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Structure and Vulnerability of Pacific Northwest Tidal Wetlands

A Summary of Wetland Climate Change Research by the Western Ecology Division, U.S. EPA'

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Structure and Vulnerability of Pacific Northwest Tidal Wetlands – A Summary of Wetland Climate Change Research by the Western Ecology Division, U.S. EPA

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Introduction:

Tidal wetlands, including both submerged aquatic vegetation (SAV) and emergent marsh, are key habitats in the Pacific Northwest (PNW) playing valuable roles biologically through fostering local and regional biodiversity and as nursery habitat for commercial fish and crab species and through providing critical ecosystem services including protecting coastlines from storms, sequestering carbon and trapping anthropogenic nitrogen (N) from watershed inputs (e.g., Philips, 1984; Deegan et al., 2000; Williamson, 2006; Ferraro and Cole, 2007; Spalding et al., 2014). However, tidal wetlands are considered particularly vulnerable ecosystems due to their unique location - transitional ecotones positioned between land, ocean and rivers (Wasson et al., 2013) where they are susceptible to changes in the conditions of the habitats surrounding them. According to the Oregon Climate Change Report (2010), PNW wetlands are expected to experience greater rates of long term coastal wetland loss than any other areas of the U.S., making research on these ecosystems of particular significance. Furthermore, traditional paradigms of tidal wetland vegetation structure and environmental determinants developed in east coast US tidal wetlands do not necessarily hold true for PNW wetlands due to differences in the frequency of tidal inundation and the unique chemical and physical factors of PNW wetlands (Weilhoefer et al., 2013). As we report in the literature within, it is also these unique conditions that make PNW tidal wetlands the most biologically diverse in the U.S.

In an effort to forecast potential effects of changing environmental conditions on PNW tidal wetlands, the Western Ecology Division (WED) of the U.S. EPA, in collaboration with the U.S. Geological Survey (USGS) and other partners has undertaken a series of research projects aimed at broadening our understanding of the biological and physical processes that determine PNW tidal wetland structure and function. Increasing our understanding of the mechanisms at work within tidal wetlands, adjacent intertidal areas and associated watersheds will increase our ability to predict how these habitats will respond to anthropogenic stressors, such as climate change. In this document, we first briefly summarize some of the major climate change threats to tidal wetlands and then summarize the recent climate change research conducted by WED, USGS, and other partners (see Table 1).

A major consequence of global climate change is sea level rise (SLR). Increased global temperatures are causing land-ice to melt and ocean water to expand, thereby increasing the volume of the world's oceans. An increase in relative sea level will change the location of the land-water interface and therefore may impact the aerial extent and community structure of marshes, macroalgal beds, and seagrass meadows. Although projections of future SLR vary due to uncertainty and differences in local factors (Ruggiero et al., 2010, NRC, 2012; Mielbrecht et al., 2014), sea level rise in the region from northern California to Puget Sound is predicted to range between -3.5 inches to +22.7 inches (-8.9 to 57.7 cm) by 2030; and -2.1 inches to +48.1 inches (-5.3 to 122.2 cm) by 2050 compared to 2008 (Mielbrecht et al., 2014). Interactions between spatial and temporal physical processes such as isostatic subsidence or uplift, natural variability in atmospheric and ocean circulation and local topography all contribute to the rate and potential impact of SLR along the Oregon coast (Ruggiero et al., 2010).

Historically, wetlands have been able to maintain themselves by "biological and physical feedbacks that couple the rate of sea level rise to the rate of vertical accretion" (Kirwan & Megonigal 2013). Models suggest that under a medium SLR scenario tidal marshes with adequate sediment supply are capable of maintaining their current elevation as they have in the past through dynamic 'cause and effect' biological loops. For instance higher temperatures and CO_2 levels are predicted to increase above-ground vegetation growth which, in turn, will slow tidal velocities and allow more sediment to precipitate from the water column. Below-ground biomass may also increase in response to environmental changes producing more *in-situ* organic plant material and increase elevation through sub-surface soil expansion (Thom, 1992; Morris et al., 2002; Kirwan et al., 2010; Stralberg et al., 2011; Nelson & Zavaleta, 2012; Thorne et al., 2012; Kirwan & Megonigal, 2013). In areas where little sediment is available for accretion, erosion of the seaward marsh edge is expected resulting in deterioration of soil structure and vegetation 'drowning'. Whether tidal wetlands and seagrass beds can sustain their current geographic extent and condition in the face of today's unprecedented environmental pressures will depend mostly on the degree of human activity surrounding individual wetlands (e.g. water diversion, natural gas extraction and eutrophication) and the rate of SLR acceleration.

