Coquille Estuary Climate Change Vulnerability Assessment

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This project is dedicated to Kristle Volin, who worked tirelessly to help the Coquille River estuary remain beautiful for all to enjoy

Special thanks to Nicholas Jones, Rich Young and Dan Uthman for their expertise in SLAMM, GIS, and cartography

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Table of Contents | Page

Appendices (under separate cover)

Preface

Return to contents

The motivation for this project was a desire to pilot a method for assessing climate change vulnerability at a local, sub-watershed level, with a goal of providing useful management information to local natural resource managers and stakeholders. The goal was not only to provide specific information on key habitats and species in the Coquille Estuary, but also to create a template for conducting relatively low budget vulnerability assessments for estuaries in other relatively small coastal watersheds.

As the field of planning for climate change continues to evolve, this process will be easier for others in the future due to the expansion of the amount and availability of downscaled climate projections. This kind of detailed data was not as readily available when the project began, so the project coordinators spent considerable time and funding to obtain it for the Coquille. Likewise, there has been a recent proliferation of online tools to assist with vulnerability analyses, with more to come soon. These developments should reduce future project costs and timelines.

Climate change vulnerability assessments present significant challenges for communities and resource managers. The most significant challenge will be in how to make progress despite the many sources of uncertainty in projecting future climate conditions and predicting how species and habitats will respond to those conditions. Uncertainty affects all medium- and long-term natural resource planning efforts, and in some cases, consideration of climate change can compound uncertainty. Sources of uncertainty encountered in this project included the sensitivity and response of ecosystems, habitats, and species to climate change; the rate and amount of future greenhouse gas emissions; how to predict and model synergistic effects of climate change in combination with other perturbations such as habitat loss, invasive species, etc.; and uncertainty about human responses to climate change, including community efforts to resist or mitigate climate change effects such as rising sea levels and increased flooding.

Uncertainty should not be a reason for inaction. Individuals, resource managers, and communities will continue to make resource planning and management decisions based on the best available science and with limited budgets. A handful of approaches for accommodating uncertainty in resource management decisions are summarized in Box 1 on page 12.

With varying degrees of success, this project attempted to limit or at least acknowledge uncertainties by:

- Obtaining the latest and most credible downscaled climate change information
- Limiting climate projections to 2060 or before, thus reducing the increased uncertainties associated with longer-range projections
- Presenting projected climate changes in terms of an average value within a range of values
- Relying on multiple model outputs for climate projections
- Whenever possible, using local historic data to calibrate predictive models
- Acknowledging limitations of modeling, including the SLAMM projections of sea level rise
- To the degree possible, relying on the assessments of a local expert panel familiar with Coquille habitats and species
- Acknowledging the subjectivity and limitations of the expert review process
- Acknowledging the need to join the findings of this report with a future assessment of socio-economic climate change vulnerability in the Coquille

The project highlighted the high vulnerability of Coquille coho salmon and freshwater tidal wetlands to climate change, as discussed in detail below. While already identified in other management plans as 'at-

risk' due to other causes, this finding adds increased urgency to developing management solutions, and identifies additional stressors that need to be addressed.

In the Coquille estuary, climate change impacts are projected to occur in relatively small increments over the next 50 years. Thus, the final product is an analysis of the effects of small, incremental changes on a complex natural system, with significant uncertainties about future trends and responses. The report also points out that local tectonic uplift has so far more or less kept pace with sea level rise. It should be noted that the team working on this assessment was fully aware of the potential for changes to the Coquille estuary from a large earthquake and tsunami, which would dwarf the kinds of changes that are anticipated to result from changing climate conditions. This persistent but unpredictable geologic hazard is worth considering and incorporating into long-range habitat and species management planning for the Coquille and other areas of the Oregon coast.

Overview and Findings

Return to contents

This vulnerability assessment is a science-based effort to identify how key habitats, species, areas and resources in the Coquille River estuary and associated lowlands are likely to be affected by future climate conditions; and to what degree these projected effects warrant concern for continued production of their sustainable services to society. This assessment covers the Coquille River estuary. It focuses on seven habitats and six species that have been identified as important in local management planning documents or by local resource managers and stakeholders. Socioeconomic issues are acknowledged to affect the Coquille estuary and its uses and management, but they are not included in the scope of this project.

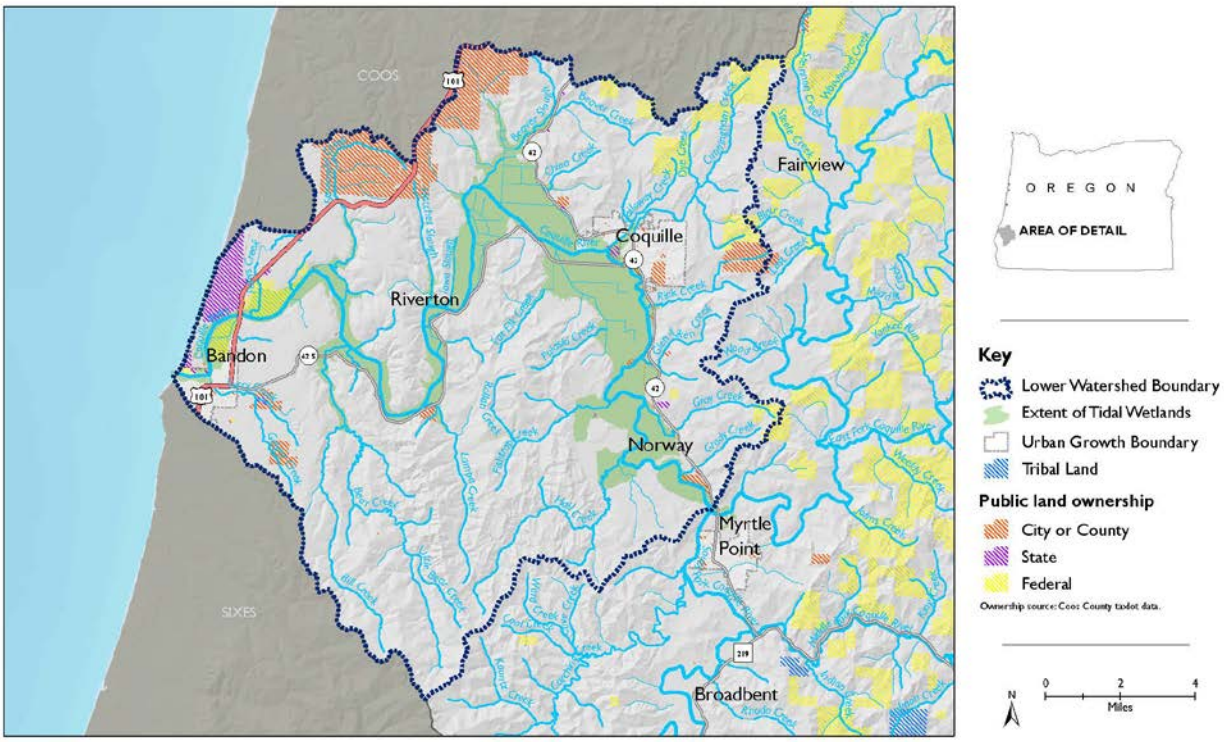
This assessment was conducted using a panel of experts in estuarine systems, estuarine habitats, or species using estuaries, which will be referred to in this report as 'the panel' or 'the expert panel.'

Project Purpose

Estuaries occur at the edges of three distinctly different systems: the ocean, the land, and the freshwater hydrologic system. Estuaries represent the transition between land and water, and more importantly, between freshwater and saltwater systems. Characteristics of two of these systems – the ocean and the freshwater hydrologic system – are fundamentally defined by climate conditions. Changes in the ocean and freshwater systems have the potential to result in significant changes to the estuary, and therefore to the habitats it supports. The Coquille River estuary as a functioning whole is more than a combination of the seven habitats and six species populations discussed here. It is comprised of a larger community of plant and animal species, their interactions, and key estuarine processes, some of which are influenced by human activities in and around the estuary. Important estuarine processes like water circulation (freshwater, marine and tidal flux), sediment transport and deposition, and nutrient cycling are all affected by climate conditions. The regular and dynamic nature of these processes make the Coquille River estuary what it is today. Climate change will very likely affect these processes to some degree (Ruggiero et al. 2010, Day et al. 2008; also see Section 3), and will therefore likely affect the Coquille estuary. The primary purpose of this project and report is to describe how anticipated changes in climate conditions would affect the Coquille estuary.

The goal of this project is to provide a foundation for integrating consideration of the effects of climate change on habitats and species into management plans and decisions that affect the Coquille River estuary. It encompasses the Coquille estuary, tributaries to the estuary, and associated lowlands, including tidally influenced freshwater areas, from the mouth of the Coquille River up to the head of tide, which is approximately two miles below Myrtle Point (Figure 1). Ideally, this report will support analyses of what can be done to maintain optimal conditions and productivity of estuarine resources, and thereby protect public investments in coastal resource conservation, use, and protection. It identifies information gaps and questions needing additional investigation, and reflect on the methodologies used.

Figure 1. The Project study area, bounded by the dashed blue line



Drivers of Change in the Coquille Estuary

Potential climate-related drivers of change in the Coquille River estuary include sea level rise, rising air temperatures, warmer water, changes in precipitation, ocean acidification, changes to upwelling, and potential changes in waves and storms. Many of these changes have the potential to change hydrology and salinity in the estuary. Historic trends and future projections provide localized information on likely future climate conditions that will affect the Coquille. Note that there is no single definitive future climate projection for the lower Coquille River estuary. Rather, projections provide ranges of possible future conditions for each of these climate-related variables, and not all projected changes are equally likely. The projections are based on state-of-the-art models and/or analyses. Projections can provide information on the rate and magnitude of changes in conditions that will affect the Coquille River estuary. A synthesis of these climate-related changes can be found in Section 3.

Habitats and Species Considered

The vulnerability to climate change of the seven habitat types and six species populations was assessed by considering their exposure and sensitivity to climate change, and their capacity to adapt to such changes. These habitats and species were identified by the expert panel as being of management, cultural, or recreational concern in local management plans, and as spanning the estuary ecosystem or playing ecological keystone roles. Climate information used is a synthesis of regional past and projected climate trends and change data for the region (Section 3). Information on the sensitivity and adaptive capacity of habitats and species was provided by a panel of estuary and species experts (Appendix A), and from the scientific literature. Each component of vulnerability was assessed to be low, moderate, or high and included a confidence ranking determined by the expert panel. Section 1 describes methods,

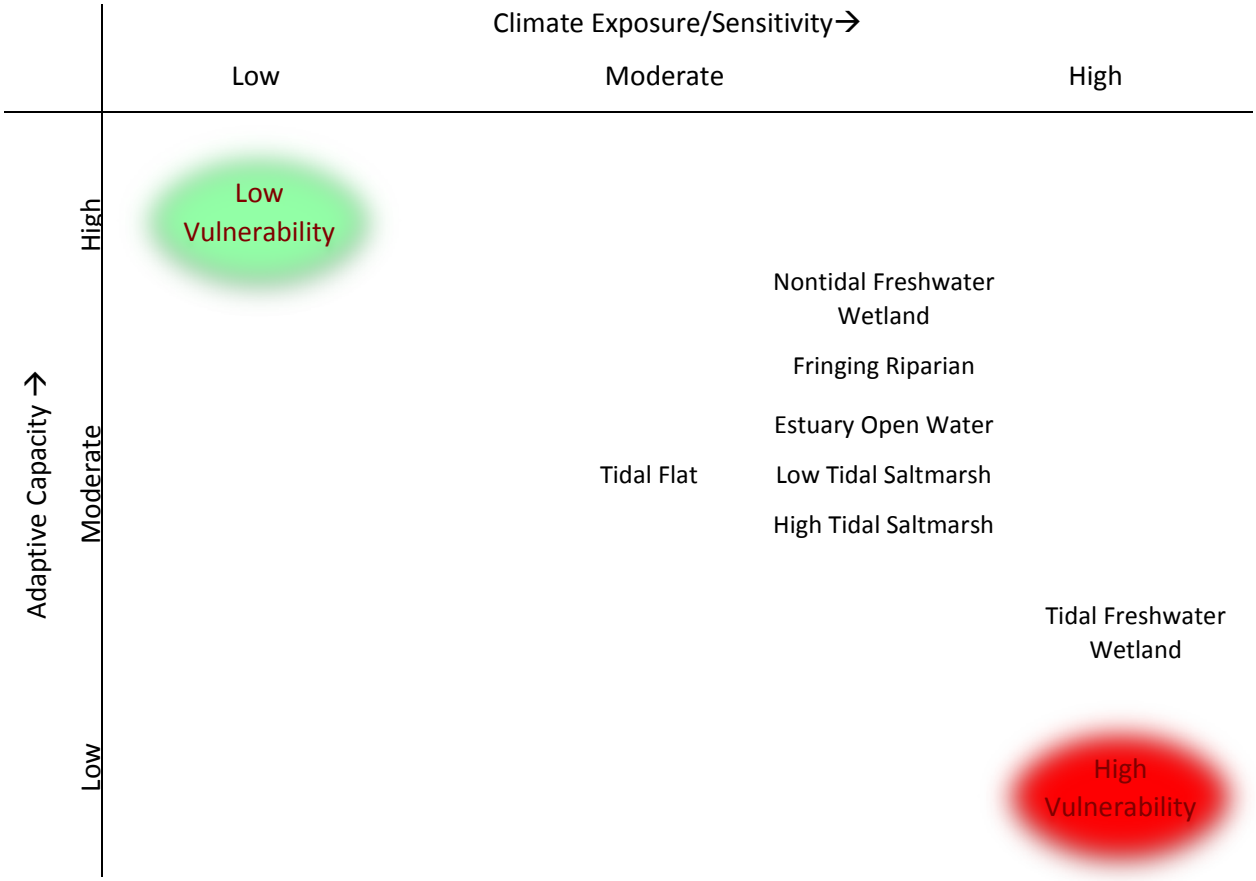
assumptions, and uncertainties in greater detail. Section 2 explains why these habitats and species were chosen, and goes into more detail about each.

Most Vulnerable Species and Habitats

Tidal freshwater wetlands and coho salmon

The vulnerability for each of the seven habitats is summarized in Figure 2. This figure is arranged such that habitats listed in the upper left region are judged to be less vulnerable than habitats listed in the lower right region. The exposure, sensitivity and adaptive capacity of most of the habitats were judged to be in the middle of the range. Tidal freshwater wetlands, however, were judged to be more vulnerable than the other habitats, having a combination of high exposure/sensitivity to climate change and low/moderate adaptive capacity. In contrast, tidal flat was considered the least vulnerable habitat having moderate climate exposure/sensitivity and moderate adaptive capacity. The climate change exposure/sensitivity of nontidal freshwater wetlands, fringing riparian habitat, estuary open water, and low and high tidal saltmarsh were considered similar to each other. The vulnerability of nontidal

Figure 2. Relative vulnerability of seven Coquille River estuary habitats through 2050, based on the climate change exposure/sensitivity and adaptive capacity of each. Vulnerability increases with increasing exposure/sensitivity and decreasing adaptive capacity so habitats listed in the upper left region are less vulnerable than those listed in the lower right region.

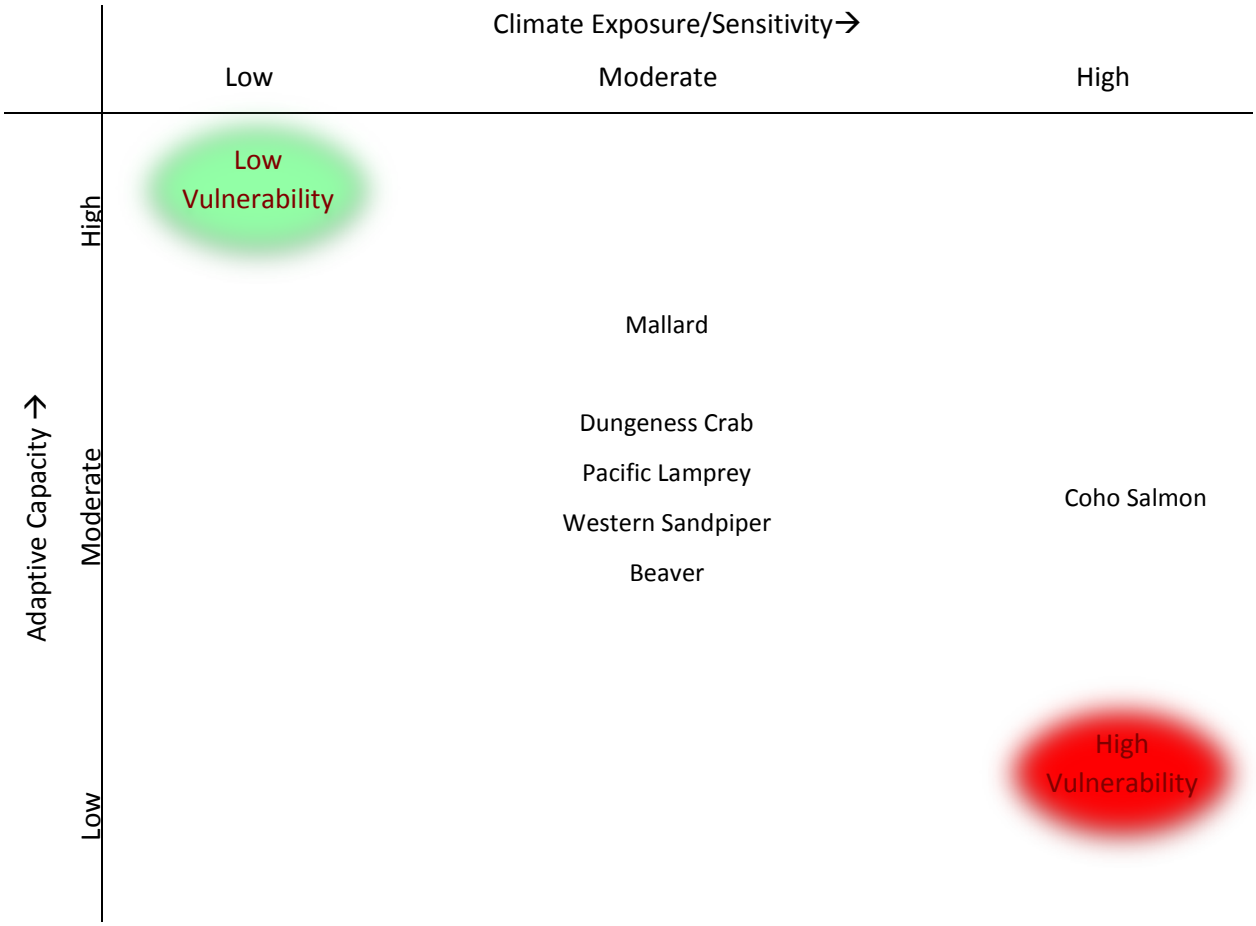


Confidence was generally moderate to high.

freshwater wetlands and fringing riparian habitat was less than the other group of habitats due to greater identified adaptive capacity. A more in-depth exploration of habitat vulnerability is presented in Section 4.

Figure 3 summarizes the vulnerability of the six species identified by the expert panel as having ecological keystone roles of management, cultural, or recreational concern. This figure is arranged similarly to Figure 2 in that species listed in the upper left region are judged to be less vulnerable than species listed in the lower right region. With the greatest vulnerability, coho salmon was the outlier species due to high climate change exposure/sensitivity and only moderate adaptive capacity. The remaining species were judged to all have moderate climate change exposure/sensitivity and mostly moderate adaptive capacity. The adaptive capacity of the mallard was determined to be greater than the other species as it has demonstrated an ability to accommodate a larger range of habitat types throughout its distribution. Species vulnerability is discussed in greater depth in Section 4.

Figure 3. Relative vulnerability of six Coquille River estuary species populations through 2050, based on the climate change exposure/sensitivity and adaptive capacity of each. Vulnerability increases with increasing exposure/sensitivity and decreasing adaptive capacity so species listed in the upper left region are less vulnerable than those listed in the lower right region.



Climate effects confidence was moderate to moderate/high
Adaptive capacity confidence was moderate/high to high, except low/moderate for western sandpiper.

The Coquille River estuary has undergone significant changes beginning with Euro-American settlement in the 1800s. These changes are well documented in regional studies (Benner 1991; Coquille Indian Tribe 2007; U.S. Fish & Wildlife Service 2013). The expert panel thought that each habitat and species considered here is sensitive to habitat loss to some degree, and that collectively, such changes are likely to reduce the resilience of the estuary to climate change. However, the expert panel discussed opportunities to work with community stakeholders and the desire to continue restoration activities, reduce local stresses, and better integrate the consideration of climate change effects into management plans.

All the habitats and species considered in this project were judged to have some vulnerability to climate change. Coho salmon and tidal freshwater wetlands were identified as the most vulnerable to projected climate change in the region. The local population of coho salmon is already a focus of regional management attention (Coquille Indian Tribe, 2007), and these efforts would benefit from integrating species specific information about climate change exposures and sensitivities. The information presented in Section 5 details coho salmon's climate change exposure, sensitivity and adaptive capacity while within the Coquille River estuary.

Section 4 provides detail on the climate change exposure, sensitivity and adaptive capacity of tidal freshwater wetland habitat, which was judged to be the most vulnerable of the habitats considered in the study. This habitat has been extensively altered to 'reclaim' tidal areas for upland land uses. Currently, a significant amount of this habitat occurs behind tidegates and dikes, or is otherwise constrained by topography, roads, or other infrastructure that can limit its ability to adapt by 'migrating' in response to climate-driven changes. Historically, this habitat type covered significantly more area within the estuary region (Benner 1991). Given its vulnerability to climate change, it warrants additional consideration in management planning.

All of the remaining habitats and species under investigation were judged to have at least moderate vulnerability to climate change, suggesting that climate change has the potential to affect the Coquille River estuary and the current services it provides to society. The details for these vulnerability rankings are presented in Sections 4 and 5. These levels of vulnerability were judged for the estuary as it is currently managed. The vulnerability of habitats and species in the Coquille River estuary is also affected by both past practices and other non-climate stressors. A comprehensive management approach would factor in the effects of both legacy conditions and current non-climate stresses. This vulnerability assessment can be used as a foundation from which management and planning can be strengthened by better integrating the effects of climate change.

