# Science Review and Data Analysis for Tidal Wetlands of the Oregon Coast

## Part 2 of a Hydrogeomorphic Guidebook

by

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for

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# Summary

This document describes the development and technical basis for the hydrogeomorphic (HGM) method for assessing tidal wetlands of the Oregon coast, as presented in an accompanying document (Part 1). Drawing from approximately 500 published sources and databases, this document reviews scientific literature on tidal wetland functions, especially as it pertains to the presented HGM method and the Pacific Northwest. Data are summarized on dozens of variables that were measured or estimated in 120 tidal wetlands during summer 2003. Although most of the data are from a single visit to each wetland, the large and diverse number of tidal wetlands surveyed provides a broader context for interpreting some tidal wetland phenomena. This document also gives reasons for not selecting particular indicators, as well as citing reasons for selecting others. Emphasis is on identifying objective but rapid ways to assess wetland integrity ("condition"), functions, and the risk to these. Rather than attempting to classify sites nominally (e.g., simply as "altered" or "unaltered"), we have defined and used multiple indices with numeric scales to estimate risk to tidal wetlands from human-related stressors. The risk indices then are compared with an integrity index based both on plant community composition and on deviation of tidal channel dimensions from those at reference sites pre-classified as "less-altered." Associations between estimates of wetland integrity, functions, and risk are examined statistically. Also, statistical analyses examined relationships of dozens of individual plant species (frequency and percent cover) and wetland plant richness to soil and water salinity, relative elevation within a marsh, marsh size, risk indices, and other variables.

## Acknowledgments

A practical need for a guidebook to assess Oregon's tidal wetlands rapidly was first identified by Dr. Jon Souder, Executive Director of the Coos Watershed Association (CWA). He procured funding for the project and served as project administrator. Funding came primarily through a competitive grants program of the US Environmental Protection Agency (EPA) (Region 10, Yvonne Vallette). The project has been implemented as an independent component of the EPA's West Coast Tidal Monitoring Venture. Under the guidance of Janet Morlan, the Oregon Dept. of State Lands (Wetlands Program) provided additional assistance and coordination. Outstanding for their voluntary assistance, equipment loans, data sharing, and good advice have been the staff of South Slough National Estuarine Research Reserve (NERR) (notably Steve Rumrill, Craig Cornu, Sue Powell, and Michele Koehler), as well as Dan Bottom, Laura Brophy, Larry Caton, Gareth Ferdun, Bob Frenkel, Jim Good, Neal Hadley, Jon Hall, Roy Lowe, Neal Maine, Jim Mundell, Lori Robertson, Heather Stout, participants at the "tidal wetland experts workshop," the Tenmile Watershed Council, and the many landowners who said "yes" to our request for access permission. Also appreciated have been the contributions of John Baham, Jamie Carter, Leandra Cleveland, Greg Coffeen, Nick Coffey, Trevan Cornwell, John Christy, Adam Demarzo, Ralph Garono, Ren Jacob, David King, Pete Klingeman, Emily Kolkemo, Jennifer Larsen, Brad Livingston, Jay Lorenz, Tonya Haddad, Jennifer Taylor Hennessey, Justin Miner, Karen Nelson, Nancy Nichols, Mike Patterson, Corey Plank, Phil Quarterman, Doug Ray, Migs Scalici, Russell Scranton, Miranda Shapiro, Stan van de Wetering, and Dawn Wright.

**This document should be cited as:**
Adamus, P.R. 2005. Science Review and Data Analysis for Tidal Wetlands of the Oregon Coast. Part 2 of a Hydrogeomorphic Guidebook. Report to Coos Watershed Association, US Environmental Protection Agency, and Oregon Dept. of State Lands, Salem.

As of the publication date, this document, the supporting files of field and GIS data, and the other documents in the guidebook series may be obtained from:
www.oregonstate.edu/~adamusp/HGMtidal

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# 1.0 Introduction

This is the second part in a series of five products that together comprise the “Oregon Tidal Wetland Guidebook” series:

| | |
|---|---|
| *1. A Rapid Assessment Method for Tidal Wetlands of the Oregon Coast* | a method that may be applied during a single visit to assess indicators of the functions and condition of a particular tidal wetland relative to others of its subclass |
| *2. Science Review and Data Analysis Results for Tidal Wetlands of the Oregon Coast* | a detailed synopsis of literature and data upon which the rapid assessment method is partially based, with emphasis on research from the Pacific Northwest, including statistical analyses of new field data collected for calibrating the rapid assessment method listed above |
| *3. Wetland Profiles of Oregon’s Coastal Watersheds and Estuaries* | tabular and narrative summaries and interpretations — by watershed and estuary — of the distribution, properties, and geomorphic settings of wetlands (not just tidal wetlands) as derived from GIS analyses of available spatial data layers |
| *4. Software and Database for Selected Tidal Wetlands of the Oregon Coast* | a CD-ROM containing (a) a spreadsheet that automatically calculates scores for functions and condition, (b) a database of raw data collected from 120 tidal wetlands of the Oregon coast, (c) photographs of sites on public lands |
| *5. Revised Maps of Tidal Wetlands of the Oregon Coast* | a DVD containing refinements of the National Wetland Inventory maps, specifically: (a) increased detail in boundaries of intertidal emergent and intertidal forested wetlands based on enlarged May 2002 color infrared aerial photographs (1:24,000 original scale), field observations, and other data sources, (b) labeling of these wetlands to conform with a hydrogeomorphic classification, (c) labeling of some non-tidal wetlands as “Restoration Consideration Area” if they might have geotechnical potential for restoration of tidal circulation, (d) improved depiction of tidal creeks within some wetlands. The DVD also includes spatial data on other themes pertinent to assessing condition and function of Oregon tidal wetlands. Some of this information may also be available at: http://www.coastalatlas.net or www.coastalatlas.net/metadata/TidalWetlandsofOregonsCoastalWatersheds,Scranton,2004.htm |

The purpose of this volume is to describe and document the technical basis for key elements of the guidebook:

- the classification scheme for tidal wetlands
- the process for characterizing potential stressors and risks to wetlands
- the process for selecting reference wetlands
- the data collection protocols
- the use of particular indicators of wetland function and condition
- the manner in which the indicators are combined in scoring models
- the process for calibrating the scoring models

It also presents initial results of a statistical analysis of Oregon tidal wetland data, primarily data collected from 120 tidal wetlands during summer 2003. Those data are available on the accompanying CD and are listed and described in Appendix C.

Like the rapid assessment method itself (Part 1), this document does not cover tidal wetlands of the Columbia River estuary, eelgrass beds, backdune wetlands, and tidegated wetlands inundated less than annually by tides. It focuses primarily on documenting 12 functions of tidal emergent and forested wetlands of the Oregon coast. This volume applies to both emergent (marsh) and shrub/forested tidal wetlands. However, note that throughout the narrative, the terms "tidal marsh" and "tidal wetland" are used interchangeably to denote both forested and emergent tidal wetlands, but not tidal aquatic bed (e.g., eelgrass) wetlands, which aren't covered by this guidebook. Also note that the terms "variable" and "indicator" are used interchangeably, although there are subtle differences.

The national framework for development of regional hydrogeomorphic (HGM) guidebooks (Smith 1993, Smith et al. 1995) has four key components:

1. A small number of HGM categories (subclasses) is defined, and individual wetlands are provisionally placed in these subclasses.
2. Structural characteristics believed to be indicative of wetland integrity and function ("indicators") are assessed (measured or estimated) during a single visit to a series of wetlands representing each of the subclasses in a region. The wetlands are selected to span a range of presumed disturbance, from both natural and human sources. Assessments also use data compiled in the office using GIS, aerial photographs, and other sources.
3. Within each HGM subclass, one or more individual wetlands are identified as likely being the least altered in the region. (This step may be accomplished with or without reference to the collected data, and before or after #2).
4. All indicator data are converted to indices of wetland integrity or function, and the index values from all assessed wetlands are divided by (calibrated to, relativized to) the index values from the least-altered wetlands in the same subclass. Where appropriate, the measurements of individual indicators — not just the final index values — are first calibrated to measurements of the same indicators from the least-altered sites.

Understanding this process fully requires understanding the terms in Table 1.

## Table 1. Some key definitions

**wetland functions**: Naturally occurring physical, chemical, and biological processes.

**wetland integrity**: The ability of a wetland to support and maintain (a) dynamic hydrogeomorphic processes within the range found in wetlands that have experienced the least alteration by humans, and (b) a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that found in relatively unaltered native habitats of the region, as influenced by (and influencing) the geomorphic processes described previously. Together, these define the ability to support and maintain wetland complexity and capacity for self-organization with respect to species composition, physical and chemical characteristics, and functional processes. A wetland may be considered to have high integrity (or be in "intact" condition) when all of its natural processes and parts are functioning within their natural ranges of variation. Integrity often is used synonymously with "naturalness," although the linkage between naturalness, wetland complexity, and wetland self-organizing capacity may not be clearly apparent among some wetlands. Estimates of a wetland's integrity commonly are expressed by a single word or score.

**wetland values**: Characteristics of a wetland, its processes, or functions that are desired or considered detrimental. Includes the economic, ecological, and/or social importance or detriment assigned subjectively to a function, as determined partly by the opportunity to support the function, the effectiveness or potential of a wetland in supporting the function, and the local, regional, and national significance of the function. The latter is influenced partly by the scarcity of the function and the wetland's position in the landscape. Includes the goods and services delivered to society by a wetland.

**stressors**: Factors, processes, and their agents that potentially diminish the condition, functions, and/or sustainability of wetlands, their biological communities, and processes. Normally used to describe extreme conditions associated with anthropogenic (human-related) disturbances, such as aberrant levels or regimes of surface water or soil moisture, habitat connectivity, nutrients, sediments, organic loads, chemical contaminants, shade, temperature, acids, salts, and others. Levels that are within the range of natural variation (to which native species presumably are adapted) are instead called "natural disturbances."

**risk (to wetland integrity)**: The probability that stressors may, over the short or long term, threaten a wetland's geomorphic and/or biological integrity, primarily as related to the magnitude and duration of the stressor rather than to the intrinsic sensitivity of the wetland.

**indicators**: Variables that correspond closely with, and in some cases help determine, the relative level of a wetland function, risk, integrity, or other attribute.

**scoring models**: Decision rules, criteria, or equations by which information on variables is summarized into a score, qualitative rating, rank, index, or other representation of an attribute. Scoring models use "operators," which are symbols denoting a mathematical operation or decision rule, e.g., division, subtraction, addition.

**scaling**: The process of converting categorical or continuous numeric data (e.g., counts of large woody debris) to an ordinal range or scale (e.g., none = 0, 1–30 pieces = 0.5, >30 pieces = 1.0)

**calibration**: The process for converting numbers representing the condition of indicators and/or functions to a scale defined at the upper end by the scores of one or a few sites, e.g., the least-altered wetlands, or by each function's theoretical maximum score.

# 2.0 The Process Behind the Development of this HGM Method

## 2.1 Overview

To develop the rapid-assessment method presented in Part 1, the national HGM framework summarized above was applied to tidal wetlands of the Oregon coast. This was implemented as several integrated tasks completed over a multi-year period:

1. Prepare bibliography of literature on tidal marsh functions, emphasizing literature from the Pacific Northwest. Conduct initial review of this literature with regard to implications for classifying Oregon tidal wetlands and assessing their functions and condition.
2. In consultation with other regional wetland experts, identify no more than three regional subclasses of the national HGM wetland class, "tidal fringe," and draft criteria for recognizing these subclasses.
3. Obtain existing digitized maps of Oregon tidal wetlands, coastal hydric soils, marine habitats, and non-tidal wetlands of coastal watersheds. Obtain spatial data layers for other themes pertinent to characterizing wetlands and their functions. Overlay and compile these, providing a multi-attribute characterization of every tidal wetland on the Oregon coast, as well as all non-tidal wetlands mapped in Oregon coastal watersheds.
4. From these results, select a preliminary list of tidal wetlands for further study. Conduct a preliminary roadside reconnaissance to verify that they encompass a full range of disturbance conditions and types. Contact property owners, by mail and phone, to request access permission.
5. Continue reviewing the regional literature, identifying candidate indicators for each tidal wetland function, and for tidal wetland integrity in general. Develop protocols for assessing each indicator. Recruit regional tidal wetland experts to review the indicators and circulate a draft. Convene the experts in a workshop to discuss the indicators, ways to combine them into scoring models, and the field procedures. Revise based on workshop input.
6. Finalize landowner contacts and train field crews.
7. Visit 120 tidal wetlands, assessing the approved indicators.
8. Construct reference databases by entering and quality-checking all field and GIS data.
9. Analyze data on "risk" indicators to identify the least-altered wetland sites from among those visited.
10. Calibrate the preliminary scoring models (from #5) using the compiled field data.
11. Draft the rapid assessment method and circulate to a few experts for field-testing the clarity of its indicator descriptions.
12. Finalize the rapid assessment method and accompanying databases, spreadsheets, spatial data layers, and technical reports

Approximately 6,800 hours were required to complete this project, listed as follows by task:

| | |
|---|---|
| GIS characterizations of tidal wetlands | 1,000 |
| Site selection, preliminary reconnaissance, field crew training | 400 |
| Identifying and contacting landowners for access permission | 500 |
| Field data collection (two crews, two people per crew, 75 field days, 120 sites) | 2,400 |
| Data entry and quality assurance | 500 |
| Science review, data analysis, method and database development, report preparation | 2,000 |

The following sections describe three of the most important tasks required to develop this method: site selection (section 2.2), identification of candidate indicators (2.3), field data collection (2.4), development of scoring models (2.5), and the calibration of those indicators and models (2.6). Other statistical procedures that were used are described in section 2.7.

## 2.2 Wetland Site Selection

Our initial goal was to assess 120 tidal marshes. We call these “surveyed wetlands,” “wetland sites,” or “assessment units” rather than “reference sites” because of confusion about the latter term, which to some resource managers means only the least-altered (“benchmark”) wetlands, whereas to others it can include all wetlands sampled by a project.

The number of selected sites (120) was a number considered feasible to visit during a single field season (75 days), assuming that each of two crews could assess one site per day, and no fewer than 30 sites per subclass would be assessed. Due to the large number of variables that can influence functions within a particular HGM subclass, traditional measures for recommending sample size (e.g., species accumulation curves, cluster analyses, and statistical power analyses) are likely to recommend sample sizes (numbers of sites) far in excess of what is practical to assess. Moreover, such analyses often require the existence of large initial data sets for generating variance estimates before the site selection process can even begin.

A wetland site usually was a single tidal marsh containing one or more HGM subclasses. Tidal marshes seldom exist as discrete units in space and time. Some clearly are separated from others by rocky headlands and wide stretches of subtidal water, but others intergrade gradually, separated by narrow mudflats or roads. Most of the sites (96 of 120) were separated from other tidal wetlands by more than 100 meters. The following sites were separated by less than 100 meters: 964N and S; 1048N and S; 1545E and W; 2079 and 2094; 2148E and W; 2188 and 2195; 2932E and W; 2942E and W; 2977 and 2981; 3033E and W; 3141P and H; and 2385D, N, and S. Spatial autocorrelation in the statistical analyses is expected to be potentially the most severe for these sites.

The two most common approaches to selecting sample sites are (a) hand-picking them according to an implicit or explicit stratification or gradient such as disturbance level, HGM subclass, salinity, estuary, or region, or (b) selecting them using a spatially distributed random-sampling process, which may include a minimal amount of pre-stratification. The latter approach was not used for several reasons. First, it was not a goal of this project to make probability-based estimates of the condition or functional capacities of the tidal wetlands of Oregon’s coast. Second, the sampling units (tidal wetland polygons) are not discrete and spatially independent (in the manner of, say, watersheds or desert springs) and so their status as autonomous units subject to probabilistic sampling is diminished. Third, it frequently turns out that landowner permission for access to a large proportion of sites is not granted. Although the better statistical designs implement weighting factors that partially compensate for this, as the proportion of access denials increases sharply, the ability to make sound inferences from collected data may drop significantly (D. Stevens, Oregon State University, pers. comm.). For these reasons, the first-described approach to site selection was used.

The survey sites were selected judgmentally in an attempt to meet the following considerations:

- select at least one site in every estuary

- select an approximately equal number in each of the three tidal-fringe HGM subclasses overall, and ideally attempt to select at least one of each per estuary
- include sites whose integrity and/or functions may be at high, moderate, and low risk from restricted tidal circulation (e.g., partially diked), watershed development, excessive grazing, or other factors — this was verified during a ground-level tour of candidate sites
- achieve spatial dispersion of sites within estuaries, ideally selecting at least one site per salinity zone
- favor sites where research and/or monitoring by other projects is ongoing or completed, to allow for possible comparisons of data in the future (e.g., Oregon Sea Grant salmonid study sites; South Slough National Estuarine Research Reserve, and restoration sites of watershed groups and the US Fish and Wildlife Service or US Forest Service)
- include sites situated on every major hydric soil type that is typical of tidal wetlands of the Oregon coast
- include a variety of wetland sizes (polygon areas)

These sites were selected from a digital coverage that was custom-built for this project by an Oregon State University graduate student (Scranton 2004; see: www.coastalatlas.net or www.coastalatlas.net/metadata/TidalWetlandsofOregonsCoastalWatersheds,Scranton,2004.htm Sources of digital spatial data were:

(a) National Wetlands Inventory (NWI) maps that were based on mid-1980s imagery. We selected all polygons labeled estuarine emergent (Eem) or tidally influenced palustrine emergent, scrub-shrub, or forested (PEM, PSS, PFO with suffix of -R, -S, or -T). This defined 417 polygons.
(b) ODFW's habitat classification maps from the 1970s as described by Cortright et al. (1987). We selected all polygons labeled "tidal marsh."
(c) SSURGO soil maps, from NRCS. We selected all hydric soil polygons within 0.5 miles of tidewater. As expected, some of these polygons were later found to be non-tidal, or were tidal gravel bars rather than wetlands.

Each polygon was assigned a unique identifying number. Before doing so, the polygons originating from the first two sources, when overlapping, were unioned into a single polygon. There were 60 discrete polygons mapped by ODFW as undiked tidal marsh that were not mapped as such by the NWI. A small number of additional polygons mapped by NRCS as hydric soil were depicted as tidal wetland polygons only in tidal areas not covered by the other sources. A total of 508 discrete polygons were defined spatially. From these, a series of wetland sites were selected to fill out the categories defined by the above criteria. Although our intent was to visit 120 sites, we initially selected many more than this number from the 508 polygons in anticipation of being denied access to some sites located partially on private property.

Requests for access permission began by identifying and contacting owners of the 120 "priority sites." These persons were contacted by mail and asked to return a postcard indicating access approval, disapproval, or "more information requested." When no written response was received (and in a few instances where permission was initially denied), follow-up attempts were made to contact the landowner by phone and request permission. When access was denied, another site with similar characteristics with regard to the above criteria was substituted, its owner was identified, and contact was made by phone. Ultimately, contacts were made with 266 landowners of 203 wetland polygons, and 43% granted access permission, i.e., permission to access 87 wetland polygons on private lands (62 of which were actually visited). The remaining 58 sites are publicly owned. All contacts with private landowners were made by the Coos Watershed

Association, whose employees told landowners that data collected from wetlands on their property would not be identified geographically to the general public, i.e., no geographic coordinates or maps. Table 2 provides a breakdown of surveyed sites by estuary and HGM subclass, and Table 3 shows the percent of each estuary's tidal wetland acreage that was surveyed.

**Table 2. Surveyed wetlands summarized by estuary, HGM subclass, area, and estuarine position**

(MSH = Marine-sourced high marsh, MSL = Marine-sourced low marsh, RS = River-sourced)

| | Number of Survey Sites | | | Mean Area (acres) Assessed per Site | | | Mean Distance (mi) to Marine Waters | | | Mean Distance (mi) to Head-of-Tide | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | MSH | MSL | RS | MSH | MSL | RS | MSH | MSL | RS | MSH | MSL | RS |
| Alsea | 4 | 4 | 3 | 33.10 | 9.42 | 9.90 | 2.18 | 1.84 | 6.31 | 10.63 | 12.13 | 4.20 |
| Beaver Cr. | 0 | 0 | 1 | 0.00 | 0.00 | 58.08 | 0.00 | 0.00 | 1.31 | 0.00 | 0.00 | 0.00 |
| Chetco | 1 | 0 | 0 | 3.82 | 0.00 | 0.00 | 0.79 | 0.00 | 0.00 | 1.86 | 0.00 | 0.00 |
| Coos | 8 | 16 | 5 | 13.68 | 18.02 | 15.46 | 9.55 | 9.49 | 9.97 | 4.12 | 11.58 | 1.53 |
| Coquille | 2 | 0 | 1 | 53.06 | 0.00 | 17.32 | 1.56 | 0.00 | 18.34 | 36.31 | 0.00 | 20.02 |
| Ecola | 1 | 0 | 0 | 0.84 | 0.00 | 0.00 | 0.30 | 0.00 | 0.00 | 0.27 | 0.00 | 0.00 |
| Elk R. | 0 | 0 | 1 | 0.00 | 0.00 | 3.27 | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 |
| Greggs Cr. | 0 | 0 | 1 | 0.00 | 0.00 | 1.03 | 0.00 | 0.00 | 0.22 | 0.00 | 0.00 | 0.00 |
| Necanicum | 3 | 2 | 0 | 15.92 | 12.38 | 0.00 | 1.92 | 0.35 | 0.00 | 0.60 | 1.31 | 0.00 |
| Nehalem | 2 | 1 | 1 | 94.49 | 9.79 | 6.02 | 3.31 | 2.70 | 6.53 | 4.57 | 11.05 | 7.67 |
| Nestucca | 1 | 2 | 0 | 29.50 | 53.56 | 0.00 | 0.81 | 1.56 | 0.00 | 5.71 | 4.50 | 0.00 |
| Netarts | 2 | 1 | 0 | 76.77 | 14.52 | 0.00 | 0.00 | 0.00 | 0.00 | 0.93 | 2.95 | 0.00 |
| New R. | 0 | 0 | 1 | —- | 12.17 | —- | —- | 2.65 | —- | 0.75 | —- | —- |
| Rogue | 0 | 0 | 3 | 0.00 | 0.00 | 4.95 | 0.00 | 0.00 | 1.44 | 0.00 | 0.00 | 3.30 |
| Salmon R. | 1 | 2 | 0 | 145.38 | 54.28 | 0.00 | 0.91 | 0.65 | 0.00 | 2.95 | 3.21 | 0.00 |
| Sand Lake | 1 | 2 | 0 | 35.71 | 8.69 | 0.00 | 0.54 | 0.42 | 0.00 | 1.90 | 2.05 | 0.00 |
| Siletz | 3 | 0 | 3 | 46.50 | 0.00 | 8.11 | 2.42 | 0.00 | 5.26 | 18.85 | 0.00 | 9.58 |
| Siltcoos | 0 | 0 | 1 | 0.00 | 0.00 | 9.88 | 0.00 | 0.00 | 0.32 | 0.00 | 0.00 | 2.14 |
| Siuslaw | 1 | 6 | 1 | 26.16 | 62.40 | 0.78 | 7.20 | 5.90 | 13.05 | 8.27 | 14.49 | 8.77 |
| Tenmile | 0 | 0 | 3 | 0.00 | 0.00 | 12.47 | 0.00 | 0.00 | 0.21 | 0.00 | 0.00 | 0.50 |
| Tillamook | 2 | 4 | 1 | 64.13 | 24.06 | 3.81 | 6.34 | 5.35 | 8.05 | 5.35 | 7.71 | 0.83 |
| Twomile | 1 | 0 | 0 | 0.84 | 0.00 | 0.00 | 0.53 | 0.00 | 0.00 | 0.90 | 0.00 | 0.00 |
| Umpqua | 8 | 4 | 3 | 61.38 | 5.90 | 30.83 | 6.95 | 5.32 | 12.27 | 19.33 | 21.38 | 10.76 |
| Yaquina | 1 | 3 | 2 | 24.09 | 15.38 | 11.68 | 8.01 | 4.35 | 14.76 | 15.55 | 20.84 | 9.78 |
| TOTAL | 42 | 47 | 31 | | | | | | | | | |

**Table 3. Percent of tidal marsh assessed, by estuary**

| | All tidal wetland as % of estuary's area | Percent of estuary's tidal marsh assessed in 2003 | Acres assessed in 2003 |
|---|---|---|---|
| Alsea Bay/River | 22 | 29 | 199.77 |
| Beaver Creek | 75 | 60 | 58.08 |
| Chetco River | 3 | 60 | 3.82 |
| Coos Bay/River | 13 | 24 | 475.05 |
| Coquille River | 16 | 29 | 123.43 |
| Ecola Creek | 42 | 10 | 0.84 |
| Elk River | 18 | 18 | 3.27 |
| Euchre Creek | 20 | 16 | 1.03 |
| Necanicum Estuary | 37 | 43 | 72.52 |

|  | All tidal wetland as % of estuary's area | Percent of estuary's tidal marsh assessed in 2003 | Acres assessed in 2003 |
|---|---|---|---|
| Nehalem Bay/River | 24 | 29 | 204.79 |
| Nestucca Bay/River | 16 | 62 | 136.62 |
| Netarts Bay | 55 | 27 | 168.06 |
| New River | 41 | 6 | 12.17 |
| Rogue River | 6 | 38 | 14.84 |
| Salmon River | 68 | 43 | 253.94 |
| Sand Lake | 10 | 20 | 53.08 |
| Siletz Bay/River | 28 | 26 | 163.85 |
| Siltcoos River | 36 | 55 | 9.88 |
| Siuslaw River | 32 | 29 | 401.32 |
| Tenmile Creek | 59 | 44 | 37.42 |
| Tillamook Bay | 12 | 20 | 228.3 |
| Twomile Creek | 34 | 13 | 0.84 |
| Umpqua River | 16 | 39 | 607.09 |
| Winchuck | 3 | 0 | 0 |
| Yaquina Bay/River | 18 | 10 | 93.57 |

## 2.3 Selection of Indicators of Functions

For this project, the indicator selection and model development process began with a review of indicators used by other tidal wetland assessment methods (Appendix A), particularly the national estuarine fringe models proposed by Shafer and Yozzo (1998). It quickly became apparent that, while those indicators and models seemed conceptually sound, their appropriateness for the Pacific Northwest and for different types of tidal wetlands (marine-sourced high, marine-sourced low, river-sourced tidal) was not optimal. Questions also were raised about their sensitivity (i.e., would the indicators and models be able to distinguish between moderately and slightly altered wetlands?), the repeatability of assessments using some of their indicators (e.g., surface roughness), and the relevance to Oregon tidal wetlands of some functions (e.g., storm surge attenuation) and rating scales (e.g., effective patch size). In response, we identified and reviewed regional literature, and proposed some additional indicators and model formulations during a peer review workshop of about 20 estuarine scientists from the Pacific Northwest. Subsequent field work assessed those indicator variables. Others were derived from other types of field data we collected. Final versions of the scoring models for the 12 wetland functions, wetland risk, and wetland integrity together use 55 indicators. Indicators of functions that describe features outside a wetland were included only if they directly benefit something that is characteristic of the wetland. For example, the diversity of plants found in the upland buffer zone adjoining a wetland might not be an appropriate indicator of the wetland's capacity to support a diversity of characteristically wetland plant species. It might, however, be a useful indicator of risk to the wetland, e.g., if low diversity was due to something that could similarly affect wetland plants.

## 2.4 Field Procedures

After initial training, two two-person crews collected the field data, one crew assessing wetlands mostly from the Umpqua estuary southward and the other assessing wetlands mostly to the north. During 5–10 days of the 15-week field season, one of the persons in each crew switched crews to help increase standardization in the application of the peer-reviewed data collection protocols.

Also, several volunteers joined the field crews at various times (generally for just 1 day) and assisted with data recording while learning about field techniques. By intent, data were collected on many more variables than ultimately were used in the scoring models. All field data collected, plus data compiled from existing sources using GIS, are contained in the accompanying DVD, except (as noted above) the geographic identifiers of private lands.

*Quantitative Procedures*

At each site, field crews collected data from the time of daily low to daily high tide (~ 6 hours), or vice versa. At each site, field data were collected primarily along two types of transects: **marsh** transects and **channel** transects (Figure 1 in Part 1). A minimum of two **marsh transects** were surveyed at each site. Most marsh transects were perpendicular to the adjoining bay or river. They began at the edge between the vegetated wetland and non-wetland intertidal or subtidal habitats (e.g., mud flat), and proceeded on a beeline until coming within a few meters of the wetland-upland edge. The lower vegetated wetland edge generally began at or near the elevation of mean daily low tide.

Five **channel transects** also were surveyed at most sites, generally along the marsh's largest accessible internal channel. All were cross-sectional transects oriented perpendicular to the channel. One began at the channel's lowest wadeable point (i.e., closest to the adjoining bay or river) and the four others were situated progressively up the same internal channel, at locations where channel morphological changes seemed most pronounced, and spread across the variety of channel orders. The two-plus marsh transects were located on opposite sides of the internal channel, in a manner so as to avoid intersecting the channel transects, and usually no more than about 400m apart. Technically, the unvegetated channels themselves are not jurisdictional wetlands because they mostly lack hydrophytic vegetation. However, tidal channels are an integral component of tidal marshes. Depending on the site and its topography, they may or may not contain surface water at daily low tide. The lowest parts of the marsh and channel transects were visited at low tide. Sites were accessed by foot (often requiring "mudders"), canoe, inflatable raft, motorboat, or hovercraft.

Relative percent cover of plant species was assessed in 1 x 1m square plots (quadrats). At most sites, a minimum of 10 quadrats were situated equidistantly along each of the two transects, for a total of at least 20 per site. Among all sites visited, the median number of quadrats per site was 21 (range 4–40), for a total of 2,576 among all sites. Spacing between quadrats averaged 11.75m (range 2 to 67m). In narrow marshes where positioning of the marsh transects and their quadrats would have resulted in placement of quadrats within 2 meters or less of each other, the orientation of the marsh transects was changed from perpendicular to oblique, and/or more than two transects were used but their length was shortened. More than two transects (and more quadrats) also were used to cover some very large marshes. When a transect intercepted predominantly bare areas (<80% vegetative cover), the spacing of the requisite 10 quadrats was adjusted to avoid the bare areas, the transect was realigned, or additional quadrats containing vegetation were assessed. In addition to assessing vegetation in the quadrats, crew members often made a note of small channels, dikes, and pannes when these were crossed by a transect. They also noted obvious changes in predominating plant species (i.e., vegetation zones) that occurred between quadrats and at the upland end of each transect. However, the recording of vegetation transitions and the other features was not comprehensive, and percent cover was estimated only within the quadrats. Plant communities in some quadrats that intercepted high spots in the marsh may be comprised largely of upland species, but generally upland areas were avoided. Transect-based sampling was used rather than random plot-based sampling because of (a) the need to ensure that elevational gradients and consequent vegetation composition shifts were adequately encompassed, and (b) the number of random quadrats required for statistical significance, and the time required to locate them, likely would have exceeded the time available onsite. A strategy of selecting "representative" quadrats also was avoided, due to the inherent biases and often low repeatability of that strategy.

A laser level (surveyor's transit, Topcon™ RL-H3A) with two stadia rods with sensors was used to measure relative elevation of all quadrats, inter-plot features (pannes, channels, vegetation transitions), and up to seven geomorphic features along each channel transect (channel bottom, right and left vegetated channel edge, right and left bank top, right and left marsh plain). Along the channel transects, the marsh plain elevations were measured consistently at 15m from the channel center. With a digital camera, field crews also photographed the upstream and downstream views from each channel transect and the starting and ending points of each marsh transect. A handheld GPS unit (Garmin Rino™ 120), with a precision of no more than about 50 ft, was used to obtain geographic coordinates at both ends of each marsh transect and at one end of each channel transect.

For measuring relative elevations, the laser level was placed at a point, generally near the middle of the marsh, from which both the upland boundary and the mouth of the major internal channel were simultaneously visible. At a few sites it was necessary to move and recalibrate the laser level at least once to obtain elevations of all points. The vertical precision of the laser level readings is estimated at ±1cm, and degrades somewhat when readings are taken at distances of farther than about 200m (especially at mid-day when heat shimmer is greatest). Before leaving a site, crews attempted to use the laser level to survey to an established USGS, ODOT, or other benchmark of known absolute elevation. Locations of such benchmarks were obtained from http://www.ngs.noaa.gov/ims/NgsMap2/viewer.htm , or benchmarks were discovered by searching for them at likely postings, e.g., nearby bridge abutments. Unfortunately, very few of the reported benchmarks could be found (owing to their destruction over the years or poor locational description) or were too distant from our sites (>0.5 mile) to be worth the enormous time required to survey to them. Moreover, confirmed elevations could not be found for some benchmarks, and for some the elevational datums upon which they were based could not be determined easily. We dealt with the absence of readily accessible, permanent benchmarks by establishing a temporary benchmark, to which all our elevations were tied, along a road or other easily accessible point near each marsh. We described and photographed its location in case resources will be available in the future to survey it to a distant permanent benchmark, or to use a "total station" survey unit to establish its absolute elevation. Ultimately, because of the severe limitations noted above and because of a need to allow at least some crude comparisons among sites, we chose to standardize all elevation readings to two scales: (1) the lowest point among a site's marsh transects (for marsh plain data) or among a site's channel transects (for channel data); this was abbreviated *RelElev* in our database, and (2) the lowest *vegetated* point in each of these contexts; this was abbreviated *RelVelev* in our database.

