Light trans.
TT160	Washington Coast	R/V Thompson	August 1981	180	Neil-Brown Mark III CTD, Sea Tech Transmissometer	P, T, S, Light trans.
W8305a	Astoria Canyon	R/V Wecoma	May 1983	33	Neil-Brown Mark III CTD	P, T, S
W9010	Columbia R. Plume	R/V Wecoma	October 1990	133	SBE911 CTD	P, T, S, C, Dyn. Ht.
W9101	Columbia R. Plume	R/V Wecoma	January-February 1991	296	SBE911 CTD	P, T, S, C, Dyn. Ht.

Table 2. Water profile data. Units of the variables are Pressure (P), decibars; Temperature (T), degrees C; Salinity (S), unitless; Conductivity (C) milli-Siemens per centimeter; Dynamic Height (Dyn. Ht.), meters; Light Transmission (Light trans.), percentage. Time in files is GMT.

c) Modeled layers

Gridded data layers were derived from a three-dimensional biophysical simulation implemented in ROMS (Regional Ocean Modeling System), the research community standard. The model has 40 vertical layers and 2 km horizontal resolution on the continental shelf, and is forced by realistic atmospheric inputs, ocean inputs, and freshwater from the Columbia, Fraser, and 15 Puget Sound rivers. Modeled hindcasts for the period 2004-2007 have been validated against moored and ship-based measurements of temperature, salinity, currents, chlorophyll, nitrate, and oxygen on the coasts of northern Oregon, Washington, and southern Vancouver Island, as well as satellite observations of temperature and chlorophyll, and a variety of biological process experiments. Papers describing this work are in preparation by S. Giddings et al., K. Davis et al., and S. Siedlecki et al.

For MSP, the full model results (four years of hourly high-resolution fields) were condensed into mean seasonal cycles (four three-month averages) for each variable. The first three months of the 2004 hindcast were treated as spinup (the period necessary for the model to became stable and results to be valid) for physical variables, and all of 2004 was treated as spinup for biogeochemical variables. Spinup data were not included in averages. A full list of variables can be found in Table 3 below.

Our team collaborated with the Wecker UW team to convert our model output into ESRI-format GIS layers. This included reconciliation of cartographic issues such as disparate representations of the coastline, and also manual translation of the nonlinear color scales that we use in the oceanographic setting to highlight significant features of each dataset. This collaboration produced a stable workflow that will streamline the process in future phases of this work.

Variable	Metrics	Analysis Time Period	Task
Bathymetry	1 km gridded	—	4
Bottom current speed	instantaneous mean, max (10 m above bottom)	2005	3
Surface temperature	seasonal mean, min, max	Apr 2004–Dec 2006	5
Bottom temperature	seasonal mean, min, max (continental shelf and slope)	Apr 2004–Dec 2006	5
Surface salinity	seasonal mean	Apr 2004–Dec 2006	5
River influence index	defined as % of time with surface salinity < 31.5 psu	Apr 2004–Dec 2006	5
Integrated chlorophyll	seasonal mean;	2005–2006	1
Bottom oxygen	seasonal mean, min	2005–2006	2
Hypoxia intensity index	annual average	2005–2006	2
Hypoxia frequency index	annual average	2005–2006	2

Table 3

Discussion

The contracted work was organized into five separate tasks. Notes are given below on the relationship between the original tasks and the final set of data layers.

Task 1: Prepare and transfer data sets on plankton productivity
Deliverable: mean seasonal cycles of phytoplankton productivity and zooplankton productivity, gridded to 2-5 km.
Relevance: food and prey availability, a primary factor in productivity of commercial fisheries and commercial aquaculture

Result: As is common in oceanography, mean chlorophyll concentration was taken to stand for plankton productivity. We tested a number of more complicated representations: 1) distinguishing chlorophyll (the standing stock of phytoplankton) from productivity per se (the rate of growth of that standing stock, generally balanced by losses to grazing); 2) differentiating between phytoplankton and microzooplankton productivity; and 3) including additional statistics regarding phytoplankton variability, such as the seasonal min/max and a delineation of regions of particularly high productivity. Our conclusion was, however, that all the standing stocks and rates of productivity are quite well-correlated on the time and space scales relevant to planning activities, and that variability is high everywhere that productivity is high. Chlorophyll concentration seems to us, from an oceanographic process perspective, to be the simplest and best metric of overall productivity. Conversations with stakeholders confirmed that this level of condensation is appropriate to the questions being asked at present.