Box 1. Uncertainty and how to incorporate it into decision-making

Resource managers and planners are accustomed to making decisions within the context of uncertainty. Natural systems have inherent stochasticity, while human community responses are similarly unpredictable. For example, we are not always certain when the next extreme event will be, if it will be a good salmon return year or not, or what impact human responses will have on outcomes of future events. Yet, we have developed decision-making frameworks that allow us to reasonably accommodate uncertainty, complexity and variability in order to move forward and improve outcomes. Historically we have used past experience to help inform our future actions. Accommodating climate change-related uncertainty requires that we evaluate present and future events, posing new challenges for communities and resource managers who may have relied on evaluation of past experience (Hulme and Carter 1999, Refsgaard et al. 2013).

An evolving variety of tools and approaches are being used by managers to prepare for the potential range of future conditions that are often provided by climate data. These include:

- Scenario planning (Peterson et al. 2003),
- Adaptive Management (Hansen & Hoffman 2011),
- Contingency planning/Bet hedging (Hansen et al. 2003)
- Precautionary principle (Hansen & Hoffman 2011)

The uncertainties around climate change cannot be a reason for inaction and ignoring uncertainty is equally irresponsible when making decisions in regard to climate change. Rather it is incumbent that uncertainty be explicitly considered in order to evaluate the complexity and variability that it represents.

Section 1: Project Approach and Methodology

Return to contents

This vulnerability assessment is a science-based effort to identify how key habitats, species, areas, and resources in the Coquille River estuary and associated lowlands are likely to be affected by future climate conditions, and to what degree these projected effects warrants concern for their sustained production of services to society. The analyses and conclusions are based on available information and expert opinion. The assessment focuses on habitats and species identified as important in local management planning documents or by local resource managers, and is therefore expected to be relevant to decisions that affect such habitats and species. Other important habitats and species may also be affected by climate change, but they were not explicitly examined in this project.

The goal of this project is to provide a foundation for integrating the effects of climate change on habitats and species into management plans and decisions that affect the Coquille River estuary. This report aims to 1) identify historic climate trends and likely changes in future climate conditions with potential to affect conditions in the lower Coquille River estuary, and 2) assess the vulnerability of key habitats and species to those future conditions. Ideally, this resource will support analyses of what can be done to help maintain optimal conditions and productivity of estuary resources, and thereby protect public investments in coastal resource conservation, use, and protection.

The region under study is the Coquille River estuary, its estuarine tributaries, and associated lowlands from the mouth of the Coquille River up to the head of tide, which is approximately 2 miles below Myrtle Point (Figure 1).

Assessment Objectives

- Identify climate trends and significant changes in future climate conditions that have the potential to affect estuarine resources
- Highlight key estuary habitats and species that are vulnerable to changes in climate conditions
- Provide information in a form that can be used in planning and decisions affecting the Coquille River estuary
- Provide climate change information that can be used in nearby areas to help adapt to the effects of future climate conditions

Approach and Methodology

A climate change vulnerability assessment can provide two kinds of information that are helpful in adaptation planning: 1) identify which species or habitats are most likely to be affected by projected changes; and 2) establish why those resources are likely to be vulnerable to such changes, including linkages between climate other local conditions. Knowing which resources are most vulnerable allows managers to evaluate management priorities. Understanding why resources are vulnerable allows for the development of appropriate management responses (Glick et al. 2011).

Vulnerability to climate change was assessed by considering 1) the exposure and sensitivity to climate change; and 2) the adaptive capacity of each habitat or species population. *Exposure* is defined as, "the nature and degree to which a system is exposed to significant climate variations" (Glick et al. 2011). *Sensitivity* is, "the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli" (Glick et al. 2011). Lastly, *adaptive capacity* is, "the ability of a system to adjust to climate change (including climate extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences" (Glick et al. 2011). Adaptive capacity can also encompass management's ability to respond. Overall vulnerability considers all three components in the following combination:

Vulnerability = Climate Exposure + Climate Sensitivity - Adaptive Capacity

Exposure and sensitivity are additive and vulnerability increase as they increase. Adaptive capacity is subtractive and vulnerability decreases as adaptive capacity increases. Readers may review *Scanning the Conservation Horizon: A Guide to Climate Change Vulnerability Assessment* by Glick et al. (2011) for additional information and application of this convention.

In this assessment, the components of vulnerability were assessed at three levels (low, moderate, and high). In this report, the exposure and sensitivity components are often combined (sensu from Comer et al. 2012). Confidence in each determination was also ranked as low, moderate, or high.

Stakeholder Involvement and the Expert Panel

A project initiation workshop was held in Bandon, Oregon on April 18, 2012, to engage key stakeholders and regional managers. This introduced climate change information for the region and the vulnerability assessment process. Input was gained from participants on management, planning, and opportunities where this report could help inform planning processes. This project focuses on the species and habitat types identified during the workshop that are most important to stakeholders and are likely to be management foci in the future.

As the next step, an expert panel was formed from local and regional managers and scientists working in federal and state agencies, local associations, universities, and conservation organizations, which helped provide, integrate and review information for this report. Expert panel members and affiliations are listed in Appendix A. A full-day workshop held at the South Slough National Estuarine Research Reserve on March 20, 2013, to provide the opportunity for panel members to work together in small groups to complete questionnaires that examined the components of vulnerability in multiple ways. The work groups were provided information on regional climate trends and projections; information on species-habitat relationships; and climate change sensitivity information suggested by the literature. Appendix B includes the information package sent to the expert panel. Participants were asked to integrate their local knowledge of species, habitats, and resource management. This information was captured on habitat and species vulnerability worksheets prepared specifically for this project, blank versions of which are included in Appendix C. Many panelists worked together in groups on the worksheets but others, who were unable to attend the workshop, filled out the worksheets by themselves.

This vulnerability assessment relied heavily on the expert panel for climate change sensitivity and adaptive capacity information for local habitats and species, and for the interpretation of exposure information. This project used an expert elicitation, or scientific consensus, approach to characterize uncertainty and fill data gaps where scientific information was not available. This approach can be limited by inconsistencies in local knowledge, unfamiliarity with complex ecological relationships, and a small number of expert participants. Therefore, the expert panel's conclusions are considered qualitative and applicable only within the context of the habitats and species considered.

Vulnerability of Key Habitats and Species

The vulnerability of key lower Coquille River estuary habitats was estimated by gathering and analyzing different kinds of generally qualitative information on climate change exposure, sensitivity and adaptive capacity. Climate data specific to the Coquille River estuary, such as regional temperature, precipitation, and hydrologic changes, were obtained from the literature or specifically synthesized by project collaborators. Qualitative exposure information was also obtained from the project's expert panel during the workshop held on March 20, 2013. Information on the sensitivity of specific habitats and key habitat components was obtained from the literature and from the expert panel's consideration of key

climate change variables, habitat composition, disturbance regimes, and other non-climate stressors. The adaptive capacity of habitats was established from expert panel input on a number of relevant parameters including a habitat's extent, integrity, mobility, resilience, and its management potential, among others. Each parameter was ranked qualitatively (low, moderate, high) along with an indication of the panel's confidence in that ranking (also low, moderate, high). The climate effects, adaptive capacity, and confidence rankings were calculated by assigning numeric scores to the low, moderate, and high rankings (1, 2, 3, respectively) and then computing the mean. Finally, the means were assigned rankings in five levels, according to this distribution: low (1.00-1.3); low/moderate (1.4-1.7); moderate (1.8-2.2); moderate/high (2.3-2.6); and high (2.7-3.0).

The vulnerability of key species was assessed in a process similar to that used for habitats; however the vulnerability of each species' primary habitat(s) within the Coquille River estuary was also considered.

Section 2: Key Habitats and Species Considered

Return to contents

A. Habitats

The seven habitat types included in the vulnerability assessment are a subset of habitats in the lower Coquille River estuary. These habitats were selected because of management concern in local management plans, supported by input from local stakeholders. The habitats considered are: estuarine open water, tidal flat, low tidal salt marsh, high tidal salt marsh, tidal freshwater wetlands, non-tidal freshwater wetlands, and fringing riparian.

By necessity, the habitats selected for analysis preclude historical wetland habitats no longer present. This is illustrated by the historical Coquille wetland map in Appendix E, which depicts habitat types no longer present. One such habitat that was likely common in the Coquille, is brackish tidal wooded swamp, an important and increasingly rare Oregon wetland type (expert panel; paraphrased from *The Oregon Estuary Plan Book*).

Brief descriptions of each habitat analyzed follow. Appendix D contains a 'crosswalk' that shows the relationships between these habitat types analyzed by the expert panel; habitats used in modeling future sea levels using the Sea Level Affecting Marshes Model; and the National Wetlands Inventory habitats. Currently existing project habitats are mapped in Figures 4-9, based on National Wetland Inventory data that was amalgamated and mapped (as shown on the Appendix D table) into the habitat categories used by the expert panel.

1. Estuary Open Water (1,270 acres)

This habitat includes areas of constant open water, the water column, and the subtidal areas beneath. Eelgrass meadows are included in this category. There are currently approximately 1,270 acres of estuary open water habitat in the Coquille River estuary[1]. Open water habitat has some measurable salinity and extends from the mouth of the estuary up to the salt / fresh water transition area in the river. Salt water has been noted upstream as far as river mile 21 (Mayer 2012), though river mile 14-16 may be more common. This habitat is influenced both by the marine and riverine systems. Salinities are moderate to high in the summer, and vary considerably depending on tides and the magnitude of freshwater flow (paraphrased from the Oregon Estuary Plan Book).

2. Tidal Flat (279 acres)

Tidal flats are the intertidal areas generally comprised of mud and sand, but lacking significant vascular plant cover. Currently, there are approximately 279 acres of tidal flat in the study area. Tidal flat sediments vary from fine muds to cobbles. They are generally sheltered from strong currents and wave action and their gradual slopes tend to dissipate wave and tidal energies. As a result, flats can provide a relatively stable environment for colonizing species. In addition, large shallow flats store heat and may have an important role in the temperature budget of the entire estuary. Shallow water depths, high levels of irradiance and warm temperatures often result in extensive algae blooms in the spring and summer, when many flats could be classified as intertidal aquatic beds. Ultimately, tidal flat community structure is influenced by sediment size, currents, wave action, temperature, and salinity (Paraphrased from the Oregon Estuary Plan Book).

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[1] Project habitat areas are based on amalgamations of habitat types in the National Wetlands Inventory Database. Please see Appendix D for habitat relationship.

3. Low Tidal Saltmarsh (276 acres) and
4. High Tidal Saltmarsh (407 acres)

Salt marshes are characterized by rooted herbaceous or woody hydrophytes (plants that tolerate regular salt water inundation) that grow between about mid tide level and upland habitat. Tidal saltmarsh is often classified as high or low saltmarsh with infrequent and frequent tidal inundation respectively. Currently there are approximately 276 acres of low tidal saltmarsh and 407 acres of high tidal saltmarsh within the study area. Plant composition in Pacific Northwest salt marsh communities varies with tidal elevation, sediment types, and salinity regime (Hutchinson 1988, Janousek and Folger 2013).

Saltmarshes are an important habitat for invertebrates, waterfowl, small terrestrial mammals, and insects. Detritus-feeding snails, scavenging crabs, and a variety of amphipods and other invertebrates seek the food and/or protection of marshes. Well-defined channels in high marshes are heavily used by juvenile Dungeness crab and a variety of small fishes. In some areas, they may provide important rearing habitat for juvenile Chinook salmon. Marshes also provide resting and feeding areas for large populations of migrating waterfowl.

Salt marshes have been ranked among the most productive ecosystems in the world. Primary producers in salt marshes include marsh grasses, macroalgae entwined among the grass stems, microalgae on the mud surface, and phytoplankton in the water column. Organic material and nutrients stored by marsh plants and algae are consumed directly, or transferred to other portions of the estuary as detritus.

Marshes are important sediment traps. They help stabilize sediments and shorelines, help dissipate flood waters, and buffer areas further inland from the erosive effects of waves. Marsh plants filter and process nitrates, phosphates, and other wastes, thus providing a pollution buffer between upstream and adjacent upland activities and the estuary.

5. Tidal Freshwater Wetlands (685 acres)

Tidal freshwater wetlands include tidal freshwater marsh, swamp habitats, and tidally influenced portions of the river. Altogether, they comprise approximately 685 acres, but 575 acres of this total are actually river bed beneath tidally influenced portions of the river. Therefore, only 110 acres of freshwater marsh and swamp remain. Tidal freshwater marshes are above saltwater influence and are located in a narrow elevation band at the upslope margin of emergent tidal marshes. This was historically the most extensive habitat type in the estuary and is the wetland type most impacted by human activity. In the past, this habitat was often dominated by Sitka spruce (*Picea sitchensis*) and shrubs (U.S. Fish & Wildlife Service 2013; Benner 1991). Most of the historical tidal freshwater wetlands in the Coquille are currently cut off from tidal influence by tidegates and dikes.

6. Nontidal Freshwater Wetlands (22,714 acres)

This is the most common habitat type in the study area and includes freshwater emergent marshes and fringing freshwater shrub-scrub swamp above tidal influence. Currently, there are approximately 22,714 acres of nontidal freshwater wetlands in the study area. Most of it is highly altered by human activity. Note that this total includes 1,610 acres of cranberry bogs that are not part of the estuary. These wetlands are often temporarily or seasonally flooded floodplain, pasture, or farmland. Many of the seasonal wetlands created by winter rains and runoff fall into this category (expert panel). The majority of this habitat within the Coquille River estuary is diked pasture and farmland, where dikes may trap water in fields (Benner 1991). As noted above, most of this habitat type was historically tidally influenced and much of it was wooded.

7. Fringing Riparian (acreage unknown since not mapped on National Wetland Inventory)

Riparian habitat is a denser narrow band of trees and shrubs at the edge of a water body or wetland. Riparian vegetation buffers estuarine waters from adjacent land uses and is an important wildlife habitat. Riparian habitat is probably most important because it is a concentration point for a great variety of wildlife, providing food and cover near water. It also protects the quality and quantity of water for wildlife, and often provides important habitat structure and food source for fish. Riparian vegetation also provides cooling shade for adjacent water bodies. Increasing the extent of shade is often a key component in riparian restoration activities aimed at enhancing fish habitat suitability, especially for thermally sensitive salmon species. Riparian vegetation also provides food and building resources and nesting areas for beaver, songbirds, bald eagle, osprey, herons, egrets, and wood ducks. Elk and deer use riparian vegetation for cover (Paraphrased from the Oregon Estuary Plan Book).

Figure 4. Overview map showing relative locations of areas shown in Figures 5 – 9