Plant community composition but not percent cover was noted at each of the seven points along each of a site's five channel transects. Also, at intermediate points along each channel transect, crews noted — and measured elevations of — pannes, smaller channels, and major shifts in plant communities. Crews also recorded the plant species that predominated along channel banks between the channel transects. Emergent and woody vascular plants were identified to species whenever possible. However, this project was not intended to comprehensively inventory all plants at each site, or to search specifically for invasive species. Field activities focused on identifying mainly the predominant intertidal species in each quadrat and channel cross-section point. Submerged aquatic plants that extend into the subtidal zone (e.g., *Zostera* spp., seaweeds) were reported erratically. The following species identifications are among those believed to have been the least consistent, in some cases due to hybridization or disagreements among taxonomic authorities. Nonetheless, the vast majority of the records labeled to the named species are believed to be accurate: *Schoenoplectus acutus* vs. *S. tabernaemontanii* (one or both present in 2% of quadrats); *Agrostis stolonifera (alba)* vs. *A. capillaris (tenuis)*, *A. gigantea*, and *A. exarata* (9%); *Carex lyngbyei* vs. *C. obnupta* (12%); *Juncus balticus* vs. *J. gerardii* (6%); *Hordeum brachyantherum* vs. *H. jubatum* (2%); *Grindelia stricta* vs. *G. integrifolia* (10%); *Triglochin maritimum* vs. *T. coccinum* (5%); *Spergularia salina (marina)* vs. *S. macrotheca* and *S. canadensis* (1%); *Galium triflorum* vs. *G. trifidum*, and *Ammophila arenaria* vs. *Elymus mollis* (1%). For the specified purpose of assessing wetland *functions*, the implications of these particular omissions or misidentifications are expected to be minor. Also, some species that emerge earlier or later in the growing season might not have been detected because each marsh was visited only once. To roughly portray the relative intensity of spatial coverage of each site, we divided the summed transect lengths by the square root of the wetland assessment area.

The upland border of a marsh was defined, in theory, as the line of maximum *annual* incursion of tidal water. Difficulty often was encountered in locating this, and consequently our data include some species and areas that may not typify tidal marshes. The tidal water intrusion maximum varies from year to year depending on weather events and, consequently, river outflow. Near head of tide, the usual indicators of previous high water (wrack lines, drift logs, etc.) do not necessarily indicate the source of flooding (spring tides or river discharge), thus limiting their usefulness in distinguishing tidal from non-tidal marshes. A break in slope or transition from herbaceous to woody vegetation does not automatically signify the upland boundary because, especially near the head of tide, many tidal marshes merge gradually into non-tidal emergent marsh or to woody vegetation due to minimal or infrequently elevated salinity.

At each site, water surface salinity was measured with a handheld refractometer at low and high tide from at least three points: in the adjoining bay or river, at the first channel cross-section, and near the farthest upgradient point in the internal channel network that contained surface water at low tide. At sites with salinity less than about 1–2 ppt, the specific conductance was measured rather than the salinity. Precision is estimated at ±1 ppt for salinity. Salinity also was measured in soil samples; at least three points in each marsh were chosen to represent the marsh's three dominant plant communities. Soil in the upper few inches was extracted with a corer, compressed, and its water squeezed through a coffee filter before being measured with the refractometer. Attempts to extract water from samples from all three of the major plant communities were unsuccessful at some marshes due to their sandy or compacted texture and/or drought conditions. Panne surface water salinity also was occasionally measured. The times of all field sampling were recorded and referenced to times and projected tidal heights for that date as published in tide tables.

### *Qualitative Procedures*

Even if they had been situated probabilistically, the two marsh transects and five channel cross-sections would have been insufficient, in either a statistical or logical sense, for portraying conditions for the marsh as a whole. To provide that perspective, overall vegetative cover, the extent of each HGM subclass, and many other indicators pertinent to assessing disturbance, condition, or function were estimated visually and qualitatively over the entire marsh during the site visit. These are shown in the "Mesoscale" data form (Appendix B).

## 2.5 Formulation of Scoring Models for Risk, Wetland Integrity, and Functions

The summer's experience using the above procedures to assess the indicators in 120 tidal wetlands produced many insights regarding which ones might need adjustment or shouldn't be included at all in the final models, e.g., because their variability among wetlands was too small (making them insensitive) or too great (due to within-site spatial and tidal variation, or variability among crews assessing them). Some of the originally proposed indicators were substituted with ones measured from topographic maps or airphotos after the field work was completed. Data entry and quality checking of all data required a very substantial time component. Attention then shifted to finishing the formulations of the scoring models. The new indicators resulting from the 2003 field season were substituted or otherwise incorporated into the draft models that had been peer reviewed in the May 2003 workshop. In a few instances, new indicators were added to the original models based on literature published post-2003 in professional journals.

Final scoring models for the wetland functions are presented in section 3.4.3 and a rationale is given for each. Scoring models ultimately were developed to represent not only wetland functions, but also ***risks*** to wetland integrity. This is necessary because one objective of wetland rapid-assessment methods is to estimate the degree to which a wetland has become degraded, i.e., what is the wetland's condition or biological integrity? Degradation can be inferred from the type and relative dominance of different plants and animals ("bioindicators") in a wetland, as well as from the condition of geomorphic indicators ("geoindicators"). Alternatively, or in addition, degradation sometimes can be *inferred* from the presence of factors that are known (from research elsewhere) to potentially pose a risk to wetland plants, animals, and/or functions. When directly or indirectly associated with humans, such factors are sometimes called "stressors." A variety of approaches for describing stressors to wetlands have been tried in other regions (e.g., www.uri.edu/ce/wq/mtp/html/risk_indicators.pdf ). These can be categorized as **landscape** approaches (e.g., Detenbeck et al. 2000), **BPJ** (best professional judgment) approaches, and **measurement-and-modeling** approaches.

Landscape approaches focus mainly on the proximity of the wetland to various types of land cover, e.g., as measured using GIS to determine percentages of various land cover types within concentric "buffer" rings extending progressively outward from a wetland perimeter (Jones et al. 2000). In stream or non-tidal wetland studies, this approach has generated significant correlations between altered land cover and altered wetland structure, for example, in Florida, Pennsylvania, the Great Lakes (Crosbie and Chow-Fraser 1999), and Oregon (Yandong et al. 2004). In tidal systems specifically, the landscape approach has uncovered significant correlations in some instances between representations of land cover and contamination (Paul et al. 2002) and/or altered biological communities (Wigand et al. 2001, DeLuca et al. 2004). However, in other tidal systems some researchers have failed to find such correlations (Oviatt et al. 1977, Pennings et al. 2002) or found somewhat equivocal ones (Carlisle et al. 1998, Wilcox et al. 2002). One would expect ambiguity in regions where land cover in wetland watersheds is relatively intact, and/or in situations where the most obvious losses to wetland functions have resulted from diking and other alterations that occurred or are occurring within, rather than adjoining, the wetlands. In many ways that describes coastal Oregon.

At least four issues must be addressed when using a landscape approach to accurately predict wetland biological and geomorphic condition. First, the results depend on how "land cover" is defined. For example, before performing correlations, is it better to (a) create separate variables for residential, commercial, and industrial land cover types, (b) lump them into a single "developed land" variable, or (c) ignore existing land-cover classifications and measure impervious surface instead? Statistically, does it matter, and if so, when? Which expression of land cover is theoretically most pertinent to species, communities, and functions expected to occur within a particular region and wetland type? Second, how much additional "weight" should be assigned to closer land-cover types, as opposed to ones farther away but which may be more detrimental? At what distance is the correlation between land-cover composition and wetland condition maximized? Should more weight be given to particular land-cover types if they exist on steep slopes and/or erodible soils? Third, information on many important stressors, such as chemical contamination, often cannot be obtained from interpreting aerial photographs or using existing spatial data layers. The local magnitude of these stressors cannot automatically be assumed to be represented well by land-cover categories. Fourth, landscape approaches almost always have focused entirely on present-day land-cover conditions. However, disturbances that occurred years if not decades ago might now be having an equal or greater effect than present-day disturbances in shaping some wetland functions and condition. Estimating whether a wetland has "recovered" or is "recovering" from such historic disruptions is nearly impossible when based only on single-visit observations.

**The BPJ approach** also must address some of these same issues, but attempts to do so without the aura of seeming objectivity and precision sometimes imparted by the landscape approach's use of GIS. Because the BPJ approach is not limited to variables determinable using only aerial imagery, it may allow greater flexibility in considering "special circumstances" such as historical activities at a site, contaminant point sources, and hydrologic disrupters (e.g., dams, dikes) whose effects on wetlands are typically much greater than suggested merely by the space they occupy in the landscape. For assessing risk of wetland exposure to stressors, the BPJ approach is used commonly, especially when developing rapid, HGM-based methods (e.g., Hruby et al. 1999, Hruby 2001).

The third approach to wetland risk assessment — **measurement-and-modeling** — features the development and calibration of mathematical models that are intended to mechanistically relate stressors to food-web impacts in a causal and predictive manner. Such an approach currently is being implemented for Oregon estuaries by the USEPA through its research laboratory in Newport (P. Eldridge, J. Compton, and others). Once developed and validated, those models could be very useful, at least for assessing risks of estuarine overenrichment and of other chemical stressors.

In this HGM method, two landscape-scale variables are used as presumed indicators of wetland risk (*BuffAlt, BuffCov*). Additional risk indicators included in this HGM method were derived mainly from observations (the BPJ approach) made during the field visits. The measurement-and-modeling approach was not used. By employing both landscape-scale and BPJ approaches, the risk to each of the 120 surveyed wetlands was scored in three separate but partially interdependent ways.

In the first approach, a standardized checklist was drafted of 26 observable stressors thought to influence Oregon tidal wetlands, or to have influenced them historically. Field crews assigned each potential stressor a "0" (not present), "1" (minor presence), or "2" (extensive presence). Further, field crews assigned these ratings for two spatial domains (within the wetland and/or offsite but within 100 ft of the wetland perimeter) and for two temporal periods (within the past 5 years and/or more than 5 years ago but likely to still be affecting some wetland functions). Field crews used BPJ to assign these ratings initially, but some ratings were adjusted when follow-up review of published literature, airphotos (1930s and present), and/or interviews with knowledgeable local citizens suggested a need for adjustment. Adjustment was particularly needed in ratings assigned for historically occurring stressors. Historical review of wetlands that appear to be in near-pristine condition sometimes challenges that assumption (e.g., Hennessey 2005). Due to a paucity of information, the ratings of historical stressors were probably the least reliable. Resulting data are shown in Volume 3 Table 2 of this guidebook. After the data had been entered, the list's 26 potential stressors were aggregated thematically into five groups as shown in Table 4 below.

**Table 4. Aggregation of potential stressors into thematic groups**

| Group | Potential Stressors (mostly from Field Form D) |
|---|---|
| Hydro Risk | Dikes |
| | Ditches/excavation |
| | Road, paved |
| | Weir/dam |
| Sediment Risk | ATV use |
| | Bulldozing |
| | Dredging |
| | Eroding upland |
| | Fill (other than dike) |
| | Log dumping |
| | Logging, clearcut |
| | Logging, other major |
| | Riprap |
| | Road, dirt |
| | Utility, underground |
| Nutrient Risk | Feedlot/manure spreading/daily |
| | Golf course |
| | Lawn |
| | Residence w. septic |
| | Garden/tillage |
| Chemical Risk | Industrial facility (including sewage treatment) |
| | Outfall pipes |
| Vegetation Risk | Grazing |
| | Haying |
| | Mowing |
| | Utilities, overhead |

In ways described later in section 3.4.3, this information was combined to create a series of risk indices, each scored on a scale of 0 to 1.

In a second approach, the above information was used to draft simpler indicators, (#1-13 in the final HGM data form provided in Part 1) with similar themes, and some additional indicators were added (some of them shown in Table 5). This was done because the above protocol was considered too intensive to include in the final HGM method. Each of these derived or new indicators was scored on a scale ranging from 0 to 1.

Finally, in a third approach the surveyed sites were categorized simply as "least altered" or not, and "less altered" or not, i.e., with two binary scales, each allowing only scores of 0 *or* 1. "Least altered" wetlands were prejudged, based on risk factors, to be the least likely to have sustained lasting damage from human activities. "Less altered" wetlands were prejudged to have experienced potentially somewhat more (but still minimal) disturbance from humans.

It is critical to note that, for reasons explained later in section 3.4.1, the prevalence of non-native plant cover or other direct signs of biological degradation was *not* used to categorize a site as less- or least-altered.

**Table 5. Some of the indicators of wetland exposure to human presence that were used to assess the 120 surveyed sites**

Road contact score = 0 (none) to 2 (extensive)

Boat traffic score = 0 (none) to 6 (much). Calculated by scoring 0 (absent) or 1 (present) in each of the following categories, then assigning weights and summing the scores:

ship traffic (frequent/close); weight = 4
ship traffic (infrequent/distant) weight = 3
small-boat traffic (frequent/close) weight = 2
small-boat traffic (infrequent/distant) weight = 1

Visitation score = 100 (minimal) to 220 (extensive and frequent). Calculated by estimating the percents of the site that are visited by people on foot daily, moderately, or rarely (<10 days/yr). Each of the percents is multiplied by a weighting factor (3, 2.1, respectively) and then summed.

| Site | Distance (ft) to Nearest Building | Road Contact Score | Boat Traffic Score | Visitation Score |
|---|---|---|---|---|
| 222 | 200 | 0 | 1 | 120 |
| 307 | 1000 | 2 | 0 | 150 |
| 380 | 500 | 0 | 2 | 100 |
| 388 | 800 | 0 | 2 | 150 |
| 405 | 500 | 2 | 2 | 130 |
| 488 | 300 | 1 | 2 | 150 |
| 542 | 2300 | 0 | 2 | 101 |
| 543 | 1000 | 1 | 2 | 101 |
| 610 | 2000 | 2 | 5 | 101 |
| 620 | 1400 | 2 | 5 | 101 |
| 675 | 1600 | 0 | 1 | 101 |
| 692 | 100 | 1 | 2 | 111 |
| 761 | 300 | 0 | 2 | 210 |
| 767 | 100 | 1 | 2 | 182 |
| 773 | 100 | 1 | 2 | 220 |
| 787 | 200 | 0 | 1 | 120 |
| 791 | 300 | 1 | 1 | 110 |
| 832 | 100 | 1 | 1 | 200 |
| 865 | 200 | 0 | 2 | 100 |
| 869N | 500 | 0 | 2 | 110 |

| Site | Distance (ft) to Nearest Building | Road Contact Score | Boat Traffic Score | Visitation Score |
|---|---|---|---|---|
| 883 | 4000 | 0 | 2 | 101 |
| 889 | 2000 | 1 | 2 | 100 |
| 938 | >5000 | 0 | 2 | 101 |
| 941 | 3300 | 0 | 2 | 195 |
| 964E | 300 | 0 | 2 | 101 |
| 964N | >5000 | 0 | 2 | 110 |
| 964S | >5000 | 0 | 2 | 110 |
| 965 | 3300 | 2 | 2 | 105 |
| 980 | 100 | 2 | 2 | 110 |
| 1048N | 2000 | 0 | 2 | 100 |
| 1048S | 2000 | 0 | 2 | 100 |
| 1129 | 1000 | 1 | 2 | 107 |
| 1172 | 1100 | 1 | 1 | 120 |
| 1182 | 500 | 1 | 2 | 117 |
| 1188 | >5000 | 0 | 1 | 200 |
| 1236 | 4000 | 0 | 2 | 110 |
| 1240N | 400 | 1 | 2 | 100 |
| 1240W | 2000 | 0 | 2 | 110 |
| 1403 | 20 | 2 | 2 | 225 |
| 1410 | 800 | 2 | 2 | 105 |
| 1462 | 200 | 2 | 1 | 101 |
| 1465 | 4000 | 0 | 2 | 100 |
| 1474L | 2000 | 0 | 2 | 100 |
| 1474U | 2500 | 0 | 2 | 110 |
| 1494 | 200 | 1 | 2 | 101 |
| 1532 | >5000 | 0 | 2 | 125 |
| 1545E | 100 | 2 | 2 | 210 |
| 1545W | 100 | 2 | 2 | 205 |
| 1723 | >5000 | 0 | 1 | 105 |
| 2079 | >5000 | 0 | 5 | 100 |
| 2089 | 200 | 1 | 4 | 101 |
| 2094 | >5000 | 0 | 5 | 155 |
| 2105 | 1000 | 0 | 5 | 100 |
| 2146 | 1300 | 2 | 5 | 120 |
| 2148E | 500 | 0 | 5 | 120 |
| 2148W | 800 | 0 | 3 | 160 |
| 2149 | >5000 | 0 | 5 | 115 |
| 2152 | >5000 | 0 | 5 | 105 |
| 2157 | 800 | 0 | 5 | 101 |
| 2158 | >5000 | 0 | 5 | 105 |
| 2188 | >5000 | 0 | 5 | 100 |
| 2195 | >5000 | 0 | 5 | 100 |
| 2203 | 4600 | 2 | 5 | 101 |
| 2238 | 100 | 2 | 5 | 180 |
| 2263 | 1000 | 2 | 5 | 120 |
| 2385D | >5000 | 0 | 0 | 100 |
| 2385N | >5000 | 0 | 0 | 120 |
| 2385S | >5000 | 0 | 0 | 100 |
| 2536 | 200 | 2 | 5 | 110 |
| 2731 | 200 | 1 | 6 | 106 |
| 2739 | 1000 | 0 | 6 | 240 |
| 2766 | 1000 | 0 | 6 | 210 |

| Site | Distance (ft) to Nearest Building | Road Contact Score | Boat Traffic Score | Visitation Score |
|---|---|---|---|---|
| 2771 | 1000 | 0 | 5 | 140 |
| 2772 | 100 | 2 | 5 | 170 |
| 2783 | 1000 | 1 | 4 | 110 |
| 2787 | >5000 | 0 | 4 | 100 |
| 2792 | >5000 | 0 | 6 | 100 |
| 2801 | >5000 | 0 | 6 | 101 |
| 2829 | 300 | 1 | 6 | 100 |
| 2838 | 2000 | 0 | 6 | 196 |
| 2904 | 200 | 1 | 5 | 110 |
| 2932E | 400 | 0 | 1 | 101 |
| 2932W | 400 | 0 | 2 | 102 |
| 2935 | 300 | 0 | 2 | 110 |
| 2938 | 1300 | 0 | 2 | 105 |
| 2940I | >5000 | 0 | 2 | 100 |
| 2942E | 200 | 0 | 2 | 100 |
| 2942W | 2000 | 1 | 1 | 101 |
| 2950 | 100 | 1 | 6 | 112 |
| 2963 | 200 | 1 | 5 | 110 |
| 2964 | 200 | 0 | 5 | 101 |
| 2973 | 1000 | 1 | 1 | 101 |
| 2976 | 200 | 1 | 2 | 110 |
| 2977 | 100 | 2 | 2 | 205 |
| 2980 | >5000 | 0 | 2 | 100 |
| 2981 | 1200 | 0 | 2 | 100 |
| 2987N | 200 | 0 | 2 | 105 |
| 2987S | >5000 | 0 | 1 | 100 |
| 2987I | >5000 | 0 | 2 | 101 |
| 2994 | 200 | 1 | 5 | 101 |
| 3033E | 200 | 2 | 4 | 105 |
| 3033W | 200 | 2 | 5 | 110 |
| 3060 | >5000 | 0 | 5 | 100 |
| 3070 | >5000 | 0 | 4 | 100 |
| 3086 | >5000 | 0 | 5 | 102 |
| 3103 | >5000 | 0 | 4 | 100 |
| 3113 | >5000 | 0 | 5 | 101 |
| 3128E | 300 | 2 | 5 | 200 |
| 3128N | 1000 | 2 | 4 | 100 |
| 3140 | >5000 | 0 | 4 | 105 |
| 3141H | >5000 | 0 | 4 | 107 |
| 3141P | >5000 | 0 | 5 | 100 |
| 3145 | >5000 | 0 | 5 | 101 |
| 3149 | >5000 | 0 | 4 | 120 |
| 3154 | >5000 | 0 | 6 | 170 |
| 3170 | 200 | 1 | 1 | 200 |
| 3250 | 200 | 2 | 1 | 200 |
| 3425 | 500 | 2 | 2 | 107 |
| 3451 | >5000 | 0 | 2 | 190 |
| 3729 | >5000 | 0 | 0 | 100 |
| 3944 | >5000 | 0 | 0 | 100 |

## Table 6. Surveyed sites categorized as least- or less-altered

Function scoring models were calibrated against data from least-altered sites only. A few indicators with continuous numeric data were calibrated using both the less-altered and least-altered data, due to larger number of replicates needed for regression.

| Estuary | ID # | Assigned Site Name | Predominant HGM Subclass* | Acres Assessed | Type of Reference |
|---|---|---|---|---|---|
| Alsea Bay/River | 1410 | Alsea Eckman | MSL | 19.89 | Less altered |
| Alsea Bay/River | 2976 | Alsea South | MSL | 8.86 | Less altered |
| Alsea Bay/River | 2980 | Alsea Drift Cr. | RS | 16.22 | LEAST altered |
| Alsea Bay/River | 2987I | Alsea Islands | MSH | 121.8 | LEAST altered |
| Alsea Bay/River | 2987N | (private) | MSH | 1.1 | Less altered |
| Alsea Bay/River | 2987S | Alsea north shore | MSH | 8.43 | Less altered |
| Alsea Bay/River | 675 | (private) | RS | 10.21 | LEAST altered |
| Beaver Creek | 2973 | Beaver Creek | RS | 58.08 | Less altered |
| Coos Bay/River | 2536 | North Inlet | MSH | 52.52 | Less altered |
| Coos Bay/River | 2739 | North Spit N | MSL | 3.8 | Less altered |
| Coos Bay/River | 2766 | North Spit C | MSL | 0.4 | Less altered |
| Coos Bay/River | 2771 | North Spit S | MSL | 2.82 | Less altered |
| Coos Bay/River | 2792 | Cooston Island | MSL | 132.59 | LEAST altered |
| Coos Bay/River | 3033E | (private) | MSL | 16.01 | Less altered |
| Coos Bay/River | 3033W | (private) | MSH | 11.24 | Less altered |
| Coos Bay/River | 3060 | Valino Island | MSH | 2.09 | Less altered |
| Coos Bay/River | 3070 | Rhodes | MSL | 7.09 | Less altered |
| Coos Bay/River | 3103 | Eliot Creek | RS | 17.52 | Less altered |
| Coos Bay/River | 3113 | Hidden Creek S | MSH | 10.02 | LEAST altered |
| Coos Bay/River | 3128N | (private) | MSH | 17.06 | Less altered |
| Coos Bay/River | 3145 | Wasson-Fredrickson | MSH | 11.91 | Less altered |
| Coos Bay/River | 3154 | Anderson Cr. tidal | RS | 16.3 | Less altered |
| Coquille River | 3425 | Bandon NWR | MSH | 94.32 | LEAST altered |
| Ecola | 832 | Elk Creek | MSH | 0.84 | Less altered |
| Elk River | 222 | (private) | RS | 3.27 | Less altered |
| Necanicum Estuary | 761 | Sandbar | MSL | 5.71 | Less altered |
| Necanicum Estuary | 773 | High School | MSH | 7.39 | Less altered |
| Necanicum Estuary | 787 | Neawanna | MSH | 33.09 | Less altered |
| Nehalem Bay/River | 865 | Nehalem Island | RS | 6.02 | LEAST altered |
| Nehalem Bay/River | 883 | West Island | MSH | 183.36 | LEAST altered |
| Nehalem Bay/River | 889 | (private) | MSL | 9.79 | Less altered |
| Nestucca Bay/River | 1236 | Straub | MSH | 29.5 | LEAST altered |
| Nestucca Bay/River | 1240N | Nestucca FWS north | MSL | 68.37 | Less altered |
| Nestucca Bay/River | 1240W | Nestucca FWS south | MSL | 38.75 | Less altered |
| Netarts Bay | 1048N | Netarts North | MSL | 14.52 | LEAST altered |
| Netarts Bay | 1048S | Netarts South | MSH | 52.22 | Less altered |
| Netarts Bay | 1129 | Netarts Jackson | MSH | 101.32 | Less altered |
| New River | 3944 | New River | RS |  | LEAST altered |
| Rogue River | 380 | Rogue Island | RS | 10.11 | Less altered |
| Salmon River | 2932E | Ymarsh East | MSH | 145.38 | LEAST altered |
| Salmon River | 2932W | Ymarsh West | MSL | 44.53 | Less altered |
| Salmon River | 2935 | Mitchell Marsh | MSL | 64.03 | Less altered |
| Sand Lake | 1172 | Sandlake Beach | MSL | 9.42 | Less altered |
| Sand Lake | 1182 | Whalen | MSH | 35.71 | Less altered |
| Sand Lake | 1188 | Sandlake Islands | MSL | 7.95 | Less altered |
| Siletz Bay/River | 2940I | Siletz Island | MSH | 10.02 | Less altered |

| Estuary | ID # | Assigned Site Name | Predominant HGM Subclass* | Acres Assessed | Type of Reference |
|---|---|---|---|---|---|
| Siletz Bay/River | 2942E | Millport East | MSH | 75.74 | LEAST altered |
| Siletz Bay/River | 2942W | Millport West | MSH | 53.75 | Less altered |
| Siletz Bay/River | 543 | (private) | RS | 0.35 | LEAST altered |
| Siltcoos River | 1723 | Siltcoos | RS | 9.88 | Less altered |
| Siuslaw River | 1465 | Siuslaw swamp | RS | 0.78 | LEAST altered |
| Siuslaw River | 1474L | (private) | MSL | 99.01 | Less altered |
| Siuslaw River | 1474U | (private) | MSL | 36.92 | Less altered |
| Siuslaw River | 1494 | (private) | MSH | 26.16 | LEAST altered |
| Siuslaw River | 1532 | Cox Island | MSL | 171.78 | LEAST altered |
| Tenmile Creek | 2385N | Tenmile North | RS | 13.42 | Less altered |
| Tillamook Bay | 938 | Bayocean North | MSL | 2.74 | LEAST altered |
| Tillamook Bay | 941 | Bayocean South | MSL | 9.22 | Less altered |
| Tillamook Bay | 964N | (private) | MSL | 79.15 | Less altered |
| Tillamook Bay | 964S | (private) | MSH | 120.19 | Less altered |
| Tillamook Bay | 965 | (private) | MSH | 8.07 | Less altered |
| Tillamook Bay | 980 | (private) | MSL | 5.12 | Less altered |
| Twomile Creek | 3729 | Twomile | MSH | 0.84 | Less altered |
| Umpqua River | 2079 | Steamboat Island | MSH | 300.21 | Less altered |
| Umpqua River | 2094 | Umpqua Dunes C | MSL | 3.46 | Less altered |
| Umpqua River | 2105 | Umpqua Dunes N | MSL | 9.69 | Less altered |
| Umpqua River | 2148E | (private) | RS | 21.01 | Less altered |
| Umpqua River | 2148W | (private) | MSH | 132.98 | LEAST altered |
| Umpqua River | 2149 | East Gardiner | MSH | 12.19 | Less altered |
| Umpqua River | 2152 | Blacks Island | MSH | 39.57 | LEAST altered |
| Umpqua River | 2157 | (private) | MSL | 9.24 | Less altered |
| Umpqua River | 2158 | Umpqua Dunes S | MSH | 4.06 | Less altered |
| Umpqua River | 2188 | (private) | MSH | 1.17 | LEAST altered |
| Umpqua River | 2195 | (private) | MSL | 1.21 | LEAST altered |
| Yaquina Bay/River | 2963 | (private) | MSL | 14.17 | Less altered |
| Yaquina Bay/River | 2964 | (private) | MSL | 24.8 | LEAST altered |
| Yaquina Bay/River | 2994 | Yaquina Point | MSH | 24.09 | LEAST altered |
| Yaquina Bay/River | 620 | (private) | RS | 7.72 | LEAST altered |

*MSH = marine-sourced high marsh; MSL = marine-sourced low marsh; RS = river-sourced

## 2.6 Calibration of the Function Scoring Models

Estimates of various indicators typically have disparate scales, e.g., one indicator expressed in units of feet, another as number of species, another as a percent. If these indicators are to be combined mathematically in scoring models that represent function capacity, their units first must be standardized to a common scale, i.e., "scaled." With the HGM Approach, an ordinal 0-to-1 scale is recommended for scaling each indicator (Smith et al. 1995), with the low end of the scale (depending on the indicator) usually representing an indicator condition that is least likely to support the associated function and/or least likely to be found in the least-altered sites. Also, calibration can involve anchoring the scores of individual *indicators* to scores for those indicators at surveyed sites, scores of individual *functions* to scores for those functions at surveyed sites, or both. For this particular HGM method, scores of only a few *indicators* were considered to be sufficiently precise to be calibrated against scores for those indicators at surveyed sites. In contrast, scores for *all functions* were calibrated against scores for those functions at surveyed sites of the same predominant HGM subclass.

At the outset of this project, our plan had been to develop, for each indicator, a separate scale for each of the three tidal-fringe wetland HGM subclasses. In some cases, a separate scoring model also was envisioned for each HGM subclass. However, it quickly became apparent during field work that most of our sampling units (tidal wetland polygons) and the data obtained from them could not be partitioned cleanly into one of the three subclasses. Frequently, tidal channels and pannes with "low marsh" characteristics penetrated high marshes, and banks of some tidal channels that wandered through low marshes often had "high marsh" characteristics. Because of the difficulties (described elsewhere) in precisely referencing our quadrat locations, channel cross-sections, and other data to verified benchmarks, and also due to the lack of established tidal datums near our survey sites, it was not possible to define precisely the elevational line separating high from low marsh at any of our sites. Therefore, separate scales and models were not developed for each HGM subclass. Instead, two approaches have been used to address the differences between HGM subclasses:

First, users are advised to compare the function scores that are generated *only with those from wetlands of the same subclass*. Although most of the wetlands we surveyed were comprised of multiple HGM subclasses, they have been assigned to the single most-predominant subclass they contained, and their function scores (Table 26, Table 27, Table 28) serve as reference points for function scores from other sites that may be assessed in the future.

Second, for a very few indicators, field data were analyzed using a procedure called "robust regression," and the best resulting statistical model was programmed into the spreadsheet. It was statistically allowable to apply this procedure only to indicators having continuous (not categorical) numeric data. As defined in section 3.3.2, those were a channel morphology index (*RatioC*, which is the mean of Ratios C1-C5 in Table 7 ) and the botanical indicators (*SpPerQd, AllGT90, NNgt20, AnnFq, TapAvgPC, StolPCavg, TuftAvgPC)*. Robust regression (Montgomery and Peck 1992, and implemented by the statistical package NCSS) was used in two ways: first, to identify which independent variables were having the greatest influence on these indicators (dependent variables); and second, to then provide an equation — to be programmed into the HGM method's spreadsheet — for adjusting for the statistical effects of those independent variables. In that way, any remaining variation found among wetlands should be attributable largely to human-related alteration, because the independent variables that were evaluated by robust regression were mostly ones describing factors that vary naturally and are expected to be highly correlated with HGM subclass, i.e., because they indirectly characterize a site's wetness, salinity, and substrate. The statistical models (equations) that were generated by robust regression and programmed into the spreadsheet are shown in Table 7.