Research has documented profound shifts in wetland communities as vegetation follows salinity optimums as they shift inland concurrent with longer periods of tidal inundation. Evidence of plant distributional shifts exist in New England where a low-marsh species, cordgrass has rapidly moved landward at the expense of higher-marsh species (Donnelly & Bertness, 2001), in Florida where mangroves are retreating landward in response to increased saltwater intrusion (Raabe et al., 2012); and in the lower elevation marshes of San Francisco Bay, CA as more salt-tolerant species are increasing in cover and replacing less salt-tolerant species (Watson and Byrne, 2012). Such changes in wetland community structure will likely have consequences to the ecosystem overall through changes in productivity, detrital respiration, or change in habitat or food availability for invertebrates, resident birds and waterfowl. Physiological stress of salinity appears to be a dominant mechanism determining lateral migration of vegetation shifts (Watson & Byrne, 2012).

The availability and condition of upland habitat adjacent to the threatened wetland ultimately determines the degree to which the habitat can migrate. Anthropogenic barriers such as levees, seawalls and the presence of housing, aquaculture facilities and agriculture limit the natural response patterns of wetland plants (Galbraith et al., 2002; Feagin et al., 2010). Due to relatively low human populations in coastal PNW watersheds, wetlands do not have the degree of armoring and urbanization found in other parts of the U.S., however, land-ward migration of wetland and intertidal habitats is often constrained by another physical barrier - the natural morphology of their watersheds. Coastal wetlands in Oregon and Washington are usually relatively small, starting along the fringes of estuaries and extending to the base of steep watershed hillsides making them particularly vulnerable to 'coastal squeeze' (Torio and Chmura, 2013), a phenomenon whereby steep gradients in adjacent upland prevent wetland vegetation from migrating in response to stressors induced by SLR. Palustrine marshes, located at the upper end of tidal inundation zones, often terminate in valleys with steep hillsides, and have been shown to consistently sequester more organic carbon, nitrogen and phosphorous due to lower rates of soil decomposition relative to saltwater marshes located closer to the mouth of estuaries (Craft, 2007; Craft, 2009a; Loomis and Craft, 2010). Coastal squeeze may result in loss of habitat area for low-salinity tidal wetlands resulting in reduced ecosystem function.

Less predictable factors such as more frequent and intense storms and increased winter precipitation along the Oregon coast may overwhelm a wetlands natural ability to sustain itself through vertical or horizontal adaptability and limits our ability to predict the future of coastal wetlands. Powerful storm water surges flowing through wetland arteries are known to cause slumping of tidal creek banks and extreme erosion along marsh edges. Conversely increased precipitation may facilitate the rate of vertical accretion due to a greater supply of organic matter passing over the marsh surface from highly turbid rivers. In the case of seagrass, intense scouring from high wave energy can eliminate a large patch of seagrass in one storm event. Data on the environmental tolerances of wetland species, including elevation and other environmental determinants presented in this research will allow us to better predict future distributions of PNW intertidal and marsh vegetation in response to SLR and to assess the variability within these systems. The magnitude and degree of these complex and interactive environmental changes are becoming apparent on both large and small scales along coastlines all over the world.

As climate change accelerates, managers and conservation biologists are in need of practical tools to help them understand the relative impacts of climate change on tidal wetlands. One frequently used tool is the moderate resolution model, "Sea Level Affecting Marshes Model" (SLAMM). SLAMM has been used to evaluate 11sites in Puget Sound, in coastal Washington and northwestern Oregon (Glick et al., 2007). Model runs have suggested that "52 percent of brackish marsh will convert to tidal flats, transitional marsh and saltmarsh" assuming a net 0.69 meters (27.3 inches) sea level increase by 2100. SLAMM was used more recently in a vulnerability assessment of the Coquille Estuary in Oregon which also predicted similar changes in wetland distributions under various SLR scenarios (Mielbrecht et al., 2014).