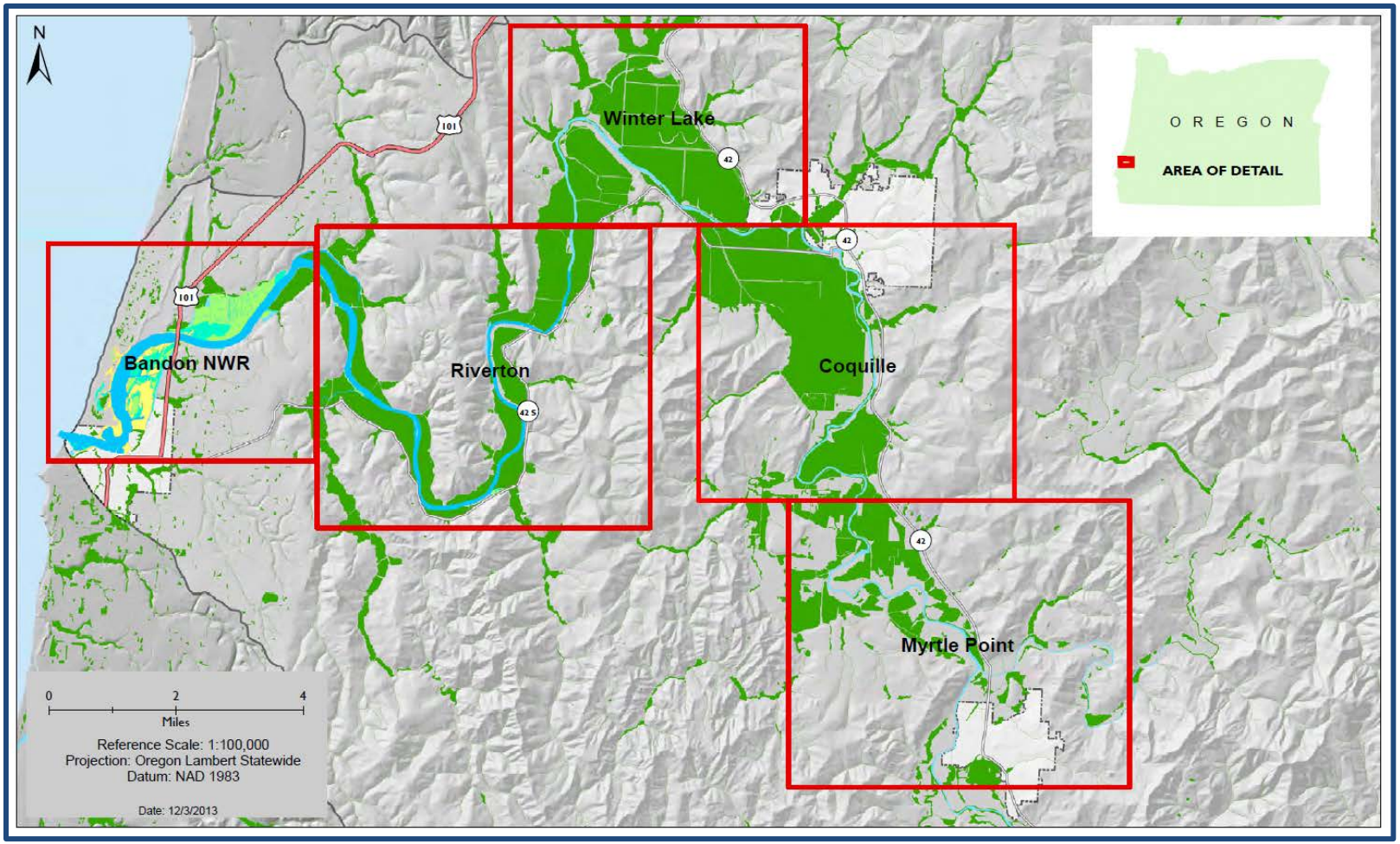


Figure 5. Current wetland habitat types near Bandon NWR

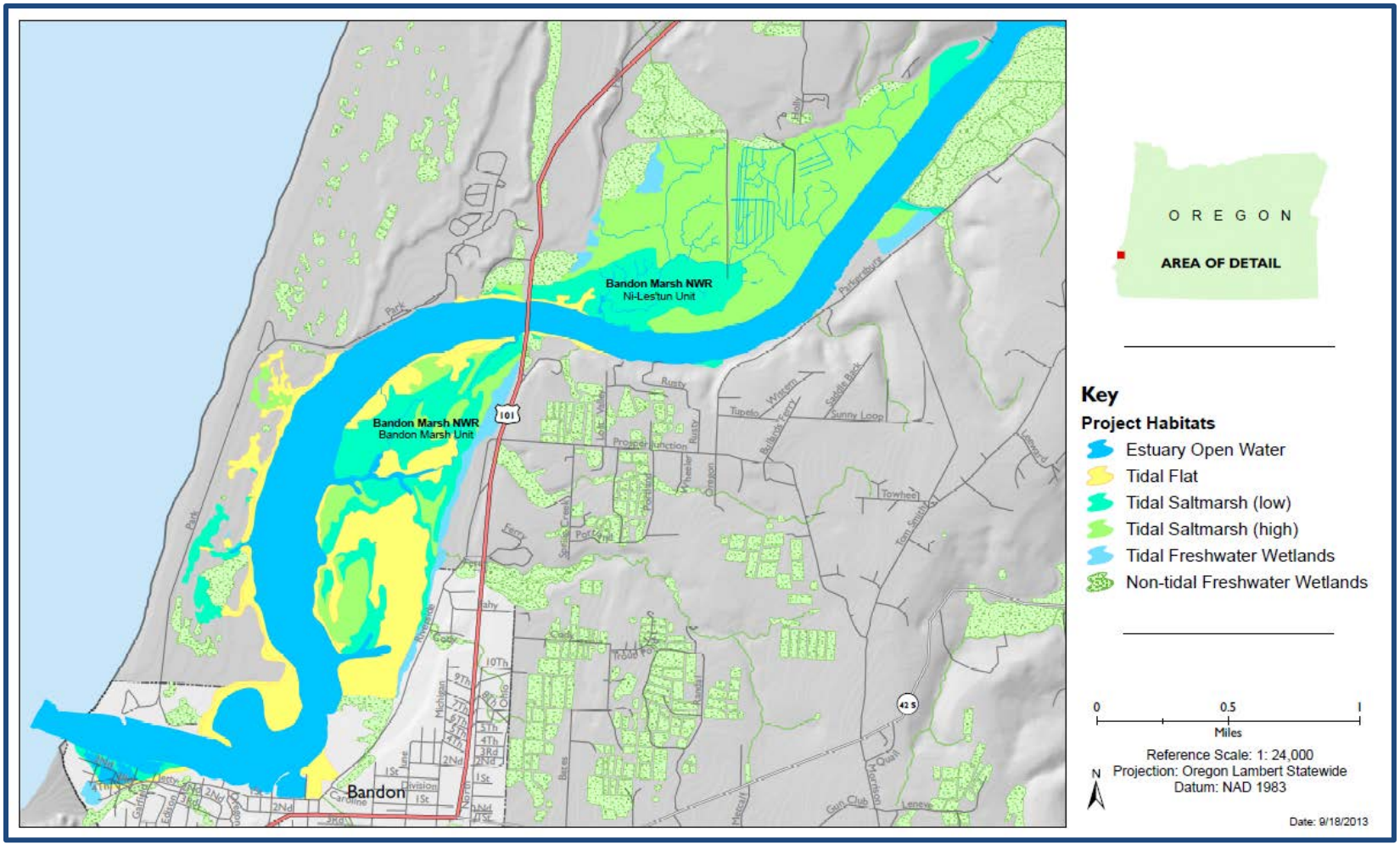


Figure 6. Current wetland habitat types near town of Riverton

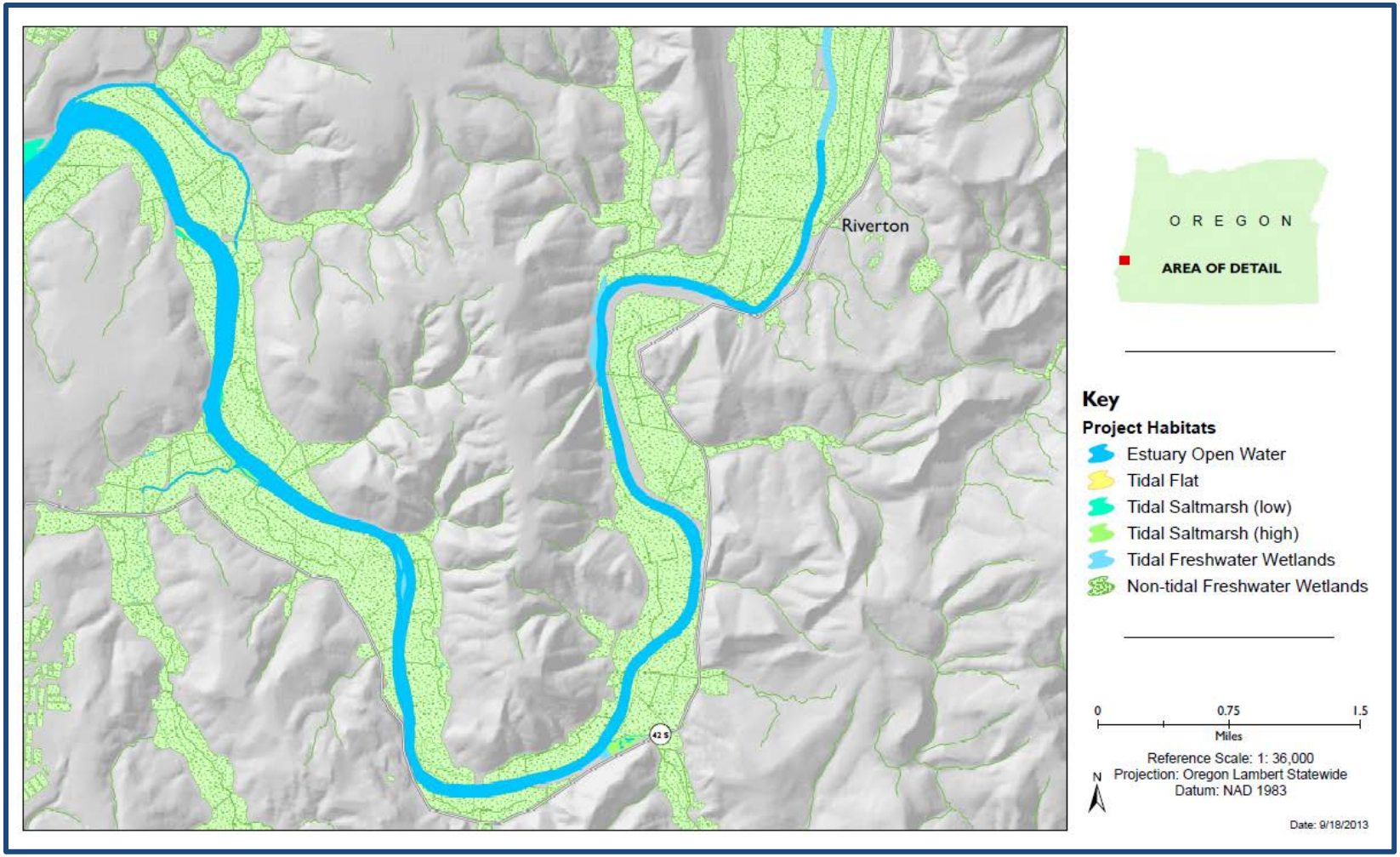


Figure 7. Current wetland habitat types near Winter Lake

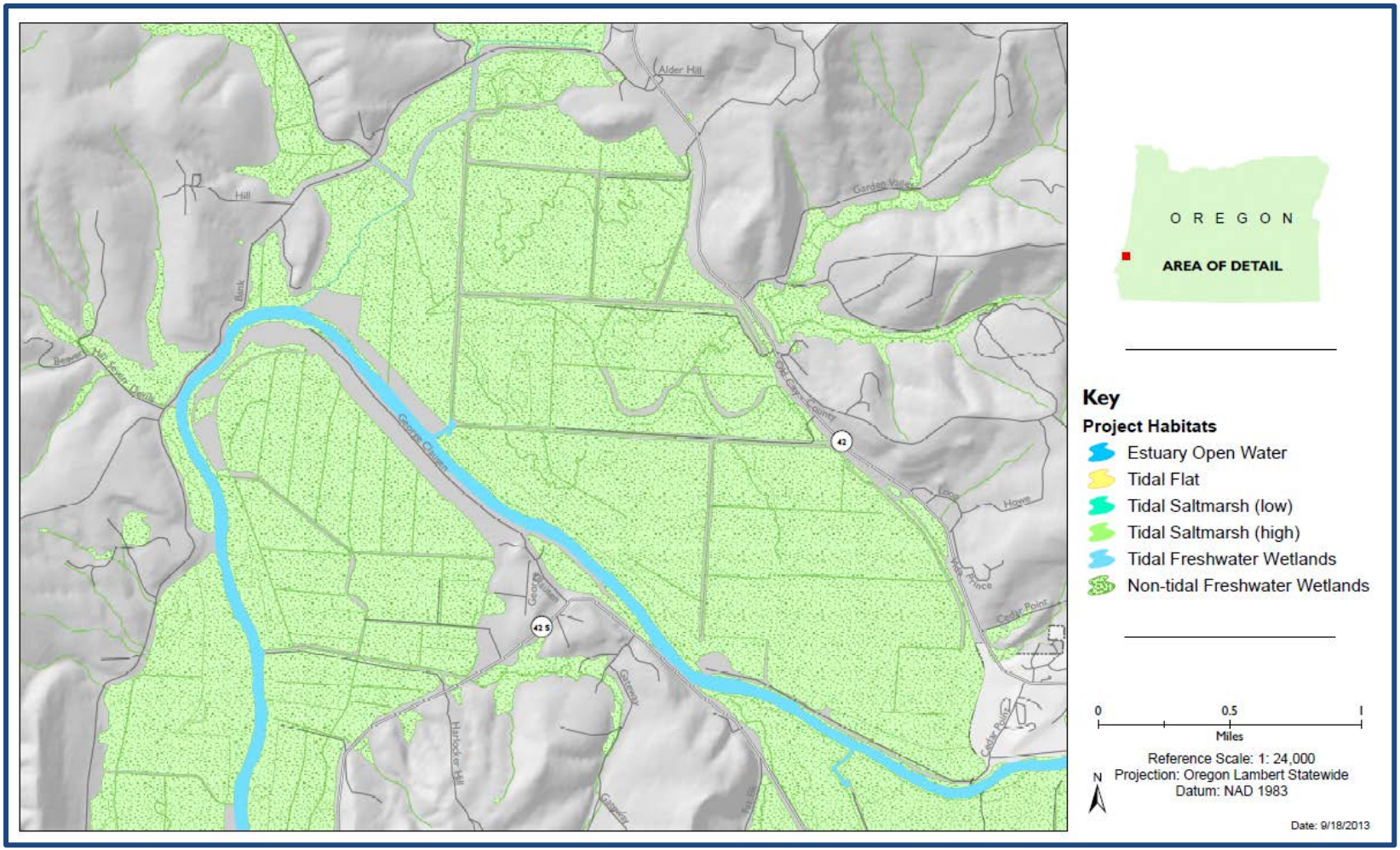


Figure 8. Current wetland habitat types near the town of Coquille

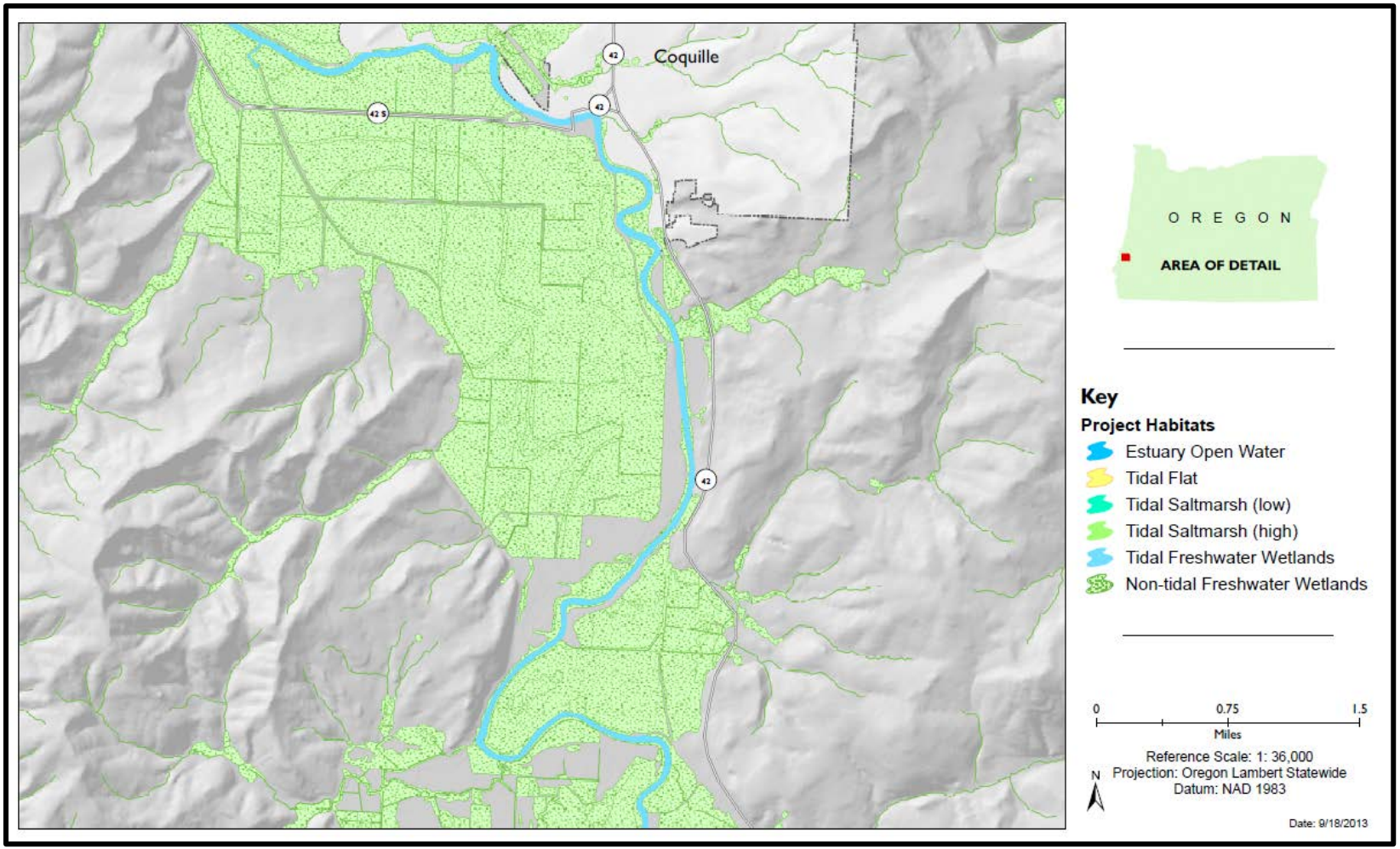
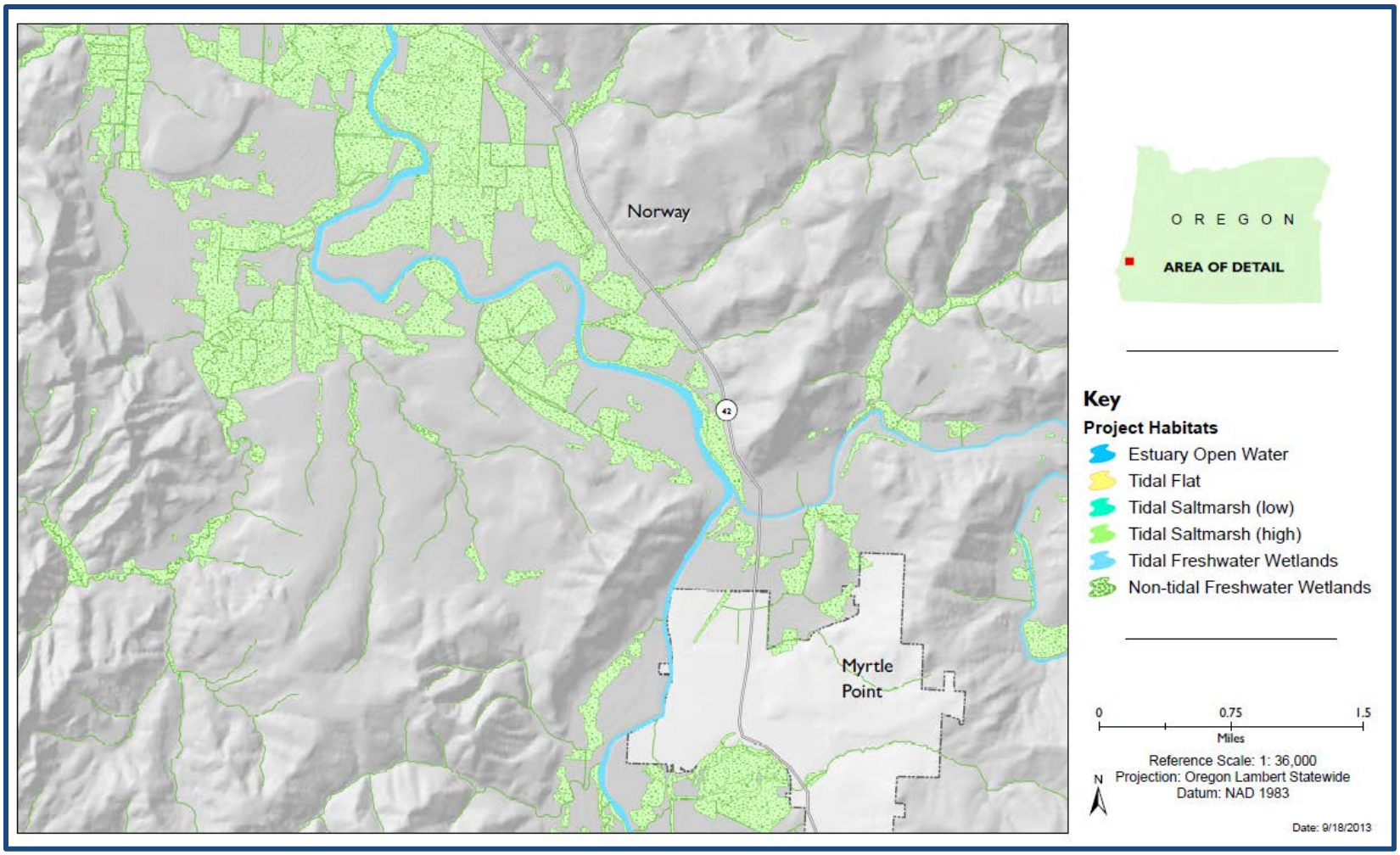


Figure 9. Current wetland habitat types near the town of Myrtle Point



B. Species

Species populations are the second focus area for the assessment. They are: (aquatic) Dungeness crab, coho salmon, pacific lamprey, (birds) mallard, western sandpiper, and (mammal) beaver. The intent was not to focus only on particularly sensitive species or those that might be the best to monitor as indicators of climate change. Rather, the expert panel selected these six species because they:

- Are species of management, cultural, and recreational concern
- Use one or more of the estuarine habitats in the study area
- Collectively use all of the estuarine habitats in the study area, and
- Are species for which management changes are possible

Vulnerability of species populations was assessed based on a combination of direct vulnerability and habitat-based vulnerability. Table 1 lists the species considered in this assessment and their regional management, cultural, or recreational relevance.

1. Dungeness Crab (*Metacarcinus magister*)

Dungeness crab was considered in this vulnerability assessment due to its cultural, recreational, and commercial significance and for its importance to managers. Its population size within the Coquille River estuary appears to be unknown, though recreational and charter crabbing recorded for the Port of Bandon (Ainsworth et al. 2012) is comparable to catch rates at other Oregon coastal ports. Within the lower estuary, juvenile Dungeness crab are likely to utilize and remain in the shallow estuarine areas among protective structures (eelgrass, etc.) for up to two years. Adults can be found in sandy and muddy areas from the shallowest parts of the lower estuary to 200 ft depth offshore. These include the estuary open water, tidal flat, and low and high tidal saltmarsh habitats.

2. Coho Salmon (*Oncorhynchus kisutch*)

The coho's regional importance as a cultural, recreational and commercial species makes it an important species to include in the vulnerability assessment. It is a vulnerable and threatened species in Oregon and has been listed as "threatened" under the Endangered Species Act in 1997, moved to a "not warranted" status subsequently (State of Oregon 1997, Coquille Indian Tribe 2007), and moved back to "threatened" status since then. Formal salmon recovery efforts have been underway in Oregon since 1997 (State of Oregon 1997). Efforts to sustain and enhance the local population are ongoing (Coquille Indian Tribe 2007). The average population in the Coquille river from 1990 to 2003 was 8,500 and the desired status is 8,400 – 67,900 returning adults, depending on ocean conditions. While the top end of this target is significant, it is still roughly 10% of historic levels (Coquille Indian Tribe 2007).

Coho salmon utilize all regions of the watershed at different stages in their life cycle. Coho spawn in upper watershed freshwater streams. Within the lower estuary, juveniles and summer parr utilize the tidal reach and estuary regions. Overwintering juveniles may utilize the saltmarsh channels. During the February to May out-migration, smolts remain in the estuary for 2-3 weeks for acclimation before venturing into the open ocean. Adults will return in the fall at two-to-three years of age and migrate through the estuary to reach spawning streams (Coquille Indian Tribe 2007).

3. Pacific Lamprey (*Entosphenus tridentatus*)

The Pacific lamprey has significant cultural importance within the Coquille River estuary and is considered a vulnerable species in Oregon. Its local spawning population has not been recently surveyed but is estimated to be between 2,500 and 10,000 (Luzier et al. 2011). Compared to salmon, not much is known about pacific lamprey across its range, though they spawn in freshwater streams in habitat similar to coho salmon. Adult lamprey generally migrate up the estuary to freshwater habitats from late

spring to fall and may remain there for up to a year before spawning. Larvae (ammocoetes) remain in fresh water for three to seven years. After metamorphosis they migrate down the watershed to the ocean where they remain one to three years before they return to spawn. Lamprey do not have as rigid a spawning-stream affinity as coho salmon (Luzier et al. 2011); that is, they do not necessarily return to their natal stream to spawn.

4. Mallard (*Anas platyrhynchos*)

The Mallard is an important recreational species in the Coquille River estuary. As both a permanent resident and seasonal migrant with populations wintering in northern California, it has a secure conservation status. Mallards are generalists and can be found throughout the estuary, although the population size is unknown. All estuary habitats are used for feeding (aquatic plants, seeds, invertebrates, insects and fish), while breeding activities are limited to the more inland reaches of the estuary, including tidal and nontidal freshwater wetlands and riparian areas.

5. Western Sandpiper (*Calidris mauri)*

Western sandpiper is an important recreational and management species. They are common within the estuary but have a limited breeding range. They are a management priority given that they are included in the U.S. Shorebird Conservation Plan as suspected of being a population in decline (Brown et al. 2001). The population within the estuary is estimated to be up to 100,000 during their migratory stops in spring and fall for foraging and roosting (expert panel). Estuary use is longer during the southward leg of their trip. It is a mudflat specialist limited to shoreline, beaches, tidal mudflats and flooded fields.

6. Beaver (*Castor canadensis*)

The North American Beaver is an ecologically significant keystone species that plays an important engineering role in aquatic ecosystems. Beaver create new surface water habitat behind their dams, and this surface water can increase groundwater recharge and trap sediment (Pollock et al. 2003). They are fairly common in the estuary and possibly number in the 1000's (expert panel). They are herbivorous, year round residents in the riparian and freshwater wetlands of the uppermost Coquille River estuary. Beaver ponds have also been demonstrated to be important for coho salmon rearing habitat (Pollock et al. 2004).

Table 1. Summary Information on species considered in the Coquille estuary vulnerability assessment and their Habitat Associations.