**Table 7. Statistical models generated by robust regression for factoring out the influence of natural and sampling variation on selected botanical and channel morphometric indicators**

See section 3.3.2 and Appendix C for definitions of the coded indicators.

| |
|---|
| Allgt90 = (- 0.6083775 + (0.1509656*WETPCAV) - (0.00101623*MARPCAV) - (0.3112025*MARQDPCT) - (0.1259233*(LOG(1+TRANL))) -(0.2043147*FRQDPCT) - (0.002224719*MARQDPCT) + (0.0224365*POSTN) - (0.02674779*SAND) + (0.03729241*TRIBL) - (0.06239758*(LOG(1+JCTS)))) |
| AnnFq = (0.5043042 - (0.09116694*WETPCAV) + (0.004082995*MARPCAV) + (0.2150886*MARQDPCT) + (0.1750098*(LOG(1+TRANL))) + (0.1948457*FRQDPCT) - (0.001945676*MARQDPCT) - (0.2353217*SAND) - (0.02937582*(LOG(1+EXITS))) - (0.1981525*(LOG(1+JCTS)))) |
| NNgt20 = (2.021556 - (0.1507233*WETPCAV) - (0.004603391*MARPCAV) - (0.09447266*(LOG(1+TRANL))) - (0.2018425*TRIBL)) |

| |
|---|
| RatioC1 =2.362572+(0.8648501*Sand)+(0.2668522*Trib)+(0.9510881*(LOG(Exits+1))) - (0.5107238*(LOG(Jcts+1))) |
| RatioC2 =1.528158+(0.4737956*Sand)+(0.3314972*Trib)+(1.023391*(LOG(Exits+1))) + (0.1864663*(LOG(Jcts+1))) |
| RatioC3 =1.327538+(0.7810041*Sand)+(0.3765976*Trib)+(0.8909062*(LOG(Exits))) |
| RatioC4 =2.344948-(0.6507016*(LOG(Jcts+1))) |
| RatioC5 =1.672734+(1.580871*Sand) - (0.2923233*(LOG(Exits))) |
| SpPerQd =(9.153849-(0.982845*WETPCAV) - (0.01173281*MARPCAV)+(3.069793*MARQDPCT)+(0.7650238*(LOG(1+TRANL)))+ (1.382466*FRQDPCT)-(0.2393506*TRIBL)+(0.8817692*(LOG(1+EXITS)))-(0.5777943*(LOG(JCTS+1)))) |
| AnnPct = (0.5043042 - (0.09116694*F2) + (0.004082995*O2) + (0.2150886*P2) + (0.1750098*(LOG(1+G2))) + 0.1948457*H2) - (0.001945676*P2) - (0.2353217*K2) - (0.02937582*(LOG(1+L2))) - (0.1981525*(LOG(1+M2))) |
| StolPCavg = (242.3615 - (24.60724*WETPCAV) - (0.274287*MARPCAV) + (24.35362*MARQDPCT) - (28.01786*FRQDPCT) + (7.190266*POSTN)) |
| TapAvgPC = (-4.968985 + (2.582165*MARQDPCT) + (1.90888*(LOG(1+TRANL))) + (0.3902988*POSTN) + (5.27691*SAND) + (0.9259862*TRIBL) + (2.456926*(LOG(1+EXITS))) - (2.946003*(LOG(JCTS+1)))) |
| TuftAvgPC = (68.40195 - (7.416469*WETPCAV) + (1.832365*MARQDPCT) + (1.971077*(LOG(1+TRANL))) - (7.381773*FRQDPCT) + (0.04529605*MARQDPCT) - (1.467767*SAND) + (0.9931501*TRIBL) - (1.510536*(LOG(1+JCTS)))) |

*Legend for independent variables*:

**Exits**: number of channel exits (an indicator of marsh structural complexity and size)

**FrQdPct**: proportion of quadrats with freshwater (salt-intolerant) species, an indicator of salinity regime

**Jcts**: number of channel junctions (an indicator of marsh structural complexity and size)

**MarPCav**: mean percent cover of marine (salt-tolerant) plants among quadrats, an indicator of salinity regime

**MarQdPct**: proportion of quadrats with marine (salt-tolerant) plants, indicator of salinity regime

**Postn**: relative position of wetland in its estuary (1 = near ocean, 2 = mid, 3 = near head of tide)

**SAND**: sandy soils predominate? 0 = no, 1 = yes

**TransL**: summed length of both marsh transects, an indirect indicator of marsh size

**TribL**: freshwater tributary enters marsh? 0 = no, 1 = yes

**WetIndexAv**: mean species wetness index among quadrats, a presumed indicator of overall marsh elevation

NOTE: A constant was added to each of the above equations to ensure that most outputs would be positive numbers, making interpretation easier. The constants are: SpPerQd (+6), AllGT90 (+1), NN20PC (+1), AnnQdsPct (+1), StolPCav (+90), TapPCav (+7), TuftPCav (+26). This was done to minimize user mistakes when interpreting scales. The coefficients of determination of all regression equations were in the 0.70–0.85 range.

As opposed to conventional (least squares) regression, robust regression has less-restrictive assumptions. Specifically, it provides much better regression coefficient estimates when outliers are present in the data and when data are non-normally distributed, as was often the case with our data for these indicators. The regression models in Table 7 accounted for 70–85% of the variance in the data, according to their coefficients of determination. This use of regression follows the general suggestion of Boesch and Paul (2001), who recommended its consideration, along with non-parametric approaches, where difficulties are encountered in finding appropriate (e.g., clearly defined and comparable) reference sites.

The above discussion of robust regression modeling pertained only to the few indicators shown in Table 7. Now, consider instead the majority of indicators that were estimated using a categorical rather than a continuous scale. The scaling of these took into account (in priority order):

(a) empirical relationships to functions where known (mostly used to set the approximate midpoint of the scale),

(b) maximum score among least-altered sites (to set the upper ends of the scale), and

(c) median condition among all sites of the indicator (to set the approximate midpoint of the scale).

Also, in setting the *number* of score choices, we considered the anticipated ability of users to distinguish between various described levels, as well as confidence intervals associated with percentiles of the data.

The foregoing discussion has addressed the calibration of indicators. The other aspect of calibration is the calibration of scores for functions. For this, there exists no consensus among wetland scientists as to whether a "1" on the 0-to-1 scale should represent (a) the condition present in least-altered sites, or (b) the condition believed to be most indicative of high levels of the function present at many sites belonging to the target subclass, even if those sites are not perceived as being the least altered (there may be no way to independently prove that sites perceived as being least altered actually are). The spreadsheet accompanying the guidebook generates function scores based on either assumption. For each site, the spreadsheet takes the raw score from the scoring model output and subtracts the minimum score for that function among all surveyed sites. This converts the raw scores to the 0-to-1 scale, and they then are divided by a number that is the maximum score among all surveyed sites for that function, to reflect assumption (b), or they are divided by a number that is the maximum score among all least-altered surveyed sites for that function, if that number is lower, to reflect assumption (a).

Finally, one feature that is perhaps unique to this HGM method is that users are asked not only to assess the condition of each indicator, but to assign a 0-to-1 estimate of "certainty." Users are provided with guidance for doing this in Part 1. The certainty scores of the indicators are combined into a certainty score for the function using the same model structure used for the function. Certainty scores may be used to advise priorities for follow-up data collection.

## 2.7 Other Statistical Analyses

Somewhat apart from the effort to develop the HGM method, data were analyzed statistically for the purpose of identifying possible relationships among variables. Spearman rank correlations ($p<0.05$) were computed automatically for nearly all pairs (>50,000) of variables, and the pairs were sorted in order of their statistical significance. In some instances, correlations were sought only after grouping data by subclass. A small portion of the results is highlighted in section 4. Considerably more potential exists to analyze this data set in ways that will produce stronger insights and to interpret more comprehensively the correlations already identified. Compared to its alternative (Pearson correlation), Spearman correlation is relatively tolerant of non-normally distributed data, but at the same time is less able to detect significant relationships among variables. Also, in the process of examining such a large number of pairings, as many as 5% of the supposedly significant correlations may be due to chance alone. Nonetheless a correlation analysis such as this helps formulate hypotheses for future testing, and highlights situations where indicators might be unintentionally and implicitly double-weighted.

# 3.0 The Method's Foundation: Available Science and Theory

## 3.1 Tidal Wetland Classification

Compared with non-tidal wetlands, tidal wetlands have received much less attention from scientists who develop classification schemes. The national guidebook for HGM assessment of tidal fringe wetlands (Shafer and Yozzo 1998) does not define any subclasses of the national tidal fringe class, nor does its regional version for the Gulf of Mexico (Shafer et al. 2002). For a wetland to be considered tidal, the National Wetland Inventory (NWI) requires not only that it be influenced by tides, but also that its salinity be greater than 0.5 ppt. (Cowardin et al. 1979). This is a difficult situation to assess, given the wildly fluctuating salinity conditions typically present near the heads of tide. NWI further splits tidal wetlands based on vegetation (aquatic bed, emergent, shrub-scrub, forested) and low vs. high marsh (= regularly vs. irregularly flooded). Because these categories are widely accepted by scientists (e.g., Bottom et al. 1979), the flooding-regularity component is reflected in our split of the marine-sourced subclass (high vs. low marsh).

A few wetland scientists have attempted to split tidal wetlands further based on botanical and/or geomorphometric attributes (Table 8). For example, along tidal parts of the Hudson River in New York, Findlay et al. (2002) placed tidal emergent wetlands in three subclasses: Fringe, Sheltered, Enclosed. Researchers in Maine (Wood et al. 1989) categorized tidal wetlands as Back-Barrier, Fluvial, Bluff-toe, or Transitional (or alternatively as Back Barrier, Finger, or Fringe). In the accompanying databases we have subclassified all Oregon tidal wetlands in a somewhat similar manner (see data file: SiteGeo, fields: ChanBay and Confinemt). Previously in Oregon, Jefferson (1975) classified tidal marshes based on flooding regime, substrate, vegetation, and stage of development:

> 1) *Low sandy* marshes occur on sandy substrate, typically in low energy areas. They are flooded by most high tides and are covered by scattered vegetation near the tidal edges and progressively continuous vegetation as the distance from the water increases.
> 2) *Low silty* marshes develop on fine-textured sediments, silt, or mud substrate in low energy areas. They are typified by high sedimentation rates, regularly flooded by high tides, drained and flooded by a diffuse pattern of channels, and are covered by clumps of plants which are discontinuous at lower elevations.
> 3) *Sedge marshes (Carex* spp.) form on silt, are flooded regularly by high tides, and drain and flood via channels. They exhibit lower soil salinities, contain abundant levels of organic matter, and are characterized by vegetation that is continuous and low in diversity.
> 4) *Immature high* marshes are located on silty substrate and contain abundant levels of organic matter. They are frequently flooded by high tides and are characterized by a well-defined system of channels that flood and drain the marsh. They usually are densely vegetated.
> 5) *Mature high* marshes are composed of peaty soils and are characterized by a dendritic network of steep-sided channels. They have widely fluctuating salinity levels and are vegetated continuously.
> 6) *Bulrush and sedge* marshes are low, brackish marshes that are located on silty or sandy substrate. They are inundated regularly by high tides, drained diffusely, and are continuously vegetated.

7) *Intertidal gravel* marshes are relatively rare and develop on sand and gravel in high energy areas. They are supplied with ample flows of fresh water, and are marked by discontinuous, low salinity-tolerant vegetation.

While useful for some purposes, Jefferson's classification was considered too detailed to use in this HGM project, partly because it would have required gaining access permission to a significant number of replicates of each of the above types. Nonetheless, representatives of all the above types are included among our 120 surveyed wetlands, and all the indicators embodied in Jefferson's classification are included in this HGM method (Part 1). The importance of flooding regime and stage of development was highlighted further by Elliott (2005) in her studies of Columbia River tidal wetlands.

**Table 8. Classification schemes for tidal wetlands, emphasizing the Pacific Northwest**

| |
|---|
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Weinstein, M.P., K.R. Philipp, and P. Goodwin. 2000. Catastrophes, near-catastrophes, and the bounds of expectation: success criteria for mesoscale marsh restoration. pp. 777–804 In: M.P. Weinstein and D.A. Kreeger (eds.). Concepts and Controversies in Tidal Marsh Ecology. Kluwer Academic Publishers, Boston, MA.

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## 3.2 Tidal Wetland Functions and Values

Each subsection below discusses a tidal wetland function and is organized as follows.
*Definition and Documentation*: This explains the function and gives one example (of many possible) of its quantification. Peer-reviewed literature in support of the function is cited, especially newer literature from the Pacific Northwest when available.
*Values*: This describes the basis for the indicators used in the "values" part of the rapid-assessment method.

### 3.2.1 Produce Aboveground Organic Matter

**Definition and Documentation**: the capacity of marsh plants to use sunlight to create particulate organic matter (e.g., leaves, wood, detritus) above the surface of the soil, to a degree that is characteristic of their HGM subclass. If measured quantitatively, this function could be expressed as:

*grams of carbon gained (via photosynthesis) per unit area of wetland per year*

For decades, tidal marshes have been reputed to be among the most productive types of ecosystems. That is, they are extremely efficient at using sunlight to create plant material. Although discussions of tidal marsh production traditionally have focused on vascular plants, algae within the marshes or elsewhere in the estuary may have equal or greater levels of production (per unit area) during winter and early spring, and sometimes year-round (Sullivan and Currin 2000). However, algae usually are impractical to assess in the context of a rapid-assessment method. Similarly, production of organic matter beneath the ground (roots, burrowing organisms) can be substantial and significant, as can belowground microbial transfer of energy via sulfur compounds (Mitsch and Gosselink 2000). In Oregon, attempts to measure productivity of tidal marsh communities have been made by Eilers 1975, 1979; Hofnagle et al. 1976, 1979; Kibby et al. 1980; Gallagher and Kibby 1981; Frenkel and Morlan 1991; Gilman 1993; and others. Each year, marsh plant growth begins initially in the lowest marsh and proceeds upslope as the season progresses (Eilers 1975). A similar pattern has been noted for intertidal green algae (Pregnall 1983).

**Values**: The large quantity of organic matter produced by a tidal marsh supports many other functions and services. Most fundamentally, it is an essential driver of the marsh food web and contributes importantly as well to food webs in receiving waters of the estuary. Fisheries, livestock grazing, biodiversity, ecotourism — all ultimately are supported by the production of organic matter, much of it coming from the marsh. Organic matter also modifies the chemical and physical environment, both in the water and in sediments. Organic deposits create an oxygen demand and a chemically reducing environment, especially in fine sediments (Howes et al. 1981). This can affect the retention, mobilization, and bioavailability of many nutrients and contaminants throughout an estuary (Hopkinson and Vallino 1995). The influence of organic matter exported from wetlands on estuarine water quality and production in receiving waters is greater in poorly flushed, warmer estuaries.

Adequate organic matter (not just dissolved organic carbon, Jacinthe et al. 1998) is a key energy source for denitrification, a major component of nitrogen cycling. Denitrification is correlated positively with organic matter, as represented by plant height and percent cover in newly constructed tidal marshes (Craft et al. 2003).

The progressive accumulation of organic deposits (peat) in the subsided substrate of restored, formerly diked tidal marshes is vital to gradually returning these wetlands to fully functioning tidal marshes. Organic deposits often play a larger role than sediment deposits in such marsh accretion, especially near the upland fringe of marshes (Turner et al. 2004). In addition, research in freshwater systems has documented the ability of organic matter in the water column to counteract potentially lethal effects of ultraviolet (uv-B) radiation on aquatic organisms.

The degree to which primary production of a *specific* marsh might be valued depends on its quantitative contribution, relative to non-marsh sources of carbon, to processes and services such as the ones described. If tidal marshes comprise a large proportion of an estuary, and the remainder of the estuary is relatively unproductive (e.g., due to a watershed being largely devoid of vegetation, open bay waters being very turbid with suspended sediments that limit algal production), then production from tidal marshes assumes a greater role and value.

### 3.2.2 Stabilize and Accrete Sediment; Process Carbon, Nutrients, and Metals

**Definitions and Documentation:** This section describes the "water quality" (water purification) functions of tidal wetlands.

*Stabilize and Accrete Sediment***:** the capacity to minimize the resuspension (by water or wind) of primarily inorganic sediments deposited within the wetland, to allow accretion of sediment. If measured quantitatively, one expression of this function would be:

> *proportion of the [suspended sediment load] that retained in the wetland, per year*

*Process Carbon, Nutrients, and Metals*: the capacity to physically capture suspended organic particles, and to biochemically process carbon and nitrogen associated with these particles or in solution. If measured quantitatively, this function could be expressed (for example) as:

> *proportion of the grams of incoming [soluble inorganic nitrogen] converted to grams of [particulate organic nitrogen] per year*

The variety of particles, elements, and compounds that potentially can be processed by tidal marshes is enormous, as is the variety of forms they can be converted to. Early research focused mainly on the role of tidal marshes in capturing sediment, anchoring shorelines, and processing inorganic nitrogen. Other roles include the entrainment of organic matter (both living and detritus; introduced via runoff, channel flow, and tidal currents), conversion of the detained organic matter to dissolved compounds, processing and retention of phosphorus and some heavy metals (Gallagher and Kibby 1980), and transformation of silica, which is critical to the growth of some algae that form estuarine food webs (Hackney et al. 2000). Some evidence suggests that tidal wetlands are more capable of processing particular hydrocarbon pollutants than are permanently flooded or drained sediments (Catallo and Junk 2003).

The capacity of tidal marshes to entrain and take up or remove most substances is influenced by their geomorphology (including sediment types and their associated oxygen conditions), hydrology (duration and frequency of inundation, which influences opportunity for interaction between waterborne substances and vegetation), and vegetation (especially the ability of plant stems to entrain organic particles, and the capacity of roots of some plants to oxygenate soil, consequently oxidizing and mobilizing iron and other important elements). Marsh capacity to process many substances also is influenced by their bacteria. Due to extensive organic deposits in marshes, bacteria and fungi may be present at much greater density and diversity in vegetated marshes than in adjoining bay waters.

Each major substance included under this function is now documented:

*Sediment*

Tidal marshes are the physical expression of the equilibrium between stress (wave and tidal, partly as they affect sediment water content) and strength (sediment cohesiveness and stabilization by vegetation). In the long run, tidal marshes develop in a manner that resists morphological change and distributes the dissipation of tidal and wave energy over space. Tidal channels in particular are a significant means of dissipating tidal energy (Coats et al. 1995). Deposition of sediment load occurs with a decrease in channel gradient, a reduction in velocity, or a decrease in water volume. Deposited sediments initially are stabilized by rapidly growing algae and eventually by plant roots. Estimates of sedimentation or accretion rates in tidal marshes of the Pacific Northwest have been published by Thom 1992, Cornu and Sadro 2002, and others. Accretion of sediment typically is accompanied by retention of phosphorus and metals, because these strongly adsorb to the sediment particles being deposited and buried.

*Phosphorus*

The mobility of phosphorus in tidal wetlands is strongly influenced by salinity. In fresher parts of tidal wetlands (or in most river-sourced tidal wetlands generally), phosphorus typically is bound to sediments rich in iron or aluminum, and/or is rapidly sequestered by organic matter in the water column and sediments. This ultimately makes it less available to algae and other components of estuarine food webs. Closer to the ocean, phosphorus that is adsorbed to sediments that typically are richer in calcium tends to be mobilized more freely. In a study of naturally developing tidal marshes, retention of ammonium and phosphate by young marshes was not much different than in older marshes (Osgood 2000). This was attributed partly to higher rates of porewater flow (i.e., shorter hydraulic residence times) in the coarser sediments of young marshes.

*Heavy Metals and Pesticides*

In general, the fine soil textures, high humic content, and reducing conditions that typify wetland soils are favorable for processing many contaminants, although sometimes with undesirable impacts on wetland fauna. Metals and pesticides can be transported into tidal wetlands via surface runoff, groundwater (Spinelli et al. 2002), direct precipitation (Torres et al. 2003), and river (Bergamaschi et al. 2001) or tidal currents. A calibrated, mechanistic model of a Connecticut estuary predicted that tidal marshes were removing an amount of metal equivalent to

20–30% of the metal flux from the river (Rozan and Benoit 2001) before it reached the harbor. In New Jersey, Dubinski et al. (1986) found that a tidal marsh retained several introduced heavy metals (cadmium, chromium, copper, lead, zinc), but only cadmium and chromium remained after marsh plants had senesced in the autumn (Dubinski et al. 1986). Marsh plants were important for detaining introduced metals, although only temporarily (Simpson et al. 1983). Overall, the marsh sediments and detritus were equally or more important than living marsh vegetation for retaining metals. Yet, even the sediments have a finite capacity for retaining some heavy metals (Kufel 1991). Thus, overloading of sediments with metals increases concentrations of metals in porewaters, which are vulnerable to export (Millward et al. 2001). In a *Spartina* marsh in Massachusetts, most metals were retained to a greater degree in the high (irregularly flooded) portion of a marsh than in the low (regularly flooded) marsh or along tidal channels. This was attributed to the less-frequent flushing of metals from the high marsh, coupled with greater sulfide concentrations and stronger reducing conditions and in soils there (Giblin et al. 1980). Vegetated areas of a tidal marsh surface tended to have higher concentrations of mercury because of the presence of near-surface iron and manganese oxides whose formation was facilitated by tidal marsh plant roots (Micaelo et al. 2003). However, these root coatings (plaques) also can inhibit the retention of other heavy metals, especially at higher pH (Batty et al. 2000). In some instances sediments in tidal channels and mudflats may have higher sulfide concentrations than marsh surfaces, and thus may be more effective for retaining some heavy metals through formation of metal sulfides (Otero and Macias 2002).

Marsh sediments with high clay content tend to retain heavy metals and phosphorus. Although some studies have suggested that the extensive organic matter found in tidal marsh sediments can promote mobilization of heavy metals, a recent study in Maryland found the opposite, at least for copper and zinc (Knight and Pasternak 2000). Microbial communities associated with marsh plant detritus are particularly effective for taking up heavy metals, at least seasonally (Zawislanski et al. 2001). The potential for metal uptake and retention also varies by plant species (Kraus 1988).

Relatively little is known regarding the capacity of different wetland types to process other priority pollutants. Evidence from one study suggested that moderate loading of tidal marshes with heavy metals would not impair growth of some native plants (Vance et al. 2003).
A very few studies (e.g., Seybold and Mersie 1999) have found tidal marshes to be capable of processing particular herbicides.

*Nitrogen*

Particulate nitrogen enters a marsh passively as plant matter or actively in the form of immigrating animals and their excrement. Soluble nitrogen (generally nitrate) enters marshes in surface runoff, direct precipitation, groundwater (Krest et al. 2000), and river or tidal currents. In the Yaquina estuary, between 84% (dry year) and 94% (wet year) of the annual load of dissolved nitrate is transported to the estuary during the winter. The actual load ranges from 2,588 (dry year) to 22,586 kg per day (wet year), and daily increases are greatest during storms, whereas increases in phosphorus and ammonium are less storm-driven and are in proportion to river discharge (Sigleo and Frick 2003).

Predominant sources of nitrogen to tidal marshes vary greatly among estuaries and regions (Castro et al. 2003). Nitrogen also may be introduced by algae and microbes that “fix” nitrogen gas. Nitrogen borne in channels by river or tidal currents seldom seeps very far laterally from the channel, due to low permeability of marsh sediments (Dacey and Howes 1984), so is provided little opportunity for processing by plant roots. In contrast, nitrogen borne by dispersed runoff or shallow groundwater (including lateral subsurface flow, Ursino et al. 2004) sometimes has greater opportunity to interact with plant roots and associated microbial communities, and so can be an important source of nitrate for tidal marshes (Harvey and Odum 1990, Portnoy and Giblin 1997, Valiela and Teal 1979, Howes et al. 1996, Tobias et al. 2001*a,b*). Such is likely to occur in watersheds with steep topography and permeable soils. However, in other topographic settings and during some seasons, laterally moving groundwater may move too deeply below tidal marshes to allow the marsh any opportunity to process its associated nitrate (Bokuniewicz 1992, Howes et al. 1996). Moreover, ocean waters advected into some Pacific estuaries may carry in substantial loads of nutrients, perhaps more than many of these estuaries receive from human-related (riverine) sources (Fong et al. 2004).

Regardless of its origin, once soluble nitrogen is transported into a tidal wetland it can be (a) converted to nitrogen gas (and thus removed from the estuary) through the process of denitrification, (b) transformed to reduced forms of inorganic nitrogen (e.g., ammonium), and/or (c) taken up by living plants, plant litter, and associated microbial communities, and consequently converted to particulate and dissolved organic nitrogen. That organic matter can be buried deeply by sediments, resulting in long-term nitrogen retention, but more often it is cycled again within the marsh or estuary. The relative influence of these three processes may depend on season and tidal phase. In warmer months, denitrification and hydrophyte uptake are relatively influential and cause a shift in the dominant form of nitrogen from nitrate to ammonium. This has been confirmed by measurements in the Yaquina estuary (Sigleo 2004). Removal of soluble nitrate via denitrification is greatest where soil texture is fine (especially above 65% silt and clay, Pinay 2000), sediment organic matter content is high but not strongly acidic (Pinay et al. 1993, Pinay et al. 2003), and water level fluctuation is sufficient to produce aerobic sediment conditions in close proximity to anaerobic sediments, especially for extended periods.
In winter, algal uptake of nitrogen may be significant because algae flourish as shade from plants and grazing by invertebrates is temporarily reduced (Howes 2000).

During falling tide, less nitrate and more organic nitrogen typically are exported (Vorosmarty and Loder 1994). Salinity also influences total nitrogen availability to estuarine food chains through its influence on various forms of ammonia. Increased frequency of upriver intrusions of seawater, e.g., during drought, spring tides, or periods of excessive consumptive use of river flow, can mobilize nitrogen in the form of ammonium (Gardner et al. 1991), and increased freshwater runoff was shown in the Yaquina estuary to have the opposite effect (Sigleo and Frick 2003). Under conditions of very low salinity, fewer of the nutrients originating in sediment organic matter are able to reach the overlying water than under saline conditions, because both denitrification and phosphorous adsorption tend to be greater where water is fresher. In more saline sediments, higher levels of sulfide can inhibit denitrification, and heavy inputs of chloride from atmospheric deposition of sea salts closer to the ocean can displace nitrate from the soil. Together these two factors might result in release and subsequently less processing of sediment nutrients and organic matter (and perhaps also, the runoff-borne nutrient load), within concomitant decline in estuarine oxygen concentrations. Similar effects can occur when tidal circulation is restored to diked wetlands (Portnoy and Giblin 1997).

### *Carbon*

"Mature" marshes typically have larger reserves of soil organic carbon (Craft et al. 1988) and might slowly release accumulated nutrients, as do some old-growth forests, whereas in younger (but well-vegetated) marshes, nutrient uptake rates may be higher (Craft et al. 2003). Or, because of their extensive organic reserves, "mature" marshes might support a higher level of microbial activity that results in more efficient processing of a variety of soluble substances. Export (or net flux) of various forms of organic carbon from different types of tidal marshes during different seasons and tidal conditions has not been studied in Oregon. Rainfall may be a particularly effective mechanism for exporting organic carbon from tidal marshes (Torres et al. 2003).

**Values**: Several harbors in Oregon estuaries require costly dredging as a result of chronic sediment loading. Tidal marshes help intercept, retain, and stabilize river-borne sediment before it reaches deeper waters where it causes such problems, and so can help offset this problem. Retention of sediment by marshes also is important to the productivity of subtidal estuarine waters. Sediments not stabilized by marshes remain suspended in the water column, especially in estuaries characterized by persistent upwelling currents and waves. Suspended sediments reduce available light and consequently reduce the primary production essential to estuarine food webs. However, high concentrations of suspended sediment are common in waters of even the least-altered estuaries and may help make juvenile fish less visible to vertebrate predators (Healy 1982).

Sediment retention is particularly valuable in formerly diked, newly restored tidal marshes, where accumulation of sediment is needed to offset undesirable effects of marsh elevational subsidence. Indeed, effective retention of incoming sediment is vital to sustaining the tidal wetlands themselves in the face of possible long-term increases in sea level. For part of San Francisco Bay, an average supply of at least 50–100mg/L sediment was estimated as necessary to sustain tidal marshes if sea level rises no more than 3–5mm per year over the next century (Crooks et al. 2002). Deposition of sediments also buffers the chemically reducing conditions otherwise present in marsh soils, thus making a better environment for belowground plant production (Anisfeld 1999).

With regard to carbon, nutrients, and metals, the levels of these that are appropriate for maintaining (or not harming) healthy estuaries in Oregon have not been defined. Without such criteria, it is difficult to assign relative value to tidal marshes that have the capacity to regulate such substances. On one hand, enrichment of estuaries with excessive loads of nutrients often has been linked to algal blooms, seagrass declines, oxygen deficits, fish die-offs, and other problems (Fong et al. 1993, Teal and Howes 2002). On the other hand, nearly all such studies have been done in estuaries outside of the Pacific Northwest, where they are exposed to much higher levels of anthropogenic nutrient input than experienced here. Long before the arrival of European settlers, estuaries in the Pacific Northwest received substantial nutrient inputs from the carcasses of spawned-out anadromous fish (Sugai and Burrell 1984, Stockner et al. 2000), from leaves of nitrogen-fixing riparian alder (*Alnus rubra*) shrubs, from extensive deposits of downed wood, from seasonal concentrations of waterfowl, and from nitrogen-fixing algae and microbial communities. Salmon runs and some of the other sources are now much diminished so nutrients should be scarcer, at least seasonally. Unknown at this point is the degree to which increasing anthropogenic nutrient sources in the region compensate for declines in some of the natural sources of nutrients, in terms of quantity, timing, and form — and how this translates into possible changes in food webs, growth rates, and occupancy patterns among fish that use the estuary as a nursery (Dill et al. 1981). Some evidence suggests that organic matter and associated nutrients from urban and agricultural watersheds tend to be more rapidly available (i.e., carbon-to-nitrogen ratio is lower) to aquatic food chains than when the source is forested land (Uhlenhopp et al. 1994).

In New England, estuaries with a larger proportion of tidal marshes have substantially more remaining eelgrass than those with a smaller proportion of tidal marshes. Some scientists have speculated that processing of nitrate runoff by those tidal marshes has protected the downgradient eelgrass beds, which are very intolerant of nitrate additions, from excessive enrichment (Teal and Howes 2000). There is some evidence to support this in New England (Wigand et al. 2004) but whether this is the case in Oregon is unknown. Eelgrass productivity is not nutrient limited in the Coos Bay estuary (S. Rumrill, SSNERR, pers. comm.).

Of course, processing of nutrients and other substances in estuaries can be attributed to more than just the tidal marshes. Macroalgae (seaweeds) can be particularly effective, at least for short-term cycling. In one Oregon estuary, they essentially depleted all the river-borne nitrogen and phosphorus during summer and fall (Collins 1987). However, during winter (when most river-borne nutrients arrive), macroalgae were mostly dormant so were ineffective. Microbial communities in subtidal sediments also are effective processors of incoming substances. In one series of measurements in an Oregon estuary, the rates of sediment uptake of ammonium, and rates of uptake and regeneration of nitrate, were found to be among the highest ever reported, implying correspondingly high rates of denitrification (Collins 1987).

Estuarine morphology can influence the influx and concentration of sediment and nutrients, and consequently the opportunity for marshes and other habitats in the lower estuary to retain or process them. In some instances, unrestricted entrances of estuaries allow for increased transport of relatively enriched marine waters into the estuary. In other instances, natural bars seal off the entrance in summer, allowing runoff and low flows from river discharge to accumulate in the estuary. Marine-sourced waters bring greater concentrations of phosphorus and (in summer) nitrate, whereas river waters bring much of the silica and wintertime nitrate (Park et al. 1970, Sigleo and Frick 2003).

In summary, the degree to which the sediment retention and chemical processing functions of a *specific* marsh might be valued depends on the site's capacity, relative to capacities of non-marsh environments, to perform this function. Value probably is greatest if (a) the marsh comprises a large proportion of an estuary, and (b) opportunity for retaining sediment, nutrients, and other substances is substantial because inputs of these from the watershed are large (e.g., due to erodible soils, characteristically intense precipitation, denuded land cover), and (c) the marsh is subsided or eroding, or excessive sediments in the estuary are causing some of the problems described above.

### 3.2.3 Export Aboveground Plant and Animal Production

**Definition and Documentation**: the capacity to export organic matter from the marsh to adjoining waters that are inundated permanently. If measured quantitatively, this function could be expressed simply as:

*grams of carbon exported per year*

Tidal marshes export many substances, but usually only carbon is exported from marshes in a sustainable manner. That is, a marsh cannot indefinitely export an element such as phosphorus or iron because eventually the pool of that element within the marsh will be exhausted. In contrast, tidal marshes can continually renew their pool of organic carbon as a result of photosynthetic activity by algae, vascular plants, and some microbes, thus allowing the opportunity for sustained export. Carbon can be exported in its dissolved forms or as living or dead organic forms such as algal cells, vascular plant parts, invertebrates, fish, and birds. Dissolved organic and inorganic carbon actually might represent a greater marsh contribution to estuarine food webs than particulate organic carbon, which more often has been the focus of research (Eldridge and Cifuentes 2000). Export can be passive (e.g., facilitated by diffusion or physical forces such as tides and wind) or active (movements of animals). Export can occur in subsurface or surface flows. Export of organic matter from marshes has sometimes been termed "marsh outwelling." In the Pacific Northwest, most marsh plants senesce in September–November, and outwelling of the decomposed plant material occurs during high river discharge conditions mostly in February, March, and April (Eilers 1975, Thom 1981). This slightly precedes or coincides with the peak in detritivorous invertebrates that are consumed by young salmon and many other fish (Simenstad et al. 2000), as well as with blooms of some marsh algae that later in the season are restricted by shading from marsh plants.

Physical processes within marshes strongly influence the breakdown of particulate organic matter (detritus — essentially carbon), making it more available for export. Breakdown of coarse particulate matter and subsequent conversion to dissolved organic matter probably occurs faster in marshes that experience greater tidal, wave, and current energies, as predicted partly by marsh surface elevation. Invertebrates also can play a major role in physical breakdown. Some tidal marsh plant species, particularly succulent species, tend to shed plant tissues regularly throughout the growing season, and also decompose more rapidly than others (Science Applications Inc. and Woodward-Clyde Consultants 1981, cited in Simenstad 1983). Green algae can leach dissolved organic carbon directly into the water as they grow, especially when it rains (Pregnall 1983). However, it remains unclear to what degree differences in decomposition and carbon leaching rates can be attributed to morphology and chemistry of the species, and how much to the facilitating physical and biological characteristics of the microhabitat the species typically inhabits.

**Values.** For supporting estuarine and marine food webs in Oregon, the relative importance of *marsh*-derived carbon, as opposed to carbon derived from other sources (e.g., upland vegetation, subtidal eelgrass, phytoplankton, macroalgae, wastewater) is unknown. It likely depends on the time of year, the form (molecular weight) of the carbon being exported, the particular food chain of interest, relative area and distribution pattern of tidal marshes vs. other carbon-producing sources, and hydrodynamics of the particular watershed and estuary. In some estuaries where eelgrass and seaweed beds are more productive than tidal marshes (Thom 1984), less value might be assigned to the contribution of the tidal marshes. However, more than just relative productivity should be considered. If tidal marshes export carbon in a form that is more readily processed by microbial and invertebrate communities, or if they export it at times when other sources are not being exported, or in parts of an estuary that are relatively deficient in appropriate carbon compounds, then the contribution of marshes could be quite valuable. Presumably, the presence of multiple well-dispersed carbon sources (marsh plants, macroalgae, eelgrass, etc.) within an estuary implies greater availability of sustained energy sources throughout a year, and that may mean greater capacity for sustaining diverse food webs. However, evidence for existence of such relationships in Oregon is lacking. In addition to its role in supporting food webs, the exported carbon is potentially valuable for its role in nitrogen cycling (e.g., support of denitrification) and minimizing adverse effects of natural ultraviolet radiation on aquatic animals.