The recent climate change wetland research by WED and its partners addresses several of the issues related to climate impacts on tidal wetlands, and recent products are listed in Table 1. Products summarized in this document are categorized into two sections: Section 1 summarizes observational and experimental studies from the field and laboratory that evaluate and improve the reliability of the classification system of the National Wetlands Inventory (NWI) in the Pacific Northwest. NWI provides critical data used for SLR modeling. Section 2 focuses on models and GIS tools developed to explore various climate change scenarios. The products summarized here are aimed at providing researchers and managers with the knowledge and tools available to assess the relative vulnerability of different marsh plants, macroalgae, and seagrass to climate change as well as providing reference data to be used in mitigation and planning scenarios. We note that the summaries in this document are reproduced, or adapted from the published paper's abstract or summary.

Table 1. Recent climate change tidal wetland research publications and tools developed by the U.S. EPA Western Ecology Division, USGS, and other partners.

Section 1: Field Surveys and Manipulative Experiments

Title	Authors	Reference / URL	Research Focus
I. Variation in tidal wetland plant diversity and composition within and among coastal estuaries: assessing the relative importance of environmental gradients	Janousek, C. and Folger, C	Journal of Vegetation Science 2014 Vol. 25:534-545	Marsh community structure
II. Patterns of distribution and environmental correlates of macroalgal assemblages and sediment chlorophyll *a* in Oregon tidal wetlands	Janousek, C. and Folger, C	Journal of Phycology 2012 Vol. 48:1448–1457.	Macroalgal distribution & environmental factors
III. Plant responses to increased inundation and salt exposure: Potential sea-level rise effects on tidal marsh productivity	Janousek, C. and Mayo, C	Plant Ecology 2013 Vol. 214:917-928	SLR effects on marsh species
IV. Concordance between marsh habitat classes and vegetation composition in Oregon estuaries: Implications for assessing coastal wetland structure and function	Janousek, C. and Folger, C	Chapter in 'Report on uncertainty, scaling and transferability of ecological production functions'. 2013. Internal EPA Report for Sustainable and Health Communities Research Program.	Evaluation of NWI classification
V. Inter-specific variation in salinity effects on germination in Pacific Northwest tidal wetland plants	Janousek, C. and Folger, C	Aquatic Botany 2013 Vol. 111:104-111	Salinity effects on germination of marsh plants

Section 2: Models and Predictive Tools

Title	Authors	Reference / URL	Research Focus
VI. Sea Level Affecting Marshes Model (SLAMM) - New Functionality for Predicting Changes in Distribution of Submerged Aquatic Vegetation in Response to Sea Level Rise. Version 1.0	Lee II, H., Reusser, D.A., Frazier, M.R., McCoy, L.M., Clinton, P.J., and Clough, J.S.	EPA Report (2014): Office of Research and Development, National Health and Environmental Effects Research Laboratory, Western Ecology Division. EPA/600/R-14/007	Predict SLR impacts on *Zostera marina*
VII. Potential Climate-Induced Runoff Changes and Associated Uncertainty in Four Pacific Northwest Estuaries	Steele, M.O., Chang, H., Reusser, D.A., Brown, C.A., and Jung, I-W.	USGS Open-File Report 2012-1274 http://pubs.usgs.gov/of/2012/1274/	Changes in flow in response to changes in precipitation

VIII. Tidal Wetlands of the Yaquina and Alsea River Estuaries, Oregon: Geographic Information Systems Layer Development and Recommendations for National Wetlands Inventory Revisions	Brophy, L.S. with contributions from Reusser, D.A. and Janousek, C.N.	USGS Open-File Report 2012-1038 http://pubs.er.usgs.gov/publication/ofr20121038	Update NWI layers in two Oregon estuaries
IX. WestuRe: U.S. Pacific Coast Estuary/Watershed Data and R tools	Frazier, M.R., Reusser, D.A., Lee II, H., McCoy, L.M., Brown, C. and Nelson, W.	EPA Report (2013): EPA/600/R/13/067 http://www.epa.gov/wed/pages/models/ WestuRe/WestuRe.htm	Tool to synthesize PNW estuary, watershed, and climate information

Section 1: Field Surveys and Manipulative Experiments:

***I. Variation in tidal wetland plant diversity and composition within and among coastal estuaries: assessing the relative importance of environmental gradients* (Janousek and Folger, 2014)**

Evaluating coastal wetland responses to climate change requires an understanding of how plant diversity and composition vary within and among estuaries and habitats and how changes in soil conditions, inundation times and salinity affect vegetation structure in coastal wetlands. To help address these questions we surveyed species presence, cover and richness; and environmental factors (soil salinity, grain size, soil nitrogen and elevation) in tidal wetlands in four Oregon estuaries (Figure 1).