Species	Species Relevance	1. Estuarine Open Water	2. Tidal Flat	3. Tidal Saltmarsh Low	4. Tidal Saltmarsh High	5. Tidal Freshwater Wetlands	6. Nontidal Freshwater Wetlands	7. Fringing Riparian
Invertebrates								
Dungeness crab (*Metacarcinus magister*)	Important to mangers Important cultural, recreational & commercial species. Secure species in OR	Juveniles (2yr): Shallow estuarine areas with protective structures, woody debris, eelgrass; 2 years Adults (3+yr): sandy and muddy areas in shallowest parts of lower estuaries and to 200ft. depth						
Fish								
Coho salmon (*Oncorhynchus kisutch*)	Important to managers and tribes Important cultural and recreational species Vulnerable & threatened species in OR Local spawner Long Distance Migrant	Habitat: Bay/Sound, river mouth/ Tidal River Juveniles: overwinter in lower watershed, off-channel habitats. Summer Parr (may-June): utilize tidal reach/ estuary, slow cold water, off-channel habitats Overwinter rearing: salt marshes and off-channel habitats (less common) Smolt migration: remain in estuary 2-3 wks for acclimation, cold water, off-channel habitats Food: Insects, aquatic inverts, fish			Above the Estuary: Streams most important: spawning, early life stages Habitat: Big, Medium River, Pools, Riffle Stream spawning/rearing/overwintering: woody debris, structural cover, shade, pools, complex channels Food: Insects, aquatic inverts, fish			
Pacific lamprey (*Entosphenus tridentatus, Lampetra tridentata*)	Important to managers and tribes Vulnerable species in OR Long Distance Migrant	Habitat: Bay/Sound, River mouth/Tidal river; Predatory phase ocean, stream mouths in estuaries Migrate up estuary to freshwater streams for spawning. Juveniles migrate down estuary to ocean for adult life stage				Spawning in freshwater streams. Ammocoete life stage in freshwater streams. Prefer habitat similar to salmon Food: Larval stage filter feeders		
Birds								
Mallard (*Anas platyrhynchos*)	Important recreational species Secure species in OR Permanent resident, short & long distance migrant	Habitat: River mouth/tidal river, lagoon, tidal flats/shore Feeding: aquatic plants, seeds, aquatic inverts, insects		Habitat: Herbaceous wetland. Winters brackish waters Feeding: aquatic plant seeds, aquatic inverts, insects, fish		Habitat: Herbaceous wetland, riparian; Winters freshwater lagoons Breeding: Marshes, ponds in grasslands, associated with seasonal & semi permanent wetlands Feeding: aquatic plant seeds, aquatic inverts, insects, fish		
Western Sandpiper (*Calidris mauri*)	Important to managers Important recreational species Secure species in OR Permanent resident, short & long distance migrant		Habitat: Tidal flats, tidal saltmarsh, tidal transitional marsh, tidal freshwater marsh, herbaceous wetland, riparian; Winters freshwater lagoons Breeding: Marshes, ponds in grasslands, associated with seasonal & semi permanent wetlands Feeding: aquatic plant seeds, aquatic inverts, insects, fish					
Mammals								
Beaver (*Castor canadensis*)	Important to managers Ecological keystone species Secure population in OR Permanent resident				Habitat: Riparian, deciduous tree and shrub communities Beaver lodges/dam in tidal scrub/shrub in Puget Sound Food: Herbivore			

Section 3: Local Climate Change Projection and Exposure Summary

Return to contents

The climate change information used in this vulnerability assessment is primarily derived from four recent reports on climate change in the Coquille Basin and surrounding region: *Climate Change and the Lower Coquille Watershed* (Sharp, 2012), *Bandon Marsh National Wildlife Refuge Comprehensive Conservation Plan And Environmental Assessment* (U.S. Fish & Wildlife Service 2013), *Coquille River Basin Stream Temperature Assessment* (Mayer, 2012), and *Potential Climate-Induced Runoff Changes and Associated Uncertainty in Four Pacific Northwest Estuaries* (Steele et al. 2012). The findings in these reports are summarized in Table 2 and the narratives below.

Potential climate-related drivers of change in the Coquille River estuary include increased average air and water temperatures and changes in precipitation patterns. These changes in climate conditions drive other changes in the ocean and the estuary and its watershed, including rising sea levels and changes in estuarine hydrology and salinity. Changes in atmospheric composition are resulting in changes in ocean chemistry; specifically, ocean waters are becoming more acidic. There is potential for changes in waves and storms; the research on changes in upwelling is inconclusive. Historic trends and climate projections provide localized information on the direction of future trends, but there is no single definitive future climate projection for the Coquille River estuary. Rather, projections are expressed as ranges of possible future conditions for each climate-related variable. Not all potential changes are equally likely. The projections used are based on scenarios and conditions that are projected to occur, generally using outputs from state-of-the-art computerized climate models. Together, these projections of future climate conditions can provide a sense of the rate and magnitude of possible change that will affect the Coquille River estuary.

Table 2. Historical and Projected Climate Change Summary

Climate-Related Parameter	Historical Change and Projections
Temperature (Sharp 2012)	Historical: There has been a warming trend of 0.1°C (0.2°F) per decade (1903-2010 period at North Bend weather station). While this warming trend has varied by season, all seasons show a warming trend. Projections: 2040s: Increase in the annual mean air temperature of 1.3°C (2.3°F), range 0.7-1.9°C (1.3-3.4°F). 2060s: Increase in the annual mean air temperature of 1.8°C (3.2°F), range 1.2-2.6°C (2.1-4.7°F). For both decades, the summer months have the largest projected temperature increase, as well as the largest projected range.
Precipitation (Sharp 2012)	Historical: There is no statistically significant trend in precipitation (1903-2010 at North Bend weather station). However, average yearly precipitation has decreased more than 15 percent (and more so in the summer and fall) over the last 30 years of that period. Projections: 2040s and 2060s: Inconclusive; little or no change outside the historical range of variability. The data suggest drier summers, but are inconclusive as to whether total annual precipitation will increase or decrease. Data suggests an increase in winter extreme precipitation events.
Ocean	Historical: Over the past 250 years, there has been about a 16 percent decrease in

Acidification (Sharp 2012)	aragonite and calcite saturation state in the Pacific Ocean due to ocean acidification processes (calcifiers, such as shellfish and some plankton, depend on calcite and aragonite for shell building). Recently-published results of oceanographic surveys in the Pacific Ocean show accelerating ocean acidification trends over the past 14-year period (average 0.34 percent per year decrease in aragonite and calcite saturation state of surface seawater). Projections: pH will continue to drop (i.e. increased acidification). Annual mean pH by 2050 projected to drop to 7.82 +/-0.04 (10 km nearshore, A2 emissions), compared to a pre-industrial value of 8.03 +/-0.03.
Local Relative Sea Level Rise (Sharp 2012)	Historical: Globally, sea level has risen approx. 22 cm (8.7 inches) since 1870. In the Coquille River estuary, the land is rising due to local geologic forces, and thus the area has not experienced significant sea level rise since 1870, when tidal records begin. Projections: The range of sea level rise in the region from northern California to the Puget Sound (due to many localized factors) is -3.5 inches to +22.7 inches by 2030; and -2.1 inches to +48.1 inches by 2050 compared to 2008. For Coos Bay, average sea level rise is projected to increase +9 cm (+3.5 inches) by 2030; and +24 cm (+9.4 inches) by 2050 relative to 2008. Projections for the Coquille River estuary would be lower due to the area's current upward vertical land movement.
Hydrology/ Stream Flow (Steele et al. 2012)	Historical: No historic record. Projections: Higher mean flow in the fall likely, with the possibility of lower mean flow in the late summer. Probable increase in high flow events (top 5 percent). (Projections are for 2041-2065 compared to 1971-1995). (Steele et al. 2012)
Stream Temperature (Mayer 2012)	Historical: Stream temperature data are mostly available for sites at and upstream of the mouths of the three major tributaries (North Folk, Middle Fork and South Fork). The 7-day average summer maxima range from 22˚C (71.6°F) to 24.6˚C (76.3°F) (the temperature criterion is 16˚C [60.8°F]). Daily average temperature for the lower main stem Coquille (only four days of data from Sept 11-14, 2007) was 19.9˚C (67.8°F) at river mile (RM) 30 and 20.2˚C (68.4°F) at RM 23 (the temperature criterion is 20˚C [68.0°F]). Projections: Stream temperatures at the mouths of all three tributaries are estimated to increase about 0.7°C (1.3° F) by the 2040s and 0.9°C (1.6°F) by the 2060s given the projections in air temperature increases for the area.
Upwelling (Sharp 2012)	Historical and Projections: Inconclusive. Some data suggests increased upwelling.
Waves/ Storms (Sharp 2012)	Historical and Projections: Suggestion of increased waves/storms. Data suggest more frequent wind and wave related flood events, with some west coast locations experiencing 100 year events every 5 years.
Sea Surface Temperatures (Sharp 2012)	Historical: The global mean sea surface temperature has increased by approximately +0. 6°C (+1.1°F) since 1950 Projections: Increase on the order of 1.0°C (1.8°F) by mid-century (A1B emissions scenario).

A. Sea Level Rise

Sea level rise is a concern for estuaries due to their significant areas of gradual elevation rise. Sea level rise will likely affect estuarine habitats, as such habitats are a function of elevation, tidal range, local hydrological regime, and sediment accretion. Global sea level rise is primarily due to thermal expansion

of the oceans and an increase in water volume as land ice melts. Projected effects of sea level rise on habitats in the Coquille estuary have been calculated for 2030 and 2050 using the Sea Level Affecting Marshes Model (SLAMM)[2]. The sea level rise estimate used for the SLAMM model runs and reported here was selected to be consistent with regional projections for the Oregon coast (NRC 2012), and adjusted based on the local vertical land movement reported in Komar et al. (2011) (Sharp 2012).

The southern Oregon coast is currently experiencing local tectonic uplift, resulting in sea level rise rates that are lower than U.S. West Coast and global averages. To some degree, this reduces the vulnerability of Coquille River estuary habitats to the effects of rising ocean water levels. The SLAMM simulations and sea level rise reported here are lower than that calculated for the Coos Bay tidal gage station (+9 cm [+3.5 inches] by 2030; and +24 cm [+9.4 inches] by 2050 relative to 2008), as recommended in Komar et al. (2011) (a reference from Sharp 2012).

Table 3. Modeled sea level rise compared to 2011 and locally corrected for the Coquille River estuary (based on Sharp 2012)

	2011-2030	**2011-2050**
Coquille SLR[3]	8cm / 3in	21cm / 8in
(Range)	(2-20cm / 1-8in)	(5-49cm / 2-19in)

The SLAMM simulations show a minimal increase in project habitat area overall by 2030 and by 2050, compared to 2011. The greatest changes for the 2030 time point were simulated to be for tidal low salt marsh (gain), non-tidal freshwater wetlands (minimal loss), and for estuary open water (minimal gain). The 2050 time point simulated similar individual habitat changes, tidal low salt marsh (gain), non-tidal freshwater wetlands (minimal loss), and for estuary open water (minimal gain), (Table 4).

Table 4. Change in estuary habitat area at 2030 and 2050 due to simulated sea level rise by SLAMM, assuming existing dikes and levees remain in place and 2011 developed dry land does not change)

Habitat Types	**Gain/Loss 2011 to 2030**	**Gain/Loss 2011 to 2050**
Estuary Open Water	Minimal Gain	Minimal Gain
Tidal Salt Marsh (low)	Gain	Gain
Tidal Salt Marsh (high)	No Change	No Change
Tidal Flat	No Change	No Change
Tidal Freshwater Wetlands	No Change	No Change
Non-tidal Freshwater Wetlands	Minimal Loss	Minimal Loss
Riparian	N/A	N/A

Appendix B contains SLAMM-generated maps of habitat changes predicted for 2030 and 2050 using the above sea level rise estimates. SLAMM simulates the dominant processes involved in wetland conversions and shoreline modifications during long-term sea level rise, and was used to simulate changes in habitat area within the Coquille River estuary. The model uses information on local sea level

[2] See Appendix B for SLAMM metadata, technical information and the input variables used.

[3] Coquille SLR Scenario is based on the A1B maximum emission scenario (IPCC Fourth Assessment Report); Range low end – A1B minimum emission scenario; high end – assumed 1.65m global average sea level rise.

rise rates, sediment accretion rates, salinity regime, current spatial extent of habitats, and data on elevations and subsidence or uplift. However, its complexity is limited; its outputs are simplifications and are only as reliable or accurate as the information used as inputs. For instance, accretion rates critically affect whether intertidal wetlands will keep pace with sea level rise, but had to be estimated as a single value for the entire estuary. It is not possible to use site specific accretion rates. The model's salinity regime component is simple and does not take into account complex sea level rise driven hydrologic change. Finally, SLAMM oversimplifies the habitat conversion and transition potential.

In addition to the limitations of SLAMM projections, it is important to consider three additional caveats regarding the exposure of the Coquille area to sea level rise: 1) Local tectonic uplift is currently almost keeping pace with sea level rise, but the rate of sea level rise is predicted to increase geometrically until at least 2100 and will eventually outpace tectonic uplift (Dalton et al. 2013); 2) Although the collision of tectonic plates and resulting subduction of oceanic plates under the mainland creates localized coastal uplift, the increasing pressure between plates will eventually be released in a large earthquake that will significantly lower some coastal areas very quickly, resulting in instantaneous sea level rise (Komar et al. 2011) in the form of a tsunami; and 3) the expert panel based its analysis on the assumption that existing dikes, levees, tide gates, and roads would remain in place – structures which currently isolate the wetlands behind them from salinity increases and sea level rise and will continue to do so in the future if left intact. However, this analysis purposefully does not address any of these three caveats because (for 1 and 2) the time frames and effects of these processes on relative sea level rise cannot be well quantified, and (for 3) because the future condition of existing dikes and levees depends on social and economic factors beyond the scope of this study.

B. Air Temperature

Historically there has been a warming trend of 0.1°C (0.2°F) per decade from 1903 to 2010 based on records from North Bend, OR, the nearest station (Sharp 2012). The last 30 years of these data show warmer winters and summers, and cooler springs than the 1903-2010 average (U.S. Fish & Wildlife Service 2013). Future temperature trends for the Coquille region have been derived from an ensemble of nine regional climate models and project higher temperatures in mid-century with the summer months showing the greatest increase. These projections use a middle of the range greenhouse gas emissions scenario (the A2 emissions scenario in the IPCC Fourth Assessment Report). Compared to a baseline period of 1970-1999, annual mean temperature is likely to increase by 1.3°C (2.3°F) (range of increase 0.7°C-1.9°C [1.3-3.4°F]) by the 2040s and 1.8°C (3.2° F) (range 1.2-2.6°C [2.1-4.7°F]) by the 2060s. For both future decades, the summer months show the greatest projected temperature increase, as well as the largest range of potential change. As in the past, future temperatures are expected to be slightly cooler closer to the ocean versus inland (Sharp 2012).

The reports by Sharp (2012) and U.S. Fish & Wildlife Service (2013) both present additional details on historic and predicted future air temperature for the Coquille watershed.

C. Precipitation

The Coquille River watershed is rainfall-dominated; that is, there is little snow accumulation in the watershed. The watershed receives about 70 inches of precipitation annually, with the majority occurring between October and June. Analysis of historic precipitation records from the North Bend station show no statistically significant changes from 1903 to 2010 (Sharp 2012). However when examining the last 30 years of that record, average yearly precipitation has decreased more than 15%, with a greater average decrease in the summer (-47%) and fall (-29%) (July through December) (U.S. Fish and Wildlife Service 2013). Future precipitation trends were derived from an ensemble of nine regional

climate models using the middle range (A2) emissions scenario in the IPCC Fourth Assessment Report. This ensemble predicts no clear change in annual average precipitation by mid-century (2040s and 2060s), but does suggest that summers are likely to be dryer. Other research efforts confirm a lack of average annual change, but do suggest a significant increase in extreme winter precipitation events (20 and 50-year return period one-day precipitation totals; Sharp 2012).

D. Water Temperature (Stream and Sea Surface)

Water temperatures in the Coquille River estuary are influenced by both marine water temperatures and the temperatures of fresh water entering the estuary through its many tributaries. Temperatures in the lower estuary are influenced mainly by tidal seawater and follow temperature trends of coastal marine waters (Ruggiero et al. 2010). Air temperatures, base stream flows, stream lengths and slopes are the major factors affecting river and stream temperatures. In Oregon, groundwater discharge can moderate summer water temperatures, especially during the lowest flow periods. However, groundwater contribution to the Coquille River system is very small, among the lowest 10th percentile of all Oregon rivers. Summer air temperatures are often warmer in upstream reaches away from the coast. Because of the influence of fresh water temperatures in the mainstem of the Coquille, water temperatures in the upper estuary are more responsive to air temperatures in the upper watershed than to air temperatures in the lower watershed (Mayer 2012). In other words, water temperatures in the estuary are not likely to be significantly affected by air temperatures in the lower watershed.

Historic and current water temperature data are very sparse for the Coquille River estuary; most of it has been collected in the tributaries rather than the mainstem. Stream temperatures in the upper mainstem Coquille are determined by contributions from the three main tributaries (North Fork Coquille, Middle Fork Coquille, and South Fork Coquille). There are only four days of recorded water temperature data for the main stem Coquille River (September 11-14, 2007) for two sites. Daily average temperatures for this period were 19.9°C (67.8°F) at river mile 30 and 20.2°C (68.4°F) at river mile 23. Both these stations are above the estuarine portion of the watershed (Mayer 2012).

Addressing the question, “how much warmer will streams get, given the projected increases in summer air temperatures?” Mayer (2012) estimated that stream temperatures will increase about 0.7°C (1.3°F) by the 2040s and 0.9°C (1.6°F) by the 2060s using regressions of the stream-air temperature relationships at the mouths of the three tributaries and at similar rivers.

Sea surface temperatures off the Oregon Coast are expected to increase 1.2°C (2.2°F) within the 2030-2059 period. However the complexities of upwelling and wind driven mixing over the coastal shelf complicate modeling future near-shore ocean temperature (Oregon Climate Assessment Report 2010).

The report by Mayer (2012) contains a more detailed description of the Coquille Watershed’s hydrology, past temperature information, and future stream temperature warming. *Oregon Climate Assessment Report* (2010), Chapter 1, provides more detail about coastal sea surface temperature predictions.

E. Hydrology

The Coquille River drains about 274,000 hectares over its approximate 100 mile length. The river widens and empties into the Coquille River estuary approximately three miles from the ocean. The 309 hectare estuary is long, narrow, and fresh-water dominated because of its relatively small size. The lower river upstream to the confluence of the North Fork (river mile 37) is considered tidally influenced. Head of tide has been observed as far upstream as river mile 41, where the Middle Fork and South Fork join. Salt water influx has been noted upstream as far as river mile 21 (Mayer 2012).

The Coquille exhibits a high degree of seasonality in stream flow as is typical of the rivers in the Pacific Northwest. There are no long term stream flow records for the main stem Coquille, though data exist for brief overlapping time-periods at the mouths of each of the three main tributaries (See Mayer 2012 for flow data). There is no change evident in historic average January or December flows for the South Fork between 1930 and 2010 (Sharp 2012). Model results suggest that climate change may accentuate seasonal differences in the future. Higher summer temperatures and decreased precipitation will decrease summer stream flows (Sharp 2012; Steele et al. 2012). The lack of significant groundwater input further exacerbates this trend (Mayer 2012). Model simulations by Steele et al. (2012) suggest higher mean flow in the fall season by 2065 compared to historic means (1971-1995).

High streamflows associated with storms are likely to increase slightly in the future; the number of days when streamflows fall within the top five percent of high daily streamflow amounts are expected to increase in the future (2041-2065) compared to the reference period (1971-1995).

F. Ocean Acidification

Increasing atmospheric CO_2 concentration will continue to change the chemistry of ocean waters, making them more acidic. With increased acidification (lower pH), shell-building organisms may have difficulty building or maintaining their hard body parts. Other biological functions of marine organisms that respond to ocean acidification include photosynthesis, respiration, growth, calcification, reproduction and recruitment (Gazeau et al. 2007). Recent reports demonstrate that increased acidification in estuaries can impact oyster production (Barton et al. 2012).

Acidification rates within the Coquille River estuary have not been measured. However, since the estuary is tidally influenced, acidification in the Pacific Ocean is likely relevant. There has been about a 16% decrease in aragonite and calcite saturation state (another way to gage acidification) over the past 250 years in the Pacific Ocean due to inputs of CO_2 from the atmosphere to the ocean (Feely et al. 2012). Recent research shows acidification is accelerating in the Pacific Ocean. Over the past 14 years aragonite and calcite saturate state has decreased an average of 0.34% per year in surface seawater. Ocean acidification trends along the Oregon coast are similar. By 2050, nearshore coastal water may see an annual mean pH as low as 7.82 ± 0.04 compared to a pre-industrial pH of 8.03 ± 0.03 (Gruber et al. 2012). Localized upwelling of deeper more acidic water can add to this (Oregon Climate Assessment Report 2010).

G. Upwelling

Upwelling brings colder, denser, more acidic, nutrient-rich and oxygen-poor water to the surface along Oregon's coast. Through tidal cycles this water enters coastal estuaries. Long-term historic data show no conclusive trends in upwelling along the southern Oregon coast (Sharp 2012). More recently, upwelling was more intense in each year from 2005 to 2008 compared to the previous 20 years, though it varies latitudinally along the Oregon coast (Oregon Climate Assessment Report 2010). Current research suggests little future change in upwelling, since modeled future trends in average along-shore coastal winds show little change for 2030-2059 compared to 1960-1999 (Oregon Climate Assessment Report 2010).

H. Waves/Wind

Research is still continuing regarding the potential for changes in future average wind and wave height along Oregon's coasts. However, some global-scale research does suggest future long-term increases in wave height and wind speed in the northeast Pacific Ocean (Sharp 2012).

In the near term, modeling suggests sea level rise can be magnified by a factor of five, on average, by storm surges. This dramatically increases the recurrence, or return periods, of storm surge events. By 2050, 100-yr storm related flood events may occur as often as every five years (Charleston, Coos bay, OR location) (Sharp 2012). Periodic inundation due to storm surge may play a more significant role in habitat change in the Coquille River estuary than sea level rise since sea level rise is currently being offset by regional tectonic uplift.

Section 4: Assessment of Habitat Vulnerability

Return to contents

The vulnerability of selected Coquille River estuary habitats was estimated by the expert panel through interpretation of available climate change exposure information, its understanding of climate change sensitivities, and integrating what was known of the adaptive capacity for each habitat. Section 1 describes the process undertaken to arrive at these vulnerability estimates. Tables 5 - 9 summarize overall vulnerability and potential climate exposure and sensitivity for habitats. These tables are a good place to start when exploring habitat vulnerability results.

The exposure and sensitivity of each habitat and its component species were estimated by considering the following eight factors: 1) sea level rise; 2) changes in air and water temperature; 3) changes in hydrology; 4) ocean acidification; 5) changes in upwelling; 6) changes in waves/wind/storms/flooding; 7) changes in other climate and non-climate factors; and 8) sensitivities to specific disturbance regimes and other significant sensitivities not captured above.

The assessment of adaptive capacity of each habitat type considered five factors: 1) habitat extent, integrity and permeability; 2) habitat heterogeneity; 3) resistance, recovery and refugia; 4) management potential; and 5) other factors. Adaptive capacity can potentially reduce the impact of high exposure and sensitivity.