### 3.2.4 Sustain Habitat for Native Invertebrates

**Definition and Documentation**: the capacity to sustain life requirements of a diversity and abundance of native resident or visiting invertebrates that reside on, in, or above marsh soils and plants. Some of these may originate in terrestrial environments, some in the tidal wetland, and some in deeper waters. If measured quantitatively, this function could be expressed in any of several ways. For example:

- *density of native marsh invertebrate fauna typical of the HGM subclass*
- *number of native marsh invertebrate species per unit area of marsh*
- *percent of marsh invertebrate species that are native*

This function addresses a large variety of invertebrates that have varying (and often unknown) degrees of dependence upon Oregon’s tidal marshes. These represent a wide variety of functional groups and include but aren’t limited to worms, crabs, clams, snails, butterflies, flies, pollinating bees, midges, and dragonflies. Non-native species — such as New Zealand mud snail (*Potamopyrgus antipodarum*), mouse-eared snail (*Ovatella myosotis*), and European green crab (*Carcinus maenas*) — are not included in this assessment because of their sometimes-damaging effect on native invertebrate communities. In the vicinity of South Slough National Estuarine Research Reserve in Coos Bay Estuary, non-native species are establishing at a rate of about one new species per year (Carlton 2001).

Tidal marshes host a wide variety of invertebrate taxa, some which occur in few or no other habitats. Among restored marshes, those that have recovered the longest tend to have a larger proportion of benthic crustaceans and polychaete worms, and a smaller proportion of larval aquatic insects, freshwater isopods, and oligochaetes (Shreffler et al. 1992, 1993; Simenstad and Thom 1996; Cordell et al. 1992; Cordell and Morrison 1996; Tanner et al. 2002; Talley and Levin 1999; Levin and Talley 2002). If only the total numbers (density) of invertebrates are considered, recovery time of wetlands following restoration of tidal circulation may be 2 to 3 years (Levin and Talley 2002). Chemical contamination of sediments poses a serious threat to many tidal marsh invertebrates (Long 2000).

**Values**: Invertebrates typically are the largest contributors to a region’s pool of species, and the diverse array of invertebrate species that are present specifically in tidal marshes comprise a significant part of this contribution. This is likely to be the case because tidal marshes contain species that are specially adapted for life in saline vegetated soils, which on the Oregon coast occur only in tidal marshes. Maintaining a diversity of invertebrate species that are characteristic of tidal marshes also should help marsh food webs adjust better to future changes in sea level and climate, with consequent associated changes in salinity, nutrients, and sediment geochemistry. Invertebrate species diversity implies diversity of life history strategies and functional groups. In turn, this suggests that more-diverse invertebrate communities, over the span of months or a year, are more likely to contain effective detritivores when sharp pulses of organic matter enter the estuary, and might thus smooth the temporal peaks of these pulses.

Of course, marsh invertebrates also are key to supporting other tidal marsh functions, such as sustaining plants, fish, and wildlife; influencing the physical structure and geochemistry of sediments; and affecting water quality through breakdown of plant materials. For example, loss of some marsh invertebrates (e.g., due to toxins or invasive species) can trigger formation of algal mats on the marsh surface (which otherwise would have been grazed by the invertebrates), causing increased sulfate reduction in marsh soils and altered chemical cycling (Gribsholt and Kristensen 2002). On occasion, some marsh invertebrates serve as vectors for disease. On the other hand, some might serve to control potential pathogens as yet undocumented by science.

Regardless, invertebrate biodiversity is valuable in its own right, as the manifestation of eons of natural selection, and for the aesthetic variety it sometimes provides. Greatest value might be assigned to tidal marshes that support many rare or declining invertebrate species, or assemblages of native invertebrate species (or life history groups) that are unusually diverse for the particular wetland subclass, or individual species that in Oregon are confined almost entirely to tidal marshes (or even, perhaps, to specific plant hosts within tidal marshes).

### 3.2.5 Sustain Fish Habitat

**Definition and Documentation**: the capacity to sustain life requirements of fish that inhabit the marsh and/or its channels during any part of the year. If measured quantitatively, one expression of this function could be:

*number of fish-days of marsh use per unit area (or water volume)*

Three “fish functions” (or fish groups) are recognized by this guidebook’s assessment method and are based on fish residence patterns and source areas. The discussion of these has been combined into a single section. They are:

Sustain Habitat for Anadromous Fish
Sustain Habitat for Visiting Marine Fish
Sustain Habitat for Other Visiting and Resident Fish

**Anadromous fish** are those that spend a portion of their life cycle in the ocean, but migrate to fresh water to spawn. Anadromous fish use tidal marshes (and/or channels that extend into tidal marshes) for periods lasting from days (short-duration) to weeks or even months (long-duration). Anadromous fish that use tidal marshes most regularly are as follows (primarily from Simenstad et al. 2000):

*Longer-duration Use*: chum salmon (*Oncorhynchus keta*), “ocean type” chinook salmon (*Oncorhynchus tshawytscha*), “ocean type” coho salmon (*Onchorhynchus kisutch*)
*Shorter-duration Use*: pink salmon (*Onchorhynchus gorbuscha*), steelhead (*Oncorhynchus mykiss*), sockeye salmon (*Onchorhynchus nerka*), sea-run cutthroat trout (*Oncorhynchus clarki*), river lamprey*(Lampetra ayresi),* Pacific lamprey *(Lampetra tridentata)*

**Visiting marine fish** are those that normally breed in marine environments (pelagic or nearshore ocean species), but find food or refuge in the marsh and its channels during part of the year. Marine fish that visit tidal marshes most regularly are as follows:

longfin smelt (*Spirinchus thaleichthys*), eulachon (*Thaleichthys pacificus*), Pacific herring (*Clupea harengus pallasi*), northern anchovy (*Engraulis mordax*), surf smelt (*Hypomesus pretiosus*), topsmelt (*Atherinops affinis*), jacksmelt (*Atherinops californiensis*), walleye surfperch (*Hyperprosopon argenteum*), white surfperch (*Phanerodon furcatus*), Pacific sand lance (*Ammondytes hexapterus*), snake prickleback (*Lumpenus sagitta*)

**Other visiting and resident fish** are non-anadromous, mostly non-marine species that visit and/or reside for much of the year in the marsh and its channels. These include:

Pacific staghorn sculpin (*Leptocottus armatus*), prickly sculpin (*Cottus asper*), threespine stickleback, arrow goby (*Clevelandia ios*), bay goby (*Lepidogobius lepidus*), peamouth chub (*Mylocheilus caurinus*), "resident" cutthroat trout (*Oncorhynchus clarki clarki),* largescale sucker (*Catostomus macrocheilus*)(mainly RS marshes), redside shiner (*Richardsonius balteatus*), shiner perch (*Cymatogaster aggregata*), starry flounder (*Platichthys stellatus*), English sole (*Pleuronectes vetulus*), snake prickleback (*Lumpenus sagitta*), saddleback gunnel (*Pholis ornata*)

Tidal marshes provide ideal conditions as anadromous fish transition gradually to the ocean. This allows salmonids to acclimate slowly to full-strength seawater, while feeding on an abundance of invertebrate foods and finding shelter from some predators. Survival of salmon smolts in the open ocean, as well as in highly saline parts of estuaries, depends on how soon they enter these saline areas, because smolts that leave sooner are smaller and have a harder time adjusting physiologically to seawater, making them vulnerable to predation (Kepshire and McNeil 1972, Holtby et al. 1990). Both the timing and the size of coho smolts moving toward the ocean are influenced by rearing conditions within a watershed (Quinn and Peterson 1996), including its wetlands. An increasing number of research studies are discovering the relative importance of tidal wetlands and associated internal channels for supporting riverine, estuarine, and marine fish, including stocks of several species considered to be regionally threatened. Some evidence suggests that loss of quality estuarine wetlands may adversely affect chinook to a greater degree than coho (Magnuson and Hilborn 2003). Young chinook and coho forage opportunistically in tidal marshes and their internal creeks mostly during the springtime and in lesser numbers through the remainder of the year, depending on the estuary (Shreffler et al. 1990, Miller and Simenstad 1997). Growth rates of coho fry in tidal creeks have been shown to be nearly twice those of fry that rear in non-tidal freshwater creeks upstream (Tchaplinski 1988, Miller and Sadro 2002), yet connections between non-tidal and tidal waters have been widely interrupted (Roegner et al. 2002).

**Values**: Salmon and other anadromous fish are of obvious commercial, recreational, spiritual, and aesthetic value in the Pacific Northwest. In addition, they potentially serve as prey for a host of other species (Table 9) and as an energetic and nutrient link between marine waters, estuaries, rivers, and headwaters. Their regionwide decline to under 5% of historic levels has caused widespread concern. Because anadromous fish often move considerable distances within an estuary, even in the course of a day, it is difficult to assign value to just a single tidal marsh. However, the collective degradation of multiple marshes would surely impact salmon and other anadromous fish. Greater value can be assigned to marshes that are nearly the only ones still providing minimally suitable habitat in an estuary, or to marshes where significant public funds have been invested for land purchase and/or habitat restoration. A goal set by the Oregon Salmon Plan is restoration of 5,000 acres of altered estuarine habitat (not just estuarine marshes). Our data indicate a maximum of 44,517 acres might be available for restoration on Oregon's coast (see Part 3 of this guidebook). This figure is four times the current area of tidal wetland, so clearly is an overestimate. The actual acreage of restorable land will be much lower after accounting for landowner willingness, site-specific geotechnical factors, and other considerations.

### 3.2.6 Sustain Habitat for Nekton-feeding Wildlife

**Definition and Documentation**: the capacity to sustain life requirements of a diversity and abundance of birds, seals, otter, and other species that feed on nekton (mobile invertebrates and fish). If measured quantitatively, one expression of this function could be:

*number of bird-days of marsh use, per unit marsh area*

The most regularly occurring of these species in Oregon tidal marshes are listed in Table 9.

**Values**: Although some of these species are viewed as a nuisance due to their predation on fish and invertebrates of commercial importance, most do not feed regularly on such resources, and in any event are valued for their aesthetic appeal. Perhaps more importantly, by their very diversity, size, and numbers, they contribute to the ecological and functional stability of Oregon's estuarine systems. None of the species in this group are known to use tidal marshes exclusively or to a consistently greater degree than they use non-tidal wetlands and/or other estuarine habitats. Greater value also might be assigned to marshes that consistently support an exceptional abundance or variety of these species, or which provide the only significant habitat in an estuary for one of the species.

**Table 9. Nekton-feeding bird species that occur regularly within or near Oregon tidal marshes**

1 = species feeds directly *on or above* the marsh, but usually only briefly; 2 = species feeds directly *on or above* the marsh, often for substantial periods of time
MSL = marine-sourced low marsh, MSH = marine-sourced high marsh, RS = river-sourced marsh
Abundance (uncommon, common, abundant) represents maximum density *within (or over) tidal marshes* and *their internal channels* coastwide during an average year; local densities may be lower
"Seasons" are the seasons of usual occurrence (W = winter, M = spring/fall migration, B = early summer breeding, Su = summer non-breeding)

| | MSL | MSH | RS | Abundance | Season |
|---|---|---|---|---|---|
| Bittern, American* | | | 1 | uncommon | M |
| Cormorant, Brandt's | 1 | | | uncommon | MW |
| Cormorant, Double-crested | 2 | | 2 | abundant | BMW |
| Cormorant, Pelagic | 1 | | | uncommon | MW |
| Egret, Great | 2 | 2 | 2 | common | BMW |
| Grebe, Eared* | 1 | | 1 | uncommon | W |
| Grebe, Horned* | 1 | | 1 | common | W |
| Grebe, Pied-billed* | | | 1 | common | BMW |
| Grebe, Red-necked | 1 | | 1 | uncommon | W |
| Grebe, Western | 1 | | | common | BMW |
| Gull, Bonaparte's* | 1 | 1 | 1 | uncommon | M |
| Gull, California* | 1 | 1 | 1 | common | MW |
| Gull, Glaucous-winged* | 2 | 1 | 1 | abundant | BMW |
| Gull, Heermann's* | 1 | 1 | | uncommon | M |
| Gull, Herring* | 1 | 1 | | uncommon | MW |
| Gull, Mew* | 1 | 1 | 1 | common | W |

| | | | | | |
|---|---|---|---|---|---|
| Gull, Ring-billed* | 1 | 1 | 1 | common | MW |
| Gull, Western* | 2 | 1 | | abundant | BMW |
| Heron, Great Blue | 2 | 2 | 2 | abundant | BMW |
| Heron, Green | 1 | 1 | 2 | uncommon | BM |
| Kingfisher, Belted | 2 | | 2 | common | BMW |
| Loon, Common | 1 | | | uncommon | MW |
| Loon, Pacific | 1 | | | uncommon | MW |
| Loon, Red-throated | 1 | | 1 | uncommon | MW |
| Night-Heron, Black-crowned | 1 | | 2 | uncommon | Su |
| Osprey | 2 | | 2 | common | B |
| Pelican, Brown | 1 | 1 | | common | W |
| Tern, Caspian | 2 | | | common | M |
| Tern, Common | 1 | | | uncommon | M |

*Feeds largely on marsh invertebrates, probably less often on fish

### 3.2.7 Sustain Habitat for Ducks and Geese

**Definition and Documentation**: the capacity to sustain life requirements of a diversity and abundance of duck and goose species plus swans, primarily during winter and migration. If measured quantitatively, one expression of this function could be:

*number of bird-days of marsh use by waterfowl, per unit marsh area*

The most regularly occurring of these species in Oregon tidal marshes are listed in Table 10.

**Values**: Waterfowl are valuable to estuarine food webs as transformers and transporters of both terrestrial and aquatic organic matter. Prized by hunters and birders, ducks and geese provide recreational opportunities in seasonal concentrations that contribute to local economies during the usual tourist off-season. Moreover, the diversity of waterfowl species is valuable in its own right, as the manifestation of eons of natural selection, and for the aesthetic variety it provides. Waterfowl also can influence plant cover, species composition, and other functions within individual tidal marshes (Crandell 2001). Greatest value might be assigned to tidal marshes that consistently support waterfowl species or subspecies whose populations are declining or rare (e.g., Aleutian and dusky Canada goose, brant), either locally or continentally. Greater value also might be assigned to marshes that consistently support an unusual variety of waterfowl species, or which provide the only significant waterfowl habitat in a particular estuary. The importance to waterfowl of specific Oregon estuaries, and in some cases of specific tidal wetlands, is described in ODFW 1994a, 1994b. The stated goal of these coastal plans is to maintain waterfowl populations equal to the greatest population since 1970, specifically by maintaining north coast habitat so it is capable of supporting a peak population of 3,000 brant, 200 tundra swans, 1,000 Canada geese, and 37,000 ducks; and by maintaining south coast habitat so it can support a peak population of 1,000 tundra swans, 200 Canada geese, and 36,000 ducks.

## Table 10. Ducks, geese, and swans occurring regularly in Oregon tidal marshes

*Legend*
• = species feeds directly *on or above* the marsh
MSL = marine-sourced low marsh, MSH = marine-sourced high marsh, RS = river-sourced marsh
Abundance (uncommon, common, abundant) represents maximum density *within tidal marshes* and *their internal channels* coastwide during an average year; local densities may be lower
"Seasons" are the seasons of usual occurrence (W = winter, M = spring/fall migration, B = early summer breeding, Su = summer non-breeding)

| | MSL | MSH | RS | Abundance | Season |
|---|---|---|---|---|---|
| Brant, Black | ● | ● | ● | common | M |
| Bufflehead | ● | | ● | abundant | W |
| Canvasback | ● | | ● | common | W |
| Coot, American | | | ● | uncommon | W |
| Duck, Ruddy | | | ● | uncommon | W |
| Duck, Wood | | | ● | uncommon | W |
| Gadwall | ● | ● | ● | common | W |
| Goldeneye, Common | ● | | ● | uncommon | W |
| Goose, Canada | ● | ● | ● | abundant | W |
| Goose, White-fronted | ● | ● | ● | uncommon | M |
| Mallard | ● | ● | ● | abundant | W |
| Merganser, Common | ● | | ● | common | W |
| Merganser, Hooded | ● | | ● | uncommon | W |
| Merganser, Red-breasted | ● | | | common | W |
| Pintail, Northern | ● | ● | ● | abundant | W |
| Redhead | ● | | | common | W |
| Scaup, Greater | ● | | ● | common | W |
| Scaup, Lesser | ● | | ● | common | W |
| Scoter, Black | ● | | | uncommon | W |
| Scoter, Surf | ● | | | uncommon | W |
| Scoter, White-winged | ● | | | uncommon | W |
| Shoveler, Northern | | ● | ● | common | W |
| Swan, Tundra | | ● | ● | uncommon | W |
| Teal, Blue-winged | ● | ● | ● | uncommon | M |
| Teal, Cinnamon | ● | ● | ● | uncommon | M |
| Teal, Green-winged | | ● | ● | abundant | W |
| Wigeon, American | ● | ● | ● | abundant | W |

### 3.2.8 Sustain Habitat for Shorebirds

**Definition and Documentation**: the capacity to sustain life requirements of a diversity and abundance of shorebirds. If measured quantitatively, one expression of this function could be:

*number of bird-days of marsh use by all shorebird species, per unit marsh area*

Shorebirds primarily include sandpipers and plovers. Wading birds (herons and egrets) are sometimes grouped with shorebirds but differ in being primarily fish consumers, so are not included here. Shorebird species that occur in Oregon tidal marshes are listed in Table 11. Physical habitat preferred by most shorebirds is predominantly mudflat, shallow pools, and other sparsely vegetated wet soils, e.g., Stralberg et al. 2003. Within tidal marshes, shorebird use is favored by uneven topography, which creates a large and dynamic interspersion pattern between vegetation and flooded areas (Stralberg et al. 2003). Shorebirds use high marshes to a much lesser degree than low marshes. When they do, it is primarily for roosting and mainly occurs when wide high marshes directly adjoin or are very near the low marshes.

In Oregon, no shorebird species uses tidal marshes exclusively, and no shorebird species nests in tidal marshes regularly. Most shorebirds use tidal marshes primarily during spring and fall migration. Most shorebird use of Oregon tidal marshes occurs as the birds pass through the region as they migrate between their Arctic nesting grounds and coastal wintering grounds within or south of Oregon. When cold snaps cause inland soils to freeze, shorebirds may move locally to the coast to forage in tidal wetlands and mudflats that provide the only unfrozen soil in which shorebirds may continue to probe for invertebrates. When mudflats are covered with water at high tide or during stormy periods, tidal marshes (along with large beaches, offshore ledges, and sparsely vegetated islands and pastures) provide important resting areas for migratory and wintering shorebirds. Moreover, much of the productivity of mudflats preferred by shorebirds likely is attributable to their adjoining tidal marshes.

**Values**: Like waterfowl, shorebirds are valuable to estuarine food webs as transformers and transporters of both terrestrial and aquatic organic matter. The diversity of shorebird species is valuable as the manifestation of eons of natural selection, and for the aesthetic variety it provides. This diversity is the basis for Coos Bay's annual Shorebird Festival, which for years has attracted birders from all over the state. Greatest value might be assigned to tidal marshes that consistently support shorebirds whose populations are declining or rare, either locally or continentally. Greater value also might be assigned to marshes that consistently support an exceptional abundance or variety of shorebird species, or which provide the only significant shorebird habitat in a particular estuary. The importance to shorebirds of specific Oregon estuaries, and in some cases of specific tidal wetlands, is described in ODFW 1994a, 1994b. The stated goal of these coastal plans is to maintain shorebird populations equal to the greatest population since 1970, specifically by maintaining north coast habitat so it is capable of supporting a peak population of 150,000 shorebirds, and by maintaining south coast habitat so it can support a peak population of 40,000 shorebirds.

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### Table 11. Shorebird species that occur regularly in Oregon tidal marshes

*Legend*

2 = species typically feeds directly *on* the marsh; 1 = mostly uses marsh for roosting during daily high tides.

MSL = marine-sourced low marsh, MSH = marine-sourced high marsh, RS = river-sourced marsh

Abundance (uncommon, common, abundant) represents total density *within marshes* and *their internal channels* coastwide during an average year, but local densities may be lower

"Seasons" are the seasons of usual occurrence (W = winter, M = spring/fall migration)

Note: Three species that occasionally use tidal marshes and might be included as shorebirds (Wilson's Snipe, Virginia Rail, Sora) are not included in the scoring model because their needs for denser vegetation differ significantly from the needs of the species listed below.

| | MSL | MSH | RS | Abundance | Seasons |
|---|---|---|---|---|---|
| Dowitcher, Long-billed | 2 | 1 | 2 | common | MW |
| Dowitcher, Short-billed | 2 | 1 | 2 | common | M |
| Dunlin | 2 | 1 | 2 | common | MW |
| Godwit, Marbled | 2 | 1 | 2 | uncommon | M |
| Killdeer | 2 | 2 | 2 | common | MW |
| Plover, Black-bellied | 2 | 1 | 2 | uncommon | MW |
| Plover, Semipalmated | 2 | 1 | 2 | common | M |
| Sanderling | 2 | 1 | 2 | uncommon | MW |

| | | | | | |
|---|---|---|---|---|---|
| Sandpiper, Baird's | 2 | 1 | 2 | uncommon | M |
| Sandpiper, Least | 2 | 1 | 2 | common | M |
| Sandpiper, Pectoral | 2 | 1 | 2 | uncommon | M |
| Sandpiper, Spotted | 2 | 1 | 2 | uncommon | M |
| Sandpiper, Western | 2 | 1 | 2 | common | M |
| Whimbrel | 2 | 1 | 2 | uncommon | M |
| Willet | 2 | 1 | 2 | uncommon | M |
| Yellowlegs, Greater | 2 | 1 | 2 | common | MW |
| Yellowlegs, Lesser | 2 | 1 | 2 | uncommon | M |

### 3.2.9 Sustain Habitat for Native Landbirds, Small Mammals, and Their Predators

**Definition and Documentation**: the capacity to sustain life requirements of a diversity and abundance of native landbirds, small mammals, and their predators, e.g., raptors. If measured quantitatively, one expression of this function could be:

*mean number of landbird species visiting or nesting in the marsh, per unit marsh area*

In Oregon, landbirds, small mammals, and their predators do not breed in low marshes but feed there extensively. Even in high marshes and river-sourced tidal marshes, relatively few species are present as breeders compared with other coastal habitats. High marshes provide feeding grounds for many upland species, particularly swallows, flycatchers, blackbirds, raptors, otter, raccoon, and deer. Mammals known to use Oregon tidal marshes are listed in Table 12, and the most regularly occurring of the native landbird and raptor species that use Oregon tidal marshes are listed in Table 13. The only non-native birds and mammals that use Oregon's tidal marshes regularly are European starling and black rat. Life history information on Oregon coastal mammals is provided by Maser et al. (1981), but this source does not specifically describe use of tidal marshes.

**Values**: Songbirds, raptors, and small mammals that inhabit tidal marshes are valuable to estuarine food webs primarily for their role in cycling nutrients between terrestrial and aquatic environments. They also are valued by a broad sector of the public for the aesthetic diversity and recreational opportunities (birding) they provide. None of Oregon's landbird and mammal species or subspecies that are known to use tidal marshes depend on them exclusively. Populations of peregrine falcons and bald eagles — once very rare and declining nationwide — appear to be stable or increasing. At a local scale, high marshes sometimes provide the most important (or only) nesting and/or feeding habitat for purple martin, marsh wren, savannah sparrow, northern harrier, and white-tailed kite. In late summer and again in early spring, some tidal marshes provide important staging areas for huge swarms of swallows. Greater value also might be assigned to marshes that consistently support an exceptional abundance or variety of landbirds, small mammals, or their predators, or which provide the only significant habitat in an estuary for one of the species in this group.

## Table 12. Native mammals documented from some Oregon tidal marshes

M = Magwire 1976 (Coos Bay); S = Stout et al. 1976 (Netarts Bay); SS = South Slough NERR scientists; PC = personal observation or communication from landowners or biologists

| Common Name | Scientific Name | Source |
|---|---|---|
| Bear, black | *Ursus americanus* | PC |
| Beaver, American | *Castor canadensis* | M, SS |
| Bobcat | *Lynx rufus* | M |
| Coyote | *Canis latrans* | M |
| Deer, black-tailed | *Odocoileus hemionus* | PC |
| Elk, Roosevelt | *Cervus elaphus* | PC |
| Fox, gray | *Urocyon cinereoargenteus* | M |
| Mink | *Mustela vison* | M |
| Mouse, deer | *Peromyscus maniculatus* | M |
| Mouse, Oregon meadow | *Microtus oregonii* | M |
| Mouse, western red-backed | *Clethrionomys occidentalis* | M |
| Muskrat | *Ondatra zibethicus* | M |
| Otter, river | *Lutra canadensis* | M,SS |
| Raccoon | *Procyon lotor* | M, S, SS |
| Shrew, Trowbridge | *Sorex trowbridgii* | M |
| Shrew, vagrant | *Sorex vagrans* | M, S |
| weasel species | *Mustela* spp. | M |
| bat species | Chiroptera spp. | PC |

## Table 13. Landbirds and raptors found most regularly in tidal marshes of the Oregon coast

*Legend*
MSL = marine-sourced low marsh, MSH = marine-sourced high marsh, RS = river-sourced marsh (may include Sitka spruce and other tree and shrub species as minor components)
1 = species feeds on insects over the marsh but does feed or nest in it; 2 = species feeds in the marsh but typically does not breed in it; 3 = species breeds within the marsh
Abundance (uncommon, common, abundant) represents total density *within or over marshes* and *their internal channels* coastwide during an average year, but local numbers may be lower
"Seasons" are the seasons of predominant occurrence (W = winter, M = spring/fall migration, B = early summer breeding)

| | MSL | MSH | RS | Abundance | Seasons |
|---|---|---|---|---|---|
| Blackbird, Brewer's | 2 | 2 | 2 | common | B |
| Blackbird, Red-winged | 1 | 2 | 3 | abundant | BM |
| Cowbird, Brown-headed | | 3 | 3 | uncommon* | B |
| Crow, American | 2 | 2 | 2 | abundant | BMW |
| Eagle, Bald | 2 | 2 | 2 | uncommon | BMW |
| Flycatcher, Olive-sided | | 1 | 1 | uncommon* | BM |
| Flycatcher, Pacific-slope | | 1 | 1 | uncommon* | BM |
| Goldfinch, American | | 2 | 2 | common | BMW |
| Harrier, Northern | 2 | 3 | 2 | uncommon | BMW |
| Hawk, Coopers | | 2 | 2 | uncommon | BMW |
| Hawk, Red-shouldered | | 2 | 2 | uncommon | BMW |
| Hawk, Red-tailed | | 2 | 2 | common | BMW |
| Hawk, Rough-legged | | 2 | 2 | uncommon | W |
| Hawk, Sharp-shinned | | 2 | 2 | uncommon | BMW |
| Hummingbird, Allen's | | 2 | 2 | uncommon | B |
| Hummingbird, Anna's | | 2 | 2 | uncommon | B |

|  | MSL | MSH | RS | Abundance | Seasons |
|---|---|---|---|---|---|
| Hummingbird, Rufous |  | 2 | 2 | uncommon | BM |
| Jay, Steller's |  | 2 | 2 | uncommon* | BMW |
| Junco, Dark-eyed |  | 2 | 2 | common | BMW |
| Kestrel, American |  | 2 | 2 | uncommon | BMW |
| Kite, White-tailed |  | 2 | 2 | uncommon | BMW |
| Martin, Purple | 2 | 2 | 2 | uncommon | B |
| Merlin | 2 | 2 | 2 | uncommon | MW |
| Nighthawk, Common |  | 2 | 2 | uncommon | BM |
| Owl, Barn |  | 2 | 2 | uncommon | BW |
| Owl, Great Horned |  | 2 | 2 | common | BW |
| Owl, Northern Pygmy |  | 2 | 2 | uncommon* | BW |
| Owl, Saw-whet |  | 2 | 2 | uncommon* | BW |
| Owl, Short-eared |  | 2 | 2 | uncommon | MW |
| Owl, Western Screech |  | 2 | 2 | uncommon* | BW |
| Phoebe, Black |  | 2 | 2 | uncommon* | W |
| Pigeon, Band-tailed |  | 2 | 2 | uncommon* | BM |
| Pipit, Water | 2 | 2 | 2 | common | MW |
| Raven, Common | 2 | 2 | 2 | common | BMW |
| Robin, American | 2 | 2 | 2 | abundant | BMW |
| Shrike, Northern |  | 2 | 2 | uncommon* | MW |
| Sparrow, Fox |  | 2 | 2 | common* | MW |
| Sparrow, Golden-crowned |  | 2 | 2 | common* | MW |
| Sparrow, Lincoln's |  | 2 | 2 | uncommon* | MW |
| Sparrow, Savannah |  | 3 | 3 | common | MW |
| Sparrow, Song |  | 3 | 3 | abundant | BMW |
| Sparrow, Swamp |  | 2 | 2 | uncommon | W |
| Sparrow, White-crowned |  | 2 | 2 | abundant* | BMW |
| Swallow, Bank | 2 | 2 | 2 | uncommon | B |
| Swallow, Barn | 2 | 2 | 2 | abundant | BM |
| Swallow, Cliff | 2 | 2 | 2 | common | BM |
| Swallow, Northern Rough-winged | 2 | 2 | 2 | uncommon | BM |
| Swallow, Tree | 2 | 2 | 2 | abundant | BM |
| Swallow, Violet-green | 2 | 2 | 2 | common | BM |
| Swift, Vaux's | 2 | 2 | 2 | common | BM |
| Tanager, Western |  | 1 | 1 | uncommon* | BM |
| Thrush, Swainson's |  | 1 | 1 | uncommon* | BM |
| Towhee, Spotted |  | 2 | 2 | uncommon* | BMW |
| Vulture, Turkey | 2 | 2 | 2 | common | BM |
| Warbler, Yellow-rumped |  | 1 | 1 | common* | BMW |
| Waxwing, Cedar |  | 2 | 2 | common* | BM |
| Wood-Pewee, Western |  | 2 | 2 | uncommon* | BM |
| Wren, Marsh |  | 3 | 3 | common | BMW |
| Yellowthroat, Common | 1 | 3 | 3 | common | BM |

*Mostly restricted to spruce or shrub tidal wetlands and to the wooded edges of marshes

### 3.2.10 Sustain Native Botanical Conditions

**Definition and Documentation**: the capacity to sustain life requirements of native vascular plant species and communities (especially the most sensitive ones) that are characteristic of tidal wetlands. These species are listed in Table 14. If measured quantitatively, this function could be expressed as:

*frequency* and *percent cover (across an entire site) of native marsh flora typical of the HGM subclass*

**Values**: Through changes in species composition and spatial pattern, plant communities forewarn of more fundamental and serious impacts to natural processes within wetlands. Many plant species that occur in Oregon's tidal marshes occur seldom if ever in non-tidal habitats, and so are valued for their substantial contribution to local and regional biodiversity. Their diversity, although limited compared with many other habitats, in turn supports diverse assemblages of other organisms and biogeochemical processes. This is partly because different plant species mature and decay at different rates, implying a more seasonally sustained source of food and cover for invertebrate communities. A greater variety of invertebrates (especially insects) is likely to occur where marshes contain structurally diverse communities of herbaceous plants (Keer and Zedler 2002). Taller plants can provide refugia from spring tides, and shorter plants can provide shelter from the elements.

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## Table 14. Plant species found in tidal marshes of the Oregon coast

List is not comprehensive. It was compiled from many sources (e.g., Jefferson 1975, Hofnagle 1976, Frenkel and Morlan 1990, Shaffer 1999). Contains all common species and many species not generally characteristic of tidal marshes, but present along fresher margins.