Our findings suggested that the relative importance of measured environmental gradients on plant occurrence differed by species. Soil salinity or elevation explained the most variation in the distribution of the majority of common marsh species. Estuarine hydrology, soil nitrogen and soil clay content were usually of secondary or minor importance. Overall plant assemblage composition and species richness varied most strongly with tidal elevation. Local soil salinity also affected composition, but differences in estuarine hydrology had comparatively less effect on plant composition and richness. Higher-elevation wetlands supported larger species pools and higher plot-level richness. Additionally, fresher marshes had larger species pools than more saline marshes even though plot-level richness was relatively invariant to differences in soil salinity.

Based on our findings we concluded that elevation and salinity tended to exert more influence on the vegetation structure of emergent marshes than estuarine hydrology or other edaphic variables. With relative sea-level rise expected to increase, both flooding intensity and salinity exposure in future wetlands, global climate change might lead to changes in species distributions, altered floristic composition and reduced plant species richness in PNW tidal wetlands.

***II. Patterns of distribution and environmental correlates of macroalgal assemblages and sediment chlorophyll a in Oregon tidal wetlands* (Janousek and Folger, 2012)**

Algae have important functional roles in estuarine wetlands along the Pacific coast of the United States. We quantified differences in macroalgal abundance, composition and diversity, and sediment chlorophyll *a* and pheophytin *a* among three National Wetlands Inventory emergent marsh classes in four Oregon estuaries spanning a range of riverine to marine dominance (Figure 1). We also assessed the strength of macroalgal-vascular plant associations and the degree to which environmental variables correlated with algal community metrics across all marsh and woody wetlands sampled.

The frequency of occurrence of most macroalgal genera, total benthic macroalgal cover, macroalgal diversity, and sediment chlorophyll *a* content were several times higher in low emergent marsh than in high marsh or palustrine tidal marsh. Conversely, pheophytin *a*: chlorophyll *a* ratios were highest in high and palustrine marsh. Attached macroalgae (*Fucus* and *Vaucheria*) were strongly associated with plants common at lower tidal elevations such as *Sarcocornia perennis* and *Jaumea carnosa*; *Ulva* (an unattached alga) was not strongly associated with any common low marsh plants.

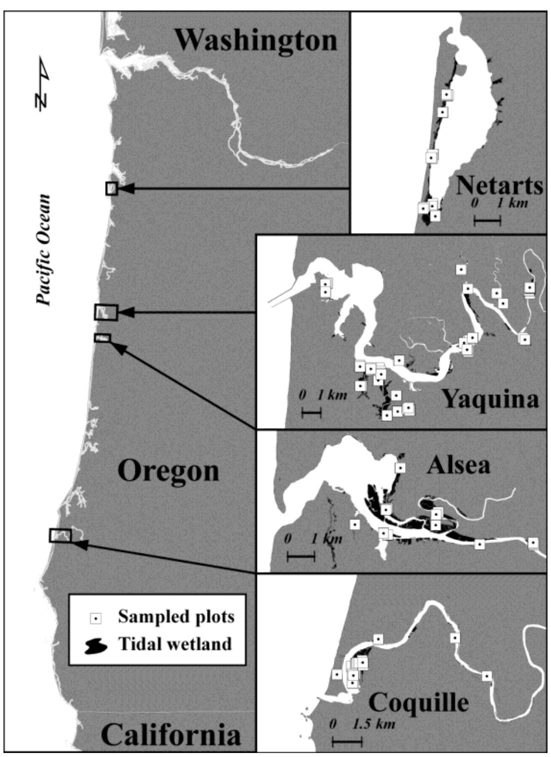

Figure 1: Four Oregon estuaries evaluated for macroalgal abundance, wetland species composition and diversity.

In step-wise multiple regression models, intertidal elevation and soil salinity were the most influential predictors of macroalgal cover and richness and chlorophyll *a*. Though common taxa such as *Ulva* spp. occurred across a broad range of salinities, marshes with oligohaline soils (salinity < 5 ppt) had the lowest macroalgal diversity and lower sediment chlorophyll *a*. These types of baseline data on algal distributions are critical for evaluating the structural and functional impacts of future changes to coastal estuaries including sea-level rise, altered salinity dynamics, and habitat modification.