Table 5. Summary of Habitat Vulnerability to Climate Change

	Vulnerability	
Habitat Name	**Climate Exposure/Sensitivity**	**Adaptive Capacity**
1. Estuarine Open Water	Moderate/High (Confidence Moderate/High)	Moderate (Confidence Moderate)
2. Tidal Flat	Moderate (Confidence Moderate)	Moderate (Confidence Moderate)
3. Tidal Saltmarsh Low	Moderate/High (Confidence Moderate/High)	Moderate (Confidence High)
4. Tidal Saltmarsh High	Moderate/High (Confidence Moderate/High)	Moderate (Confidence High)
5. Tidal Freshwater Wetlands	High (Confidence Moderate/High)	Low/Moderate (Confidence Moderate/High)
6. Nontidal Freshwater Wetlands	Moderate/High (Confidence Moderate/High)	Moderate/High (Confidence High)
7. Fringing Riparian	Moderate (Confidence Moderate/High)	Moderate (Confidence High)

Table 6. Habitat Climate Change Exposure Estimates

Habitat	Coquille Mid SLR (SLAMM) 2030 Dikes Intact	Coquille Mid SLR (SLAMM) 2050 Dikes Intact	Air Temperature	Water Temperature	Precipitation	Hydrology / Flow	Ocean Acidification (Water pH)	Upwelling	Waves/Wind/Storms/ Flooding
	Exposure								
1. Estuarine Open Water	8cm / 3in SLR (eustatic)	21cm / 8in SLR (eustatic)	+1.8°C annual mean air temp +2.3°C in summer (2060)	+0.9°C at top of estuary (2060) +1°C at ocean (2050 A1B)	Overall Annual precipitation unchanged Drier summers Increased winter extreme events	Somewhat lower flows in summer Higher flow in fall Increased winter flood/high flow events possible Salinity changes possible	Nearshore pH may be as low as 7.82 (2050)	Inconclusive	Wave and wind change is inconclusive Increase in SLR+wind+wave driven flooding (100yr floods every 5 years)
2. Tidal Flat				+0.9°C at mouths of three tributaries (2060)					
3. Tidal Saltmarsh Low									
4. Tidal Saltmarsh High									
5. Tidal Freshwater Wetlands									
6. Nontidal Freshwater Wetlands									
7. Riparian									
<10% = less than 10% change		~ = no significant change							

Table 7. Habitat Climate Change Sensitivity Estimates

Habitat (Area)	Coquille Mid SLR (SLAMM) 2030 Dikes Intact (change in habitat area)	Coquille Mid SLR (SLAMM) 2050 Dikes Intact (change in habitat area)	Air Temperature	Water Temperature	Precipitation	Hydrology / Flow	Ocean Acidification (Water pH)	Upwelling	Waves/Wind/Storms/ Flooding
	SENSITIVITY								
1. Estuarine Open Water (1,270 acres)	Minimal Gain	Minimal Gain	Eelgrass wasting disease affected by temp	Water temp is a major factor driving physiology and respiration, transpiration water quality, dissolved oxygen both affected Eelgrass wasting disease affected by temp	(see hydrology/flow)→	Increasing salinity in summer possible Increasing winter freshwater flood events possible- delivering sediment, nutrients, woody debris Eelgrass wasting disease affected by salinity	Early life stages and shell building organisms sensitive to decreasing pH	Tidally delivered nutrient availability may change Anoxic events may be exacerbated	Increased shore erosion, changes in channels Flood driven changes, sediment & debris movement
2. Tidal Flat (279 acres)	No Change	No Change	Increases in air temperature may cause more drying, especially in low tide systems						
3. Tidal Saltmarsh Low (276 acres)	Gain	Gain							
4. Tidal Saltmarsh High (407 acres)	No Change	No Change							
5. Tidal Freshwater Wetlands (685 acres)	No Change	No Change	Increases in air temperature may cause more drying, especially in low tide systems Shrub scrub and forested wetlands are relatively resilient		Drought events		N/A	N/A	
6. Nontidal Freshwater Wetlands (22,714 acres)	Minimal Loss	Minimal Loss			Increasing winter freshwater flood events possible Drought events	N/A			
7. Fringing Riparian (N/A)	N/A	N/A	Shrub scrub and forested wetlands are relatively resilient						

<10% = less than 10% change

Table 8. Expert Panel Summary of Habitat Exposure and Sensitivity to Climate Change

Habitat	Sea Level Rise	Air Temperature	Water Temperature	Precipitation	Hydrology / Flow	Ocean Acidification	Upwelling	Waves/Wind/Storms/ Flooding
	Climate Exposure / Sensitivity							
1. Estuarine Open Water	Low (Confidence Low)	N/A	Moderate/High (Confidence Moderate/High)	N/A	Moderate (Confidence Not Reported)	Moderate/High (Confidence Moderate/High)	Moderate/High (Confidence Moderate/High)	Moderate/High (Confidence Moderate/High)
2. Tidal Flat	Low (Confidence Low)	High (Confidence Moderate)	N/A	N/A	Moderate (Confidence Moderate)	High (Confidence Moderate)	High[1] (Confidence Moderate)	High (Confidence Moderate/High)
3. Tidal Saltmarsh Low	High (Confidence High)	Low (Not reported)	Low (Not reported)	N/A	Moderate/High (Confidence Moderate/High)	Low/Moderate (Confidence Low/Moderate)	Low1 (Not reported)	Moderate (Confidence Low/Moderate)
4. Tidal Saltmarsh High	High (Confidence High)	Low (Not reported)	Low (Not reported)	Moderate (Confidence Low)	High (Confidence High)	Low (Confidence Not Reported)	Low (Confidence Not Reported)	Moderate (Confidence Low)
5. Tidal Freshwater Wetlands	High (Confidence High)	Moderate (Confidence Low)	Low (Not reported)	Low (Not reported)	High (Confidence High)	N/A	N/A	Moderate (Confidence Moderate)
6. Nontidal Freshwater Wetlands	Low/Moderate (Confidence Moderate)	Moderate (Confidence Moderate)	Moderate (Confidence Moderate)	Moderate (Confidence Moderate)	Moderate (Confidence Moderate)	N/A	N/A	Moderate/High (Confidence Moderate)
7. Fringing Riparian	Low (Confidence High)	Moderate/High (Confidence High)	Moderate/High (Confidence Moderate/High)	High (Confidence High)	Moderate (Confidence Moderate)	N/A	N/A	Moderate (Confidence Moderate/High)

Table 9. Expert Panel Summary of Adaptive Capacity of Habitats to Climate Change

Habitat	Habitat Extent, Integrity & Permeability	Habitat Heterogeneity	Resistance, Recovery & Refugia	Management Potential	Other Adaptive Capacity Factors
	Adaptive Capacity				
1. Estuarine Open Water	Low (Confidence High)	Low (Confidence Low/Moderate)	Moderate (Confidence Low)	High (Confidence High)	Low (Confidence Low/Moderate)
2. Tidal Flat	Low/Moderate (Confidence Moderate/High)	Moderate (Confidence Low/Moderate)	Moderate (Confidence Low)	High (Confidence High)	Moderate (Confidence Moderate)
3. Tidal Saltmarsh Low	Low/Moderate (Confidence Moderate/High)	Low (Confidence High)	Moderate (Confidence High)	Moderate/High (Confidence High)	Low/Moderate (Confidence Low)
4. Tidal Saltmarsh High	Low/Moderate (Confidence High)	Moderate (Confidence High)	Moderate (Confidence Moderate)	Moderate/High (Confidence High)	Low/Moderate (Confidence Low)
5. Tidal Freshwater Wetlands	Low (Confidence Moderate/High)	Low/Moderate (Confidence High)	Low (Confidence Moderate)	Moderate (Confidence High)	N/A
6. Nontidal Freshwater Wetlands	Moderate (Confidence High)	Moderate (Confidence Moderate/High)	High (Confidence Moderate/High)	Moderate/High (Confidence High)	N/A
7. Fringing Riparian	Moderate (Confidence High)	Moderate/High (Confidence High)	Moderate (Confidence High)	Low/Moderate (Confidence High)	N/A

Below are the narratives generated by the expert panel, separated by habitat type, that expand upon the above summary tables.

A. Estuary Open Water

Underlying benthic areas, including eelgrass beds, are included in this habitat.

Overall vulnerability for estuary open water

- Climate Effects: Moderate/High (Confidence Moderate/High)
- Adaptive capacity: Moderate (Confidence Moderate)

Exposure and Sensitivity

This habitat is exposed to changes to sea level, water temperatures, hydrology, ocean acidification, and upwelling. Waves/wind/storms affect this habitat to a lesser degree.

1. Sea Level Rise

- Exposure: Low (Confidence Moderate)
- Sensitivity: Low (Confidence Low due to uncertainty of sediment transport and accretion rates)

Approximately 3 inches (8 cm) of sea level rise by 2030 and 8 inches (21 cm) by 2050 is likely to occur in the Coquille River estuary. The SLAMM simulation estimated minimal gain in open water habitat due to sea level rise throughout this period (Table 6). Sea level rise will likely have little effect on species that move freely within the open water habitat, but may affect sessile species of the underlying substrates. Eelgrass and other algae and aquatic plant species depend on sunlight which may decrease with increasing depths or with water clarity.

2. Water Temperature

- Exposure: High (Confidence High)
- Sensitivity: Moderate/High (Confidence Moderate/High)

Water temperatures will have a greater effect than air temperatures on this habitat. Water temperatures in the upper estuary are predicted to be 0.9°C (1.6°F) warmer by 2060 and, and 1°C (1.8°F) warmer at the ocean end of the estuary by 2050. These changes in water temperature have implications for organism physiology (e.g. respiration, development), physiochemical factors (e.g. water quality, dissolved oxygen) and the success of pathogens and invasive species. Eelgrass wasting disease for example is mediated by temperature (Short et al. 1987). The expert panel noted that stream temperatures above the estuary are already increasing and water quality is already affected by *E. coli* and coliform bacteria outbreaks.

3. Hydrology & Flow

- Exposure: Low/Moderate (Confidence Moderate)
- Sensitivity: Moderate (Confidence Not reported)

River and stream flows into the estuary are predicted to be somewhat lower in the summer and higher in the fall than in the past, with potential for increased winter floods and high flow events. Changes in hydrology may drive changes in salinity, such as higher salinity in the summer and lower salinity in the winter. In addition to lowering salinity, winter freshwater pulses from flooding may also deliver sediments, nutrients and woody debris to the open water system. Again, eelgrass wasting disease is a concern in this part of the estuary and it is also affected by salinity (Short et al. 1987).

4. Ocean Acidification

- Exposure: High (Confidence Low)

- Sensitivity: Moderate/High (Confidence Moderate/High)

Nearshore ocean water may have a pH as low as 7.82 by 2050, and it is likely that this water will influence the pH of estuary water through tidal influx. This has implications for early life stages of many organisms, as well as all life stages of shell building organisms, since pH influences the availability of dissolved shell-building minerals. However, increased aqueous CO_2 might lead to higher productivity in aquatic plants such as eelgrass (Palacios & Zimmerman 2007).

5. Upwelling

- Exposure: High (Confidence Low)
- Sensitivity: Moderate/High (Confidence Moderate/High)

Projections for changes in coastal upwelling are inconclusive for the region but changes could alter temperature, pH, nutrient availability, and dissolved oxygen in nearshore and estuary water. Upwelling brings nutrient rich water to the coastal surface waters, but can also bring water with low dissolved oxygen to coastal ecosystems (Oregon Climate Change Research Institute 2010).

6. Waves/Wind/Storms/Flooding

- Exposure: Low/Moderate (Confidence Moderate)
- Sensitivity: Moderate/High (Confidence Moderate/High)

Modeling suggests sea level rise can be magnified by storm surge (Table 5). The expert panel considered the estuary open water habitat moderately/highly sensitive to wind, waves, and storm surge flooding. For the open water portions of the estuary this can result in increased shore erosion, changes in channels, plus mobilization of sediment and movement of debris.

7. Other Climate Driven Sensitivity Factors

- Sensitivity: Moderate/High (Confidence Moderate/High)

Sensitivity and exposure factors identified by the expert panel and not discussed elsewhere include climate driven changes in sediment dynamics (transport, distribution, accretion) and concerns about changes in the patterns of invasive and opportunistic species. Little is known or available in the literature about how climate change will affect these factors and their effect on estuarine habitats, although there is considerable evidence that invasive species alone can dramatically change estuary habitats or an entire estuarine system.

8. Other Non-climate Sensitivity Factors

- Current effects of these stressors: Moderate/High (Exposure was considered Low/Moderate) (Confidence High)
- Degree stressors increase sensitivity to climate change: High

Non-climate related sensitivity factors identified by the expert panel include industrial, municipal, agricultural, and other activities on shorelands or in the watershed that may affect conditions in the estuary enough to disturb or destroy habitats. These factors can indirectly increase a habitat's sensitivity to climate change stressors.

Adaptive Capacity

1. Habitat Extent, Integrity and Permeability

- Adaptive capacity: Low (Confidence High)

The estuary open water habitat overall was judged by the expert panel as constricted by existing roads, culverts, dikes and levees. However, it was not considered fragmented. The ocean side was seen as less restricted.

2. Habitat Heterogeneity

- Adaptive capacity: Low (Confidence Low/Moderate)

The physical and biological heterogeneity of estuary open water habitat was considered low by the expert panel. The habitat's moderate size, historic disturbance, and general lack of information on species composition and abundance contributed to a lack of understanding of the habitat's adaptive capacity.

3. Resistance, Recovery and Refugia

- Adaptive capacity: Moderate (Confidence Low, lack of historic data)

The ability of the habitat to resist or recover from stresses was influenced by the expert panel's belief that there may not be much in the way of climate refugia within the habitat, and by historic stress due to water quality issues and habitat loss. There was a lack of confidence on this issue however owing to a lack of historic data.

4. Management Potential

- Adaptive capacity: High (Confidence High (Low for Value))

The effect of the management potential factor for estuary open water habitats was considered high by the expert panel. The local community appears to value this habitat highly and there are meaningful management planning processes and collaborations in place. According to the expert panel, the high adaptive capacity stems from the management potential represented by the ability to update local estuary plans, efforts by the Oregon Department of Transportation to identify vulnerable infrastructure, and other infrastructure planning efforts that include estuary restoration projects. The Bandon Marsh National Wildlife Refuge management process is also considering climate change responses within the estuary (U.S. Fish & Wildlife Service 2013). The strengthening collaboration between the Refuge, the Coquille Watershed Association, ODOT, the Coquille Tribe, the Oregon Department of Fish and Wildlife, The Nature Conservancy, and other agencies and organizations also supports a higher level of adaptive capacity.

5. Other Adaptive Capacity Factors

- Adaptive capacity: Low (Confidence Low/Moderate)

The expert panel thought the growing engagement by the local community may help push planning toward adapting for climate change. However, the range of adaptation options for estuary open water habitat may be constrained by the limitations discussed above.

B. Tidal Flat

<u>Overall vulnerability for tidal flat</u>

- Climate effects: Moderate (Confidence Moderate)
- Adaptive capacity: Moderate (Confidence Moderate)

Exposure and Sensitivity

Exposure of tidal flats to climate change is primarily through changes in water depth due to sea level; air temperature; hydrology; and waves/wind/storms. This habitat may be impacted by ocean acidification.

It is uncertain how changes in upwelling would be manifested. Each of these conditions can affect the habitat but that effect depends on the habitat's sensitivity.

1. Sea Level Rise

- Exposure: Low (Confidence Moderate)
- Sensitivity: Low (Confidence Low)

As stated previously, approximately 3 inches (8 cm) of sea level rise is projected by 2030 and 8 inches (21 cm) is projected by 2050 in the Coquille River estuary (Table 5). Model runs using these projections in SLAMM resulted in no change in future tidal flat habitat area within the Coquille River through 2050 (Table 6).

2. Air and Water Temperature

- Exposure: water temperature Low (Confidence High); air temperature High (Confidence High)
- Sensitivity: High (Confidence Moderate)

Air temperature changes may have a greater effect than water temperature on this habitat as intertidal species can generally withstand wide thermal variation. Temperature changes will be most pronounced during the low tides at peak summer temperatures. Water temperature could influence physiology.

3. Hydrology and Precipitation

- Exposure: Moderate (Confidence Moderate)
- Sensitivity: Moderate (Confidence Moderate)

Hydrology and flow changes include precipitation changes for the tidal flat habitat. River and stream flows into the estuary are projected to be slightly lower in the summer and slightly higher in the fall than in the past, with increased winter flood/high flow events. These alterations may affect salinity, such as higher salinity in the summer and lower salinity in the winter. Any increase in the incidence of flood events will increase erosion and sediment delivery to the estuary. Increased sediment loading could help intertidal wetlands accrete material over time, which could in turn reduce spatial migration of some wetlands.

4. Ocean Acidification

- Exposure: High (Confidence Low)
- Sensitivity: High (Confidence Moderate)

Nearshore ocean water may have a pH as low as 7.82 by 2050 (Table 5) and it is likely that this water will affect the pH of estuary water through tidal influx. This has implications for early life stages of many organisms, as well as all life stages of shell building organisms since shell creation is affected by the pH mediated availability of dissolved shell-building minerals. Species that utilize tidal flat habitats are very likely to be sensitive to ocean acidification, though the expert panel did identify this sensitivity.

5. Upwelling

- Exposure: High (Confidence Low)
- Sensitivity: High (Confidence High, supported by literature)

Upwelling was not identified by the expert panel as a sensitivity factor for tidal flats, though exposure to changes in upwelling were considered potentially high. Upwelling is very likely to be a factor in the condition of tidally delivered ocean water and therefore may affect tidal flat habitat lower in the estuary (Roegner 2011).

6. Waves/Wind/Storms/Flooding

- Exposure: High (Confidence Moderate)
- Sensitivity: High (Confidence Moderate/High)

Research is still continuing regarding the potential for changes in future average wind and wave heights off Oregon's coast. However, the regional projections for sea level rise, wind and waves all combine to drive ocean flooding, perhaps increasing the 100 year flood frequency to every five years (Table 5). For the tidal flats portions of the estuary this will result in increased shore erosion, changes in channels, and sedimentation and debris movement from storm waves and flooding.

7. Other Non-climate Sensitivity Factors

- Current effects of these stressors: Moderate (Confidence Moderate)
- Degree stressors increase sensitivity to climate change: Moderate (based on cumulative and synergistic effects) to High (based on maladaptation potential) (Confidence Low)

Non-climate stressors identified by the expert panel that will interact with climate change include dredging activities, habitat loss, development (industrial, municipal and agricultural) and invasive species. Dredging activity concerns include historic dredging activity and spoils disposal locations. Formerly the majority of disposal took place in the bay, but it has now generally moved offshore. Habitat loss has resulted in "habitat squeeze" and overall fragmentation. It has also caused a loss of the filtration function of the estuary. Invasive species of concern in the tidal flat include *Spartina*, crabs and snails. There is also concern about maladaptive responses close to roadways and town infrastructure related to protective actions.

Adaptive Capacity

1. Habitat extent, integrity and permeability

- Adaptive capacity: Low/Moderate (Low for extent and integrity, Moderate for permeability) (Confidence Moderate/High)

Tidal flat habitat is not very widespread in the Coquille River estuary. Roads and other infrastructure fragment the tidal flat that does exist. These obstructions, including Highway 101, in addition to geological features and the estuaries constrained channel act as barriers to habitat expansion and migration in response to climate change.

2. Habitat heterogeneity

- Adaptive capacity: Moderate (Confidence Low/Moderate)

Overall tidal flat has low diversity of component species, functional groups and physical/topographic characteristics. However the expert panel rated it as moderate.

3. Resistance, recovery and refugia

- Adaptive capacity: Moderate (Confidence Low)

The ability of tidal flat to resist and recover from the impact of stressors, as well as offer refugia is seen as limited due to modest area and limited local refugia. It was also deemed to be dependent on accretion rates, pH and pCO_2. Geologic features and constrained channels (dikes/levees) further limit the tidal flats to respond to change.

4. Management potential

- Adaptive capacity: High (Confidence High)

Often management opportunities, approaches and agencies can affect the adaptive capacity of a system. In the case of tidal flats the expert panel identified a potential for enhanced adaptive capacity due to valued attributes (accessible and native wildlife viewing), coupled with governance by the county, state parks and the USFWS. Additionally, restoration efforts are already underway, accretion rate data are being gathered, and little future development is expected in the region. Further opportunities for beneficial management were seen in the planned retreat work with ODOT, the Port, the Town of Bandon and private landowners.

5. Other factors affecting adaptive capacity

- Adaptive capacity: Moderate (Confidence Moderate)

The expert panel highlighted that transportation infrastructure and planning efforts are leading to increased local community engagement which has the potential to lead to increased adaptive capacity. Given that there is little opportunity to increase the perimeter fringe habitat due to geomorphology and elevational constraints these society responses appeared most useful. Additionally the current low development pressure provides an opportunity to better set the stage for the future.

C. Low Tidal Salt Marsh

<u>Overall vulnerability for low tidal salt marsh</u>

- Climate Effects: Moderate/High (Confidence Moderate/High)
- Adaptive capacity: Moderate (Confidence High)

Exposure and Sensitivity

The climate change exposure of this habitat is primarily through sea level rise, water temperature, air temperature, hydrology, ocean acidification, upwelling, and waves/wind/storms.

1. Sea Level Rise

- Exposure: High (Confidence Moderate)
- Sensitivity: High (Confidence High)

Approximately 3 inches (8 cm) of sea level rise by 2030 and 8 inches (21 cm) by 2050 is likely to occur in the Coquille River estuary (Table 5). The SLAMM simulated future low tidal saltmarsh habitat area is estimated to increase moderately by 2030 and continue to remain at that extent through 2050 (Table 6). Species composition of this habitat varies with tidal elevation, sediment types, and salinity regime to some degree. The expert panel considered inundation regime to be a key driver in the location and composition of this habitat within the estuary. While this habitat is predicted to expand with sea level rise by SLAMM simulation, this also suggests potential migration of existing habitat and conversion of adjacent habitat such as loss of high marsh.