*Legend*

*Elevation*: H = high marsh, L = low marsh, HL = both high and low (or mid-elevation only)

*Salinity Requirement*: F = fresh (e.g., "pasture" or "seep" species), B = brackish (semi-tolerant species), S = saline species (i.e., halophytes), FBS = widely tolerant

*Indicator Status*: according to USFWS list, 1996 (unofficial) version:

| | | |
|---|---|---|
| OBL | Obligate Wetland | Occurs almost always (estimated probability 99%) under natural conditions in wetlands |
| FACW | Facultative Wetland | Usually occurs in wetlands (estimated probability 67–99%), but occasionally found in non-wetlands |
| FAC | Facultative | Equally likely to occur in wetlands or non-wetlands (estimated probability 34–66%) |
| FACU | Facultative Upland | Usually occurs in non-wetlands (estimated probability 67–99%), but occasionally found on wetlands (estimated probability 1–33%) |
| U | Upland | Not on list |
| NI | | No Indicator/Insufficient Information |
| +, - | (modifier) | + slightly wetter, - slightly drier |

| | Elevation | Salinity | Indicator Status | Native? |
|---|---|---|---|---|
| **Aquatic bed herbaceous species** | | | | |
| *Lilaeopsis occidentalis* | L | BS | OBL | yes |
| *Myriophyllum spicatum* | H | F | OBL | yes |
| *Potamogeton foliosis* | H | F | OBL | yes |
| *Potamogeton natans* | H | F | OBL | yes |
| *Ruppia maritima* | L | BS | OBL | yes |
| *Zostera japonica* | L | S | OBL | no |
| *Zostera marina* | L | S | OBL | yes |
| **Emergent or upland herbaceous species** | | | | |

| | Elevation | Salinity | Indicator Status | Native? |
|---|---|---|---|---|
| *Achillea millefolium* | H | FB | FACU | no |
| *Agropyron repens* | H | F | FACU | no |
| *Agrostis stolonifera (A. alba)* | HL | FBS | FACW | no |
| *Alisma plantago-aquatica* | H | F | OBL | yes |
| *Alopecurus geniculatus* | H | F | OBL | yes |
| *Alopecurus pratensis* | H | F | FACW | no |
| *Anaphalis margaritacea* | H | FB | U | yes |
| *Angelica lucida* | H | F | FAC+ | yes |
| *Anthoxanthum odoratum* | H | FB | FACU | no |
| *Argentina egedii*<br>*(Potentilla anserina var. pacifica)* | H | FBS | FAC- | yes |
| *Athyrium filix-femina* | H | F | FAC+ | yes |
| *Atriplex leucophylla* | H | F | FAC | yes |
| *Atriplex patula* | HL | FBS | FACW | yes |
| *Barbarea orthoceras* | H | F | FACW+ | yes |
| *Bidens cernua* | H | F | FACW+ | yes |
| *Calamagrostis nutkaensis* | H | F | FACW | yes |
| *Callitriche spp.* | H | F | OBL | yes |
| *Carex laeviculmis* | H | F | FACW | yes |
| *Carex lyngbyei* | HL | FBS | OBL | yes |
| *Carex macrocephala* | H | F | FAC- | yes |
| *Carex obnupta* | H | F | OBL | yes |
| *Carex rostrata* | H | F | OBL | yes |
| *Carex vesicaria v. major* | H | F | OBL | yes |
| *Castilleja ambigua* | HL | BS | FACW+ | yes |
| *Chenopodium humile* | H | B | FAC+ | no |
| *Cicuta douglasii* | H | F | OBL | yes |
| *Cirsium arvense* | H | FB | FAC- | no |
| *Conioselinum gmelinii* | H | F | FACW | yes |
| *Conium maculatum* | H | F | FACW- | no |
| *Convolvulus arvensis* | H | F | U | no |
| *Cordylanthus maritimus ssp. palustris* | H | F | OBL | yes |
| *Cotula coronopifolia* | HL | BS | FACW+ | no |
| *Cuscuta salina* | L | S | OBL | yes |
| *Deschampsia caespitosa* | H | FBS | FACW | yes |
| *Distichlis spicata* | L | BS | FACW | yes |
| *Echinochloa crusgalli* | H | F | FACW | no |
| *Eleocharis palustris* | HL | FB | OBL | yes |
| *Eleocharis parvula* | HL | S | OBL | yes |
| *Elymus mollis* | H | FBS | U | yes |
| *Epilobium ciliatum ssp. watsonii* | H | FB | FACW- | yes |
| *Equisetum arvense* | H | F | FAC | yes |
| *Erechtites minima* | H | FB | U | no |
| *Euthamia occidentalis* | H | F | FACW | yes |
| *Festuca arundinacea* | H | F | FAC- | yes |
| *Festuca rubra* | H | FB | FAC+ | yes |
| *Galium aparine* | H | FB | FACU | yes |
| *Galium trifidum* | H | FB | FACW+ | yes |
| *Glaux maritima* | L | BS | FACW+ | yes |
| *Grindelia stricta* | H | FB | OBL | yes |
| *Heracleum lanatum* | H | FB | FAC+ | yes |
| *Holcus lanatus* | H | F | FAC | no |

| | Elevation | Salinity | Indicator Status | Native? |
|---|---|---|---|---|
| *Honkenya peploides* | H | F | FACU | yes |
| *Hordeum brachyantherum* | HL | FB | FACW- | yes |
| *Hordeum jubatum* | H | FB | FAC- | yes |
| *Impatiens noli-tangere* | H | F | FACW | yes |
| *Isolepis cernua (Scirpus cernuus)* | HL | BS | OBL | yes |
| *Jaumea carnosa* | HL | BS | OBL | yes |
| *Juncus acuminatus* | H | F | OBL | yes |
| *Juncus articulatus* | H | F | OBL | yes |
| *Juncus balticus* | HL | FB | FACW | yes |
| *Juncus bolanderi* | H | F | OBL | yes |
| *Juncus bufonius* | H | F | FACW | yes |
| *Juncus effusus* | H | F | FACW | yes |
| *Juncus ensifolius* | H | F | FACW | yes |
| *Juncus falcatus* | H | F | FACW | yes |
| *Juncus gerardii* | HL | S | FACW+ | yes |
| *Juncus lesueurii* | H | FBS | FACW | yes |
| *Juncus marginatus* | H | F | NI | yes |
| *Juncus tenuis* | H | F | FACW- | yes |
| *Lathyrus palustris* | H | FB | OBL | yes |
| *Limonium californicum* | H | F | OBL | yes |
| *Limosella aquatica* | HL | F | OBL | yes |
| *Lolium perenne* | H | F | FAC | no |
| *Lotus corniculatus* | H | F | FAC | no |
| *Lysichiton americanus* | H | F | OBL | yes |
| *Lythrum salicaria* | H | FB | FACW+ | no |
| *Melilotus albus* | H | F | U | no |
| *Mentha pulegium* | H | F | OBL | no |
| *Oenanthe sarmentosa* | H | F | OBL | yes |
| *Parentucellia viscosa* | H | F | FAC- | no |
| *Paspalum distichum* | H | F | FACW | yes |
| *Phalaris arundinacea* | H | FB | FACW | no |
| *Phragmites australis (P. communis)* | H | FB | FACW+ | no |
| *Plantago coronopus* | H | F | FACW | yes |
| *Plantago maritima* | HL | BS | FACW+ | yes |
| *Plantago subnuda* | H | F | FACW | yes |
| *Plectritis congesta* | HL | FB | FACU+ | yes |
| *Poa pratensis* | H | F | FAC | no |
| *Polygonum aviculare* | H | F | FACW- | no |
| *Polygonum fowleri* | H | F | FACW | yes |
| *Polygonum hydropiperoides* | H | F | OBL | yes |
| *Polypogon monospeliensis* | H | F | FACW | no |
| *Polystichum munitum* | H | F | FACU | yes |
| *Puccinellia pumila* | L | S | FACW+ | yes |
| *Ranunculus repens* | H | F | FACW | no |
| *Ranunculus sceleratus* | H | F | OBL | yes |
| *Rorippa nasturtium-aquaticum* | H | F | OBL | no |
| *Rumex acetosella* | H | F | FACU+ | no |
| *Rumex conglomeratus* | H | FB | FACW | no |
| *Rumex crispus* | H | FB | FAC+ | no |
| *Rumex maritimus* | HL | FB | FACW+ | yes |
| *Rumex obtusifolius* | H | F | FAC | no |
| *Rumex occidentalis* | H | FB | FACW+ | yes |

| | Elevation | Salinity | Indicator Status | Native? |
|---|---|---|---|---|
| *Sagittaria latifolia* | H | F | OBL | yes |
| *Salicornia virginica* | L | S | OBL | yes |
| *Schoenoplectus (Scirpus) acutus* | H | F | OBL | yes |
| *Schoenoplectus (Scirpus) americanus* | L | FB | OBL | yes |
| *Schoenoplectus (Scirpus) maritimus* | HL | BS | OBL | yes |
| *Schoenoplectus (Scirpus) microcarpus* | H | F | OBL | yes |
| *Schoenoplectus (Scirpus) robustus* | H | F | OBL | yes |
| *Schoenoplectus (Scirpus) subterminalis* | H | F | OBL | yes |
| *Schoenoplectus (Scirpus) acutus* | HL | FB | OBL | yes |
| *Sidalcea hendersonii* | HL | BS | FACW+ | yes |
| *Sparganium emersum* | H | F | OBL | yes |
| *Sparganium eurycarpum* | H | F | OBL | yes |
| *Spartina patens* | H | S | OBL | yes |
| *Spergularia canadensis* | L | S | FACW | yes |
| *Spergularia macrotheca* | HL | BS | FAC | yes |
| *Spergularia rubra* | H | FB | FAC- | no |
| *Spergularia salina* | L | BS | OBL | no |
| *Spergularia villosa* | L | S | U | no |
| *Stellaria calycantha* | HL | BS | FACW | yes |
| *Stellaria humifusa* | HL | FBS | OBL | yes |
| *Symphyotrichum (Aster) subspicatus* | H | FB | FACW | yes |
| *Trifolium repens* | H | F | FAC- | no |
| *Trifolium wormskioldii* | H | FB | FACW+ | yes |
| *Triglochin concinnum* | HL | S | OBL | yes |
| *Triglochin maritimum* | HL | BS | OBL | yes |
| *Triglochin palustre* | HL | F | OBL | yes |
| *Triglochin striatum* | HL | F | OBL | yes |
| *Typha latifolia* | H | F | OBL | yes |
| *Veronica americana* | H | F | OBL | yes |
| *Vicia americana* | H | F | FAC | yes |
| *Vicia nigricans ssp. gigantea* | H | FB | NI | yes |
| | | | | |
| **Woody species** | | | | |
| *Alnus rubra* (alder) | H | F | FAC | yes |
| *Cornus sericea* (dogwood) | H | F | FACW | yes |
| *Fraxinus latifolia* (ash) | H | F | FACW | yes |
| *Lonicera involucrata* (honeysuckle) | H | FB | FAC+ | yes |
| *Malus fusca* (crabapple) | H | F | FAC+ | yes |
| *Myrica californica* (wax myrtle) | H | F | FACW | yes |
| *Physocarpus capitatus* (ninebark) | H | F | FACW | yes |
| *Picea sitchensis* (Sitka spruce) | H | F | FAC | yes |
| *Rhamnus purshiana* (cascara) | H | F | FAC- | yes |
| *Rubus spectabilis* (salmonberry) | H | F | FAC+ | yes |
| *Salix hookeriana* (willow) | H | FB | FACW | yes |
| *Spiraea douglasii* (hardhack) | H | F | FACW | yes |
| *Thuja plicata* (western red cedar) | H | F | FAC | yes |

## 3.3 Rationales for Tidal Wetland Indicators

### 3.3.1 Introduction

This chapter discusses indicators of risks to wetland integrity, indicators of integrity itself, and indicators of functions. In the following pages, the various indicators are listed in the same sequence in which they appear on the HGM method's data form (see Part 1 and accompanying spreadsheet). They are grouped under these headings:

A1. Rapid Indicators of Risks to Wetland Integrity and Sustainability
A2. Indicators of Wetland Integrity
B1. Rapid Indicators of Function That May Be Estimated
B2. Rapid Indicators of Function Requiring Airphotos or Measuring Equipment

Indicators of "values" (of the functions) are not documented because of the subjectivity in selecting those.

### 3.3.2 Indicators of Risks to Wetland Integrity

*A1. Rapid Indicators of Risks to Wetland Integrity and Sustainability*

**BuffAlt**: Simply describing the land cover in the buffer zone around a wetland does not fully account for risks to the wetland's integrity. When disturbed land is present, much of its impact on a wetland depends on the steepness and soil type of the buffer, with steeper buffers and coarser soils having greater capacity to allow the transport of contaminants from disturbed lands. Wetlands that receive significant runoff from pavement, roadside ditches, or clearcut lands sometimes experience aberrant patterns of runoff, characterized by sharper peaking of water levels after storms and less runoff entering the wetland during dry periods. In Oregon, type and extent of land cover have been shown in some situations to accurately predict water quality and types of aquatic algae in receiving waters (Yangdong et al. 2004). Many native plant species are poorly adapted to these aberrant hydroperiods and so do not persist in the impacted wetlands. These botanical impacts have been well documented in freshwater wetlands and streams but seldom have been investigated in tidal wetlands. A Rhode Island study found that plant zonation in tidal marshes correlated negatively with surrounding residential land use (Wigand et al. 2001) that was accompanied by marsh contamination (Paul et al. 2002).

Because of the difficulty of estimating slope angle rapidly, this method uses relative elevation of the upland as a surrogate for slope and limits the buffer assessment to the area within 100 ft of the wetland. Land cover at farther distances can be difficult to assess accurately while onsite. Also, this threshold is used because under normal circumstances most contaminants in runoff are processed within 100 ft (Sheldon et al. 2005). Consideration of upland land cover is moot on islands consisting entirely of wetlands. The percentage categories used to score land cover in the method presented in Part 1 are based on data suggesting that wetlands and streams whose contributing areas contain more than about 15% developed land tend to have reduced avian diversity (DeLuca et al. 2004). Of the 120 tidal wetland sites we assessed, only 30 had development (roads, buildings) in more than 15% of their upland buffer. Thus, unlike the situation in more-urban states, proportionately few tidal wetlands in Oregon are adjoined by large expanses of pavement or housing.

The score distribution for this indicator is shown in Table 15. Higher scores indicate that buffer areas around a site were considered to be less effective due to their land cover, soils, and/or slope. The formula used to combine these factors disregards steepness and soil type if land cover of the buffer zone is unaltered. Considering just the correlations that were significant statistically, the function indicators whose scores correlated negatively with *BuffAlt* scores were (in descending order): *SoilFine, BlindL, Width, Jcts, LWDmarsh, Roost, Panne, Exits,* and *Fetch*. Ones that correlated positively were *Island, UpEdge, HomeDis, Fresh, FootVis,* and *FormDiv*. By HGM subclass, River-sourced Tidal Wetlands tended to have somewhat greater buffer alteration scores.

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**Table 15. Score distribution among the 120 surveyed wetlands for indicators of risk to wetland integrity**

Lower scores indicate less risk. As an example of how to interpret percentiles, consider the first row (BuffAlt). This reports that 95% of all surveyed wetlands scored a 0.69 or lower for BuffAlt, i.e., only 5% scored higher than that. In contrast, of the least-altered wetlands, 95% scored 0.40 or less, i.e., only 5% scored higher than that, so they generally were at lower risk than all wetlands together. The 50th percentile is the same as the median score. "Least altered" wetlands were prejudged to be the least likely to have sustained lasting damage from human activities. There is some circularity in the statistics below because risk scores were used to help decide which wetlands should be categorized as least-altered, but this table illustrates that the selection of least-altered sites was systematic and not entirely subjective.

| | All Surveyed Wetlands (n = 120) | | | | | Wetlands Deemed "Least-Altered" (n = 25) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| percentile: | 5th | 25th | 50th | 75th | 95th | 5th | 25th | 50th | 75th | 95th |
| BuffAlt | 0.01 | 0.20 | 0.20 | 0.30 | 0.69 | 0.01 | 0.10 | 0.20 | 0.30 | 0.40 |
| ChemIn | 0.01 | 0.01 | 0.01 | 0.33 | 0.66 | 0.01 | 0.01 | 0.01 | 0.01 | 0.33 |
| NutrIn | 0.01 | 0.01 | 0.33 | 0.33 | 1.00 | 0.01 | 0.01 | 0.33 | 0.33 | 0.66 |
| SedShed | 0.01 | 0.01 | 0.50 | 0.50 | 1.00 | 0.01 | 0.01 | 0.01 | 0.50 | 1.00 |
| SoilX | 0.01 | 0.10 | 0.20 | 0.30 | 0.59 | 0.01 | 0.01 | 0.10 | 0.20 | 0.30 |
| DikeDry | 0.01 | 0.01 | 0.01 | 0.01 | 0.64 | 0.01 | 0.01 | 0.01 | 0.01 | 0.33 |
| DikeWet | 0.01 | 0.01 | 0.01 | 0.01 | 0.33 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| FootVis | 0.01 | 0.01 | 0.01 | 0.33 | 1.00 | 0.01 | 0.01 | 0.01 | 0.01 | 0.60 |
| Boats | 0.01 | 0.40 | 0.40 | 0.80 | 1.00 | 0.07 | 0.40 | 0.40 | 0.80 | 0.94 |
| HomeDis | 0.01 | 0.01 | 0.50 | 0.75 | 1.00 | 0.01 | 0.01 | 0.25 | 0.75 | 0.75 |
| RoadX | 0.01 | 0.01 | 0.01 | 0.40 | 0.80 | 0.01 | 0.01 | 0.01 | 0.01 | 0.40 |
| Invas | 0.01 | 0.01 | 1.00 | 1.00 | 1.00 | 0.01 | 0.38 | 1.00 | 1.00 | 1.00 |
| Instabil | 0.01 | 0.10 | 0.30 | 0.50 | 0.60 | 0.01 | 0.10 | 0.20 | 0.40 | 0.57 |

**ChemIn**: Developed land is assumed to be a potential source of contamination of tidal marshes (Paul et al. 2002). Contaminants such as pesticides (Pohlman et al. 2002) and heavy metals pose important and well-documented threats to tidal wetland integrity and some functions (Gallagher et al. 1996, Thompson and Lowe 2004, and see Appendix A of Part 3 of this guidebook). However, estimating this potential rapidly and without direct measurement presents a daunting challenge, so "Certainty" normally should be scored low. This guidebook's method assesses the potential based on three factors: the expected toxicity of contaminants, dilution, and extent of the wetland likely to be affected. Because of the difficulty of visually estimating pollution status, users of the method are given a fair amount of discretion in estimating these factors, and only four score choices are allowed. The formula used to combine the factors disregards dilution and extent of impact if there is no expected toxicity. This indicator also was used to score four functions: Inv, Afish, Mfish, Rfish. The score distribution is shown in Table 15. Higher scores indicate that potential for chemical impacts to a site was considered greater due to contaminant type, lack of dilution, and other factors. Considering just the correlations that were significant statistically, the only function indicators whose scores correlated negatively with ChemIn were *FreshSpot* and *Island.*

**NutrIn**. Overenrichment of wetlands can degrade their biological integrity, but estimating this potential rapidly without direct measurement is a major challenge because at lower concentrations nutrients are beneficial. Fertilization can increase the utilization of marsh plants by waterfowl (Lovvorn and Baldwin 1996). Up to some limit, waterfowl numbers may be greater in estuaries that are more nutrient rich, and birds can, in turn, add to the nutrient loading of marshes (Andersen et al. 2003). Several experiments and empirical studies have demonstrated increased growth of tidal marsh plants dosed with nutrients — occasionally phosphorus (Valiela et al. 1992) and especially nitrogen (e.g., Estrada et al. 1974, Bertness and Pennings 2000, Teal and Howes 2000, Boyer et al. 2001). Other responses sometimes include increased species relative dominance, height (but seldom density), and productivity (Rabalais and Nixon 2002, Boyer and Zedler 1999). One study in Rhode Island found that nitrogen concentration in marsh plant leaves correlated positively with surrounding residential land use (Wigand et al. 2001), and a nationwide survey, with the use of isotopes, documented a direct link between nutrients specifically from wastewater and increases in some tidal marsh plants (Cole et al. 2004). In contrast, one laboratory study reported no increased growth of a native tidal marsh plant in response to soil fertilization (Vance et al. 2003). Some non-native plants seem more able than native plants to exploit nutrient increases, and this may be a factor in their spread (Wigand et al. 2003).

Macroalgae in Oregon appear to be phosphorus-limited (especially in spring and summer) in upper parts of estuaries but nitrogen-limited in lower estuaries (Collins 1987). Marsh plants may have only limited capacity for increasing their production sustainably in response to sporadic or sustained nitrogen additions (Zedler and Lindig-Cisneros 2000, Lindig-Cisneros et al. 2003). Also, much of the added nitrate — particularly if it enters the marsh via groundwater rather than surface water exchange — is removed by denitrification before it can become available to vascular plants (Teal and Howes 2000, Hammersley and Howes 2003). Nutrient additions may serve mainly to reduce belowground competition among plants, thus allowing aboveground factors (such as light) to assume greater influence and cause shifts in plant species composition (Bertness and Pennings 2000).

Whether tidal wetlands can endure, over the long term, the types of nutrient loads described by this indicator remains an open question. In the Pacific Northwest, marsh plants have evolved in or successfully colonized an environment that annually received large pulses of nutrients, mainly from thousands of decaying spawned-out salmon (Sugai and Burrell 1984), from leaves of nitrogen-fixing alder (*Alnus rubra*) shrubs (Wigington et al. 1998, Compton et al. 2003, Volk 2003, Volk et al. 2004), from seasonal concentrations of waterfowl, and from nitrogen-fixing algae and microbial communities. Salmon runs are now much diminished, so nutrients are presumably scarcer, at least seasonally. Consequently the relative importance of nutrients as a pivotal factor limiting marsh plant production might now be greater, and the degree to which human-related nutrient sources now compensate for the reductions in traditional sources — in timing, location, form, and amount — is unknown.

This guidebook's method assesses the potential in a manner similar to that used for *ChemIn* above. It does not attempt to distinguish between harmful vs. beneficial levels of nutrient input. This indicator also was used to score two functions: *AProd* and *Dux*. The score distribution is shown in Table 15. Higher scores indicate that the potential for nutrient inputs to a wetland was considered to be greater due to surrounding land cover, soils, and/or slope. More detailed models useful for predicting the potential for nutrient inputs to Oregon coastal wetlands are available from:

- Oregon Dept. of Agriculture (OSU's "OWQDA" model): http://eesc.orst.edu/agcomwebfile/edmat/em8705.pdf
- NRCS ("Oregon Phosphorus Index"): ftp://ftp-fc.sc.egov.usda.gov/OR/Technical_Notes/Water%20Quality/
- USEPA (Eldridge et al., in preparation)

Considering just the correlations that were significant statistically, the function indicators whose scores correlated negatively with *NutrIn* scores were (in descending order): *MudW, LWDline,* and *Fetch*. Indicators whose scores correlated positively with *NutrIn* scores were: *Fresh, TribL, WetField%, Width, Flood,* and *SoilFine.* Scores for *NutrIn* were not significantly related to HGM subclass.

**SedShed**: Although the continued growth and stability of many tidal wetlands depends on sediment inputs, excessive sediment may impair some wetland functions. Common sources include runoff from urban, agricultural, and logged lands, but the magnitude of input depends largely on geomorphic factors in a particular watershed (Chamberlin et al. 1991). In some estuaries of the Pacific Northwest, oceanographic processes outside an estuary may supply as much or more sediment to habitats within an estuary (Hickey and Banas 2003). Because of the difficulty of assessing detrimental sediment inputs using only a rapid method, users are given a fair amount of discretion in estimating this, and only three score choices are allowed. "Certainty" normally should be scored low. This indicator also was used to score the *Inv* function. The score distribution is shown in Table 15. Considering just the correlations that were significant statistically, the function indicators whose scores correlated with *SedShed* scores were (in descending order): *BlindL, Fetch,* and *Exits* — all negatively. Scores for *SedShed* were not significantly related to HGM subclass.

**SoilX**: Soil compaction and erosion within a wetland can adversely affect its productivity and capacity to process pollutants, as well as its biodiversity (Gupta et al. 1989, NRCS 2003). Compaction and/or marsh surface subsidence can occur as a result of diking, as well as from concentrated use by livestock or ATVs (Wisheu and Keddy 1991) and log storage (Morlan and Frenkel 1992), and thus alter flooding regime, soil salinity, oxygen, and nutrient cycling processes, which often allows non-native species to gain a competitive advantage (e.g., Kuhn and Zedler 1997). Chronic or persistent compaction in particular can retard the establishment of viable, diverse assemblages of burrowing invertebrates (NRCS 2003). Sites with recent or ongoing, complete, and extensive disturbance of soils are less likely to sustainably support native tidal marsh plants. Four types of compaction are recognized (NRCS 2003):

> *Surface crusting* restricts seedling emergence and water infiltration. It is caused by the impact of raindrops on weak soil aggregates, especially where little plant litter persists.

*Surface compaction* occurs anywhere from the surface down to the normal tillage depth. The compacted layer can be loosened by normal tillage, root growth, and biological activity.
A *tillage pan* is a compacted layer, a few inches thick, beneath the normal tillage depth. It develops when the depth of tillage is the same year to year.
*Deep compaction* occurs beneath the level of tillage. Ground contact pressure and the total weight on the tire from the axle load significantly affect the amount of subsoil compaction. Deep compaction is difficult to eliminate and may permanently change soil structure.

Signs of compaction include:

- Vehicle tracks
- Difficulty penetrating the soil with a firm wire (survey flag) or welding rod
- Lateral root growth with little, if any, penetration of roots into compacted layers
- Discolored or poor plant growth that cannot be explained by other factors
- Excessive runoff
- Unusually platy, blocky, dense, or massive subsurface layers

The scale used for this indicator addresses not only the proportion of the site affected by potentially compacting activities, but also how recently they occurred. The score distribution is shown in Table 15. Considering just the correlations that were significant statistically, the function indicators whose scores correlated with *SoilX* scores were (in descending order): *Fetch, LWDline, Panne, LWDmarsh,* and *MudW* — all negatively. Scores for *SedX* were not significantly related to HGM subclass.

**DikeDry, DikeWet**: Diking potentially can make tidal wetlands either drier or wetter, with consequent effects on their biological integrity and functions. Depending on the particular function, near-term impacts can be positive or negative. Sites with recent or ongoing, complete, and extensive blockage of tidal circulation are less likely to sustainably support native tidal marsh plants (Roman et al. 1984, Sinicrope et al. 1990). This is partly because such sites typically have lower salinity, diminished tidal amplitude, prolonged inundation, and altered sediment chemistry (Portnoy and Giblin 1997). Specifically, prolonged exposure of saline sediments to the air makes them more acidic, causing heavy metals in sediments to enter the water once the sediments are reflooded. Restoring tidal circulation to diked wetlands diminishes the vigor and percent cover of some non-native plants, e.g., *Phalaris arundinacea* and various “pasture” species, leading to a more diverse plant assemblage (Frenkel and Morlan 1990, Tanner et al. 2002).

This assessment method attempts to address both the extent and frequency of desiccated (*DikeDry*) and persistently flooded (*DikeWet*) conditions within a wetland as a result of diking. Even where functioning dikes are apparent, these are difficult indicators to assess unless pre-diking data are available, so “Certainty” normally should be scored low. The score distributions are shown in Table 15. Considering just the correlations that were significant statistically, the function indicators whose scores correlated negatively with *DikeDry* scores were (in descending order): *Fetch, LWDline, MudW, Panne,* and *Roost*, while those correlated positively were *UpEdge, FormDiv, Fresh*, and *Island. DikeWet* scores were correlated negatively with *Fetch* and positively with *SoilFine, BuffCov,* and *FormDiv*. River-sourced Tidal wetlands had a greater tendency to be desiccated by dikes, whereas Marine-sourced Tidal wetlands tended to be flooded more by dikes.

**FootVis**: Although important for fostering appreciation of natural values, frequent visitation of tidal wetlands by people potentially can impair their integrity by increasing the spread of invasive plants and disturbing wildlife (SFDC 2001). Sometimes, individual birds can acclimate locally to disturbances, but most wading birds (excluding some gulls) are wary of humans, especially humans on foot or with unleashed dogs. Thus, marshes with heavy foot traffic within or near their edges during the season of expected wading bird presence often experience less-persistent use by certain wading birds. Scaling of this indicator is based on the spatial proportion of the wetland that is visited and the visitation frequency. The categories within the scale parallel apparent break points in the scores generated by the index that was used. The score distribution is shown in Table 15. Considering just the correlations that were significant statistically, in order of decreasing significance (increasing *p*) there were negative correlations with scores for *BuffCov, SoilFine, Estu%WL, BlindL, Eelg, Jcts,* and *Shade*, and positive correlation with *TribL.* By HGM subclass, River-sourced Tidal Wetlands tended to have less visitation by people on foot as compared with Marine-sourced Tidal Wetlands.

**Boats**: Boat traffic potentially disturbs wildlife of tidal wetlands, and in the case of some large ocean-going vessels, can accelerate marsh erosion and introduce invasive invertebrates. Scaling of this indicator is based on the proximity and frequency of boat traffic. The particular distance categories that are used are based on interpretation of published data on impacts to bald eagles in the Columbia River estuary (McGarigal et al. 1991). The score distribution is shown in Table 15. Considering just the correlations that were significant statistically, in order of decreasing significance (increasing *p*), there were negative correlations with scores for *Roost* and *SpPerQd*, and positive correlations with *SeaJoin, Eelg, EstuSal, Fetch, Pform, SoilFine,* and *LWDmarsh.* As expected, River-sourced Tidal Wetlands tended to have less boat traffic as compared with Marine-sourced Tidal Wetlands.

**HomeDis**: Like the indicator *FootVis*, the presence of occupied buildings implies increased wetland visitation by humans, and in addition implies the potential for increased disturbance from septic system runoff and pets harassing wildlife. Scaling is based on the proximity to buildings, and the score distribution (Table 15) reflects the range of conditions found among our surveyed wetlands. Considering just the correlations that were significant statistically, in order of decreasing significance (increasing *p*), there were negative correlations with scores for *Roost SpPerQd, Invas,* and *SeaJoin*. Positive correlations were with *Eelg, EstuSal, Fetch, Pform, SoilFine,* and *LWDmarsh.*

**RoadX**: Roads and their associated vehicle traffic potentially impair the biological integrity of tidal wetlands by serving as a source of contaminated runoff (both chronic and as hazardous waste spills), altered hydrologic regimes (due to increased impervious surface and blockage of natural runoff patterns), and wildlife disturbance (e.g., vehicle collisions). Scaling is based on wetland proximity to roads and the type of road (primary or secondary). The exponential distance scale assumes rapid decline of risk as roads are located farther from wetlands. The resulting score distribution is shown in Table 15. Considering just the correlations that were significant statistically, in order of decreasing significance (increasing *p*), there were negative correlations with scores for *BuffCov* and *LWDchan*. Positive correlations with function indicators were with *Island, UpEdge, FormDiv,* and *Fresh.*

**Invas**: Invasive non-native estuarine invertebrates are assumed to reduce the diversity and abundance of some native invertebrates, and thus potentially can impair biological integrity. Estuarine macroinvertebrate communities of the Oregon coast have been invaded by non-native invertebrate species believed to be associated with commercial oyster culture operations (Hewitt 1993), and oyster operations elsewhere have been shown to influence microbial communities responsible for estuarine functions (Wetz et al. 2002). Other invaders are carried to Oregon waters by strong sea currents, in ballast water discharged by large foreign vessels, or by other means. One study at Coos Bay found that 367 exotic taxa had arrived from Japan in ballast water (Carlton and Geller 1993). At least 40 such taxa have become established within South Slough NERR (Carlton 1989, Rumrill 1998). Invasion of marsh habitats specifically and the resulting effects on marsh invertebrates have not been well studied. The European green crab alone has caused $44 million in damages per year to West Coast shellfish production. A geographic database of invasive marine invertebrates and plants on the Pacific Coast is maintained by the USGS (Reusser and Lee 2003; http://nas.er.usgs.gov/queries/FactSheet.asp?speciesID=1084).

Scaling of this indicator is based on conditions in the particular estuary because this probably is the finest scale at which reliable data are available. Known presence in the estuary is accorded the highest score. Presence of oyster cultivation facilities and large-ship traffic (with potential for discharge of ballast water) are considered secondarily. The resulting score distribution is shown in Table 15. Considering just the correlations that were significant statistically, there was a negative correlation with the score for *Roost,* and positive correlations with *Eelg, SeaJoin, Pform, SoilFine, EstuSal, ShadeLM, TranAng,* and *MudW.*

**Instabil**: This indicator of risk attempts to estimate the possible long-term geomorphic instability of the site. Other factors being equal, high marshes — particularly those with woody vegetation — are assumed to have persisted for longer than low marshes and high marshes without woody vegetation, and thus are considered more geomorphically stable. Natural changes in area that are evident in aerial photographs also are considered, but that approach has several limitations. The absence of visual evidence of accretion in airphotos does not necessarily mean accretion is absent. Interpretive caution is advised because of (a) differences among photos in scales, light conditions, and assumptions, (b) uncertainty regarding which tidal stages are depicted, (c) the possibility that accretion is occurring more recently than depicted by the available photographic evidence, and (d) the possibility that accretion is occurring but has not caused outward marsh expansion due to adjoining bathymetric conditions. Moreover, the occurrence of marsh expansion historically does not necessarily mean high rates of sedimentation are continuing. Indeed, sedimentation rates tend to be greater (but not sustainable) in younger than older marshes, despite the well-developed plant communities in the latter. This is because older marshes have higher elevations relative to tides and so have limited opportunity to trap suspended tide-borne sediment (Johannessen 1964, Williams and Orr 2002, but see Cornu and Sadro 2002 for contradictory evidence). Limited evidence suggests marsh channels fed largely by tributaries and upland runoff tend to be less stable (Mitsch and Gosselink 2000), especially when natural vegetation in uplands has been extensively removed.

Where marsh surface elevation is low and sediment-laden tidal waters consequently persist within a low marsh for long periods during a daily tidal cycle, this provides greater opportunity for extensive settling (and eventual stabilization) of suspended sediment (Frenkel and Morlan 1990). Sediment accumulation rates are generally greatest in marshes only recently restored to tidal circulation, because of their low surface elevation attributable to subsidence (Taylor 1980, Gilman 1993, Thom et al. 2000). This is particularly true if dikes have not been completely removed. However, evidence of an association between marsh elevation and sedimentation is not strong. In a newly restored marsh at South Slough NERR, marsh elevation and associated tidal inundation period did not influence vertical accretion (Cornu and Sadro 2002). Moreover, the temporary paucity of stabilizing vegetation in some recently restored marshes can result in a portion of the sediment being vulnerable to washout during the first few years after restoration.

It is assumed that wetlands to which tidal circulation has been restored only recently and partially will be less stable (at least in the near term) than those whose circulation was restored long ago and completely, or which never were diked. Complete (as opposed to partial) restoration of tidal circulation allows open transport of sediments into formerly diked wetlands, although in some instances marsh erosion may instead be accelerated. Finally, coarser marsh substrates are assumed to be more dynamic over the long term than finer-particled substrates. Lacking data to suggest otherwise, these five factors were considered equal and combined through simple addition. The resulting score distribution is shown in Table 15. Considering just the correlations that were statistically significant, the indicators whose scores correlated negatively with *Instabil* scores were (in descending order): *SoilFine, Shade, Pform, EstuSal, LWDmarsh, Fetch* and *Exits.* Indicators that were associated positively were *UpEdge, Flood,* and *FreshSpot*. Overall, *Instabil* was considered to be greater in the Marine-sourced than in the River-sourced Tidal wetlands that were surveyed.