III. Plant responses to increased inundation and salt exposure: interactive effects on tidal marsh productivity (Janousek and Mayo, 2013)

Sea-level rise may increase submergence and salinity exposure for tidal marsh plants. We tested the effects of these two potential stressors on seedling growth in a transplant experiment in a macrotidal estuary in the Pacific Northwest. Seven common marsh species were grown at mean higher high water (MHHW, a typical mid-marsh elevation), and at 25 and 50 cm below MHHW in oligohaline, mesohaline, and polyhaline marshes in the Yaquina Estuary on the central Oregon coast. Increased flooding times reduced shoot and root growth in all species, including those typically found at middle or lower tidal elevations. It also generally disproportionately reduced root biomass. For more sensitive species, biomass declined by more than 50 % at only 25 cm below MHHW at the oligohaline site. Plant growth was also strongly reduced under polyhaline conditions relative to the less saline sites.

By combining inundation and salinity time-series measurements we estimated a salt exposure index for each site by elevation treatment. Higher values of the index were associated with lower root and shoot biomass for all species and a relatively greater loss of below-ground than above-ground production in most species. Our results suggest that inundation and salinity stress plants individually and (often) interactively reduce productivity across a suite of common marsh species. As relative SLR increases the intensity of stress on coastal marsh plants, negative effects on biomass may occur across a range of species and especially on below-ground production.

IV. Concordance between marsh habitat classes and vegetation composition in Oregon estuaries: Implications for assessing coastal wetland structure and function (Janousek and Folger, 2013)

Another aspect of our work was evaluating the reliability of a commonly used wetland classification system, the National Wetlands Inventory (NWI) (Cowardin et al. 1979), for summarizing structural attributes of coastal habitats. We evaluated NWI habitat classes in Oregon tidal wetlands with data from field surveys in four regional estuaries (Figure 1). Assessing the accuracy of the NWI habitat classification system is relevant to coastal modeling as it is the primary GIS layer for a commonly used sea-level rise model (SLAMM) for projecting changes to coastal landscapes. Using the established NWI habitat classification system, we compared environmental conditions and plant assemblages among and within three major estuarine emergent marsh types (low, high and palustrine) that comprise most of the tidal wetland area in the Pacific Northwest. We found that physical characteristics (canopy height, light transmission), sediment properties (total organic carbon, particle size organic matter, and salinity), elevation and plant composition differed more markedly among NWI marsh habitat types than between individual estuaries.

In general, we found that the NWI habitat classes were useful for predicting edaphic conditions and overall plant composition, but because only a few habitat classes are used to map large areas of tidal marsh in the Pacific Northwest, substantial variation in species richness and vegetation complexity (driven in part by small-scale topography) can be found within a single marsh class. A further key finding of the study was the substantial cumulative plant diversity found in Oregon tidal marshes, including at least 103 species and 12 common assemblages. Identifying the strengths and weaknesses of the NWI classification schema increases our understanding of the uncertainties associated with predictions based on NWI and how best to use data from this readily available mapping effort.

V. Inter-specific variation in salinity effects on germination in the Pacific Northwest tidal wetlands plants (Janousek and Folger, 2013)

Local climate change effects such as sea-level rise and reduced precipitation in coastal watersheds are likely to increase salinity in estuarine habitats such as high intertidal marshes and swamps (Baldwin et al. 1996). Since salt is often a stressor for vascular plants, we examined germination success under different salinity conditions to provide insight into species-level variation in salinity tolerance and inform predictions of species distribution under future climate scenarios.

In a laboratory study, we evaluated germination sensitivity to salinity in 13 tidal wetland species found in the Pacific Northwest and then compared germination responses with the distributions of established plants found along a soil salinity gradient in the field. All species examined, except *Sarcocornia perennis* and *Symphyotrichum subspicatum*, showed maximum germination and seedling lengths under fresh to oligohaline (0-5 ppt) conditions. Most species, including those commonly distributed in more saline wetland soils as adults, had reduced germination at salinities ≥10 ppt. Sensitivity to elevated salinity in *Triglochin maritima* and *Hordeum brachyantherum* did not differ markedly between sampled populations. Our results demonstrated a mismatch between germination sensitivity and adult tolerance for about half of the species we examined. Therefore, the occurrence of low salinity conditions in time or space may be necessary for optimal germination rates in these species. Future increases in estuarine salinity, either in response to sea level rise or reduced coastal precipitation, may alter germination patterns in tidal wetland plants and thereby shift plant composition.