2. Air Temperature

- Exposure: Low (Confidence High)
- Sensitivity: Low (Confidence Not reported)

The expert panel did not consider air temperature a significant driver in the habitat's vulnerability. Low tidal saltmarsh species are adapted to regular inundation and drying due to tidal flux. The expert panel identified pickleweed (*Sarcocornia perennis*) and sandspurry (*Spergularia* spp.) as important component species of this habitat that were sensitive to exposure/drying.

3. Water Temperature

Warmer water temperatures may not significantly affect this habitat due to its normal dynamic inundation cycle. The expert panel did not consider it significant.

4. Hydrology and Flow

- Exposure: Low/Moderate (Confidence Moderate)
- Sensitivity: Moderate/High (Confidence Moderate/High)

Hydrology and flow changes include precipitation changes. River and stream flows into the estuary are predicted to be lower in the summer and higher in the fall than in the past, with a potential increase in winter flood/high flow events (Table 5). These changes may affect salinity, such as higher salinity in the summer and lower salinity in the winter. Winter freshwater pulses from flooding may also deliver sediments to the low marsh. Component species were identified as species that were sensitive to salinity shifts. However, the expert panel thought that low tidal saltmarsh is fairly resistant to occasional flooding and storms.

5. Ocean Acidification

- Exposure: Low (Confidence Low)
- Sensitivity: Low/Moderate (Confidence Low/Moderate)

Nearshore ocean water may have a pH as low as 7.82 by 2050 and it is likely that this water will influence the pH of estuary water. This has implications for early life stages of many organisms, as well as all life stages of shell building organisms since shell creation is mediated by the pH-influenced availability of dissolved shell-building minerals. Low tidal saltmarsh habitat is considered sensitive to ocean acidification, but its specific effects in the Coquille River estuary were unknown.

6. Upwelling

- Exposure: Low (Confidence Low)
- Sensitivity: Moderate (Confidence Moderate supported by literature)

Upwelling is not identified as a sensitivity factor for low tidal saltmarsh by the expert panel. Upwelling is very likely to be a factor in the condition of tidally-delivered ocean water and therefore may affect low saltmarsh habitat closer to the mouth of the estuary (Roegner 2011).

7. Waves/Wind/Storms/Flooding

- Exposure: High (Confidence High)
- Sensitivity: Moderate (Confidence Low/Moderate)

Research is still continuing regarding the potential for changes in future average wind intensity and wave height along Oregon's coast. Modeling suggests sea level rise can be magnified by storm surge. The expert panel considered the low saltmarsh habitats to be moderately sensitive to wind, waves, and storm flooding. For the tidal saltmarsh portions of the estuary this can result in increased erosion, changes in channels, plus mobilization of sediment and movement of debris.

8. Other Climate Driven Sensitivity Factors

- Sensitivity: Moderate (Confidence High)

Factors identified by the expert panel and not discussed elsewhere include climate driven changes in sediment dynamics (transport, distribution, accretion) and concerns about changes in the patterns of invasive and opportunistic species.

9. Other Non-climate Sensitivity Factors

- Current effects of these stressors: Low (Confidence Moderate)
- Degree stressors increase sensitivity to climate change: Uncertain (Confidence Not reported)

Non-climate related sensitivity factors identified by the expert panel include development and construction activities and habitat loss. However, the effects of these factors were considered fairly well regulated.

Adaptive Capacity

1. Habitat Extent, Integrity and Permeability

- Adaptive capacity: Low/Moderate (Permeability considered High) (Confidence Moderate/High)

Currently, there are two areas of low tidal saltmarsh habitat within the lower Coquille River estuary and the fragmentation of these areas was thought of as low to moderate. The expert panel did consider the distribution and extent of this habitat as low, but the current landscape may allow this habitat to shift spatially to some degree.

2. Habitat Heterogeneity

- Adaptive capacity: Low (Confidence High)

The physical and biological heterogeneity within the low salt marsh habitat was considered low. According to the expert panel, low salt marsh plant communities are naturally low in biological diversity and geomorphological diversity.

3. Resistance, Recovery and Refugia

- Adaptive capacity: Moderate (Confidence High)

The ability of the habitat to resist or recover from stresses was considered to be moderate. While refugia were not identified within the existing habitat extent, the expert panel thought that this habitat could migrate up slope if needed.

4. Management Potential

- Adaptive capacity: Moderate/High (Confidence High)

The management potential for the low tidal saltmarsh habitat is moderate/high. However, the expert panel stated there was considerable conflict about the value and use of this habitat. The thought was that currently the community was mixed about the value it placed on this habitat. In the habitat's favor, the expert panel was optimistic that there was good potential for alleviating climate impacts through adaptive resource management.

5. Other Adaptive Capacity Factors

- Adaptive capacity: Low/Moderate (Confidence Low)

The expert panel thought that increasing atmospheric carbon dioxide may have a positive effect on plant physiological processes, but also thought water pH change is currently an unknown but potentially negative effect.

D. High Tidal Salt marsh

<u>Overall vulnerability for high salt marsh</u>

- Climate Effects: Moderate/High (Confidence Moderate/High)
- Adaptive capacity: Moderate (Confidence High)

Exposure and Sensitivity

The exposure of this habitat to climate change is primarily through sea level rise, water temperature, air temperature, hydrology, ocean acidification, upwelling, and waves/wind/storms.

1. Sea Level Rise

- Exposure: High (Confidence Moderate)
- Sensitivity: High (Confidence High)

Approximately 3 inches (8 cm) of sea level rise by 2030 and 8 inches (21 cm) by 2050 is likely to occur in the Coquille River estuary. However, no change in high tidal saltmarsh extent was predicted by the SLAMM simulation in this time period.

2. Air Temperature

- Exposure: Low (Confidence High)
- Sensitivity: Low (Confidence Not reported)

Air temperature is not a significant driver in the habitat's vulnerability. High tidal saltmarsh species are were considered adapted to regular drying due to tidal flux.

3. Water Temperature

- Exposure: Low (Confidence High)
- Sensitivity: Low (Confidence Not reported)

Water temperature change is not a concern.

4. Precipitation

- Exposure: Low (Confidence High)
- Sensitivity: Moderate (Confidence Low)

While overall annual precipitation is expected to remain unchanged in the Coquille River estuary, there is a trend toward drier summers, wetter falls, and increased winter extreme events (Table 5). With this may come more frequent summer droughts and increased winter inundation.

5. Hydrology and Flow

- Exposure: Moderate (Confidence Moderate)
- Exposure and Sensitivity: High (Confidence High)

River and stream flows into the estuary are projected to be slightly lower in the summer and slightly higher in the fall than in the past, with some chance of increased winter flood/high flow events. Hydrologic changes can result in changes in salinity. Periodic inundation from flooding may also deliver sediments to the tidal salt marshes. While the expert panel considered high tidal saltmarsh very sensitive to changes in hydrology, it is not clear that hydrologic changes projected for about mid-century will be significant enough to result in changes to high salt marsh habitats. Increased flooding due to sea-level rise may increase soil salinities and alter plant composition or reduce plant productivity (Janousek and Mayo 2013).

6. Ocean Acidification

- Exposure: Low (Confidence Moderate)
- Sensitivity: Low (Confidence Not reported)

The expert panel did not identify ocean acidification as a climate change sensitivity concern.

7. Upwelling

- Exposure: Low (Confidence Moderate)
- Sensitivity: Low (Confidence: Not reported by expert panel)

Upwelling was not identified by the expert panel as an important exposure or sensitivity factor for high tidal saltmarsh.

8. Waves/Wind/Storms/Flooding

- Exposure: Moderate (Confidence Moderate)
- Sensitivity: Moderate (Confidence: Low)

The expert panel considered the high tidal saltmarsh habitat moderately sensitive to periodic inundation due to storms and flooding. For the Tidal Saltmarsh portions of the estuary storms and flooding may cause increased erosion, changes in channels, plus mobilization of sediment and movement of debris.

9. Other Climate Driven Sensitivity Factors

- Sensitivity: High (Confidence: High)

Several component plant species for the high tidal saltmarsh habitat were thought of by the expert panel as highly sensitive to climate driven changes. These include Lyngbe's sedge (*Carex lyngbyei*) and marsh wren – though other animal species were not systematically considered.

10. Other Non-climate Sensitivity Factors

- Current effects of these stressors: Moderate (Confidence: High)
- Degree stressors increase sensitivity to climate change: Moderate (Confidence: Moderate)

Non-climate related sensitivity factors identified by the expert panel include development and construction activities, and industrial, municipal and agricultural activities. If substantial, these factors can indirectly increase the habitat's sensitivity to climate change stressors. However, high salt marshes and other particularly sensitive habitats in the Coquille estuary are well protected by state and local laws protecting estuarine habitats from development.

Adaptive Capacity

1. Habitat Extent, Integrity and Permeability

- Adaptive capacity: Low/Moderate (Distribution considered Moderate) (Confidence: High)

The expert panel considered the distribution and extent of this habitat as moderate within the Coquille River estuary but with high fragmentation. The permeability of the landscape to this habitat was considered low. Roads, agriculture, industrial or urban development, dikes/levees, and other geologic features were identified as potential barriers to this shift.

2. Habitat Heterogeneity

- Adaptive capacity: Moderate (Confidence: High)

The physical and biological heterogeneity within the high tidal saltmarsh habitat was considered moderate by the expert panel. Plant diversity can be high in Oregon tidal wetlands (Janousek & Folger 2013).

3. Resistance, Recovery and Refugia

- Adaptive capacity: Moderate (Confidence: Moderate)

The ability of this habitat to resist or recover from stresses was considered by the expert panel to be moderate. The expert panel thought there was low opportunity for refugia within this habitat due to artificial barriers.

4. Management Potential

- Adaptive capacity: Moderate/High (Confidence: High)

Currently, the expert panel thought the value the local community placed on the high tidal saltmarsh habitat within the Estuary was mixed. Current land use conflicts center on proposed land use changes. Despite this, the adaptive capacity due to management potential for high tidal saltmarsh was considered potentially high by the expert panel.

5. Other Adaptive Capacity Factors

- Adaptive capacity: Low/Moderate (Confidence: Low)

Similar to low tidal saltmarsh, the expert panel thought that increasing atmospheric carbon dioxide may have a positive effect on plant physiological processes, though will affect different types of plant species differently, but also thought water pH change is an unknown but potentially negative effect.

E. Tidal Freshwater Wetland

<u>Overall vulnerability for tidal freshwater wetland</u>

- Climate Exposure/Sensitivity: High (Confidence Moderate/High)
- Adaptive capacity: Low/Moderate (Confidence Moderate/High)

Exposure and Sensitivity

Exposure to climate change of this habitat is through changes in sea level, air and water temperature, precipitation, hydrology, and waves/wind/storms. This habitat was not assessed for effects related to ocean acidification or upwelling as these were not identified as significant sensitivities by the expert panel.

1. Sea Level Rise

- Exposure: High (Confidence Moderate)
- Sensitivity: High (Confidence: High)

Approximately 3 inches (8cm) of sea level rise is projected by 2030 and 8 inches (21 cm) is projected by 2050 in the Coquille River estuary. The SLAMM simulation indicated no change in the area of tidal freshwater wetland habitat (Table 6). The expert panel pointed out that the majority of historic tidal freshwater wetland is currently behind dikes. However, the remaining un-diked and unaltered tidal freshwater wetland were considered here. The species that utilize this habitat will have a wide range of sensitivities. Beaver have low sensitivity owing to their ability to relocate, while plant species will likely have higher sensitivities to increasing salinity that may accompany sea level rise.

2. Air Temperature

- Exposure: Moderate (Confidence Moderate)
- Sensitivity: Moderate (Confidence: Low)

Annual mean air temperature is projected to rise by 1.8°C (3.2°F) while mean summer air temperature is projected to rise by 2.3°C (4.1°F) in the region by 2060. Sensitivity to rising air temperature was identified by the expert panel as significant for this habitat. This increase in air temperature can affect evaporation/evapotranspiration rates, and physiology.

3. Water Temperature

- Exposure: Low (Confidence Moderate)
- Sensitivity: Low (Confidence: Not reported)

Water temperature was not identified as a sensitivity factor for tidal freshwater wetlands within the Coquille River estuary.

4. Precipitation

- Exposure: Moderate (Confidence Moderate)
- Sensitivity: High (For drought) (Confidence: High)

While the expert panel did not consider this habitat sensitive to changes in precipitation, it did indicate a sensitivity to drought. Less summer precipitation could result in drought conditions. Changes in precipitation can result in increased success and access by invasive or opportunistic species.

5. Hydrology/Flow

- Exposure: Moderate/High (Confidence Moderate)
- Sensitivity: High (Confidence: High)

The projected climate effects on hydrology and flow may result in lower summer flows, slightly higher fall flows and increasing extreme winter flow events. These changes may change salinity within the estuary. Flooding may deliver sediments and debris to tidal freshwater wetland habitats. The expert panel indicated that the majority of tidal freshwater wetlands within the Coquille River estuary were behind dikes, resulting in the habitat being more controlled with varying degrees of sensitivity to changes in hydrology. Overall, the expert panel considered tidal freshwater wetlands highly sensitive to changes in hydrology.

6. Waves/ Wind/Storms/Flooding

- Sensitivity: Moderate/High (Confidence Moderate)
- Exposure: Low/Moderate (Confidence Moderate)

The expert panel considered tidal freshwater wetlands sensitive to storms and flooding. Storms may cause increased erosion, changes in channels, plus mobilization of sediment and movement of debris.

7. Other Climate Driven Sensitivity Factors

- Sensitivity: Moderate (Confidence Low)

The expert panel did consider the tidal freshwater wetland habitat sensitive to changes in fire regimes and patterns of invasive species.

8. Other Non-climate Sensitivity Factors

- Current effects of these stressors: High (Confidence High)
- Degree stressors increase sensitivity to climate change: High (Confidence Low)

Non-climate factors that affect sensitivity in tidal freshwater wetlands include those identified in other Coquille habitats—development and construction activities, industrial/municipal/agricultural activities, habitat loss due to other activities, and invasive species. But as noted elsewhere, most of these activities do not currently occur in Oregon's tidal freshwater wetlands. However, past practices have significantly reduced the historic extent of wetlands.

Adaptive Capacity

1. Habitat extent, integrity and permeability

- Adaptive capacity: Low (Confidence Moderate/High)

Tidal freshwater wetlands are not widespread in the Coquille River estuary; those that do occur are highly fragmented. These wetlands are often bordered by roads, agriculture, industrial and urban development, dikes, culverts/tide gates, and geological features, which reduce their ability to migrate.

2. Habitat heterogeneity

- Adaptive capacity: Low/Moderate (Confidence High)

There is little variability in the physical features of this habitat type as it exists in a "narrow" geomorphological area. It also has a smaller range of species than other habitat in the estuary.

3. Resistance, Recovery and Refugia

- Adaptive capacity: Low (Confidence Moderate)

The expert panel believed that tidal freshwater wetland habitat had a good deal of potential but it was limited by lack of economic incentives to protect this swath of habitat and allow processes to demonstrate their ability to respond to change.

4. Management potential

- Adaptive capacity: Moderate (Confidence High)

The expert panel believed that this habitat type was historically undervalued and that some of the controversial aspects of wetland management in the region would affect success, especially given the fragmented nature of this habitat type. However, the expert panel indicated that there is now a well laid out framework for decision making.

5. Other factors affecting adaptive capacity

- None were identified by the expert panel.

F. Nontidal Freshwater Wetland

<u>Overall vulnerability for nontidal freshwater wetland</u>

- Climate Exposure/Sensitivity: Moderate/High (Confidence Moderate/High)
- Adaptive capacity: Moderate/High (Confidence High)

Exposure and Sensitivity

Exposure to climate change of this habitat is primarily through changes in sea level, air and water temperature, precipitation, hydrology, and waves/wind/storms. This habitat is not expected to be impacted by ocean acidification or upwelling.

1. Sea Level Rise

- Exposure: Low/Moderate (Confidence Moderate)
- Sensitivity: Low/Moderate (Confidence Moderate/High)

Approximately 3 inches (8 cm) of sea level rise by 2030 and 8 inches (21 cm) by 2050 is likely to occur in the Coquille River estuary. The SLAMM simulated future change in this habitat area within the Coquille River estuary as driven by sea level rise is estimated as minimal loss (Table 6). Although nontidal freshwater wetlands are often above the elevation where sea level rise will have an impact, higher tides could impact this habitat as some portions are only slightly above tidal influence or are protected by dikes that could be overtopped by rising seas.

2. Air Temperature

- Exposure: Low/Moderate (Confidence Moderate/High)
- Sensitivity: Moderate (Confidence Moderate)

Annual mean air temperature is projected to rise by 3.2°F (1.8°C) in the region by 2060, while mean summer air temperature is projected to rise by 4.1°F (2.3°C). This increase in air temperature will affect water temperature, as well as evaporation/evapotranspiration rates. The expert panel considered the plants, vertebrates and invertebrates of nontidal freshwater wetlands sensitive to rising air temperature.

3. Water Temperature

- Exposure: Moderate/High (Confidence Moderate/High)
- Sensitivity: Moderate (Confidence Moderate)

Water temperatures at the top of the estuary are predicted to be 1.6 °F (0.9°C) warmer by 2060 and, and 1.8°F (1°C) warmer at the ocean end of the estuary by 2050. Water may warm even more in isolated wetlands, especially as volume diminishes. Reduced volume not only reduces available habitat but it could also limit connectivity. Warmer water can affect the physiology of aquatic species. Overall it is expected that shrub scrub and forested wetlands will be relatively resilient as compared to other nontidal freshwater wetlands as they may have some buffer from warming.

4. Precipitation

- Exposure: Moderate/High (Confidence Moderate/High)
- Sensitivity: Moderate (Confidence Moderate)

While overall annual precipitation is expected to remain unchanged in the Coquille River estuary, there is a trend toward drier summers and increased winter extreme events. With this comes more summer drought and increased winter freshwater flooding. These two extremes (drought and flood) will affect the extent of nontidal freshwater wetlands. The expert panel concluded that plant and animal species would be sensitive to this change. For example, drought events can alter the community of organisms (plant and animal) that find a given wetland to be suitable habitat. Slough sedge and rush for example might be replaced and a variety of other species, including the accompanying community of macro invertebrates, would also be affected by their loss. In addition to reducing seasonal habitat availability, drought eliminates connectivity as wetlands are no longer contiguous. Flood events can restore connectivity but can also allow for introduction of new threats such as pollutants and invasive species. Extreme floods in nontidal wetlands would also allow for saltwater intrusion and reduced temperature, both of which also affect habitat suitability for aquatic species.

5. Hydrology/Flow

- Exposure: Low/Moderate (Confidence Moderate)
- Sensitivity: Moderate (Confidence Moderate/High)

Changes in precipitation will lead to changes in hydrology in nontidal freshwater wetlands during summer drought and winter flooding. This in turn can affect the species that can live in this habitat, as they will need to be better adapted to greater unpredictability in terms of water volume, location and temperature. This altered hydrology may also be more conducive to invasive species.

6. Waves/Wind/Storms/Flooding

- Exposure: Moderate/High (Confidence Moderate)
- Sensitivity: Moderate/High (Confidence: Moderate)

While waves only affect nontidal freshwater wetlands when they overtop dikes and banks to inundate these systems, more intense storms and flooding will more frequently affect wetlands. The expert panel indicated that altered flooding regimes would alter patterns of hydrology within nontidal freshwater wetlands. On the positive side, storms could increase delivery of woody debris, which can benefit this habitat by supporting revegetation, macro invertebrates, sediment transport and creation of permanent habitat. On the negative side, flooding disturbance can support introduction of invasive species.

7. Other Non-climate Sensitivity Factors

- Current effects of these stressors: Moderate (Confidence High)
- Degree stressors increase sensitivity to climate change: High (Confidence High)

The expert panel identified habitat loss, industrial/municipal/agricultural activities and invasive species, as well as energy exploration and extraction as other non-climate factors affecting nontidal freshwater wetlands in the Coquille River estuary. Activities to fill these wetlands has resulted in extensive loss of this habitat type. In addition to this direct loss, additional activities have been undertaken to dike these wetlands to limit their flooding potential. Grazing activities in these wetlands has damaged the habitat as well as introduced coliform bacteria and nutrient loading. Farming activities have changed species composition and introduced chemicals into the wetlands. Invasive species, including Reed canary grass and Eurasian milfoil compete with native plants and reduce their availability for the organisms that depend upon them.

Adaptive Capacity

1. Habitat extent, integrity and permeability

- Adaptive capacity: Moderate (Confidence High)

The expert panel indicated that nontidal Freshwater Wetland is limited in range compared to historic extent, and is governed by seasonal variability in that high water levels in winter result in high connectivity, while lower water in the summer results in greater fragmentation. This natural cycle is exacerbated by a high degree of degradation due to diking, partial draining, and removal of hardwood and coniferous forests. Seasonal water level fluctuation means that summers have lower permeability than winters, but land management (roads, agriculture, culverts, dikes) often hinders permeability even during winter months compared to historic conditions.

2. Habitat heterogeneity

- Adaptive capacity: Moderate (Confidence Moderate/High)

This habitat has low heterogeneity when compared to other wetland types in the Coquille Estuary according to the expert panel. Amphibian and fish diversity within the habitat have been assessed for the system, and fish diversity was deemed low by the expert panel.

3. Resistance, Recovery and Refugia

- Adaptive capacity: High (Confidence Moderate/High)

The ability of nontidal freshwater wetlands to resist and recover from the impact of stressors, as well as offer refugia was not easily evaluated by the expert panel. While they thought the adaptive capacity for this factor was high, the only disturbance they considered this for was sea level rise. Resistance, recovery and refugia should be reconsidered in terms of drought and flooding, as well as altered thermal regime. The panel believes there are nontidal freshwater wetland areas were sea level rise driven high tides were not likely to reach.

4. Management potential

- Adaptive capacity: Moderate/High (Confidence High)

The expert panel indicated the community varied widely in how it valued this habitat. However, given that there is a good deal of effort to restore freshwater wetlands it may be assumed that value is fairly high to at least the management sector. There are existing rules that now protect these wetlands from further loss (draining and fill), although they are occasionally violated. The restoration efforts themselves often change nontidal freshwater wetlands to Tidal Wetlands.