Task 2: Prepare and transfer data on bottom oxygen levels
Deliverable: spatial "hypoxia index" (red-yellow-green classification system) based on the frequency and severity of low-bottom-oxygen events, gridded to 2-5 km

Relevance: seasonal location of "dead zones" where fish and crustaceans may suffocate

Result: Two versions of the hypoxia index are presented here, one that measures the frequency of occurrence of hypoxic conditions, and another, which measures whether that hypoxia, when it occurs, is mild or severe. The seasonal cycle of bottom oxygen on the shelf and slope is included for context, as well as the seasonal minimum in bottom oxygen (which establishes the important contextual fact that most of the Washington shelf, not just the regions with high values of the hypoxia indices, experiences hypoxia at least occasionally).

Task 3: Prepare and transfer data on current speed
Deliverable: seasonal maps of mean and maximum current speed over the coast, gridded to 2-5 km

Relevance: probable location of alternate energy sites (wind and tides)

Result: The mean and maximum of current speed 10 m above the bottom is shown, based on hourly values for all of 2005. This represents the combination of tidal currents with wind-driven and other weather-event-scale variations in the circulation.

Task 4: Prepare and transfer data on bottom bathymetry
Deliverable: map of bottom bathymetry, gridded to 1 km

Relevance: location of submarine canyons, important for nutrient supply, fishing

Result: Bathymetry from the U.S. Coastal Relief Model, Vol. 08 (NOAA National Geophysical Data Center, *http://www.ngdc.noaa.gov/mgg/coastal/crm.html)* was provided at 1 km resolution.

Task 5: Provide information on ocean processes related to MSP, as needed
Deliverable: attend 2-3 meetings of the WA Coast Marine Advisory Council to present relevant information and advice as needed

Relevance: help ensure that the MSP process has the best possible science-based input on decisions

Result:

a) Representatives of the UW coastal group, postdocs Sarah Giddings and Samantha Siedlecki, presented an overview of Washington coastal oceanography and ongoing modeling research at the Coastal MRC Summit Science Meeting in Long Beach, WA in December 2012.

b) PI Banas participated in a teleconference with the Pacific County MRC in March, to get feedback on preliminary plans for MSP data contributions, and to discuss potential interactions between the MSP process and other modeling activities (such as our ongoing development of short- and long-term forecasting capabilities).

c) Finally, PIs Hickey, Banas and MacCready participated in an all-day workshop in Montesano, WA, April 20, 2013, with representatives of the coastal MRCs and other stakeholders, to answer questions regarding coastal processes, discuss our MSP data layers in detail, and get input on short- and long-term information needs.

Based on this ongoing conversation with stakeholders, we added several data layers to our deliverables beyond the original scope of work: surface and bottom temperature, surface salinity, and a "river influence index" derived from surface salinity.

d) PI MacCready attended a meeting on May 9, 2013 at DNR headquarters in Olympia to present preliminary findings to DNR managers. Ensuing discussions highlighted additional data layers that could be important for the planning process.

e) PI MacCready participated in a workshop on May 13, 2013 "Ecosystem Indicators on Washington's Pacific Coast" sponsored by WA State Department of Ecology (Jennifer Hennesey). This workshop included participants from NOAA and other coastal managers.

Conclusions

This initial year of MSP work has resulted in our team gathering the majority of ocean observational data generated over the last two decades in one place. This provides the important database required to further enhance tools for the MSP process.

Data generated by oceanographers is not in the format required for GIS layers. A second principal project outcome is the development of methods to allow the UW data to be used in the mapping process, which would streamline this translation process in future work.

Meetings with stakeholders highlighted four topics outside the scope of the present contract that would be particularly useful for the MSP process.

1) Ocean acidification, which is of prime concern to the shellfish industry, as well as having much broader potential ecological implications.
2) Predictions of future ocean conditions, in particular hypoxia and ocean acidification.
3) Description of water conditions inside Willapa Bay and Grays Harbor.
4) Connections between coastal water properties and specific commercial fisheries, such as salmon (connecting the dots from habitat descriptors to the economic value of fishing in particular areas).