Section 2: Modeling Potential Effects of Climate Change on Estuaries, Seagrass and Tidal Marshes:

VI. Sea Level Affecting Marshes Model (SLAMM) - New Functionality for Predicting Changes in Distribution of Submerged Aquatic Vegetation in Response to Sea Level Rise. Version 1.0 (Lee et al., 2014)

SLAMM is a two-dimensional model used to predict the effects of sea level rise on marsh habitat distribution (Craft et al. 2009a)and has been used extensively on both the west coast (e.g., Glick et al., 2007) and east coast (e.g., Geselbracht et al., 2011) of the U.S. One limitation of SLAMM, (Version 6.2) is that it lacks the ability to model distribution changes in submerged aquatic vegetation (SAV) habitat due to sea level rise. This is a major gap since SAV is a critical estuarine habitat type along the U.S. coast. In PNW estuaries, SAV in the lower intertidal and shallow subtidal is dominated by the native seagrass, *Zostera marina,* which provides important habitat for juvenile salmon, dungeness crabs, migratory shore birds, and benthic assemblages (e.g., Philips, 1984; Williamson, 2006; Ferraro and Cole, 2007; Shaughnessy et al., 2012). Because of its narrow depth range, *Z. marina* is potentially vulnerable to sea level rise.

Due to its ecological importance, U.S. EPA, USGS, and U.S. Department of Agriculture (USDA) partnered with Warren Pinnacle Consulting to enhance the SLAMM modeling software. Based on known distributions of *Z. marina* in Yaquina Bay Estuary, Oregon, we developed a logistic regression model to predict SAV distributions from readily available GIS parameters. This model was added as a new functionality in Version 6.3 of SLAMM. An R script was provided that describes how the original SAV model for Yaquina Bay was developed. The script also provides a detailed methodology to develop site-specific model coefficients for other estuaries when existing SAV GIS data layers are available. Once the site-specific model coefficients are generated, they can be input into SLAMM to evaluate impacts of sea level rise on SAV distributions under different sea level rise scenarios. To demonstrate the applicability of the R tools, we utilized them to develop model coefficients to predict *Z. marina* distributions in Willapa Bay, Washington. This new functionality in SLAMM provides a practical first-order approximation of how the distribution of *Z. marina* will change in PNW estuaries in response to sea level rise.

VII. Potential Climate-Induced Runoff Changes and Associated Uncertainty in Four Pacific Northwest Estuaries (Steele et al., 2012)

To evaluate effects of changing precipitation patterns in the PNW, we estimated changes in freshwater inputs into four estuaries: Coquille River Estuary, South Slough of Coos Bay, and Yaquina Bay in Oregon, and Willapa Bay in Washington. All modeled watersheds are located in rainfall-dominated coastal areas with relatively insignificant base flow inputs, and their areas vary from 74.3 to 2,747.6 square kilometers. The watersheds also vary in mean elevation, ranging from 147 meters in the Willapa to 1,179 meters in the Coquille. The U.S. Geological Survey's Precipitation Runoff Modeling System (PRMS) was used to model watershed hydrological processes under current and future climatic conditions in these four estuaries.

We calibrated model parameters using historical climate grid data downscaled to one-sixteenth of a degree by the Climate Impacts Group, and historical runoff from sub-watersheds or neighboring watersheds. After calibration, we forced the PRMS models with four North American Regional Climate Change Assessment Program climate models, using the A2 carbon emission scenario developed by the Intergovernmental Panel on Climate Change. With these climate-forcing outputs, we derived the mean change in flow from the period encompassing the 1980s (1971–1995) to the period encompassing the 2050s (2041–2065). Specifically, we calculated percent change in mean monthly flow rate, coefficient of variation, top 5 percent of flow, and 7-day low flow. The trends with the most agreement among climate models and among watersheds were increases in autumn mean monthly flows, especially in October and November, decreases in summer monthly mean flow, and increases in the top 5 percent of flow. We also estimated variance in PRMS outputs owing to parameter uncertainty and the selection of climate model, which showed that PRMS low-flow simulations are more uncertain than medium or high flow simulations, and that variation among climate models was a larger source of uncertainty than the hydrological model parameters. These results improve our understanding of how climate change may affect the saltwater-freshwater balance in PNW estuaries, with implications for their sensitive ecosystems.