5. Other factors affecting adaptive capacity

- No other factors were identified by the expert panel for nontidal freshwater wetlands.

G. Fringing Riparian

<u>Overall Vulnerability for Fringing Riparian habitat</u>

- Climate Exposure/Sensitivity: Moderate (Confidence Moderate/High)
- Adaptive capacity: Moderate (Confidence High)

Exposure and Sensitivity

Exposure to climate change of this habitat is primarily through changes in sea level, water temperature, air temperature, precipitation, hydrology, and waves/wind/storms, and indirectly to changes in upwelling driven fog. This habitat is not expected to be directly impacted by ocean acidification.

1. Sea Level Rise

- Exposure: Low (Confidence not reported)
- Sensitivity: Low (Confidence High)

Approximately 3 inches (8 cm) of sea level rise by 2030 and 8 inches (21 cm) by 2050 is likely to occur in the Coquille River estuary. The SLAMM simulated future change in this habitat area within the Coquille River estuary is not available as there currently are no habitat area data in the National Wetlands Inventory database for the region. Fringing riparian habitat above wetlands not protected by dikes or tide gates will be subject to some level of sea level rise driven inundation and resulting habitat change in. However, the expert panel considered exposure of fringing riparian habitat to sea level rise low enough to not be relevant and its sensitivity to sea level rise as low.

2. Air Temperature

- Exposure: Moderate (Confidence High)
- Sensitivity: High (Confidence High)

Annual mean air temperature is projected to rise by 3.2°F (1.8°C) in the region by 2060, while mean summer air temperature is projected to rise by 4.1°F (2.3°C). This increase in air temperature will affect water temperature, as well as evaporation/evapotranspiration rates. Wooded habitats can be less sensitive to warmer air temperatures with inherent shading. One working group within the expert panel did not consider fringing riparian habitat in the Coquille River estuary sensitive to rising air temperature while another working group did. Thermal tolerances of woody species vary, but the community would likely change with substantial temperature change. Changes in evapotranspiration and soil moisture could cause large scale landscape composition change.

3. Water Temperature

- Exposure: High (Confidence High)
- Sensitivity: Moderate (Confidence Moderate)

Changes in water temperature at the top of the estuary are predicted to be 1.6 °F (0.9°C) warmer by 2060 and, and 1.8°F (1°C) warmer at the ocean end of the estuary by 2050. Fringing riparian zones are not regularly inundated by definition, but may be flooded during flood and storm events. However, the expert panel considered the exposure of fringing riparian habitat to water temperature to be high. One working group considered sensitivity to water temperature to be high while the other thought it low. Warmer water can affect the physiology of emergent plant species.

4. Precipitation

- Exposure: High (Confidence High)
- Sensitivity: High (Confidence High)

While overall annual precipitation is expected to remain unchanged in the Coquille River estuary, there is a trend toward drier summers and increased winter extreme events. With this comes more summer drought and increased winter freshwater flooding. Flood events can be beneficial to fringing riparian habitat and are discussed below. Component species of this habitat are likely to be sensitive to the amount and timing of precipitation, especially drought. The expert panel considered the fringing riparian habitat to be sensitive to predicted changes in regional precipitation.

5. Hydrology/Flow

- Exposure: Moderate (Confidence Low)
- Sensitivity: Moderate (Confidence High)

Altered precipitation will lead to altered hydrology for fringing riparian habitat during summer drought and winter flooding. This in turn can affect the species that can live in this habitat, as they will need to be better adapted to greater unpredictability in terms of flow and temperature. Chanel-forming flow and high hydraulic energies can impact riparian habitat and also help transport woody debris into adjacent water bodies. Sensitivity to drought was identified as moderate/high while overall sensitivity to hydrological changes was moderate.

6. Waves/Wind/Storms/Flooding

- Exposure: Low/Moderate (Confidence Low/Moderate)
- Sensitivity: Moderate/High (Confidence: High)

Storm related waves and flooding can affect fringing riparian habitat in both positive and negative ways, though the expert panel considered exposure to these events low for this habitat. On the positive side, the expert panel indicated that extreme events do provide and move woody debris into streams, rivers and wetlands which then provide habitat to aquatic species, however flood events can cause plant mortality. Sensitivity to extreme events was considered high by the expert panel.

7. Other Non-climate Sensitivity Factors

- Current effects of these stressors: Moderate/High (Confidence High)
- Degree stressors increase sensitivity to climate change: High (Confidence High)

The expert panel identified habitat loss, Industrial/Municipal/Agricultural activities and invasive species, as well as energy exploration (water volume related), water extraction, and mal-adaptive restoration as other non-climate factors effecting fringing riparian habitat in the Coquille River estuary.

Adaptive Capacity

1. Habitat extent, integrity and permeability

- Adaptive capacity: Moderate (Confidence High)

The expert panel concluded that fringing riparian habitat is moderately/highly widespread with the estuary, but considered it moderately/highly fragmented compared to its potential extent. Roads, agriculture, industrial, and urban development, clear cutting, dikes, levees, and small earthen dams may affect regional permeability to this habitat, though moderately, according to the expert panel.

2. Habitat heterogeneity

- Adaptive capacity: Moderate/High (Confidence High)

There is moderate/high heterogeneity within this habitat when compared to other habitat types in the Coquille River estuary and with highly variable topographical and physical characteristics according to the expert panel. However, the species composition varies within the estuary landscape. The expert panel disagreed on the level of typical vegetative diversity with one working group saying it low compared to other estuary habitats and the other working group considering it diverse.

3. Resistance, Recovery and Refugia

- Adaptive capacity: Moderate (Confidence High)

The ability of fringing riparian habitat to resist and recover from the impact of stressors was identified as high by the expert panel if stressors were reduced or eliminated. However, current levels of stressors lead to low resistance and recovery capacity. Refugia within existing fringing riparian habitat areas were not identified.

4. Management potential

- Adaptive capacity: Low/Moderate (Confidence High)

The expert panel indicated the community varied widely in how it valued this habitat and that there are existing use conflicts for the resource. Existing managing of this habitat falls under county ordinances and, in the upper watershed, forest management regulations. There is good restoration potential for fringing riparian habitat in the Estuary given past momentum and moderate potential that management action can help alleviate climate impacts. But this is complicated by high impacts from land management activities, and a general lack of protection or consideration of this habitat function in existing management planning.

5. Other factors affecting adaptive capacity

The expert panel thought currently there is a lack of protection for riparian habitat and streams, and there is an opportunity to improve the management of this habitat. This is considered with Management Potential above. Interestingly, beaver activities can actually assist with the long term health of the riparian habitat.

Section 5: Assessment of Species Vulnerability

Return to contents

The vulnerability of selected lower Coquille River estuary species populations was estimated by the expert panel through interpretation of available climate change exposure information, its understanding of climate change sensitivities, and integrating what was known of the adaptive capacity for each species. Species vulnerability also included considering the vulnerability of habitats utilized within the Coquille River estuary.

Tables 10 - 13 on the following pages summarize potential climate exposure, sensitivity, and overall vulnerability for project species. These tables are a good place to start when exploring vulnerability results.

The exposure and sensitivity of each species were estimated by considering the following seven factors: 1) generalist or specialist life regime; 2) physiological sensitivity to climate-related change; 3) habitat dependency and the habitat(s) sensitivity to climate change; 4) reproductive strategy; 5) ecological relationships (e.g. foraging, predator/prey); 6) sensitivity to disturbance regimes; and 7) sensitivity to interacting non-climate stressors and other sensitivities or exposure not captured above.

The assessment of adaptive capacity of each species considered six factors: 1) dispersal and movement ability; 2) plasticity in response (e.g. physiology, behavior, phenology); 3) Evolutionary potential (e.g. fast generation time, genetic diversity); 4) diversity of life history strategies; 5) management potential; and 6) other adaptive capacity factors not captured above. Adaptive capacity can potentially reduce the impact of high exposure and sensitivity.

Following summary Tables 10 through 13 are the narratives generated by the expert panel, organized by species, which expand upon the material in the tables.

Table 10. Summary of Species Vulnerability to Climate Change

	Vulnerability	
Species	**Climate Exposure/Sensitivity**	**Adaptive Capacity**
Invertebrates		
Dungeness crab (*Metacarcinus magister*)	Moderate (Confidence Moderate/High)	Moderate (Confidence Moderate/High)
Fish		
Coho salmon (*Ncorhynchus kisutch*)	High (Confidence Moderate/High)	Moderate (Confidence High)
Pacific lamprey (*Entosphenus tridentatus, Lapmetra tridentata*)	Moderate (Confidence Moderate/High)	Moderate (Confidence Moderate/High)
Birds		
Mallard (*Anas platyrhynchos*)	Moderate (Confidence Moderate/High)	Moderate/High (Confidence High)
Western sandpiper (*Calidris mauri*)	Moderate (Confidence Moderate)	Moderate (Confidence Low/Moderate)
Mammals		
Beaver (*Castor canadensis*)	Moderate (Confidence Moderate)	Moderate (Confidence High)

Table 11. Species Climate Change Exposure Estimates

Species	Sea Level Rise	Air Temperature	Water Temperature	Precipitation	Hydrology / Flow	Ocean Acidification	Upwelling	Waves/Wind
Invertebrates	**Exposure**							
Dungeness crab (*Metacarcinus magister*)	Little change in deep estuary habitats. Eelgrass beds may decrease or shift due to lower light penetrance. Low Tidal Saltmarsh predicted to expand.	NA	+0.9°C at top of estuary (2060) +1°C at ocean (2050 A1B)	See Hydrology / Flow	Somewhat lower flows in summer Higher flow in fall Increased winter flood/high flow events possible Salinity changes possible	Nearshore pH decreasing & may be as low as 7.82 (2050)	Inconclusive	Potential increase in wave height and wind speed in the NE Pacific Ocean Increase in SLR+wind+wave driven flooding (100yr floods every 5 years)
Fish								
Coho salmon (*Oncorhynchus kisutch*) Pacific lamprey (*Entosphenus tridentatus, Lampetra tridentata*)	Little change in deep estuary habitats. Eelgrass beds may decrease or shift due to lower light penetrance. Low Tidal Saltmarsh predicted to expand.	NA	+0.9°C at top of estuary (2060) +1°C at ocean (2050 A1B) '+0.9°C at mouths of three tributaries (2060)	See Hydrology / Flow	Somewhat lower flows in summer Higher flow in fall Increased winter flood/high flow events possible Salinity changes possible	Nearshore pH decreasing & may be as low as 7.82 (2050)	Inconclusive	Potential increase in wave height and wind speed in the NE Pacific Ocean Increase in SLR+wind+wave driven flooding (100yr floods every 5 years)
Birds								
Mallard (*Anas platyrhynchos*) Western sandpiper (*Calidris mauri*)	Little change in deep estuary habitats. Eelgrass beds may decrease or shift due to lower light penetrance. Low Tidal Saltmarsh predicted to expand. Nontidal Freshwater Wetlands may decrease.	+1.8°C annual mean air temp +2.3°C in summer (2060)	+0.9°C at top of estuary (2060) +1°C at ocean (2050 A1B) '+0.9°C at mouths of three tributaries (2060)	Overall Annual precipitation unchanged Drier summers Increased winter extreme events	Somewhat lower flows in summer Higher flow in fall Increased winter flood/high flow events possible Salinity changes possible	Nearshore pH decreasing & may be as low as 7.82 (2050)	Inconclusive	Potential increase in wave height and wind speed in the NE Pacific Ocean Increase in SLR+wind+wave driven flooding (100yr floods every 5 years)
Mammals								
Beaver (*Castor canadensis*)	Little change in deep estuary habitats. Eelgrass beds may decrease or shift due to lower light penetrance. Low Tidal Saltmarsh predicted to expand. Nontidal Freshwater Wetlands may decrease.	+1.8°C annual mean air temp +2.3°C in summer (2060)	+0.9°C at top of estuary (2060) +1°C at ocean (2050 A1B) '+0.9°C at mouths of three tributaries (2060)	Overall Annual precipitation unchanged Drier summers Increased winter extreme events	Somewhat lower flows in summer Higher flow in fall Increased winter flood/high flow events possible Salinity changes possible	NA	NA	Potential increase in wave height and wind speed in the NE Pacific Ocean Increase in SLR+wind+wave driven flooding (100yr floods every 5 years)

Table 12. Species Climate Change Sensitivity Estimates

Species	Climate Change Sensitivity Database[1]	Sea Level Rise (Sensitivity of Habitat)	Air Temperature	Water Temperature	Precipitation	Hydrology / Flow	Ocean Acidification	Upwelling	Waves/Wind
Invertebrates	**Sensitivity Estimates**								
Dungeness crab (*Metacarcinus magister*)	Not Reported	Sensitive to changes in shallow estuarine habitats, eelgrass, sandy and muddy areas of lower estuary.	NA	Directly sensitive to salinity changes at certain life stages, and water quality in general. Indirectly sensitive to changes in food availability.	See Hydrology	Directly sensitive to salinity changes at certain life stages, and water quality in general.	Sensitive to decreasing pH	Sensitive to hypoxia events. Indirectly sensitive to changes in food availability.	Sensitive to flooding events
Fish									
Coho salmon (*Noorlynchus kisutch*)	Not Reported	Sensitive to changes in estuaries, rivers, salt marshes, off-channel habitats. Sensitive to change in habitat based food sources.	NA	Directly sensitive to temperature (streams, spawning, larvae)	See Hydrology	Directly sensitive to flow timing and volume (streams, spawning, larvae, eggs)	Directly and indirectly sensitive to lower pH.	Directly sensitive to hypoxia events. Indirectly sensitive to changes in food availability (adult).	Sensitive to flooding and scouring events (eggs, larvae)
Pacific lamprey (*Entosphenus tridentatus, Lapmetra tridentata*)	High (Record not yet completed)	Sensitive to changes in coastal lowlands, marshes, estuaries, beaches. Sensitive to channelization, side channel loss, scouring. Spawning in seasonal streams Sensitive to barriers	NA	Directly sensitive to elevated water temperature (ammocoetes), though not as much as salmonids.	See Hydrology	Directly sensitive to salinity changes at certain life stages, and water quality in general (streams).	Potentially directly sensitive to lower pH.	Directly sensitive to hypoxia events. Indirectly sensitive to changes in food availability (adult, juvenile).	Sensitive to flooding and scouring events (ammocoetes)
Birds									
Mallard (*Anas platyrhynchos*)	Not Reported	Sensitive to changes in nesting habitat: marshes, grassland ponds, seasonal & semi permanent wetlands (migratory stopover sites). Indirectly sensitive to habitat based food availability. Moderate philopatry.	Nesting imitation & success related to temperature, precipitation & storms	NA	Nesting imitation & success related to temperature, precipitation & storms. Habitat & food sources sensitive to precipitation & storms	Nesting and feeding habitat sensitive to hydrologic change & flooding	Indirectly sensitive to changes in food sources	Indirectly sensitive to changes in food sources	Nesting imitation & success related to temperature, precipitation & storms. Habitat & food sources sensitive to storms & flooding.
Western sandpiper (*Calidris mauri*)	Medium (Confidence Poor)	Sensitive to changes in foraging and nesting habitat: tidal mudflats, seasonal wetlands. Indirectly sensitive to habitat based food availability. Moderate philopatry.	Habitat sensitive to temperature	Aquatic invertebrate food sources sensitive to water temperature	Marsh habitat and insect food sources sensitive to precipitation changes	Nesting and feeding habitat sensitive to hydrologic change, salinity changes & flooding	Indirectly sensitive to changes in food sources	Indirectly sensitive to changes in food sources	Birds and habitat sensitive to intense storms
Mammals									
Beaver (*Castor canadensis*)	Medium (Confidence Fair)	Sensitive to changes in wetlands, vernal pools, seasonal streams, marshes, estuaries, beaches. Indirectly sensitive to habitat based food availability	Habitat sensitive to temperature	NA	Habitat & food sources sensitive to precipitation & storms	Habitat & food sources sensitive to hydrologic change & storms	NA	NA	Habitat sensitive to storms & flooding.

[1] Climate Change Sensitivity Database (http://climatechangesensitivity.org)

Table 13. Expert Panel Assessment of Species Climate Change Exposure, Sensitivity and Adaptive Capacity

Species	Exposure	Sensitivity	Adaptive Capacity	Habitat-Based Exposure/Sensitivity	Habitat Based Adaptive Capacity
Invertebrates					
Dungeness crab (*Metacarcinus magister*)	Low/Moderate (Confidence Moderate)	Moderate (Confidence Moderate/High)	Moderate/High (Confidence Moderate/High)	Moderate/High (Confidence Moderate/High)	Moderate (Confidence Moderate/High)
Fish					
Coho salmon (*Oncorhynchus kisutch*)	High (Confidence Low/Moderate)	High (Confidence High)	Moderate (Confidence High)	Moderate/High (Confidence Moderate/High)	Moderate (Confidence High)
Pacific lamprey (*Entosphenus tridentatus, Lapmetra tridentata*)	Moderate (Confidence Moderate)	Moderate (Confidence High)	Moderate (Confidence Moderate/High)	Moderate/High (Confidence Moderate/High)	Moderate (Confidence Moderate/High)
Birds					
Mallard (*Anas platyrhynchos*)	Low/Moderate (Confidence Moderate)	Low/Moderate (Confidence Moderate/High)	High (Confidence High)	Moderate/High (Confidence Moderate/High)	Moderate (Confidence Moderate/High)
Western sandpiper (*Calidris mauri*)	Low/Moderate (Confidence Moderate)	Moderate (Confidence Moderate)	Moderate (Confidence Low)	Moderate/High (Confidence Moderate/High)	Moderate (Confidence Moderate/High)
Mammals					
Beaver (*Castor canadensis*)	Low/Moderate (Confidence Moderate)	Moderate (Confidence High)	Moderate (Confidence High)	Moderate/High (Confidence Moderate/High)	Moderate (Confidence High)

A. Dungeness Crab (Metacarcinus magister)

Overall vulnerability for Dungeness crab

- Climate Exposure/Sensitivity: Moderate (Confidence Moderate/High)
- Adaptive capacity: Moderate (Confidence Moderate/High)

Dungeness crab likely utilize the estuary open water, tidal flat, and low and high tidal saltmarsh habitats within the Coquille River estuary. Juveniles prefer shallow estuarine areas with protective structures. Adults reside in sandy and muddy areas to 200 feet deep. There appears to be little written about the vulnerability of Dungeness crab populations to climate change. Potential sensitivities to water temperature, salinity change at certain life stages, and ocean acidification have been noted (Fisheries and Oceans Canada 2013). On a larger scale, climate change may influence distribution and movement during oceanic larval stages and the suitability of early life-stage habitat (Botsford 2001). Dungeness crab populations are also sensitive to local water quality.

1. Sensitivity and Exposure

- Direct Climate Exposure: Low/Moderate (Confidence Moderate)
- Direct Climate Sensitivity: Moderate (Confidence Moderate/High)

Dungeness crab are thought to be highly sensitive to water temperature, salinity (hydrology shifts), water pH, and pollution (expert panel confidence: high). Dungeness crab are generalists, but have specific predator/prey relationships, specific habitat dependencies for larval recruitment, and phenological dependencies (expert panel confidence: high). Its reproductive strategy of producing many offspring in successive cycles makes it less sensitive to climate disturbance. Its ecological dependencies (predator/prey relationships, habitat, competition) are expected to be highly sensitive to local changes in water temperature, water pH, hydrology, and upwelling (expert panel confidence: high). The expert panel considered Dungeness crab highly sensitive to wind/waves/storms/flooding, disease, and invasive species disturbances (confidence: not reported). Habitat loss, competition, industrial, municipal and agricultural activities, and water quality issues were also identified by the expert panel as significant interacting stressors, though current and future interacting effects were considered low/moderate (expert panel confidence: low).

2. Adaptive Capacity

- Direct adaptive capacity: Moderate/High (Confidence Moderate/High)

Dungeness crab larvae disperse widely, over 100 km, providing opportunity for populations to move and reestablish (high ability, high confidence). However, this dispersal can be positively or negatively affected by oceanographic processes (to a high degree, high confidence). Adult life stages are more limited in dispersal ability. The expert panel considered the Dungeness crab to have a moderate/high ability to adapt evolutionarily due to its broad distribution, high fecundity and gene flow (confidence: moderate). The expert panel also considered it to have a moderate/high ability to modify its physiology or behavior to respond to changes in climate and its effects, and more so as adults (confidence: high).

From a management potential point of view, the expert panel considered the Dungeness crab highly valued by the local community (confidence: high) and thought that the degree of management potential for this species conferred a moderate/high degree of adaptive capacity (confidence: moderate/high). The Dungeness crab fishery was important and considered well regulated, and that the estuary habitat could be sufficiently managed to maintain the population.

3. Habitat Based Sensitivity, Exposure and Adaptive Capacity

- Climate exposure/sensitivity: Moderate/high (confidence moderate/high)
- Adaptive capacity: Moderate (confidence moderate/high)

Dungeness crab likely utilize the estuary open water, tidal flat, and low and high tidal saltmarsh habitats within the Coquille River estuary. The overall habitat vulnerability for estuary open water was moderate/high for climate effects (confidence moderate/high), and moderate for adaptive capacity (confidence moderate); for tidal flat it was moderate for climate effects (confidence moderate) and moderate for adaptive capacity (confidence moderate); for low tidal saltmarsh it was moderate/high for climate effects (confidence moderate/high) and was moderate for adaptive capacity (confidence high); and for high tidal saltmarsh it was moderate/high for climate effects (confidence moderate/high) and moderate for adaptive capacity (confidence high).

B Coho Salmon (*Oncorhynchus kisutch*)

<u>Overall vulnerability for coho salmon</u>

- Climate Exposure/Sensitivity: High (Confidence Moderate/High)
- Adaptive capacity: Moderate (Confidence High)

Coho salmon use all habitat types in the Coquille River estuary throughout their various life stages. However, some areas may no longer be accessible due to habitat alteration. Coho spawn in the upper watershed freshwater streams. Juveniles and summer parr utilize the tidal reach and estuary regions. Overwintering juveniles use saltmarsh off-channel habitats. February to May smolts remain in the estuary for 2-3 weeks before venturing into the open ocean. Adults return in the fall two to three years later and migrate through the estuary to return to their natal streams to spawn (Coquille Indian Tribe 2007). Alterations in conditions in any of these habitats could affect coho success, and their Endangered Species Act designation as *Threatened* indicates that alterations are affecting the success of this culturally, recreationally and economically important species.