### *A2. Direct Indicators of Wetland Integrity that Require More-intensive Field Work*

For at least 2 decades, stream ecologists have validated and used "indices of biotic integrity" to describe the condition of streams (Karr and Chu 1998, Yangdong et al. 2004), and an increasing number of such indices are being validated for marine and estuarine habitats (Appendix A). However, no such indices have been developed successfully for tidal wetlands of the Pacific Northwest. We developed and attempted to validate such an index as part of this HGM project, using tidal marsh plants (seven indicators) as well as a single geomorphic indicator (*RatioC*). These indicators are described below, and results of the validation effort are explained in section 4.2.4.

Limited research elsewhere has suggested that aboveground biomass, stem height, soil organic carbon, and nitrogen may be the most reliable yet relatively inexpensive indicators for distinguishing constructed vs naturally occurring tidal marshes (C. Craft*, pers. comm.*). Such results do not necessarily mean those indicators will be effective in distinguishing among tidal wetlands affected by other stressors, such as excessive nutrients or chemical contamination.

**RatioC**: This indicator reflects the width-depth ratio of tidal channels and thus quantifies the present geomorphic condition of the wetland's internal channels as well as, indirectly, their possible stability, i.e., are they currently in or out of equilibrium with regard to the natural processes of tidal channel evolution? This is based on a logical but untested assumption that major deviation of the ratio (of channel topwidth to incision depth) for a particular marsh from values for the ratio in least-altered reference marshes will indicate relative channel instability, after data from both sources have been standardized by (a) relative position of the channel cross-section within a marsh, (b) marsh substrate (sand or not), (c) presence/absence of non-tidal freshwater tributaries, and (d) two measured indicators of channel network complexity, *Exits* and *Jcts* (see p. 76).

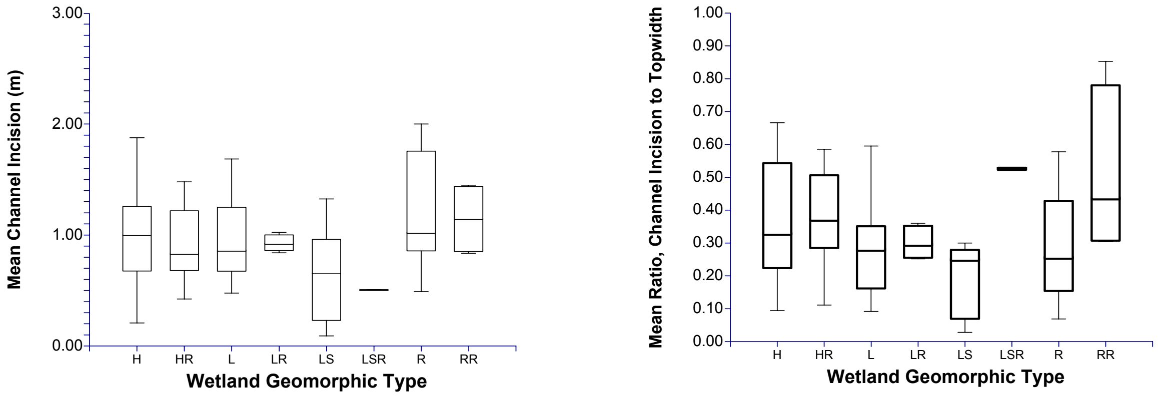
To standardize for these factors, a series of five statistical models was developed — one for each of the five relative positions of a cross-section in the channel network — using data from just the relatively unaltered wetlands we surveyed. The models were then programmed into the Excel™ spreadsheet. Note that the indicator is not the ratios themselves, but rather the mean of their residuals (these residuals being the deviations from conditions in tidal wetlands with minimal alteration). Table 16 shows the statistical distribution of the raw data for this indicator. Figure 1 shows the dimensions as a ratio.

Table 17 shows the regression equations used to compute residuals from the raw data.

Table 19 shows the distribution of the final scores. None of the correlations with risk factors (Table 20) was statistically significant, but nonetheless, based on theoretical considerations, this indicator was used as an integrity indicator as well as a function indicator in the *WQ* model (see p. 97). Channel incision depth (one of its components) increased significantly with increased mean risk (*Risk1, Risk2, Risk5*) and especially with increased risk to the wetland from past or ongoing hydrologic alterations such as dikes (risk indices *H1–H5*).

### Table 16. Percentiles of the ratio of channel topwidth (m) (Log10) to incision depth (m) (Log10) at five positions within tidal marsh channel networks

| Channel cross-section # | All Surveyed Wetlands (n = 86) | | | | | Wetlands Deemed "Least-Altered" (n = 22) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 5th | 25th | 50th | 75th | 95th | 5th | 25th | 50th | 75th | 95th |
| 1 (mouth) | 1.73 | 2.29 | 3.07 | 3.99 | 6.29 | 1.80 | 2.33 | 3.12 | 4.36 | 6.30 |
| 2 | 1.18 | 1.87 | 2.51 | 3.40 | 8.67 | 1.31 | 1.84 | 2.46 | 3.72 | 9.77 |
| 3 | 1.02 | 1.68 | 2.23 | 3.08 | 5.53 | 0.59 | 1.14 | 1.82 | 2.72 | 4.21 |
| 4 | 0.94 | 1.46 | 2.00 | 2.99 | 5.79 | 0.81 | 1.25 | 1.90 | 2.96 | 20.26 |
| 5 (highest) | 0.73 | 1.29 | 1.86 | 3.17 | 7.46 | 0.92 | 1.12 | 1.36 | 2.25 | 25.96 |



### Figure 1. Channel incision depth (left) and its ratio to topwidth (right) in tidal marshes of the Oregon coast

Data are for means of five cross-sections at each site, not log-transformed. H = high marsh, HR = high marsh reference sites, L = low marsh (excluding sandspits), LR = low marsh reference sites (excluding sandspits), LS = low marsh on sandspits, LSR = low marsh reference sites on sandspits, R = river-sourced tidal wetlands, RR = river-sourced tidal wetland reference sites.

**Table 17. Equations for RatioC as derived using robust regression from data collected from cross-sections in 45 less-altered tidal wetlands of the Oregon coast**

| Channel cross-section # | Applicable Equation |
|---|---|
| 1 (mouth) | 2.362572 + (0.8648501*Sand) + (0.2668522*Trib) + (0.9510881*LogExits) - (0.5107238*LogJcts) |
| 2 | 1.528158 + (0.4737956*Sand) + (0.3314972*Trib) + (1.023391*LogExits) + (0.1864663*LogJcts) |
| 3 | 1.327538 + (0.7810041*Sand) + (0.3765976*Trib) + (0.8909062*LogExits) |
| 4 | 2.344948 - (0.6507016*LogJcts) |
| 5 (highest) | 1.672734 + (1.580871*Sand) - (0.2923233*LogExits) |

*Legend for independent variables shown above*
Sand: Marsh substrate is predominantly sand (0 = no, 1 = yes)
Trib: Freshwater tributary enters the marsh (0 = no, 1 = yes)
LogExits: Log10 of the number of exit channels in marsh, an indicator of channel complexity and marsh size
LogJcts: Log10 of the number of channel junctions in largest internal channel, an indicator of channel complexity and marsh size

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**SpDeficit, DomDef, NN20def, AnnDef, TapPCdef, StolPCdef, TuftPCdef**: These botanical variables are defined as follows:

**SppDeficit** is related to another indicator — *SpPerQd* — the number of plant species (richness) found per square-meter quadrat, averaged over 20 quadrats placed as shown in Figure 1 of Part 1 of this guidebook. However, it actually is expressed as the *difference* between the number predicted — based on marsh size (transect length), position within the estuary (upper, middle, lower), relative elevation, salinity, and/or substrate type — and the number found (see section 2.6 for description of adjustment procedures). A constant was added to make negative values positive; thus a small value implies the difference originally was negative (fewer species than predicted) prior to adding the constant, and a large value implies the difference was positive (more species than predicted). Tidal wetlands with lower-than-predicted mean number of species per quadrat are assumed to have lower wetland integrity. The predictions were made using data from the less-altered wetlands, which tended overall to have higher values for number of plant species (richness) found per square-meter quadrat.

**DomDef** is related to another indicator — *AllGT90* — the proportion of quadrats that contain plant species with a percent cover of 90 or greater. However, it actually is expressed as the *difference* between the proportion predicted — based on marsh size (transect length), position within the estuary (upper, middle, lower), relative elevation, salinity, and/or substrate type — and the proportion found. A constant was added to make negative values positive; thus a small value implies that the difference originally was negative (smaller frequency than predicted) prior to adding the constant, and a large value implies that the difference was positive (greater than predicted). Because tidal wetlands that have a greater-than-predicted proportion of quadrats with strongly dominant plants are assumed to have lower wetland integrity, other factors being equal, the scale assigns lower scores to higher numeric values (i.e., positive deviations from the norm) and higher scores to lower numeric values (i.e., negative deviations from the norm). The norm was defined using data from the less-altered wetlands, which tended overall to have a lower proportion of their quadrats dominated by any single species.

**NN20Def** is related to another indicator — *NNgt20* — the proportion of quadrats that contain non-native plant species with a percent cover of 20 or greater. However, it actually is expressed as the *difference* between the proportion predicted — based on marsh size (transect length), position within the estuary (upper, middle, lower), relative elevation, salinity, and/or substrate type — and the proportion found. A constant was added to make negative values positive; thus a small value implies the difference originally was negative (smaller frequency of non-natives than predicted) prior to adding the constant, and a large value implies the difference was positive (greater frequency than predicted). Tidal wetlands with a higher-than-predicted proportion of quadrats with non-native plants are assumed to have lower wetland integrity. The predictions were made using data from the less-altered wetlands, which tended overall to have a lower proportion of their quadrats dominated by non-native species.

**AnnDef** is related to another indicator — *AnnFq* — the proportion of quadrats that contain characteristically annual plant species. However, it actually is expressed as the *difference* between the proportion predicted — based on marsh size (transect length), position within the estuary (upper, middle, lower), relative elevation, salinity, and/or substrate type — and the proportion found. A constant was added to make negative values positive; thus a small value implies the difference originally was negative (smaller frequency than predicted) prior to adding the constant, and a large value implies the difference was positive (greater frequency than predicted). Tidal wetlands with a higher-than-predicted proportion of quadrats with annuals are assumed to have lower wetland integrity. The predictions were made using data from the less-altered wetlands, which tended overall to have a lower proportion of their quadrats containing annuals.

**TapPCdef** is related to another indicator — *TapPCavg* — the proportion of quadrats that contain characteristically tap-rooted plant species (ones with mostly a single stout root rather than many root fibers). However, it actually is expressed as the *difference* between the proportion predicted — based on marsh size (transect length), position within the estuary (upper, middle, lower), relative elevation, salinity, and/or substrate type — and the proportion found. A constant was added to make negative values positive; thus a small value implies the difference originally was negative (smaller percent cover than predicted) prior to adding the constant, and a large value implies the difference was positive (greater percent cover than predicted). Tidal wetlands with greater-than-predicted percent cover of tap-rooted species (mean among quadrats) are assumed to have higher wetland integrity. The predictions were made using data from the less-altered wetlands, which tended overall to have higher-than-predicted percent cover of tap-rooted species in their quadrats that contained such species.

**StolPCdef** is related to another indicator — *StolPCavg* — the mean percent cover of stoloniferous plants in quadrats that contain such species (i.e., species whose individual plants are connected by aboveground runners or roots). However, it actually is expressed as the *difference* between the mean percent cover of such species that is predicted — based on marsh size (transect length), position within the estuary (upper, middle, lower), relative elevation, salinity, and/or substrate type — and the mean percent cover found. A constant was added to make negative values positive; thus a small value implies the difference originally was negative (smaller percent cover than predicted) prior to adding the constant, and a large value implies the difference was positive (greater than predicted). Tidal wetlands with a higher-than-predicted mean percent cover of stoloniferous species are assumed to have lower wetland integrity. The predictions were made using data from the less-altered wetlands, which tended overall to have lower percent cover of stoloniferous species in their quadrats that contained such species.

**TuftPCdef** is related to another indicator — *TuftPCavg* — the mean percent cover of tuft-rooted plant species in quadrats that contain such species (i.e., species whose individual plants are connected by aboveground runners or roots). However, it actually is expressed as the *difference* between the mean percent cover of such species that is predicted — based on marsh size (transect length), position within the estuary (upper, middle, lower), relative elevation, salinity, and/or substrate type — and the mean percent cover found. A constant was added to make negative values positive; thus a small value implies the difference originally was negative (smaller percent cover than predicted) prior to adding the constant, and a large value implies the difference was positive (greater than predicted). Tidal wetlands with a higher-than-predicted mean percent cover of tuft-rooted species are assumed to have lower wetland integrity. The predictions were made using data from the less-altered wetlands, which tended overall to have lower percent cover of tuft-rooted species in their quadrats that contained such species.

Table 18 shows the statistical distribution of the raw data for the botanical measures from which the above indices were derived. Table 19 shows the distribution of their final scores. Correlations with other indicators are shown in Table 20 and Table 29. And earlier in this document, Table 7 showed the regression equations used to predict each botanical indicator.

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**Table 18. Data percentiles based on raw data of the botanical indicators in the 120 surveyed wetlands**

| | All Surveyed Wetlands (n = 120) | | | | | Wetlands Deemed "Least-Altered" (n = 24) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| percentile: | 5th | 25th | 50th | 75th | 95th | 5th | 25th | 50th | 75th | 95th |
| SpPerQd | 2.01 | 3.16 | 3.89 | 4.62 | 5.80 | 2.14 | 3.81 | 4.53 | 5.48 | 6.85 |
| AllGT90 | 0 | 0.06 | 0.15 | 0.33 | 0.67 | 0 | 0.01 | 0.10 | 0.18 | 0.57 |
| NN20PC | 0 | 0.05 | 0.24 | 0.49 | 0.79 | 0 | 0.05 | 0.20 | 0.37 | 0.57 |
| AnnPC | 0 | 0.25 | 1.45 | 3.26 | 10.03 | 0 | 0.33 | 1.81 | 3.06 | 8.46 |
| TapPC | 0 | 0.55 | 2.02 | 5.21 | 19.35 | 0.07 | 0.56 | 1.51 | 4.97 | 21.35 |
| StolPC | 3.93 | 15.86 | 25.23 | 42.40 | 60.39 | 4.41 | 16.21 | 22.22 | 33.23 | 68.51 |
| TuftPC | 0 | 0.58 | 2.63 | 8.18 | 18.83 | 0 | 2.23 | 6.45 | 12.18 | 17.01 |

## Table 19. Distribution of scores for direct indicators of wetland integrity

| | All Surveyed Wetlands | | | | | Wetlands Deemed "Least-Altered" | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| percentile: | 5th | 25th | 50th | 75th | 95th | 5th | 25th | 50th | 75th | 95th |
| RatioC | 0.01 | 0.20 | 0.60 | 0.80 | 1.00 | 0.01 | 0.25 | 0.60 | 0.80 | 1.00 |
| SpPerQd | 0.01 | 0.20 | 0.50 | 0.60 | 0.99 | 0.10 | 0.30 | 0.60 | 0.85 | 1.00 |
| SpDeficit | 0.01 | 0.25 | 0.50 | 0.75 | 1.00 | 0.01 | 0.25 | 0.50 | 0.75 | 1.00 |
| All90PC | 0.01 | 0.40 | 0.60 | 0.80 | 1.00 | 0.10 | 0.50 | 0.60 | 1.00 | 1.00 |
| DomDef | 0.01 | 0.25 | 0.50 | 0.75 | 1.00 | 0.01 | 0.25 | 0.50 | 0.75 | 1.00 |
| NN20PC | 0.10 | 0.40 | 0.50 | 0.80 | 1.00 | 0.13 | 0.40 | 0.50 | 0.60 | 1.00 |
| NN20def | 0.01 | 0.01 | 0.25 | 0.50 | 0.75 | 0.01 | 0.25 | 0.50 | 0.75 | 1.00 |
| AnnDef | 0.01 | 0.01 | 0.25 | 0.50 | 0.75 | 0.01 | 0.25 | 0.50 | 0.75 | 1.00 |
| TapPCdef | 0.01 | 0.01 | 0.25 | 0.50 | 0.75 | 0.01 | 0.25 | 0.50 | 0.75 | 1.00 |
| StolPCdef | 0.01 | 0.01 | 0.25 | 0.50 | 0.75 | 0.01 | 0.25 | 0.50 | 0.75 | 1.00 |
| TuftPCdef | 0.01 | 0.01 | 0.25 | 0.50 | 0.75 | 0.01 | 0.25 | 0.50 | 0.75 | 1.00 |

## Table 20. Significant correlates of the wetland integrity indicators, as based on their raw data

Note: A "Sc" appended to a code indicates the score for that item was correlated, rather than the raw data. A larger deficit (SpDeficit, DomDef, NN20def, AnnDef, TapPCdef, StolPCdef, TuftPCdef) means there is more mean percent cover or frequency of occurrence than was predicted after accounting for the influence of marsh elevation, salinity, and other natural factors.

| **Integrity Indicator** | **Increased significantly with increasing:** | **Decreased significantly with increasing:** |
|---|---|---|
| RatioC | BuffCov | ShadeLM, FormDiv |
| SpPerQd | SpDeficit, MarQdPct, TapPCav, TuftPCav, MarPC, StolPCav, InvSc, TransL, Jcts, SbirdSc | AllGT90, AnnDef, FreshAvgPC, MarDist, DomDef, Positn, Boats, EstuSal, SeaJoin, ShadeLM, WetIndex, WetField% |
| SpDeficit | SpPerQd, WetIndex, HomeDis | FreshAvgPC, DomDef, AllGT90, NN20PC, ShadeLM, FreshQdPct |
| All90PC | DomDef, WetIndex, EstuSal, Positn, AnnDef, MarDist, SeaJoin, FreshAvgPC, Ditch, AfishSc, SoilFine | TuftPCav, SpPerQd, MarQdPct, SpDeficit, StolPCav, TapPCav, MarPC |
| DomDef | AllGT90, MarPC, TransL, LWDmarsh, MarQdPct, Hyd1RiskSc | SpDeficit, AnnDef, SpPerQd, SoilX, Ditch |
| NN20PC | NN20def, StolPCav, FreshQdPct, AnnDef, Positn, EstuSal, NutrIn, N2RiskSc, N8RiskSc, N7RiskSc, N9RiskSc, MarDist, Risk2,MaxSc, N2RiskSc, Risk3MaxSc, N4RiskSc, N1RiskSc, N6RiskSc, Risk4,MaxSc, SoilX, Risk1,SoilFine | MarQdPct, WetIndex, MarPC, TuftDef, MudW, FreshSpot, TapPCav, SalSoilMax, Hyd1RiskSc, SpDeficit, TuftPCav, RfishSc, Flood, RatioC |
| NN20def | NN20PC, StolDef, MarQdPct, StolPCavg, Trib, EstuSal, NFW, MarPC, WQ, Bare, MarDist, Width | TuftDef, TuftPCav, TapPCdef |
| AnnDef | NN20PC, AllGT90, TranAng, TapMax, Jcts, EstuSal, Eelg | MarQdPct, MarPC, SpPerQd, DomDef, TapPCav, InvSc, MFishSc, Island, BuffCov, TuftPCav, LBMsc, FormDiv, Exits |
| TapPCdef | TapPCav, Ditch | NN20def, WetIndex |
| StolPCdef | StolPCav, NN20def, Width, Area, Sbird, Jcts, Exits | TuftDef, TuftPCav |
| TuftPCdef | TuftPCav | NN20def, NN20PC, StolDef, StolPCavg, DuxSc, TribL, Estu%WL, Bare, Width |

### 3.3.3 Indicators of Tidal Wetland Functions

*B1. Rapid Indicators of Function That May Be Estimated*

**Flood**: This is probably the most functionally important indicator and yet one of the most difficult ones to assess rapidly during a single site visit. It is an attempt to describe the extent and duration of tidal inundation, both daily and monthly, and is used to assess these wetland functions: *Xpt, Afish, Mfish, Rfish, Dux, LbirdM*. The cross-sectional shape of a marsh (i.e., the configuration of its surface elevation profile, and mean elevation), as well as its estuarine position and latitude, influence the mean daily persistence of inundation. Tidal amplitude and the duration of continuous daily exposure of intertidal habitats do not change consistently from place to place within an estuary. Moving upriver in an estuary, there sometimes are "critical tide level" zones where the duration of annual continuous exposure or submergence of intertidal areas changes sharply (Doty 1946). Ecological and biogeographic ramifications of such phenomena at the landscape scale seldom have been studied but could be significant (Strehlow 1982). However, with regard to organic and nutrient export from tidal marshes, tidal amplitude seems to have greater influence on the direction (horizontal vs. vertical) than the magnitude of subsurface seepage within a marsh and consequently on export (Osgood 2000).

Many fish species benefit from increased depth, frequency, and/or duration of flooding in tidal marshes, even if (within limits) it is artificially induced, because it increases access to food and shelter. The longer such water persists, the greater is the probability that fish will have an opportunity to gain access to large portions of the marsh plain (Cornwell et al. 2001, Simenstad and Cordell 2000). Marshes that have tidal channels with low base elevations and which therefore remain inundated for long periods over much of their length, particularly during monthly extreme tides, are more suitable to anadromous fish. Sedimentation of entry channels can reduce access. Designs for tide gates, culverts, dams, and other outlet structures vary both in their suitability for passage of fish adults, fry, and smolt and in the amount of water they impound (and for how long). Waterfowl also may use the tidal wetlands that flood most extensively, i.e., that have large internal channels and high densities of ponded areas (Stralberg et al. 2003). This is especially true when uneven topography creates large and dynamic interspersion between vegetation and flooded areas. Flooding flushes invertebrates, roots, and seeds to the water surface, where they are more easily consumed. However, tidal wetlands that flood most extensively and frequently provide the poorest habitat to landbirds, small mammals, and their predators (e.g., Stralberg et al. 2003) because most species in these groups require consistently dry substrate for nesting, and sometimes for feeding. In New England wetlands whose tidal circulation had been restored, flooding duration was the most important predictor of recovery rate of characteristic tidal marsh plants, invertebrates, and birds (Warren et al. 2000).

Ideally, the determinations requested by this guidebook's method are based on multiple visits to a site or detailed elevational surveys, but lacking such data, an estimate should be made and a low score should be placed in the Certainty column. The score distribution for the 120 sites we assessed is shown in Table 21, and these scores were based entirely on visual estimates made during the single day of the visit. All the statistically significant correlations with scores of other indicators were positive, and in descending order of significance were: *TribL, Jcts, BlindL,* and *Width.* By HGM subclass, marsh access to fish (*Flood)* was considered to be greater in Marine-sourced Low Marsh than in Marine-sourced High Marsh and River-sourced Tidal wetlands.

## Table 21. Score distribution among 120 surveyed wetlands for indicators of function

Interpretation: For example, the 0.70 for the 75th percentile of *Flood* means that only 25% (= 100-75) of the sites scored higher than 0.70 for this indicator. See Appendix C for abbreviations of indicators.

| percentile: | All Surveyed Wetlands (n = 120) | | | | | Wetlands Deemed “Least-Altered” (n = 25) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 5th | 25th | 50th | 75th | 95th | 5th | 25th | 50th | 75th | 95th |
| Flood | 0.30 | 0.50 | 0.60 | 0.70 | 0.80 | 0.30 | 0.50 | 0.50 | 0.60 | 0.77 |
| Shade | 0.01 | 0.25 | 0.25 | 0.25 | 0.75 | 0.01 | 0.25 | 0.25 | 0.44 | 0.94 |
| ShadeLM | 0.01 | 0.13 | 0.25 | 0.25 | 0.43 | 0.01 | 0.25 | 0.25 | 0.25 | 0.75 |
| Bare | 0.01 | 0.01 | 0.01 | 0.50 | 0.75 | 0.01 | 0.01 | 0.01 | 0.50 | 0.68 |
| Panne | 0.01 | 0.01 | 0.01 | 0.44 | 1.00 | 0.01 | 0.01 | 0.01 | 0.50 | 1.00 |
| TranAng | 0.01 | 0.01 | 0.01 | 1.00 | 1.00 | 0.01 | 0.01 | 0.01 | 1.00 | 1.00 |
| UpEdge | 0.01 | 0.40 | 0.50 | 0.70 | 1.00 | 0.01 | 0.35 | 0.50 | 0.80 | 1.00 |
| LWDchan | 0.01 | 0.01 | 0.50 | 0.50 | 1.00 | 0.01 | 0.01 | 0.50 | 0.50 | 1.00 |
| LWDmarsh | 0.01 | 0.25 | 0.50 | 0.75 | 1.00 | 0.01 | 0.25 | 0.50 | 0.88 | 1.00 |
| LWDline | 0.01 | 0.01 | 0.25 | 0.75 | 1.00 | 0.01 | 0.01 | 0.25 | 0.88 | 1.00 |
| TribL | 0.01 | 0.01 | 0.01 | 0.01 | 0.67 | 0.01 | 0.01 | 0.01 | 0.01 | 0.57 |
| Fresh | 0.01 | 0.10 | 0.30 | 0.50 | 1.00 | 0.01 | 0.01 | 0.30 | 0.50 | 0.90 |
| Width | 0.01 | 0.20 | 0.40 | 0.78 | 1.00 | 0.01 | 0.25 | 0.60 | 1.00 | 1.00 |
| MudW | 0.01 | 0.01 | 0.01 | 0.40 | 0.99 | 0.01 | 0.01 | 0.01 | 0.50 | 0.94 |
| Roost | 0.01 | 0.25 | 0.50 | 0.75 | 0.75 | 0.01 | 0.38 | 0.50 | 0.75 | 0.75 |
| Island | 0.01 | 0.33 | 1.00 | 1.00 | 1.00 | 0.33 | 0.83 | 1.00 | 1.00 | 1.00 |
| Fetch | 0.01 | 0.01 | 0.40 | 1.00 | 1.00 | 0.01 | 0.40 | 0.60 | 0.80 | 1.00 |
| Pform | 0.25 | 0.50 | 0.50 | 0.75 | 0.75 | 0.25 | 0.50 | 0.75 | 0.75 | 0.75 |
| FormDiv | 0.01 | 0.30 | 0.40 | 0.50 | 0.80 | 0.01 | 0.30 | 0.40 | 0.60 | 0.74 |
| Alder | 0.01 | 0.01 | 0.01 | 0.33 | 0.66 | 0.01 | 0.01 | 0.33 | 0.33 | 0.66 |
| Eelg | 0.01 | 0.01 | 0.01 | 0.50 | 1.00 | 0.01 | 0.01 | 0.01 | 0.50 | 1.00 |
| SoilFine | 0.01 | 0.40 | 1.00 | 1.00 | 1.00 | 0.13 | 0.40 | 1.00 | 1.00 | 1.00 |
| EstuSal | 0.01 | 0.66 | 0.66 | 1.00 | 1.00 | 0.10 | 0.66 | 0.66 | 1.00 | 1.00 |
| SeaJoin | 0.01 | 1.00 | 1.00 | 1.00 | 1.00 | 0.16 | 1.00 | 1.00 | 1.00 | 1.00 |
| Estu%WL | 0.30 | 0.70 | 0.70 | 0.80 | 1.00 | 0.43 | 0.70 | 0.80 | 0.90 | 1.00 |
| WetField% | 0.01 | 0.01 | 0.01 | 0.25 | 0.75 | 0.01 | 0.01 | 0.01 | 0.25 | 0.93 |
| BuffCov | 0.11 | 0.70 | 1.00 | 1.00 | 1.00 | 0.26 | 1.00 | 1.00 | 1.00 | 1.00 |
| BlindL | 0.01 | 0.01 | 0.20 | 0.80 | 1.00 | 0.01 | 0.01 | 0.80 | 0.80 | 1.00 |
| Exits | 0.01 | 0.25 | 0.25 | 0.50 | 0.75 | 0.01 | 0.25 | 0.50 | 0.75 | 1.00 |
| Jcts | 0.01 | 0.01 | 0.25 | 0.50 | 1.00 | 0.01 | 0.01 | 0.25 | 0.75 | 1.00 |
| FreshSpot | 0.01 | 0.01 | 0.01 | 0.50 | 1.00 | 0.01 | 0.01 | 0.01 | 0.50 | 1.00 |

**Shade, ShadeLM**: In contrast to most other natural environments in their watersheds, tidal marshes receive tremendous inputs of solar radiation. This affects not only water temperatures and fish, but also the rates of processes as fundamental as aquatic production, respiration, and mineral cycling. Most tidal wetlands are exposed directly to the sun for nearly the entire daytime. Important exceptions are forested tidal wetlands, narrow tidal fringe wetlands adjoined by forested uplands, and tidal marshes in coves surrounded by steep topography. Moreover, deeply incised and narrow tidal channels, although comprising a relative small portion of total marsh area, potentially shade tidal waters for long periods, increasing wetland capacity for some functions (e.g., thermal refugia for fish) while decreasing others (aquatic production). Shade can reduce sunlight otherwise available for photosynthesis, and can inhibit vegetation establishment (Ewing and Seebacher 1997). But in some instances it also might benefit marsh plant production by reducing evapotranspiration and thus soil salinity (Bertness et al. 1992).

Users of this guidebook select from just three shade extent categories: <1%, 1–10%, and >10%. Field experience suggests that repeatability of estimates would decline if more than these three categories were used. The specific numeric cutoffs that define these categories have no proven, individual relationship to functions, but rather are calibrated generally to the conditions found among the surveyed wetlands (Table 21). Shade in the low marsh is scored separately from shade in the wetland as a whole because low marsh shade is especially important to fish, whereas the overall shading of the marsh encompasses effects on marsh production. The only statistically significant correlation was positive, with *SoilFine. Shade* also was greater, as expected, in River-sourced than in Marine-sourced Tidal wetlands.

**Bare, Pannes**. Mature tidal marshes normally have close to 100 percent plant cover, whereas plant cover in severely degraded or recently restored marshes is typically much less (Frenkel and Morlan 1990, 1991; Morlan and Frenkel 1992). Nonetheless, extensive wrack accumulations, channels, and pannes (naturally bare off-channel areas) all lack living vegetation, yet characterize many mature marshes (Jefferson 1975). They can be highly productive if they support extensive and sustained growths of algae. Principal factors that influence the extent of pannes and other bare areas are the duration of inundation, the availability of soil nutrients, soil salinity, and erosion from drift logs, waves, and currents. The presence of pannes — especially when located at a variety of elevations within a marsh — may indicate increased opportunity for diversification of the invertebrate fauna. Many pannes remain free of fish for several weeks, allowing a variety of insect larvae to develop in the absence of major predators. In contrast, pannes that flood often tend to have more temporally consistent temperature and lower salinity, which favor invertebrates, but they also may have less filamentous algae upon which invertebrates feed (Barnby et al. 1985). Thus, the elevation of marsh pannes directly influences their hydroperiod (i.e., duration and frequency of inundation), which in turn influences invertebrate diversity and productivity. Pannes above and below MHHW (mean higher high water) elevation tend to have less macroinvertebrate diversity than those at or close to MHHW. However, high pannes can support the most taxonomically distinctive invertebrate communities and thus contribute the most to overall diversity within a marsh (Barnby et al. 1985). Due to uneven subsidence of sediments, pools that seem superficially similar to pannes are often numerous in former tidal marshes whose circulation recently has been restored (Taylor 1980, Gilman 1993). Several resident fish species spend significant parts of their life in pannes. These include peamouth chub, threespine stickleback, and Pacific staghorn sculpin. By temporarily inhabiting pannes, these species may be less vulnerable to predatory fish, but they must tolerate high salinity and may possibly be more vulnerable to some avian and mammalian predators (Burger et al. 1982).

For both *Bare* and *Pannes*, users of this guidebook's HGM method select from five categories: 0 (no bare or pannes), 4–100 sq.m, 100–2,500 sq.m, 2,500–10,000 sq.m, or >10,000 sq.m. of pannes or other bare substrate. Field experience suggested that repeatability of estimates would decline and/or more assessment time would be required if more than these five categories were used. The specific numeric cutoffs that define these categories have no proven, individual relationship to functions, but rather are calibrated generally to the conditions found among the surveyed wetlands (Table 21). The indicator, *Pannes*, is assessed separately from the indicator, *Bare*, of which it is a subset, because of the unique importance of isolated pannes to some resident fish, invertebrates, and certain tidal plant assemblages. All the statistically significant correlations with scores of other indicators were positive, and in descending order of significance were: *Exits, LWDmarsh, Jcts, Pform, BlindL,* and *Width.* As expected, the scores of both *Bare* and *Pannes* were positively correlated with wetland size. By HGM subclass, the amount of *Bare* and especially *Panne* habitat was greater in Marine-sourced Low Marsh than in Marine-sourced High or River-sourced Tidal.

**TranAng**: Many tidal wetlands transition gradually into adjoining deeper waters, whereas others drop off abruptly as a result of prolonged exposure to strong currents or eroding waves. Such erosion can be part of natural processes and by itself does not mean a tidal marsh is biologically impaired, immature, or low-functioning. It can, however, indicate an outflux of sediment-associated elements and organic matter. Given the uncertainties in estimating this indicator and its relationship to functions, users of the HGM method are provided with just two categories for describing a site's external edge: (1) steep with extensive erosion and undercutting, or (2) gradual and/or stable. Table 21 shows the score distribution. All the statistically significant correlations with scores of other indicators were positive, and in descending order of significance were: *Exits, Width, SoilFine, BlindL,* and *LWDchan.* This indicator did not vary significantly by HGM subclass, but tended to increase with wetland size.