All of these topics can be readily addressed through modeling in conjunction with observational validation (#4 would require new research, but #1-#3 are all natural extensions of work already underway in our group with federal funding).

Data formats

Data are being provided in three formats. First, enclosed with this report is an archive of all data layers in simple .csv format, compatible with ArcGIS as well as Excel and many other analysis packages. Second, these data are being provided in native ArcGIS format as part of the database assembled by the Wecker group. Third, the Wecker group plans to electronically serve these data layers, along with the rest of their database, as a web service that can be directly tied in to the master CMSP web application.

Examples of Data Layers (below and following)

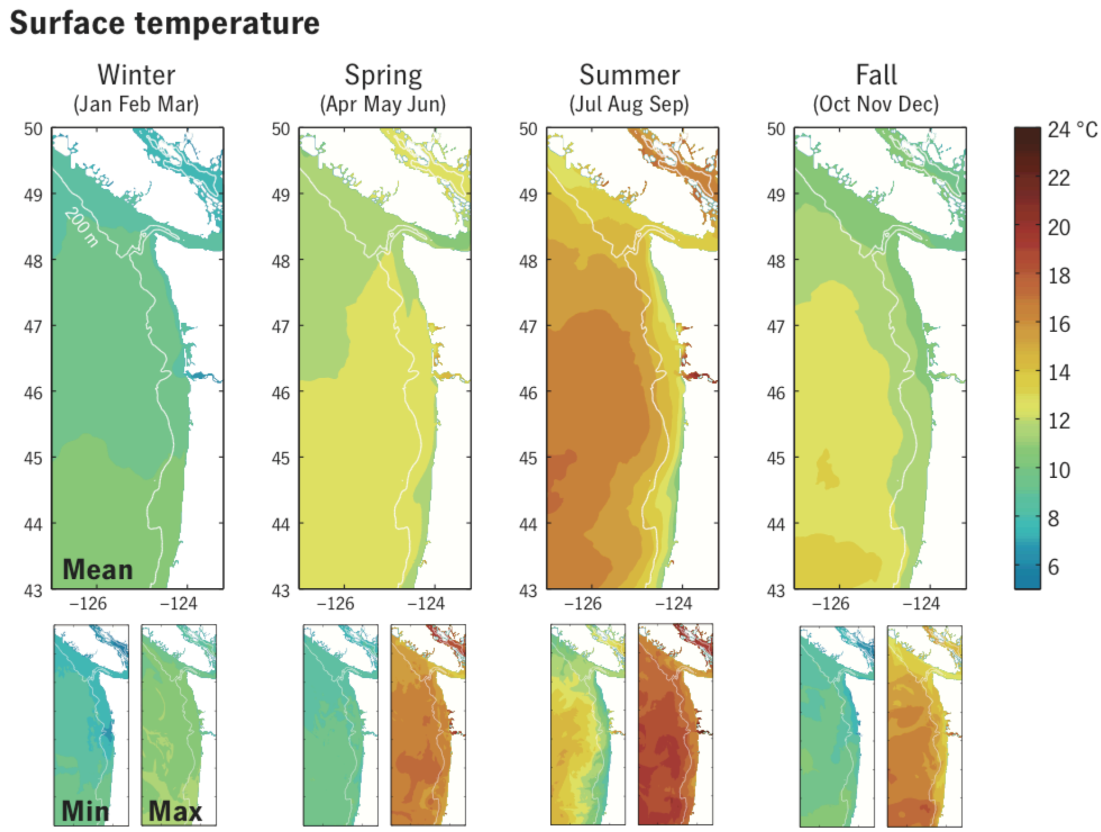

Figure 1. Mean, minimum, and maximum daily surface temperature, in four three-month averages. Cold water near the coast in summer indicates relatively undiluted upwelling of deep, cold, nutrient-rich water.