Coho are expected to be vulnerable to the effects of climate change with increasing water temperatures (ocean and estuary), increased acidity, warmer and drier summers, intensified oceanic stratification, and spring transition delay (Stout et al. 2011). Conversely, changes in upwelling could benefit coho (Wainwright and Weitkamp, 2012). Stout et al. (2011) identified sea level rise and warmer water temperatures as the main physical changes in Oregon estuaries. These changes are likely to have negative effects on salmon due to the loss of intertidal wetland habitats, increased thermal stress during migrations, and through the increased metabolic demand of coho and their predators. Additionally, the future magnitude of climate fluctuations and climate influenced changes in ocean productivity were less predictable but identified concerns. Please also see (2011), Lawson et al. (2007), Logerwell et al. (2003) for other regional perspectives.

1. Sensitivity and Exposure

- Direct Climate Exposure: High (Confidence Low/Moderate)
- Direct Climate Sensitivity: High (Confidence High)

The anadromous lifecycle of the coho salmon includes several life stages, and each one has its specific habitat and diet requirements, which makes coho salmon a specialist that has a shifting range of niches through its life. Additionally, coho only spawn one time, although their single spawning events can result in large numbers of offspring. Poor conditions in spawning habitat can result in severely impacted recruitment for a single year class. Coho salmon have many climate-sensitive ecological relationships (prey, forage, competition) and environmental limitations (water temperature, nutrients, dissolved

oxygen, pH, wind/waves, hydrology). The expert panel rated coho as being highly sensitive to effects of climate change on its ecology (confidence high). Additionally coho are sensitive to flooding, drought, pathogens/disease, upwelling changes, and invasives. The expert panel rated coho as highly sensitive to disturbance (confidence: high). Coho salmon in the Coquille River estuary are also exposed to a number of non-climate stressors (development, industrial/municipal/agricultural activities, habitat loss due to other causes and invasives). The expert panel indicated that these stressors are already substantially affecting coho (high) (confidence: high) and that these stressors make coho more sensitive to climate change (high) (confidence: high).

2. Adaptive Capacity

- Adaptive capacity: Moderate (Confidence High)

While coho salmon have a large annual dispersal distance between when they leave the estuary and when they return (>100km), they have a low likelihood of establishing new populations, since they have high site fidelity to spawning streams (confidence: high). Barriers, including roads, development, culverts, dikes and small dams, play a moderate role in limiting dispersal (confidence: high). The expert panel felt that spawning grounds were not the habitat limitation for coho salmon, rather the overwintering habitat in the lower Coquille River was the most important limiting factor. The expert panel also felt that coho were moderately plastic in their ability to change and respond to climate change, however they would rank low if compared to fish in general (confidence: high). Evolutionary adaptation was seen as a low to moderate option (confidence: high) for coho, with greater potential in terms of adapting to temperature changes (changes in timing of runs) than to ocean acidification effects (no likely way to accommodate). The expert panel saw the diverse nature of coho salmon's life history as offering low to moderate adaptive capacity (confidence: not reported). Habitat restoration was deemed to have huge potential to improve overwintering habitat and remove barriers, making management a potentially high source of adaptive capacity (confidence: high). Regional constituencies also place high value on coho salmon (confidence: high). Another factors noted as affecting adaptive capacity was overfishing of forage fish, which was rated at moderate in its effect on adaptive capacity (confidence: not reported).

3. Habitat Based Sensitivity, Exposure and Adaptive Capacity

- Climate Exposure/Sensitivity: Moderate/High (Confidence Moderate/High)
- Adaptive capacity: Moderate (Confidence High)

Coho salmon likely use most of the habitats within the Coquille River estuary. Key habitats for salmon within the estuary are ones that provide slower water, off channel habitats for over-wintering juveniles and acclimating smolts such as estuary open water (including eelgrass), low and high tidal saltmarsh, tidal freshwater wetlands, and possibly nontidal freshwater wetlands.

The overall habitat vulnerability for estuary open water was moderate/high for Climate Effects (confidence moderate/high) and moderate for adaptive capacity (confidence moderate); for low tidal saltmarsh it was moderate/high for Climate Effects (confidence moderate/high) and was moderate for adaptive capacity (confidence high); for high tidal saltmarsh it was moderate/high for Climate Effects (confidence moderate/high) and moderate for adaptive capacity (confidence high); for tidal freshwater wetland it was high for Climate Effects (confidence moderate/high) and low/moderate for adaptive capacity (confidence moderate/high); and for nontidal freshwater wetland it was moderate/high for Climate Effects (confidence moderate/high) and moderate/high for adaptive capacity (confidence high).

C. Pacific Lamprey (*Entosphenus tridentatus*)

Overall vulnerability for pacific lamprey

- Climate Exposure/Sensitivity: Moderate (Confidence Moderate/High)
- Adaptive capacity: Moderate (Confidence Moderate/High)

Compared to salmon, not much is known about pacific lamprey across their range, though they spawn in freshwater streams in habitat similar to coho salmon. Adult lamprey generally migrate up the estuary to freshwater habitats from late spring to fall and may remain there for up to a year before spawning. Larvae (ammocoetes) remain in fresh water for three to seven years. After metamorphosis they migrate down the watershed to the ocean where they remain one to three years before they return to spawn. Although the species has little recreational significance, it has high cultural importance and is listed at the state level as vulnerable. The species is widespread but it requires specific substrates and precise feeding patterns (Luzier et al. 2011).

The report, *Pacific Lamprey (Entosphenus tridentatus) Assessment and Template for Conservation Measures* (Luzier et al. 2011), reviews the status of Pacific lamprey through its range and includes a ranking of threats and limiting factors for survival using a risk assessment approach. Water temperature and climate change were both considered in the risk assessment for southern Oregon, and were ranked moderate and low in severity, respectively.

1. Sensitivity and Exposure

- Direct Climate Exposure: Moderate (Confidence Moderate)
- Direct Climate Sensitivity: Moderate (Confidence High)

Lamprey are moderately sensitive to a number of physiological challenges (water temperature, salinity, dissolved oxygen saturation and pollution (confidence: high). Ammocoetes prior to transformation are particularly salinity intolerant (Richard and Beamish, 1981). Lamprey, like salmon, are semelparous but have a longer generation time (6-10 years). Their marine life-stage prey and their non-native predators are both relationships that are anticipated to be sensitive to climate change due to changing temperature, upwelling, sea level and hydrology. The expert panel rated this sensitivity as moderate (confidence: moderate). However lamprey have a broad range from Baja to southeastern Alaska indicating that at least local populations can withstand a broad range of conditions. Events like wildfire, flooding, drought and invasive fish arrival and establishment can all be mediated by or exacerbated by climate change and may adversely affect lamprey. Wildfires can result in increased contribution of sediment to streams, while flooding and drought can alter salinity in different reaches of the estuary, and invasive species can out-compete or eat lamprey. The expert panel felt that lamprey were moderately sensitive to such disturbances (confidence: High).

2. Adaptive Capacity

- Adaptive capacity: Moderate (Confidence Moderate/High)

Adaptive capacity for Pacific Lamprey within the Coquille River estuary was determined though input from the expert panel. Although the ability of the adults to disperse was assessed at moderate (10-100km), for the younger ammocoetes it was low (100-500 m) (confidence: moderate to high). Adults, which have lower site fidelity than coho salmon, may colonize different streams when they return to spawn. Barriers such as culverts, dikes, dams and waterfalls were assessed to have a high effect on dispersal (confidence: high). Although ammocoetes have low salinity tolerance they do have fairly wide thermal range they can occupy, but they exist at lower densities in less optimum conditions. The expert panel characterized lamprey as being moderately plastic in their ability to respond to climate change

effects such as temperature (confidence: moderate). There was also a moderate potential assigned for ability to evolutionarily adapt to climate change (confidence: moderate). This mid-ranking was based on the conflicting knowledge that lamprey have low genetic diversity, but have survived as a species for nearly 350 million years (Bond, 1996). The lamprey's life history strategy was assumed to confer low adaptive capacity (confidence: moderate), in part due to its long generation time. Tribes value lamprey highly in contrast to broader society (confidence: high). It is governed by specific management (confidence: high). Despite substantially reduced harvest (only tribal for the past 20 years), the species long larval phase and high degree of habitat specificity make the expert panel uncertain of the potential for increased adaptive capacity through effective management.

3. Habitat Based Sensitivity, Exposure and Adaptive Capacity

- Climate Exposure/Sensitivity: Moderate/High (Confidence Moderate/High)
- Adaptive capacity: Moderate (Confidence Moderate/High)

The literature and expert panel suggest that Pacific Lamprey likely use all habitats within the Coquille River estuary. Eelgrass is likely to be cover for out-migrating juveniles (Hardistry and Potter, 1971). Habitat loss can reduce the distribution of lamprey in the estuary, which can increase movement to find preferred habitat and increase vulnerability to predation by native and non-native predators. The expert panel ranked habitat loss as highly enhancing the sensitivity of lamprey to the effects of climate change (confidence: high).

In summary, the overall habitat vulnerability for estuary open water was moderate/high for Climate Effects (confidence moderate/high) and moderate for adaptive capacity (confidence moderate); for tidal flat it was moderate for Climate Effects (confidence moderate) and moderate for adaptive capacity (confidence moderate); for low tidal saltmarsh it was moderate/high for Climate Effects (confidence moderate/high) and was moderate for adaptive capacity (confidence high); for high tidal saltmarsh it was moderate/high for Climate Effects (confidence moderate/high) and moderate for adaptive capacity (confidence high); for tidal freshwater wetland it was high for Climate Effects (confidence moderate/high) and low/moderate for adaptive capacity (confidence moderate/high); and for nontidal freshwater wetland it was moderate/high for Climate Effects (confidence moderate/high) and moderate/high for adaptive capacity (confidence high).

D. Mallard (*Anas platyrhynchos*)

- Climate Exposure/Sensitivity: Moderate (Confidence Moderate/High)
- Adaptive capacity: Moderate/High (Confidence High)

The Mallard is an important recreational species in the Coquille River estuary. Mallards are generalists and can be found throughout the estuary. All estuary habitats are used for feeding on aquatic plants, seeds, invertebrates, insects and fish, while breeding activities are limited to the more inland reaches of the estuary, including tidal and nontidal freshwater wetlands and riparian areas.

1. Sensitivity and Exposure

- Direct Climate Exposure: Low/Moderate (Confidence Moderate)
- Direct Climate Sensitivity: Low/Moderate (Confidence Moderate/High)

Mallards are strong generalists that occur in a variety of habitats across a broad range of conditions, including some very polluted and fragmented locations, although it is not known how well they do in the degraded locales. However as a result of their occurrence in such habitat, the expert panel deemed them to be of low physiological sensitivity (confidence: moderate). Mallards have moderate dependence

on tidal freshwater wetlands and nontidal freshwater wetlands (confidence: high). Mallards are iteroparious, breeding many times over the course of their lives but producing only a few offspring at each event. This increases the probably of having a successful clutch over their lives across a range of environmental conditions, which could be a beneficial strategy given the increased inter-annual variability associated with climate change. Ecological sensitivities identified by the expert panel included sensitivity of nesting stages to altered hydrological flow which could resulting in flooding of nests, storm events could kill young, and the potential for asynchronization with prey. These sensitivities were rated as moderate (confidence: high). Flooding, drought, insects and disease were all identified as disturbance regimes that mallards are sensitive to (confidence: high). The species was believed to currently be moderately affected by non-climate stressors including development and loss of habitat (confidence: moderate).

2. Adaptive Capacity

- Adaptive capacity: High (Confidence High)

Mallards were seen to have a high ability to disperse (confidence: high) with few barriers (arid lands perhaps) to their ability to disperse (confidence: moderate). It was even believe that refugia to climate stress could be found for mallards within the Coquille River estuary. Mallards were assessed as having a high degree of plasticity in their traits and behavior to respond to climate change and its effects (confidence: high). This might be possible through altering their opportunistic foraging behavior. However there was less trust in their ability to respond to direct human disturbance. The degree of evolutionary adaptation potential in response to climate change was also ranked as high (confidence: high) based on their abundance, ability to disperse and flexible behavior. Additionally their habitat generalist nature and observed ability to have early and late broods indicated an ability to adapt to new locations and conditions at many stages of its life history (confidence: high). Mallards are valued species (confidence: high) and there are specific management rules relevant to them. The expert panels could identify no management conflicts in the region and saw opportunity for adapting hunting regulations to maintain nesting and foraging habitat.

3. Habitat Based Sensitivity, Exposure and Adaptive Capacity

- Climate Exposure/Sensitivity: Moderate/High (Confidence Moderate/High)
- Adaptive capacity: Moderate (Confidence Moderate/High)

The literature and expert panel suggest that mallard likely use all habitats within the Coquille River estuary. The overall habitat vulnerability for estuary open water was moderate/high for Climate Effects (confidence moderate/high) and moderate for adaptive capacity (confidence moderate); for tidal flat it was moderate for Climate Effects (confidence moderate) and moderate for adaptive capacity (confidence moderate); for low tidal saltmarsh it was moderate/high for Climate Effects (confidence moderate/high) and was moderate for adaptive capacity (confidence high); for high tidal saltmarsh it was moderate/high for Climate Effects (confidence moderate/high) and moderate for adaptive capacity (confidence high); for tidal freshwater wetland it was high for Climate Effects (confidence moderate/high) and low/moderate for adaptive capacity (confidence moderate/high); and for nontidal freshwater wetland it was moderate/high for Climate Effects (confidence moderate/high) and moderate/high for adaptive capacity (confidence high).

E. Western Sandpiper (*Calidris mauri*)

- Climate Exposure/Sensitivity: Moderate (Confidence Moderate)
- Adaptive capacity: Moderate (Confidence Low/Moderate)

Western sandpiper is an important recreational and management species. They are common within the estuary. They are a management priority given that they are a U.S. Shorebird Conservation Plan prioritization category 4-species of high concern (Brown et al. 2001), meaning that they are suspected of being a population in decline. The population within the estuary is estimated to be up to 100,000 during their migratory stops in spring and fall for foraging and roosting (expert panel). Estuary use is longer during the southward leg of their trip. It is a mudflat specialist limited to shoreline, beaches, tidal mudflats and flooded fields and preys on invertebrates that burrow in the mud.

1. Sensitivity and Exposure

- Direct Climate Exposure: Low/Moderate (Confidence Moderate)
- Direct Climate Sensitivity: Moderate (Confidence Moderate)

The physiology of western sandpipers does not seem to be affected by many stresses in the Coquille River estuary. The expert panel indicated that food sources could be sensitive to climate stresses, as well as pollution. Western sandpiper food sources distribution and availability is determined by sediments, salinity and exposure to water, all of which are sensitive to climate change (Butler and Lemon, 2007). Severe storms can influence migration patterns and the ability of western sandpipers to travel to breeding grounds, or the condition of foraging habitat at stopover sites. Their life history strategy includes one clutch of four eggs per year, which could make them vulnerable to climate variability if timing of events (storms, phenology) is not a cue for reproduction. Forage, habitat and related hydrology were all labeled by the expert panel as being sensitive to climate change primarily due to changes in precipitation, pH, wind/waves, sea level, and hydrology (Sensitivity: moderate, confidence: moderate). Flooding (loss of roosting and foraging habitat), drought (affects to invertebrates), lack of insects, wind/waves (deleterious to migration) and invasives (competition for habitat use) were all identified as disturbances to which western sandpipers were moderately sensitive (confidence: moderate). Other stressors affecting the system were seen to have limited effect on this species, however pollution, development and habitat loss could increase sensitivity to climate change (confidence: moderate).

2. Adaptive Capacity

- Adaptive capacity: Moderate (Confidence Low)

Seen as having moderate dispersal ability (confidence: low), there were few barriers identified (wind) and barriers were not thought to significantly affect dispersal (confidence: high). The panel felt there was insufficient information to determine why some sites were no longer used by western sandpipers despite being within an accessible range. The panel thought the sandpiper might have a moderate degree of plasticity in its ability to alter the timing of nest initiation in the arctic or timing of migration in response to environmental variation (confidence: low). The evolutionary potential was also moderate (confidence: low) based on a larger global population with demonstrated variability in traits like bill length and foraging strategies. However it was not known if they could synchronize their timing with other organisms on which they depend as phenology changes. The potential for leveraging life history diversity to build adaptation capacity was ranked as moderate (confidence: low) based on variable foraging behavior between non-breeding males and females, as well as larger billed populations which winter farther south where they can extract prey from deeper sediments (Mathot et al. 2007, Nebel et al. 2005). Western sandpiper were judged by the expert panel to have low/moderate societal value, aside from bird watching (confidence: low), but they are protected under the Migratory Bird Treaty Act. Recent data indicate population declines but the western sandpiper has no formal designation at the state or federal level. The expert panel identified opportunities through management to increase

adaptive capacity through protection of stopover habitat from development and pollution, in addition to controlling invasive species and creating and restoring critical habitat. The expert panel thought that the western sandpiper might have more adaptive capacity that other species of shorebird, but suggested that additional understanding of the pacific flyway would help in developing improved management for this species.

3. Habitat Based Sensitivity, Exposure and Adaptive Capacity

- Climate Exposure/Sensitivity: Moderate/High (Confidence Moderate/High)
- Adaptive capacity: Moderate (Confidence Moderate/High)

The literature and expert panel suggest that western sandpiper likely use all habitats within the Coquille River estuary except open water. The overall habitat vulnerability for estuary open water was moderate/high for Climate Effects (confidence moderate/high) and moderate for adaptive capacity (confidence moderate); for tidal flat it was moderate for Climate Effects (confidence moderate) and moderate for adaptive capacity (confidence moderate); for low tidal saltmarsh it was moderate/high for Climate Effects (confidence moderate/high) and was moderate for adaptive capacity (confidence high); for high tidal saltmarsh it was moderate/high for Climate Effects (confidence moderate/high) and moderate for adaptive capacity (confidence high); for tidal freshwater wetland it was high for Climate Effects (confidence moderate/high) and low/moderate for adaptive capacity (confidence moderate/high); and for nontidal freshwater wetland it was moderate/high for Climate Effects (confidence moderate/high) and moderate/high for adaptive capacity (confidence high).

F. Beaver (Castor canadensis)

- Climate Exposure/Sensitivity: Moderate (Confidence Moderate)
- Adaptive capacity: Moderate (Confidence High)

The North American Beaver is an ecological significant species that plays an important engineering role in aquatic ecosystems. The sensitivity of beaver is important to evaluate not only out of concern for beaver as a species, but also the associated services they provide that can help to ameliorate the effects of climate change on an estuarine watershed like the Coquille. Beaver not only create new surface water habitat behind their dams, but this surface water is also known to increase groundwater recharge and trap sediment (Pollock et al. 2003). They are fairly common in the estuary and possibly number in the 1000's (expert panel). They are herbivorous, year round residents in the riparian and freshwater wetlands of the uppermost Coquille River estuary. Beaver ponds have also been demonstrated to be important for coho salmon rearing habitat (Pollock et al. 2004).

1. Sensitivity and Exposure

- Direct Climate Exposure: Low/Moderate (Confidence Moderate)
- Direct Climate Sensitivity: Moderate (Confidence High)

Beaver are specialists with specific foraging and habitat dependency (confidence: high). Physiologically they prefer low salinity (which could make them vulnerable to sea level rise and strong storm wind/waves, or at least require movement in the watershed) and are sensitive to the disease taxoplasmosis. Overall their physiological sensitivity is low (confidence: high). A long-lived iteroparous species with few offspring, beaver have annual sensitivity to extreme events and climatic shift but potential over the course of their lives to find successful strategies to increase next generation recruitment. Beavers are however highly sensitive to flood and drought, as well as disease and human impacts (confidence: high). Industrial/municipal/agricultural activities, habitat loss due to draining of wetlands and human management are all non-climatic stressors that generally have low effect on

beavers presently and are only expected to make beaver slightly more sensitive to climate change (confidence: moderate).

2. Adaptive Capacity

- Adaptive capacity: Moderate (Confidence High)

Beaver have moderate ability to disperse (1-10km per year) (confidence: high), although roads, agriculture, industry/urban/residential development, geological features, arid land and waterfalls can all be barriers to dispersal. The expert panel believed such barriers had moderate effect (confidence: high), and that the Coquille River estuary would offer some locations of refugia for beaver during particular climate stresses. Beaver plasticity was assessed as high and was not only attributed to their ability to modify they physiology and behavior but also their habitat through construction of dams (confidence: high). Additionally they can feed on a variety of species. Likewise their broad range was seen as evidence of a high degree of potential for evolutionary adaptation (confidence: high). Life history diversity was assessed to confer a moderate degree of adaptive capacity (confidence: high), however beaver do have habitat dependence and lack variability in breeding behavior. Beaver are a species highly valued by people (confidence: high) and there is a moderate level of rules governing beaver management (confidence: high). Unfortunately the rules are not very specific and may only apply to furbearers (on public lands) or predators (on private lands), but this does mean that there is potential to improve the regulations to specific protect beaver for their own sake, as well as for their habitat engineering ability which could provide broader adaptive capacity for the habitats they live in.

3. Habitat Based Sensitivity, Exposure and Adaptive Capacity

- Climate Exposure/Sensitivity: Moderate/High (Confidence Moderate/High)
- Adaptive capacity: Moderate (Confidence High)

The literature and expert panel suggest that beaver likely use all habitats within the Coquille River estuary except open water, tidal flat and tidal saltmarsh low. The overall habitat vulnerability for high tidal saltmarsh was moderate/high for Climate Effects (confidence moderate/high) and moderate for adaptive capacity (confidence high); for tidal freshwater wetland it was high for Climate Effects (confidence moderate/high) and low/moderate for adaptive capacity (confidence moderate/high); and for nontidal freshwater wetland it was moderate/high for Climate Effects (confidence moderate/high) and moderate/high for Adaptive Capacity (confidence high).

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Return to contents

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