**UpEdge**: Tidal wetlands assume a wide variety of shapes, with resulting variation in the degree of convolution of their perimeters (or expressed another way, the ratio between the proportion of the perimeter that adjoins upland vs. the proportion that adjoins water). In most marshes, the upland edge boundary is much less dynamic than the aquatic boundary. Extensive chemical processing may be associated with wetlands having convoluted marsh-upland edges (as represented by *UpEdge*) because the edges comprise an ecotone characterized by often-sharp gradients in topography, soil oxygen, sediment texture, sunlight, temperature, salinity (greater freshwater availability from groundwater seepage), and/or moisture. In this guidebook's method, the specific numeric cutoffs that define 11 "upland edge percent" categories have no proven, individual relationship to functions, but rather were defined in 10-percent intervals for convenience. Table 21 shows the score distribution. Considering just the correlations that were statistically significant, there were negative correlations with the scores for *Panne, Fetch, MudW, BlindL, Width, LWDmarsh, Jcts,* and *Roost,* whereas correlations were positive with *Island, Fresh, FormDiv,* and *TribL.* Correlations of *UpEdge* with HGM subclass were as expected, with River-sourced Tidal and River-sourced High Marsh having proportionately more upland edge than River-sourced Low Marsh.

**LWDchan, LWDmarsh, LWDline**: In recent decades the importance of large woody debris (LWD) to aquatic life in rivers and coastal streams of the Pacific Northwest has been well documented (e.g., Scott and Ford 2001). For defining "proper functioning condition" of non-tidal coastal streams, NOAA suggests that greater than 80 pieces of LWD be present (generally longer than 50 ft and with a diameter of more than 2 ft). However, the role of LWD in estuarine systems has been studied less frequently (e.g., Bustard and Narver 1975, Adamus 1987). Ongoing research by the Siletz Tribe and US Fish and Wildlife Service is documenting frequent fish use of LWD placed in tidal channels. Although the extent to which invertebrates use intermittently submerged wood in tidal marshes is undocumented in Oregon, inference from other systems and regions (e.g., Everett and Ruiz 1993) suggests that wood probably provides shelter for some marine and soil invertebrates. Incidental field observations suggest large numbers of invertebrates sometimes congregate under drift logs (*LWDmarsh, LWDline*) and amid the detrital matter (wrack) that they trap. The value of downed wood to small mammals is well documented (e.g., Manning and Edge 2004), so the presence of driftwood accumulations in high marsh habitat may extend the living space available to mammals that otherwise are confined to upland habitats.

Quantifying LWD precisely and accurately is not possible in the context of a rapid assessment method intended for application to sometimes-enormous wetlands. Thus, method users are given simple categories from which to choose. For tidal channels (*LWDchan*), the choices are 0 (no in-channel wood), 1–10 pieces, or >10 pieces. For the marsh surface (*LWDmarsh*), the choices are 0, 1–4, 5–9, 10–30, or >30 pieces. For driftwood (*LWDline*), the choices are 0, 1–9, 10–29, 30–59, or >59% of the length of the wetland-upland edge. The specific numeric cutoffs that define these categories have no proven, individual relationship to functions, but rather reflect natural break-points in the distributions found among the surveyed wetlands. Table 21 shows the score distributions. Correlates of these three indicators differed somewhat. For *LWDchan*, negative correlates were *RatioC* and *SpPerQd,* whereas positive correlates were *SoilFine, Exits, Pform, EstuSal, TranAng, FormDiv, WetField%, Width, SeaJoin,* and *ShadeLM.* For *LWDline*, negative correlates were *LWDmarsh*, *Fresh,* and *SoilFine,* whereas positive correlates were *Fetch, DikeDry, Eelg, Pform,* and *MudW.* And for *LWDmarsh*, negative correlates were *Island*, *HomeDis, UpEdge*, and *Fresh,* whereas positive correlates were *Pform, Fetch, Eelg, Bare, Panne, MudW, Boats, BlindL,* and *Exits.* By HGM subclass, *LWDline* tended to be less extensive in River-sourced Tidal than in Marine-sourced Tidal wetlands. Both *LWDchan* and *LWDmarsh* scores increased significantly with increasing wetland size.

**TribL, Fresh**. The presence of freshwater within or near much saltier tidal marshes increases their capacity to support greater diversity and/or productivity of plants, invertebrates, anadromous and resident fish, and wildlife. Salinity concentrations are often inhibitory to plant production in parts of high marshes that experience prolonged drought (Shumway and Bertness 1992). The soil salinity balance of many high marsh plant species is especially precarious during summer, and any loss of sustained freshwater seepage can reduce productivity in parts of a tidal wetland. For anadromous fish species, salinity in the upper riverine portion of estuaries, at the interface between freshwater spawning streams and estuarine waters, is especially important because this is where extended rearing of outgoing salmon primarily occurs. In such areas, young fish become accustomed to pursuing more mobile prey, as well as acclimating gradually to increased salinity (Simenstad et al. 2000). Access to freshwater is important to anadromous fish for osmotic regulation (Macdonald et al. 1988), and accessible freshwater areas also provide additional complementary habitat for spawning, feeding, overwintering (especially coho), and refuge from storms. Estuaries that regularly experience compressed salinity transition zones (i.e., salinity changing from fresh to saline within a very few km) are less hospitable to anadromous fish because of the osmotic stress such transitions cause. Consequently, marshes lacking freshwater tributaries and located in such estuaries are less likely to be used by anadromous fish (Simenstad et al. 2000). Such estuaries often occur in small watersheds that experience severe storms. Sources of freshwater in tidal systems (represented by *Fresh*) diversify the macrofaunal community by providing islands of microhabitat favorable for colonization by salt-intolerant invertebrates and plants (Yozzo and Smith 1995). Tributaries (*TribL*) originating in adjoining uplands also provide a corridor by which larval freshwater stream invertebrates (those tolerant of at least moderate salinity) can move easily into the upper marsh, thus diversifying the marsh's invertebrate macrofauna. In the Oregon Coast Range, 2,825 to 6,140 square feet of runoff-contributing area are needed to support each linear foot of channel, and geology of the contributing area seems to have relatively little influence (Niem 1976).

These two indicators presume that the longer the accessible tributary stream (*TribL*), and/or the more freshwater sources feeding a tidal marsh (*Fresh*), the higher will be its capacity for supporting the functions noted above. The categories for cumulative tributary length are based on natural breaks in the measurements made of tributaries feeding the 120 surveyed marshes. The distribution of scores is shown in Table 21. For *Fresh*, negative correlates were *Fetch, Panne, MudW, LWDline, LWDmarsh, Roost,* and *Eelg,* whereas positive correlates were *Island, FormDiv, UpEdge,* and of course *TribL.* For *TribL*, the only significant negative correlate was *Fetch*, whereas positive correlates were *FormDiv, UpEdge, Flood, Island, Fresh,* and *FreshSpot.* As expected, scores for these two indicators were significantly greater in River-sourced Tidal and Marine-sourced High Marsh than in Marine-sourced Low Marsh.

**Width**: Because tidal wetlands have a variety of shapes, their width is perhaps a better indicator of some functions than is their area. Wider marshes have a larger "core area" that is relatively isolated from pollution and disturbances originating in adjoining uplands or deeper waters. During the 2003 field season, incidental detections of birds in the visited marshes suggested that densities of at least one nesting species (savannah sparrow) might be related non-linearly to high-marsh core area. Wider marshes provide longer flow paths and thus greater opportunity for runoff-borne sediments to settle out and be stabilized by high marsh vegetation. Wider marshes also tend to have gentler slope, which encourages further slowing of runoff and less chance for scour or wind-associated resuspension. In contrast, fringe marshes that are very narrow may be more likely to be flushed by runoff, especially in urban situations, because of the short flow path between upland and deepwater. Water levels in wider marshes may change more slowly within a tidal cycle (because water has farther to travel across the marsh surface), thus allowing time for some marsh insects to move to positions more favorable for their survival. On the other hand, due to their average proximity to uplands, narrow marshes might have a proportionately larger component of terrestrial insects available to estuarine fish, and so in some circumstances might result in higher capacity for supporting that function.

For this guidebook's HGM method, maximum rather than average width is used because its measurement tends to be more repeatable, especially among tidal marshes with irregular shapes. The specific numeric cutoffs used to define 11 width categories have no proven, individual relationship to functions, but rather were defined in 10 percent intervals for convenience. Table 21 shows the score distribution, based on widths measured from recent topographic maps. Considering just the correlations that were statistically significant, there were negative correlations with *UpEdge* and *LWDchan*, and positive correlations with *BlindL, Jcts, Exits, SoilFine, Panne, Pform, TranAng, SpPerQd, Flood, BuffCov, Bare, WetField%,* and of course wetland area. Based on measurements of the surveyed sites, marsh width did not differ significantly among HGM subclasses.

**MudW**: Previously, the indicators *Bare* and *Panne* were used to describe unvegetated sediments within the wetland. In contrast, the indicator *MudW* describes unvegetated sediments that *adjoin* the wetland but are not part of it. The presence of adjoining mudflats would seem to boost the capacity of tidal wetlands to support animals such as shorebirds and crabs that use both habitats in a complementary or supplemental manner. Wide mudflats help insulate shorebirds from mammalian predators, tree-perching raptors, and human disturbance (Pfister et al. 1992, Lafferty 2001). Waterfowl use of tidal wetlands often is focused along edges with mudflats (Stralberg et al. 2003).

For this guidebook's HGM method, maximum rather than average width is used because its measurement tends to be more repeatable, especially among tidal flats with irregular shapes. As was true of the indicator *Width*, the specific numeric cutoffs used to define 11 mudflat width categories have no proven, individual relationship to functions, but rather were defined in 10 percent intervals for convenience. Table 21 shows the score distribution, based primarily on measurements made from topographic maps whose accuracy in depicting mudflat extent is arguable. Measurements from the field or from airphotos were not used because the visible extent of mudflats varies greatly according to daily tidal heights. Considering just the correlations that were statistically significant, there were negative correlations with *FormDiv, UpEdge, Fresh,* and *Island*, whereas the correlations were positive with *Fetch, Panne, Eelg, LWDmarsh,* and *LWDline.*

**Roost**: During high tides (and especially spring tides), a variety of animals that otherwise feed in low marsh habitats are forced to either swim or retreat to higher ground. Perhaps most notable among such animals are shorebirds (i.e., sandpipers, plovers, godwits, curlews), most of which feed and/or migrate in large flocks. In Oregon, some of the types of features known to be used as shorebird roosts include treeless high marshes (wider ones), treeless uninhabited islands (including offshore rock ledges), beaches or bars exposed at high tide (wider ones), nontidal marshes and ponds (wider ones), unvegetated dikes or jetties, seasonally flooded pastures (larger ones in flat terrain), and sewage treatment lagoons. Because counting these and measuring their individual sizes and proximity to a particular tidal marsh is impractical in the context of a rapid assessment, this HGM method relies on counting the *types* of potential roosts, which can be approximated from topographic maps and airphotos. A 1.5-mile radius from the assessed site is specified for searching for these potential roosts, and is based on two coastal studies of home ranges of wintering shorebirds in California and southern British Columbia (Strahlberg et al. 2003). Table 21 shows the score distribution. Statistically significant negative correlations were with *Boats, BuffCov, FormDiv, UpEdge,* and *Fresh*, whereas the significant correlations with *Panne* and *Exits* were positive. Fewer roosting opportunities were available around River-sourced Tidal wetlands as opposed to Marine-sourced High and Low Marsh. Larger marshes had significantly more potential roosting areas in their vicinity.

**Island**: Marshes located on islands that are entirely flooded on a daily (or perhaps only monthly) basis at high tide would seem to be hazardous for non-aquatic animals such as small mammals, terrestrial insects, and some songbirds because tidal flooding displaces them. Even when some unflooded habitat remains, if such habitat is small relative to the flooded portion of the island, crowding of individuals may occur during high tides, with possible loss of productivity. For this indicator, four categories of potential access to uplands are considered:

A = not an island
B = island contains some high marsh and/or undeveloped upland, this being greater than the area of low marsh
C = island contains some high marsh and/or undeveloped upland, this being less than the area of low marsh
D = island contains no high marsh or undeveloped upland, i.e., is completely underwater during daily high tide

Table 21 shows the score distribution. Statistically significant negative correlations were with *Fetch, MudW, BlindL, EstuSal,* and *Panne*. Significant correlations were positive with *Fresh, FormDiv, UpEdge, LWDmarsh, TribL,* and *SpPerQd*.

**Fetch**: Tidal marshes that adjoin large bays and other wide stretches of open water, especially those facing in the direction of prevailing winds and with abrupt drop-offs to deep water (i.e., wide *Fetch*), are probably less effective for stabilizing sediment because of the overwhelming effects of waves in keeping sediment suspended (Shafer et al. 2002). This is particularly true when the marshes are narrow. In fact, their narrow configuration sometimes may be a result of chronic erosion. Most wintering ducks and geese seem to aggregate in parts of an estuary that are sheltered the most from strong wind and waves. On a positive note, marshes with large fetch might be more subject to having their organic matter physically removed and exported. However, in such situations waves might just as easily introduce and confine foreign organic matter (wrack) and limit marsh productivity, depending on wind direction and coincidence of storms with spring high tides.

In arriving at a score for this landscape-scale indicator, this method does not limit consideration just to fetch (open water distance), but also includes consideration of potential marsh erosion/export from river floods and large boat traffic. In this guidebook's method, the specific numeric cutoffs that define the three fetch distance categories have no proven, individual relationship to functions, but rather were defined in three categories for the sake of simplicity and repeatability. Table 21 shows the score distribution. Statistically significant negative correlations were with *Fresh, UpEdge, Island, TribL,* and *FormDiv.* Significant correlations were positive with *LWDline, MudW, LWDmarsh, Panne, Eelg, EstuSal,* and *SeaJoin*. By HGM subclass, *Fetch* was clearly much greater for Marine-sourced than River-sourced wetlands.

**Pform, FormDiv.** Use of tidal marshes by some characteristic wildlife species might be attributed to the presence of a particular plant community (or a variety of plant structures) present either within the marsh (*Pform*) or in adjoining upland (*FormDiv*). Because different plant species provide food at different times and in different forms, a diversity of plant species implies the capacity to support a more varied vertebrate fauna. For example, hummingbirds potentially utilize the nectar of marsh flowers, while sparrows feed on seeds from rushes such as *Juncus balticus*, and muskrats prefer cat-tail (*Typha*) shoots. Shrubs and trees along the upland edge contribute a large number of complementary species to the tidal marsh fauna. These include both species that require shrubs or trees for nesting (e.g., American robin), denning (e.g., raccoon), roosting (e.g., bats), and feeding (e.g., raptors, flycatchers). At least three species (marsh wren, red-winged blackbird, song sparrow) that characterize many of Oregon's tidal marshes may be more prevalent in tidal marshes with greater vertical complexity, as provided (for example) by cat-tail, bulrush, and dead wood on the marsh surface (*LWDmarsh, LWDline*). Large logs that fall or drift into tidal wetlands are important as cover for small mammals and as singing perches for many birds (e.g., song sparrow). They also provide hunting perches for raptors. Within tidal marshes, vertical complexity of vegetation may increase disproportionately along channel banks and abandoned dikes (Collins and Resh 1985). A diversity of vegetation forms also can imply the presence of diverse microtopography. This is important because the deposition of sediment, particulate carbon, and associated substances suspended in the water column depends strongly on detention time, which is partly the result of hydraulic roughness ("baffle effect") of the underlying substrate (Wolaver et al. 1988; Cahoon and Reed 1995), as indicated by its microtopography. Historically, many tidal wetlands in the Pacific Northwest were once tidal spruce forests (Benson et al. 2001), but in Oregon only a small number still are.

This HGM method considers six structural features internal to tidal marshes (*Pform*) and 12 vegetation categories usually external to but adjoining tidal marshes (*FormDiv*). Because counting or measuring the area occupied by these is impractical in the context of a rapid assessment, this HGM method relies on counting the *types* of potential internal features, and the *percentages* of the external adjoining vegetation types. The categories used to describe internal structural diversity are based on knowledge of the needs of animal species that characteristically inhabit Oregon tidal marshes. The particular structural classification used to describe the adjoining vegetation is similar to many wildlife habitat classification schemes used in this region. Adjoining vegetation is estimated within 50 ft of the marsh-upland edge, despite the fact that some marsh animals use habitats much farther from the marsh, because of difficulties in consistently and accurately estimating conditions farther away. Table 21 shows the score distribution for this indicator, based on estimates obtained while visiting the 120 marshes. For *FormDiv*, statistically significant negative correlations were with *MudW, Roost, Estu%WL, LWDchan, Panne,* and *Fetch.* Positive correlates were *Island*, *Fresh, TribL, UpEdge*, and *Alder*. For *Pform*, statistically significant correlations were all positive, and were with *Eelg, LWDmarsh, BlindL, Exits, Jcts, Width, Alder, Bare, LWDchan, LWDline,* and *SoilFine.* The indicator *Pform* showed no correlation with HGM subclass but *FormDiv* tended, as expected, to be greater among River-sourced and Marine-sourced High Marsh. *Pform* was generally greater in larger wetlands.

**Alder, Eelg**: Two features that are not restricted to tidal marshes, but which can profoundly influence their functions and the species that live there, are alder (mostly *Alnus rubra* on the Oregon coast) and eelgrass (both the native *Zostera maritima* and the introduced *Z. japonica*).

Recent studies of eelgrass in the Pacific Northwest highlight its superior ability, compared with some other coastal habitats, for hosting high densities and/or diversity of macroinvertebrates. Many of these invertebrates are capable of moving into nearby marshes on the rising tide or at other points in their life cycle, providing a linkage between these habitats. This potentially diversifies the marsh macrofauna. Eelgrass, especially when located near a tidal marsh, can draw increased numbers of several waterfowl species (e.g., brant). Like tidal marshes, eelgrass beds influence estuarine nutrient cycling. A study in Yaquina Bay estimated that at current biomass levels there, eelgrass removes 50 to 60 moles of dissolved inorganic nitrogen (DIN) per hour and 0.2 to 2.2 moles of dissolved reactive phosphorus per hour from the water column.

Studies from other parts of the Pacific Northwest have identified alder leaves as a particularly important nutritional source for aquatic invertebrates (Piccolo and Wipfli 2002), possibly because this riparian species effectively fixes nitrogen (Wigington et al. 1998, Compton et al. 2003).

For this guidebook's HGM method, alder's role is represented by estimating the percent of the wetland-upland edge that is occupied by alder, whereas the contribution of eelgrass is represented by a categorical determination of whether it is present nearby (within the marsh's internal channels), slightly farther away (within 50 ft of the marsh's external edge), or not at all. While obviously important, estimating the actual *areas* of alder and eelgrass is beyond the capability of a rapid assessment method. The 50 ft distance was used because of the difficulty of detecting eelgrass at greater distances from a marsh while standing in the marsh. Table 21 shows the score distributions for these two indicators.

For *Alder*, statistically significant negative correlations were with *SoilFine* and *BuffCov,* whereas positive correlates were *FormDiv* and *Pform*. For *Eelg*, the relationship to *Fresh* was expectedly negative, and positive correlates were *Pform*, *LWDmarsh, LWDline, Fetch, MudW, BlindL,* and *Jcts.*

**SoilFine**: The type of soil or substrate upon which a tidal marsh grows influences its functions and species composition, but the direction of that influence is not always apparent. In the context of our HGM subclassification, Marine-sourced High Marsh sites may tend to have both coarser (sand) and finer (clay) soils than Marine-sourced Low Marsh or River-sourced Tidal wetlands (Elliott 2004), but the latter two may have coarser soils when located along coastal spits or gravelly rivers, for example. Marsh soils comprised mostly of sand can indicate regimes where current or wave energy is large, with consequent dilution and removal of soluble and particulate substances (Langis et al. 1991). Sandy soils tend to be more erosion-prone than finer soils and sediments, but in some cases they may indicate older, well-established marshes, whereas silty soils may reflect recent expansion of a marsh on former mudflats (Elliott 2004). Sandy soils retain water for shorter times after each flood tide, thus decreasing the time available for microbial processing of various substances and increasing thermal and salinity stress, which in turn influences vegetation species composition and perhaps productivity (Ewing 1983, Liverman 1981). Sandy soils tend to have less organic matter (Elliott 2004) and low cation exchange capacity, making them less retentive of many substances (Gallagher and Kibby 1980). Sandy soils are less prone to the anoxic (reducing) conditions that otherwise strongly support the retention of phosphorus, sulfur, carbon, iron, manganese, copper, selenium, and molybdenum (Burton and Liss 1976). Consequently, salt toxicity to plants may be a less-dominant factor in sandy soils (Bertness and Pennings 2000), and small differences in species composition of the tidal marsh plant community have been associated with differences in soil nutrient levels (St. Omer 2004). Sandy sediments along higher banks of tidal creeks frequently support denser and/or taller stands of marsh plants (Gallagher and Kibby 1981), and these can significantly influence element cycling. Pioneering marsh plants rooted in sandy soils may be more capable of taking up nutrients than the same plants rooted in well-developed marsh soils, where nutrients are less limiting to plant growth (Osgood and Zieman 1993). In the Pacific Northwest, low-marsh sand marshes commonly support *Triglochin maritima, Salicornia virginica, Spergularia canadensis, Puccinellia pumila,* and *Plantago maritima*, whereas low marshes at the same elevation on muddy substrates host only *Carex lyngbyei*. Although this species colonizes low marsh on mud, on sand it is restricted to middle marsh or higher-elevation communities (Jefferson 1975, Hughes and Mathews 2003). Soil texture also influences the species composition and density of marsh invertebrates, with greater invertebrate densities tending to be associated with moderately fine (but not strongly reducing) textures, e.g., silt with low clay content.

During this project, soil textures were assessed in three profiles (soil pits) per marsh, and accompanying plant species were noted (whenever possible, locations of the three profiles were chosen to represent the three most-dominant plant species assemblages). Because of the time and expense required, no physical or chemical laboratory analyses were conducted of soil samples. And because of the short time demands of a rapid assessment, users of this Oregon HGM method are requested only to indicate whether soils at a particular site mainly fit one of three categories: coarse sand/gravel, fine sand, or muck/silt, loam. Table 21 shows the score distribution from our 120 sites. Statistically significant negative correlations were with *Alder, LWDline,* and *SpPerQd.* Significant correlations were positive with *Jcts, EstuSal, BlindL, SeaJoin, Width, Exits, ShadeLM, Shade, LWDchan, TranAng, Estu%WL,* and *Pform.* Fine sediments were more likely to occur in the larger tidal wetlands that were surveyed. However, soil texture showed no significant correlation with HGM subclass.

**EstuSal**: Recognition is growing among salmon biologists that genetic diversification and a diversification of salmonid life histories within a river basin or estuary lead to stronger salmonid stocks over the long-term. Variation in salmonid life histories, which are partly a product of diverse conditions within a watershed that affect timing of spawning and how long young fish remain in headwaters, effectively spreads the risk of extinction across space and time, helping mitigate localized catastrophes (Weavers 1993). One factor that might support diversification of salmonid life histories is a somewhat equal distribution of salmonid habitat, including accessible tidal marshes, across the spectrum of salinities from 0 (fresh) to about 35 ppt (saltwater). Similarly, wildlife biologists commonly observe a wider variety of animal species in estuaries where otherwise suitable habitat is located across a range of salinity regimes. Thus, this landscape-scale indicator attempts to rate estuaries of which the assessed wetland is a part, placing them in one of four categories:

1. Tidal marshes are absent (or nearly absent) from two of the three salinity zones (fresh, brackish, saline)
2. Tidal marshes are absent (or nearly so) from one of the three salinity zones, with one of the two remaining zones having much more marsh acreage than the other
3. Tidal marshes are present in all three zones, with one zone containing more than 50% of the estuary's marsh acreage
4. Tidal marshes are present in all three zones, with no zone containing more than 50% of the estuary's marsh acreage

To assign each Oregon estuary to one of these categories, spatial data on tidal wetland extent were overlaid with very approximate delineations of salinity zones (mainly as compiled in Hamilton 1984), recognizing that boundaries of such zones are based on relatively few measurements (none from tidal marshes) and in any case are very dynamic. Table 21 shows the score distribution for this indicator. Negative correlates that were statistically significant were *BuffCov* and *Island*, whereas significant positive correlates were *SeaJoin, SoilFine, Estu%WL, Fetch,* and *LWDchan.*

**SeaJoin**: In a geomorphic context, Oregon estuaries are popularly classified as one of four types: drowned river mouth (the most common), river-dominated, blind, or bar built (Estuarine Plan Book, Cortright et al. 1987). The consequences of each estuarine type for tidal wetland functions in the estuary have not been investigated, but some inferences can be made. Bar-built estuaries, such as Netarts Bay, usually remain connected to the ocean but have high salinity. Thus, they are expected to provide only limited habitat for salmonid fish. Blind estuaries, such as the Elk River estuary, periodically become disconnected from the ocean due to low flow and/or drifting sediment, so also provide somewhat unfavorable conditions for anadromous fish. However, preliminary studies of tidal lagoons in Puget Sound suggest that some may be used quite extensively by salmonids. Estuaries that have deep, unconstricted connections to the nearshore ocean tend to have more fish species because marine as well as non-marine species can exist in close proximity (Bottom and Jones 1990, Monaco 1992). In Oregon, the mouths of the Alsea and Siletz estuaries are more constricted than that of the Yaquina estuary, and consequently reduce the tidal amplitude and increase tidal current velocities in these estuaries (Goodwin et al. 1970). Estuarine classification, then, can be used as an approximate surrogate for connectivity of estuaries with the ocean.

In this guidebook's HGM method, this landscape-scale indicator is applied only to the fish habitat functions. Users classify a tidal wetland as being situated in a blind estuary (lowest score), bar build estuary (intermediate), or other type of estuary (highest score). Table 21 shows the score distribution for this indicator among the sites we surveyed. Very few were of the blind or bar build types.

**Estu%WL**: Anadromous fish, being highly mobile, are capable of exploiting food resources and other favorable conditions in several tidal marshes almost simultaneously. Multiple marshes also provide multiple opportunities to temporarily escape from predators or locally stressful water quality conditions. Thus, the suitability of an individual marsh for anadromous fish cannot be assessed fairly without considering the extent of and distance to other tidal marshes (Simenstad et al. 2000). Sites located close to other tidal marshes probably are used more consistently by anadromous fish, i.e., they have higher capacity to support this function. However, isolated sites might be individually of greater *value* (see section 3.2.9).

Like the preceding indicator, this landscape-scale indicator is applied in our method to estimate only the fish habitat functions. Scaling was accomplished by ranking Oregon's estuaries by two factors — ratio of tidal marsh to subtidal water, and total marsh area — and then summing the ranks and converting them to a 0-to-1 scale (Table 21 and Table 22). The indicator's positive correlates were (in decreasing order of statistical significance) *Exits, EstuSal, BlindL, SoilFine, FormDiv,* and *Jcts.*

**Table 22. Components of the indicator, Estu%WL**

| | Ranked by Ratio of Tidal Marsh to Water (1 = smallest) | Ranked by Tidal Marsh Area (1 = smallest) | Sum of Ranks | Scaled |
|---|---|---|---|---|
| Alsea | 13 | 7 | 20 | .8 |
| Beaver | 1 | 16 | 17 | .9 |
| Chetco | 27 | 25 | 52 | .1 |
| Coos Bay | 20 | 1 | 21 | .7 |
| Coquille | 17 | 11 | 28 | .5 |
| Ecola | 5 | 22 | 27 | .5 |
| Elk | 16 | 19 | 35 | .3 |
| Euchre Cree | 14 | 24 | 38 | .3 |
| Necanicum | 7 | 15 | 22 | .7 |
| Nehalem | 12 | 6 | 18 | .9 |
| Nestucca | 18 | 13 | 31 | .4 |
| Netarts | 4 | 9 | 13 | 1 |
| New River | 6 | 14 | 20 | .8 |
| Pistol | 22 | 26 | 48 | .2 |
| Rogue | 26 | 18 | 44 | .2 |
| Salmon | 2 | 10 | 12 | 1 |
| Sand Lake | 23 | 12 | 35 | .3 |
| Siletz | 11 | 8 | 19 | .9 |
| Siltcoos | 8 | 20 | 28 | .5 |
| Siuslaw | 10 | 3 | 13 | 1 |
| Sixes | 25 | 21 | 46 | .2 |
| Ten Mile | 3 | 17 | 20 | .8 |
| Tillamook | 21 | 4 | 25 | .6 |
| Two Mile | 9 | 23 | 32 | .4 |
| Umpqua | 19 | 2 | 21 | .7 |
| Winchuck | 24 | 27 | 51 | .1 |
| Yaquina | 15 | 5 | 20 | .8 |

### *B2. Rapid Indicators of Function Requiring Airphotos or Measuring Equipment*

**WetField%**: Many bird species that characterize Oregon's tidal marshes concentrate the most in estuaries that also are surrounded by ponds, lakes, nontidal marshes, sewage lagoons, croplands, and/or dairy pastures, especially where these exist in flat terrain (Lovvorn and Baldwin 1996). Especially during winter high tides, such habitats provide waterfowl with rich alternative food sources and cover, especially during severe coastal storms or when natural foods are temporarily scarce. Some studies from other regions suggest that the distribution of such areas within about 1.5 miles of a wetland is a better determinant of wetland use than distribution measured closer or farther away. The 1.5-mile radius also approximates the home ranges of wintering shorebirds in California and southern British Columbia (Strahlberg et al. 2003).

For the 120 marshes we surveyed, the percent of these land cover types was estimated (not measured) from topographic maps and airphotos. The resulting values were scaled across five categories reflecting conditions around the wetland we studied, rather than by using some threshold known to be functionally significant. Ideally, an area-weighted index of marsh distribution should be calculated for each estuary, but that was not practical for this project. Table 21 shows the score distribution for this indicator among the sites we surveyed. The only negative correlate that was statistically significant was *SpPerQd*, and the only positive ones were *LWDchan* and *Width*. This indicator showed no statistically significant relationship to HGM subclass of the surveyed tidal wetlands.

**BuffCov**: Many rapid assessment methods use the width of naturally vegetated buffers around a wetland or riparian area as an indicator of its integrity and/or function. Unlike the situation in many other states, most of Oregon's tidal wetlands are surrounded almost entirely by natural vegetation and water. Little or no croplands, pavement, buildings, or lawn adjoin most Oregon tidal wetlands, and impacts to wetland functions from dikes and other infrastructure probably have been greater. Nonetheless, strong evidence from other areas (e.g., Chesapeake Bay tidal wetlands) suggests that land cover alterations, occupying as little as 6% of the landscape at distances at least as far as 3,000 ft from a tidal wetland, can influence the species composition of the wetland's bird community (DeLuca et al. 2004). Although residential neighborhoods commonly attract many land birds and indirectly may diversify the marsh avifauna (Stralberg et al. 2003), residences also are associated with greater densities of animals (e.g., raccoons, feral cats) that prey extensively on native songbirds and small mammals. Birds that nest in high tidal marshes are especially vulnerable because nests must be placed very close to the ground, due to the absence of trees and shrubs within most Oregon tidal marshes.

For lack of better data from the Pacific Northwest, the scale for this landscape indicator largely reflects the Chesapeake findings, with scores declining rapidly as developed land surrounding the wetland exceeds about 14%. Land cover alterations closer to a wetland (within 1,500 ft) are given greater weight than those within the zone that also extends out in a radius of 3,000 ft. For the 120 marshes we surveyed, the percent of developed land was estimated categorically (and without the benefit of GIS) from topographic maps and airphotos. Alternative similar measures, such as the average width of naturally vegetated buffer adjoining a tidal wetland, or the percent of a tidal wetland's upland edge occupied by developed land, were considered for use but rejected because of greater difficulty in measuring it consistently, and lack of data to show its superiority to the measure we (and DeLuca et al. 2004) used. Table 21 shows the resulting score distribution for this indicator among the sites we surveyed. Negative correlates of this indicator included *Roost, SeaJoin, Alder,* and *EstuSal*. Positive ones that were statistically significant were

*Width* and *Jcts*. The extent of natural vegetation surrounding the surveyed wetlands did not differ significantly by HGM subclass.

**BlindL, Exits, Jcts:** The morphology (horizontal pattern and complexity) and extent of internal tidal marsh channels, relative to marsh age and area, are among the more important indicators of tidal marsh functions (Pestrong 1965, Fagherazzi et al. 2004a). In general, a greater length of tidal channel per unit area of marsh that it drains is associated with increased tidal circulation in the marsh (Coats et al. 1995). Water exchange rates are higher closer to channels (Harvey et al. 1987, French and Stoddart 1992). Several studies (e.g., Collins et al. 1987, Elliott 2004) have found less organic matter in soils along internal marsh channel banks than in soils farther away. Tidal channels provide extensive contact zones as well as a conduit for transfer of the production to adjoining subtidal waters. Thus, the greater the degree of intersection of such channels with the marsh surface, the greater should be the capacity for export of the marsh's plant and animal production.