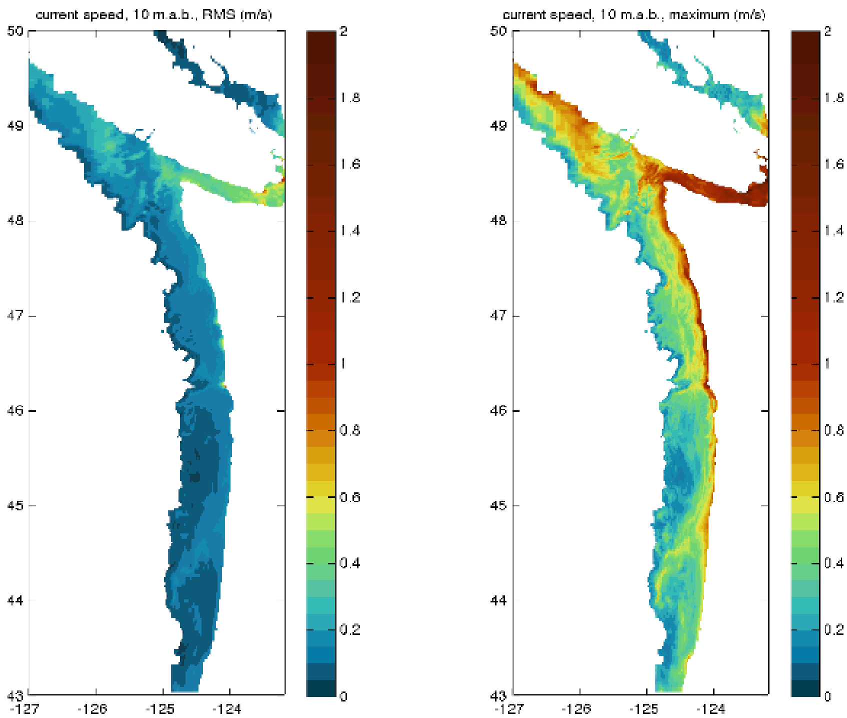

Figure 2. Typical (root-mean-square) and maximum instantaneous current speed 10 m above the bottom. The continental shelf and slope (0-400 m water depth) are shown.

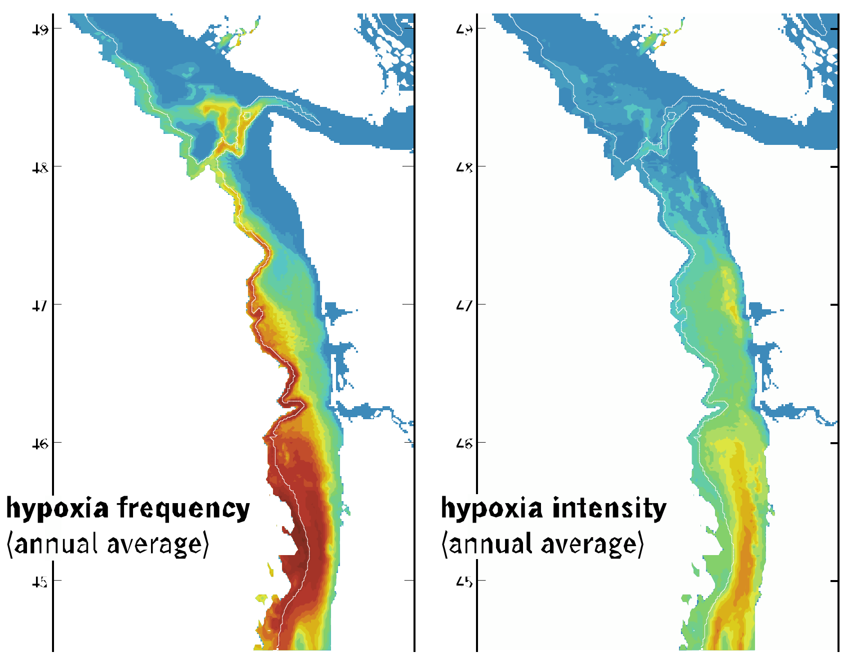

Figure 3. Two hypoxia indices (averages over the seasonal cycle, relative scale, where blue is low and red is high). The two indices are generally correlated but show some differences: for example, the inner shelf north of Grays Harbor experiences infrequent but intense hypoxia events, while the outer shelf at the same latitude experiences frequent but mild events.