VIII. Tidal Wetlands of the Yaquina and Alsea River Estuaries, Oregon: Geographic Information Systems Layer Development and Recommendations for National Wetlands Inventory Revisions (Brophy with Reusser and Janousek, 2013)

To improve SLR modeling results and enhance the accuracy and utility of the NWI for resource managers, enhanced GIS products were developed for the Yaquina and Alsea drainage basins (Oregon). These data were generated for two purposes: First, to enhance the NWI by recommending revised Cowardin classifications for certain NWI wetlands within the study area; and second, to generate GIS data for the 1999 Yaquina and Alsea River Basins Estuarine Wetland Site Prioritization study. Two sets of GIS products were generated as a result of this study: (1) enhanced NWI shapefiles; and (2) shapefiles of prioritization sites. This report also includes photographs of wetland types and plant species that are common in these estuaries.

The enhanced NWI shapefiles contain recommended changes to the Cowardin classification (system, subsystem, class, and/or modifiers) for 286 NWI polygons in the Yaquina Bay Estuary (1,133 acres) and 83 NWI polygons in the Alsea Bay Estuary (322 acres). These enhanced NWI shapefiles also identify likely former tidal wetlands that are classified as upland in the current NWI (64 NWI polygons totaling 441 acres in the Yaquina Estuary; 16 NWI polygons totaling 51 acres in the Alsea Estuary). The former tidal wetlands were identified to assist strategic planning for tidal wetland restoration. The prioritization site shapefiles contain 49 prioritization sites totaling 2,177 acres in the Yaquina Estuary, and 39 prioritization sites totaling 1,045 acres in the Alsea Estuary. The prioritization sites include current and former (for example, diked) tidal wetlands, and provide landscape units appropriate for basin-scale wetland restoration and conservation action planning. Several new prioritization sites (not included in the 1999 prioritization) were identified in each estuary, consisting of NWI polygons formerly classified as nontidal wetland or upland. The GIS products of this project improve the accuracy and utility of the NWI data, and provide useful tools for estuarine resource management.

IX. WestuRe: U.S. Pacific Coast estuary/watershed data and R tools (Frazier et al., 2013)

There are about 350 estuaries along the U.S. Pacific Coast. Basic descriptive data for these estuaries, such as their size and watershed area, are important for coastal-scale research, conservation planning, and predicting effects of climate change. However, this information is spread among many sources, making it difficult to find and standardize. The goal of the WestuRe Project is to provide a framework to: 1) make general descriptive data for estuaries and for their watersheds and climates more accessible; and 2) provide tools to make analyzing and visualizing these data easier. The WestuRe download includes data describing U.S. Pacific Coast estuaries and their corresponding watersheds from northern Washington to southern California (Tijuana Estuary), excluding Puget Sound proper.

WestuRe tools help users extract and view relevant data using the statistical program R and Google Earth, and WestuRe provides shapefiles of estuary and watershed polygons as well as .csv files summarizing geomorphological and climate data. Specifically, WestuRe allows the user to access: 1) NWI habitat polygons classified as marine, estuarine, and tidal riverine for each estuary, which can be overlaid on an image of an estuary from Goggle Earth; 2)

Delineations of watershed boundaries from Lee and Brown (2009) for both “estuarine drainage areas” (EDA) and “coastal drainage areas” (CDAs; coastal watershed that does not drain into an estuary). In total, 506 polygons are provided; 3) NOAA salinity zones describing the average annual and depth averaged salinity concentrations for 36 U.S. Pacific Coast estuaries (plus some bays); and 4) Monthly climate data for sea surface temperature outside the mouth of each estuary, air temperature at the mouth of the estuary, and air temperature and precipitation averaged over the watershed. These data allow researchers and managers easy access to key landscape and climate information for individual estuaries as well as the ability to compare estuaries, watersheds, and climates along the U.S. Pacific Coast.

Summary:

Climate change poses a serious threat to the tidal wetlands of the Pacific Northwest. In response to this threat, the U.S. EPA at the Western Ecology Division and the Western Fisheries Research Center of the USGS, along with other partners, initiated a series of studies on marsh species and communities, enhancing the SLAMM model to predict submerged aquatic vegetation (*Zostera marina*) distributions, evaluating changes in flow into coastal estuaries, and synthesizing Pacific Coast estuary, watershed, and climate data in a downloadable tool. Because the products resulting from these efforts were published in a variety of locations, we summarized them in this document. We anticipate that future research efforts by the U.S. EPA will continue to build upon these products, in particular with a focus on climate change impacts on a regional scale.

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