Tidal channels and other microtopographic features also interrupt the horizontal and vertical homogeneity of tidal marshes. In doing so, they create ecotones defined by sharp gradients in soil oxygen, sediment texture, sunlight, temperature, salinity, and/or moisture. Many chemical transformations within marshes are focused disproportionately at such ecotones, as are populations of many organisms (Minello and Rozas 2002). Thus, the more extensive and complex the channel network, the more active a marsh is likely to be for processing particulate and soluble carbon, nitrogen, and other substances. Broad, mature marshes characterized by wide channel mouths (at the junction with the receiving bay or major river), as well as by sinuous, strongly incised, complex networks of naturally evolved tidal channels, imply a greater dynamic equilibrium of energy and consequently of the marsh sediment balance. One tidal marsh study found that a channel incision of 0.5 to 1.0m caused accelerated drainage of marsh soils over an area that was at least double that caused by an incision of half that amount (Howes and Goehringer 1994). Heavily incised ("slot") channels typify many undisturbed tidal marshes, whereas shallow, wide, U-shaped tidal channels are often present in disturbed marshes.

Complex tidal channel networks also are typically associated with low marshes that are low (relative to mean low tide), compared with higher marshes that lack such networks. However, actual channel size may be influenced more by marsh surface gradient than by surface elevation (Cornu and Sadro 2002). Although ditches can diversify the marsh surface, they cause short-cutting of the naturally slow patterns of water movement and consequently provide less time for completion of chemical and microbially facilitated reactions. Ditched parts of tidal marshes, especially when also diked, have high iron concentrations in their soils (Portnoy and Giblin 1997, 1999). This can limit some plant species. Ditched stream banks also tend to erode chronically. Channel networks that contain deepwater pools that remain as the tide recedes are particularly important as refugia (Kneib and Wagner 1994, Kneib 1997), especially when they are distributed at several elevations within the channel network.

Although the space within tidal channels usually supports little vegetation, the banks formed by channels are often highly productive (Gallagher and Kibby 1981), in some cases even more productive per unit area than the rest of the marsh surface. This is due to greater exposure of plants along the banks to channel-borne nutrients, as well as bank sediments that are less prone to anoxia and consequently more fertile (i.e., nutrients are more available for plant uptake). Vascular plant cover and productivity typically increase with increasing surface elevation within low marshes, as the stresses of high salinity, prolonged inundation, and reducing conditions in sediments lessen (Jefferson 1975; Eilers 1975, 1979; Frenkel and Morlan 1990). Therefore, complex channel networks can be expected to support especially productive plant communities. Overall invertebrate density, production, and/or richness in tidal sloughs and marshes also is thought to correspond loosely with the extent of water-edge habitat, such as provided by tidal channels (e.g., Hood 2002). Edges of wetlands, such as along tidal channels, appear to support a greater diversity (and sometimes abundance) of invertebrates (Kneib and Wagner 1994, Minello et al. 1994, Peterson and Turner 1994). Invertebrate species richness and sometimes density tend to be greatest within a few meters of the marsh-water edge (Minello et al. 1994, Minello and Rozas 2002), although predation by fish also is greatest there. Tidal channels also provide refuge from some predators and allow fish to gradually acclimate to marine salinities (Hoar 1976, Iwata and Komatsu 1984, Macdonald et al. 1988). When tidal channels are artificially ditched or straightened, capacity to support fish often is diminished (Bottom et al. 1988). Waterfowl use of tidal wetlands often is focused primarily on aquatic vegetation within internal channels and other open-water areas (Stralberg et al. 2003, Mitchell et al. 2004).

Attempts to quantify the planimetric complexity of channel networks in several West Coast tidal marshes have been undertaken in British Columbia (Levy and Northcote 1981), parts of Washington (Hood 2002), and northern California (Coats et al. 1995, Williams et al. 2002, Fagherazzi et al. 2004b). However, like another critical indicator (*Flood*, described earlier), estimating the complexity of the channel network in a consistent, rapid, and functionally meaningful way poses enormous challenges for rapid assessment methods. Previous researchers have attempted to quantify channel complexity by measuring the length of tidal channel per unit area of marsh surface (e.g., Novakowski et al. 2004), or by applying a stream ordering (hierarchical numbering) scheme and computing channel length by stream order, or computing bifurcation ratios (the number of channels of order 5 divided by the number of order 4, order 4 compared to order 3, etc.). Data from selected California tidal marshes have indicated that a bifurcation ratio of about 3.5 and drainage densities of 0.01–0.02 ft of channel per sq.ft of tidal marsh (435.6–871.2 ft of tidal channel per acre of marsh) may be characteristic of "natural" marshes (Coats et al. 1995, Williams et al. 2002). However, channel complexity varies enormously even among natural marshes, due to variation in soil type, marsh age, and other factors (Zeff 1999, Marani et al. 2004), limiting the usefulness of such unadjusted indices for judging wetland geomorphic integrity.

A more salient issue is the fact that the overwhelming majority of internal tidal channels are neither shown on published maps nor are visible in even the finest-scale airphotos, because they are narrow and concealed by vegetation. Sketching these channels in the field is even more difficult, due to their concealment and the difficult-to-walk terrain. Thus, finding meaningful measures of channel complexity, especially in the context of rapid assessment, is challenging. For this assessment method, we devised three simple indices of channel complexity. One, *BlindL*, is a ratio, the cumulative length of tidal channels (excluding drainage ditches) divided by the site's maximum width. This need not actually be measured, because the categories that users choose from are fairly broad:

total channels less than half (50%) maximum width
50–100% maximum width
1–1.9 times longer
2–2.9 times longer
3–3.9 times longer
>3.9 times longer

Another index, *Exits*, is the number of points where internal channels (excluding drainage ditches) flow into waters or mudflats outside the wetland. A third is *Jcts*, the number of junctions (confluences) along the largest internal channel. *All three of these indices must be assessed using airphotos with a scale that is exactly 1:24,000*, in order to make results comparable to the reference data set from which the scoring models were derived, as well as to allow comparison with other Oregon tidal wetlands. In this guidebook's method, the specific numeric cutoffs that define the categories of each of these indices have no proven, individual relationship to functions, but rather were defined based on the distribution of scores among the surveyed wetlands. Data are depicted in Figure 2. Score distributions are summarized in Table 21. Percentiles based on raw data are shown in Table 23.

**Table 23. Data percentiles based on raw data for indicators of channel network complexity in 120 tidal wetlands of the Oregon coast**

| | All Surveyed Wetlands (n = 120) | | | | | Wetlands Deemed "Least-Altered" (n = 24) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| percentile: | 5th | 25th | 50th | 75th | 95th | 5th | 25th | 50th | 75th | 95th |
| Exits | 0 | 1 | 1 | 4 | 10 | 0 | 1.25 | 4.00 | 9.75 | 25.50 |
| Jcts | 0 | 0 | 1 | 4 | 12 | 0 | 1.00 | 3.00 | 7.00 | 17.25 |

For *BlindL*, statistically significant negative correlations were with scores for *UpEdge, Island,* and *LWDmarsh.* Positive correlates (in order of declining statistical significance) were *Jcts, Exits, Width, SoilFine, Pform*, *Panne, Estu%WL, Flood, Eelg, TranAng, Bare,* and *SpPerQd*. For *Exits*, statistically significant correlations were all positive and were with mostly the same indicators, as well as with *Roost*, *SeaJoin*, and *LWDmarsh*. For the indicator *Jcts*, an additional positive correlation was with *BuffCov*. By HGM subclass, all three of these indicators of channel network complexity increased slightly from River-sourced Tidal to Marine-sourced High to Marine-sourced Low Marsh, but the differences were not statistically significant. As expected, all three of the indicators had a statistically significant positive correlation with wetland size.

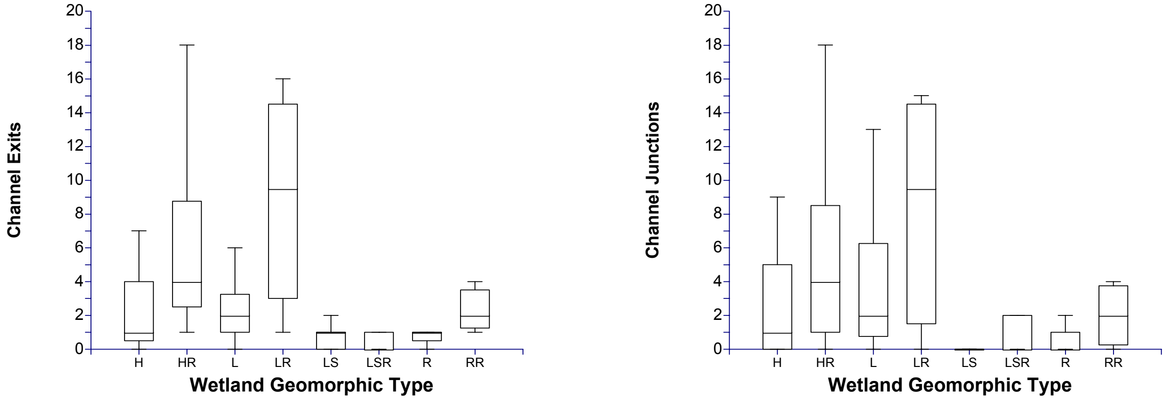

**Figure 2. Two rapid indicators of marsh geomorphic complexity: channel exits and junctions in tidal marshes of the Oregon coast**

**FreshSpot**: Areas of freshwater within tidal marshes provide opportunities for a wider variety of species, as described previously for the indicators, *TribL, Fresh, EstuSal*, and *WetField%.* Information provided by this indicator is sometimes redundant with information from those indicators, but being based on measurement (rather than estimation), it may in some ways be more reliable. Method users are asked to measure and contrast the salinity of waters within the wetland with the salinity of external waters, and then choose from three broad categories that describe the difference:

internal is <10 ppt fresher, or is more saline
internal is 10–20 ppt fresher
internal is >20 ppt fresher

Only three categories were used because of the often extreme temporal variation found among salinity measurements. The numeric cutoffs that define these three categories have no proven, individual relationship to functions, but rather were defined based on the distribution of scores among the surveyed wetlands. Score distributions are summarized in Table 21.

### 3.3.4 Variables Used Only as Covariates in Data Analyses

The following variables were not used as indicators, that is, they were not used directly as indicators of wetland functions. Instead, they were used, along with some of the indicators above, in the robust regression procedure (described in section 2.6) to "factor out" the natural factors they describe (mainly, factors that define indirectly the different HGM tidal fringe subclasses). That was done so the botanical indicators described in section 3.3.2 would be more able to detect human-related disturbance and recovery of an assessed wetland.

**WetIndexAv** (also abbreviated **SpWetIndex**): This is the "species wetness index," averaged among a site's quadrats. The index is based on the wetland indicator code assigned to each species in the US Fish and Wildlife Service's *National List of Plant Species That Occur in Wetlands* (Reed 1988, as revised in 1996). Those codes were assigned scores as follows:

| USFWS Code | Score |
|---|---|
| OBL | 10 |
| FACW+ | 9 |
| FACW | 8 |
| FACW- | 7 |
| FAC+ | 6 |
| FAC | 5 |
| FAC- | 4 |
| FAC | 3 |
| FACU | 2 |

Species not categorized as any of the above, a rare occurrence, were ignored.

To calculate *WetIndexAv*, a species' percent cover in a quadrat first was multiplied by the species' score. In other words, percent cover was used as a weighting factor for the species' score. Then the average indicator score among all species in a quadrat was determined. Quadrats with a predominance of "wetter" species (OBL's and FACW's) had higher scores and were presumed usually to be flooded longer during a tidal cycle Table 24, Table 25, Figure 3). This was not verified by simultaneously monitoring the tidal duration in each quadrat. However, the quadrat scores generally corresponded with published characterizations of their dominant species as “high marsh” or “low marsh” species, as well as with the measured relative elevation of the quadrat in which the species were found (Table 33).

**Table 24. Data percentiles for the species wetness index and for the salt-tolerance variables**

| | 5th | 25th | 50th | 75th | 95th |
|---|---|---|---|---|---|
| WetIndexAv | 7.75 | 8.67 | 9.08 | 9.36 | 9.75 |
| MarQdPct | 0 | 0.15 | 0.50 | 0.90 | 1.00 |
| MarPCav | 0 | 1.34 | 13.73 | 54.35 | 91.28 |
| FrQdPct | 0 | 0.05 | 0.21 | 0.59 | 0.99 |
| FrPCav | 0 | 2.34 | 12.58 | 24.21 | 49.87 |

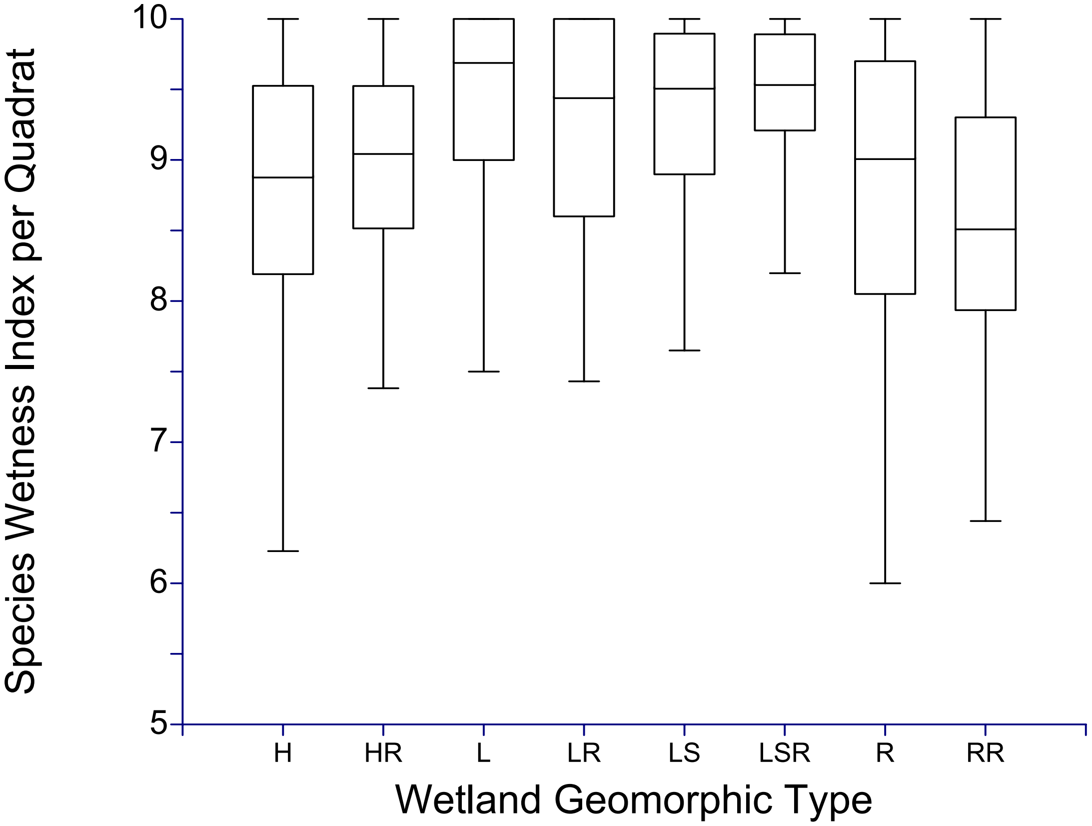

**Figure 3. Species wetness scores for tidal wetlands of the Oregon coast, means of the marsh quadrats**

H = high marsh, HR = high marsh reference sites, L = low marsh (excluding sandspits), LR = low marsh reference sites (excluding sandspits), LS = low marsh on sandspits, LSR = low marsh reference sites on sandspits, R = river-sourced tidal wetlands, RR = river-sourced tidal wetland reference sites.

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The following four intercorrelated variables were used collectively as surrogates for salinity, which is highly variable and requires frequent measurement, making it an impractical indicator. Categorizations of species as salt-tolerant or salt-intolerant were based on available published information, which for some species was quite limited. These categorizations could not be verified by simultaneously measuring soil or water salinity in every quadrat. However, species considered to be salt-tolerant or salt-intolerant from published accounts generally were found to occur at sites with higher salinity (as determined with just a few one-day measurements) and in lower positions (relative elevations) within the surveyed wetlands (Table 34). The converse was true of the species categorized as salt-intolerant.

**MarQdPct**: This is the proportion of a site's quadrats that contained any salt-tolerant species (Figure 4, Tables 24 and 25). Analysis of the data showed this to be correlated positively and significantly with salinity measured in the wetland's soils and water column.

**MarPCav**: The among-quadrat average of the percent cover of salt-tolerant species among all quadrats at a site. As was true of the above indicator, this correlated positively and significantly with salinity measured in the wetland's soils and water column.

**FrQdPct**: The proportion of a site's quadrats that contained any strictly freshwater (salt-intolerant) species. Analysis of the data showed this to be correlated negatively and significantly with salinity measured in the wetland's soils and water column, as well as with distance to head-of-tide.

**FrPCav**: The among-quadrat average of the percent cover of strictly freshwater (salt-intolerant) species in the quadrats where they were present. Analysis of the data showed this to be correlated negatively and significantly with salinity measured in the wetland's soils and water column, as well as with distance to head-of-tide.

Two additional variables were used as covariates in regression analyses of some of the botanical variables whose statistical models are shown in Table 7. These were:
**TransL**: Combined length of all transects at a site
**Positn**: The site's relative position in the major estuary (1 = lower, 2 = mid, 3 = upper)

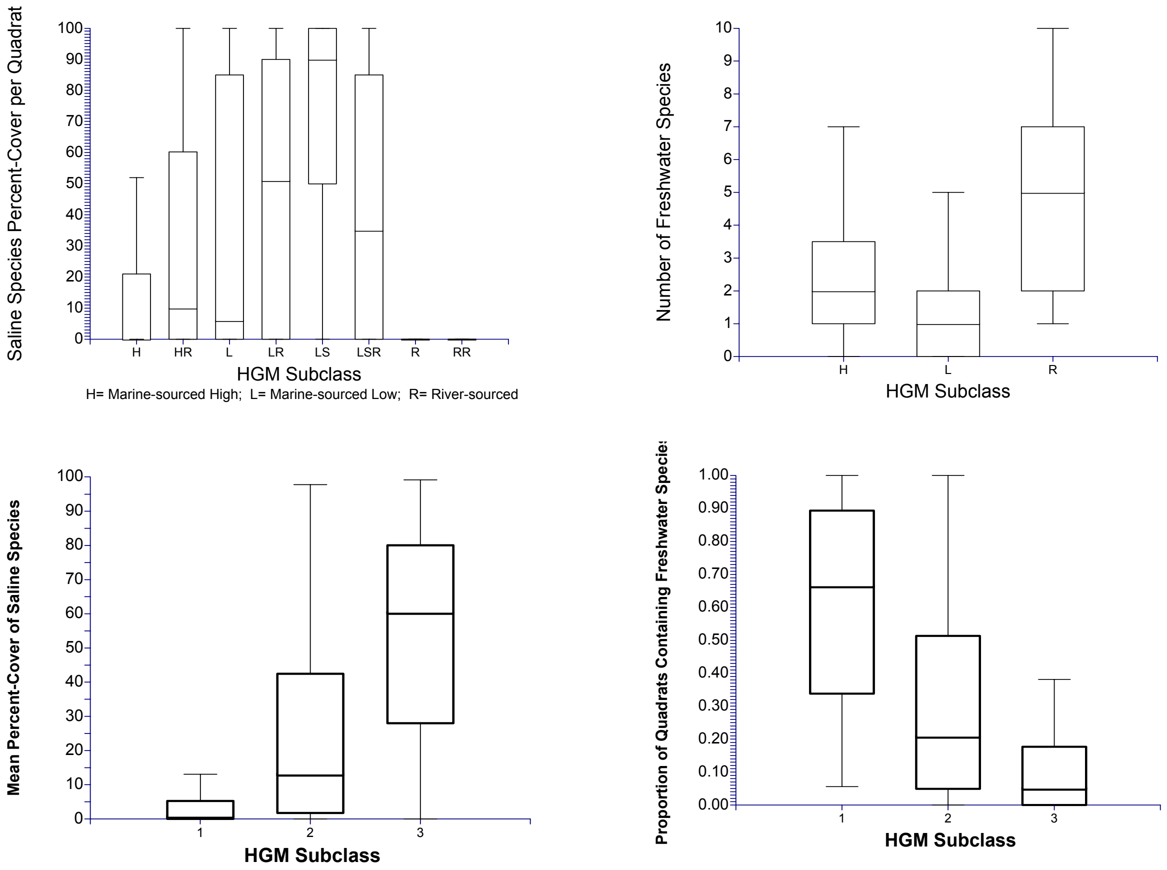

**Figure 4. Comparison of Oregon tidal marshes of different HGM subclasses based on percent cover or frequency of salt-tolerant and salt-intolerant ("fresh") species**

Subclasses (above): H = high marsh, HR = high marsh reference sites, L = low marsh (excluding sandspits), LR = low marsh reference sites (excluding sandspits), LS = low marsh on sandspits, LSR = low marsh reference sites on sandspits, R = river-sourced tidal wetlands, RR = river-sourced tidal wetland reference sites
Subclasses (below): 1 = river-sourced tidal, 2 = marine-sourced high marsh, 3 = marine-sourced low marsh

The spot measurements of salinity at each site (Figure 5) correlated positively and significantly with *MarQdPct* and *MarQdav*, and negatively but weakly with a site's relative elevation (median value along transects).

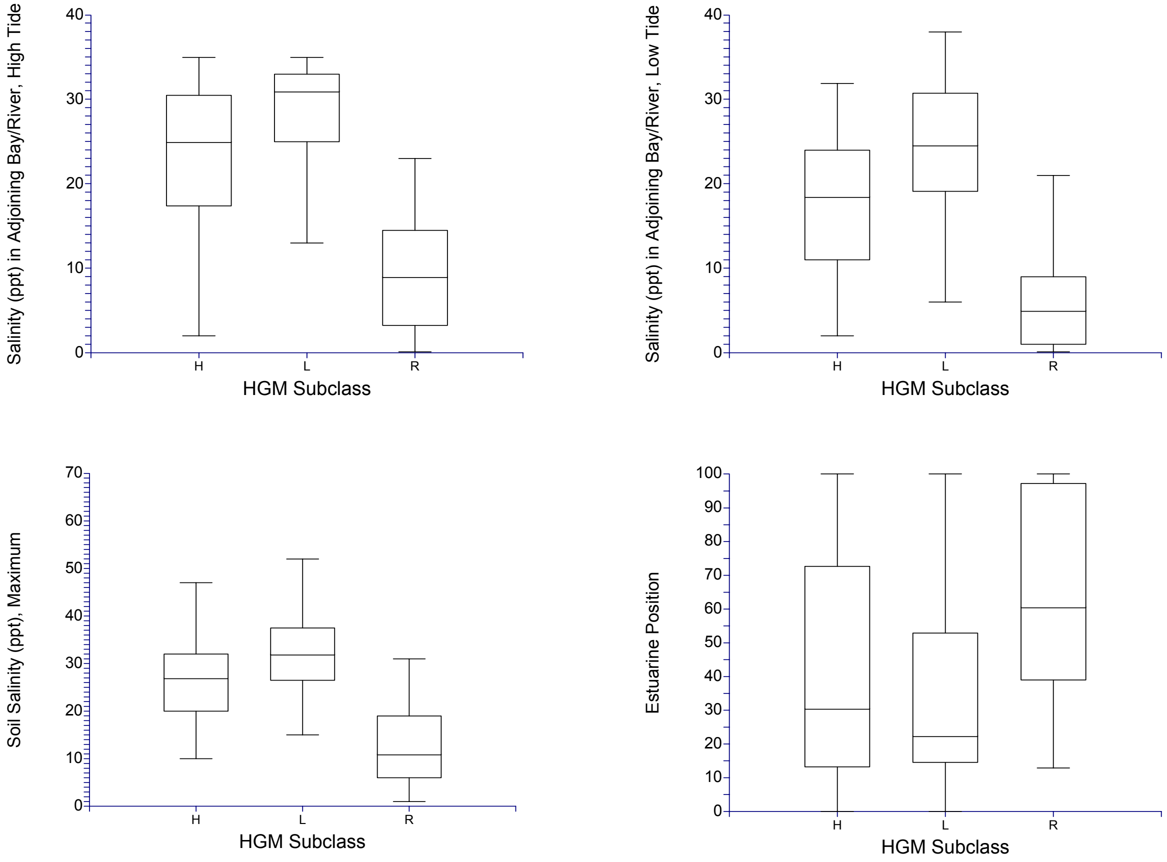

**Figure 5. Salinity and estuarine position of Oregon tidal marshes by HGM subclass**

H = marine-sourced high marsh, L = marine-sourced low marsh, R = river-sourced tidal wetland. Estuarine position (lower right) is expressed as marsh position (percent) relative to the estuary mouth (0) and main head-of-tide (100).

## Table 25. HGM subclasses, species wetness index values, and summertime salinities of 120 tidal marshes of the Oregon coast

See footnotes at end for explanation of headings

| Site | Influence | Type | % High (est.) | % Low (est.) | Wet Index min | Wet Index max | Wet Index mean | Sal. High BR | Sal. High CM | Sal. High UP | Sal. Low BR | Sal. Low CM | Sal. Low UP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 222 | RS | H | 70 | 30 | 6.13 | 9.06 | 7.74 | 4 | 4 | 0.1 | 4 | 4 | 0.1 |
| 307 | RS | H | 70 | 30 | 6.00 | 10.00 | 9.24 |  | 0.1 | 0.1 |  | 0.1 | 0.1 |
| 380 | RS | H | 50 | 50 | 7.05 | 9.35 | 8.73 | 2 | 1.9 |  | 0.1 | 0.1 |  |
| 388 | RS | H | 90 | 10 | 5.84 | 7.50 | 6.53 | 7 |  |  | 9 |  |  |
| 405 | RS | H | 50 | 50 | 3.11 | 10.00 | 8.40 | 5 |  |  | 7 |  |  |
| 488 | MS | H | 95 | 5 | 4.94 | 6.36 | 5.91 | 31 |  |  | 17 |  |  |
| 542 | RS | H | 99 | 1 | 9.02 | 9.56 | 9.36 | 19 | 20 | 12 | 11 | 17 | 11 |
| 543 | RS | H | 90 | 10 | 5.60 | 10.00 | 8.08 | 2.98 | 0.22 | 0.04 | 0.17 | 0.04 | 0.04 |
| 610 | RS | H | 99 | 1 | 5.84 | 9.96 | 7.91 | 21 | 21 | 18 | 3 | 21 | 20 |
| 620 | RS | H | 99 | 1 | 4.00 | 9.50 | 7.77 | 18 | 17 | 10 | 0.68 | 7.81 | 3.16 |
| 675 | RS | H | 95 | 5 | 6.54 | 9.33 | 8.48 | 11 | 12 | 7 | 5 | 2 | 8 |
| 692 | RS | H | 95 | 5 | 4.55 | 10.00 | 7.26 | 9 | 6 | 6 | 5 | 7 | 5 |
| 761 | MS | L | 10 | 90 | 7.95 | 9.90 | 8.71 | 33 | 33 | 33 | 28 | 18 | 30 |
| 767 | MS | L | 1 | 99 | 8.63 | 10.00 | 9.59 |  | 30 | 24 | 27 | 6 | 1 |
| 773 | MS | H | 75 | 25 | 7.33 | 10.00 | 8.65 | 32 | 32 | 35 | 24 | 25 |  |
| 787 | MS | H | 95 | 5 | 6.23 | 9.98 | 8.55 | 7 | 10 | 3 | 8 | 5 | 11 |
| 791 | MS | H | 90 | 10 | 6.80 | 9.90 | 8.97 | 16 |  |  | 12 | 15 | 15 |
| 832 | MS | H | 90 | 10 | 5.24 | 10.00 | 8.50 | 5 | 4 | 2 | 9 | 4 | 3 |
| 865 | RS | L | 5 | 95 | 6.15 | 10.00 | 9.25 | 15 | 15 | 14 | 13 |  | 15 |
| 869N | MS | H | 0 | 100 | 0.60 | 8.59 | 5.21 | 18 | 29 | 5 | 22 |  |  |
| 883 | MS | H | 60 | 40 | 8.02 | 10.00 | 9.04 | 23 |  |  |  | 26 | 21 |
| 889 | MS | L | 0 | 100 | 5.86 | 10.00 | 9.21 | 24 |  | 19 | 25 |  | 15 |
| 938 | MS | L | 1 | 99 | 6.40 | 10.00 | 9.08 | 33 |  |  | 36 |  | 25 |
| 941 | MS | L | 1 | 99 | 8.33 | 10.00 | 9.66 | 31 | 30 | 15 | 30 | 18 |  |
| 964E | RS | H | 95 | 5 | 4.72 | 9.98 | 9.08 | 5 |  |  | 5 | 8 | 9 |
| 964N | MS | L | 15 | 85 | 7.93 | 10.00 | 9.49 | 13 |  |  | 17 |  | 14 |
| 964S | MS | H | 55 | 45 | 5.80 | 9.90 | 8.66 | 17 | 15 | 10 |  |  |  |
| 965 | MS | H | 60 | 40 | 7.30 | 9.80 | 8.48 | 35 | 33 | 14 | 11 | 11 | 16 |
| 980 | MS | L | 1 | 99 | 9.79 | 10.00 | 9.97 | 24 |  | 15 | 27 |  |  |
| 1048N | MS | L | 5 | 95 | 5.88 | 10.00 | 9.09 | 35 |  |  |  |  |  |
| 1048S | MS | H | 55 | 45 | 8.29 | 9.77 | 9.11 |  |  |  |  | 18 | 20 |
| 1129 | MS | H | 95 | 5 | 6.24 | 9.86 | 8.82 | 31 | 31 | 5 | 20 | 20 | 4 |
| 1172 | MS | L | 40 | 60 | 8.05 | 9.88 | 9.17 | 32 | 27 | 4 | 19 | 6 | 4 |
| 1182 | MS | H | 70 | 30 | 7.70 | 9.98 | 9.35 | 23 | 24 | 12 | 18 | 14 | 12 |
| 1188 | MS | L | 0 | 100 | 7.08 | 9.89 | 8.99 | 35 |  |  |  |  |  |
| 1236 | MS | H | 90 | 10 | 6.70 | 10.00 | 8.87 | 26 | 26 | 4 | 25 | 21 | 5 |
| 1240N | MS | L | 40 | 60 | 6.10 | 10.00 | 8.69 | 31 |  | 5 | 20 | 22 | 8 |
| 1240W | MS | L | 20 | 80 | 8.18 | 10.00 | 9.50 | 25 | 24 | 20 | 27 | 24 | 21 |
| 1403 | MS | L | 5 | 95 | 7.80 | 10.00 | 9.20 | 35 | 27 | 7 | 35 | 29 | 3 |
| 1410 | MS | L | 1 | 99 | 7.60 | 10.00 | 8.92 | 25 | 25 | 23 | 19 | 25 | 22 |
| 1462 | MS | L | 20 | 80 | 8.05 | 10.00 | 9.14 |  |  |  | 6 | 7 | 24 |
| 1465 | RS | L | 50 | 50 | 5.16 | 10.00 | 8.53 | 11 | 11 | 14 | 14 | 5 |  |
| 1474L | MS | L | 30 | 70 | 6.40 | 10.00 | 9.23 | 15 | 15 | 14 |  | 16 | 15 |
| 1474U | MS | L | 0 | 100 | 7.60 | 10.00 | 9.48 |  | 10 | 6 |  | 7 | 8 |
| 1494 | MS | H | 90 | 10 | 4.60 | 9.98 | 7.96 | 23 | 19 | 18 | 19 | 18 | 20 |
| 1532 | MS | L | 33 | 67 | 7.89 | 10.00 | 8.72 |  | 23 | 24 |  | 25 | 24 |
| 1545E | MS | L | 5 | 95 | 8.31 | 10.00 | 9.52 | 35 | 25 | 22 | 20 | 10 | 10 |

| Site | Influence | Type | % High (est.) | % Low (est.) | Wet Index min | Wet Index max | Wet Index mean | Sal. High BR | Sal. High CM | Sal. High UP | Sal. Low BR | Sal. Low CM | Sal. Low UP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1545W | MS | L | 5 | 95 | 8.02 | 10.00 | 9.24 | 35 | 20 | 5 | 11 | 6 | 3 |
| 1723 | RS | H | 95 | 5 | 5.30 | 10.00 | 7.42 | 4 |  |  | 4 |  |  |
| 2079 | MS | H | 70 | 30 | 5.35 | 10.00 | 8.68 | 24 | 21 | 23 | 18.5 | 16.2 | 15.4 |
| 2089 | RS | H | 95 | 5 | 8.10 | 10.00 | 9.05 | 10 | 5 | 5 | 6 | 5 | 6 |
| 2094 | MS | L | 40 | 60 | 8.40 | 9.98 | 9.22 | 32.7 | 29.3 | 3 | 19.5 | 17 |  |
| 2105 | MS | L | 35 | 65 | 8.45 | 10.00 | 9.59 | 32.8 | 4.9 | 6.9 | 18.1 | 13.7 | 6.8 |
| 2146 | MS | H | 70 | 30 | 4.50 | 9.60 | 7.95 | 14 |  | 14 | 8 |  |  |
| 2148E | RS | H | 80 | 20 | 7.59 | 9.72 | 8.85 |  | 10 | 11 |  | 12 | 10 |
| 2148W | MS | H | 70 | 30 | 7.99 | 10.00 | 9.00 | 15.7 | 15.7 | 15.7 | 15 |  | 12.3 |
| 2149 | MS | H | 50 | 50 | 6.29 | 9.75 | 8.60 | 17.8 | 17.7 | 16.9 | 15 | 17.2 | 17 |
| 2152 | MS | H | 50 | 50 | 8.00 | 10.00 | 9.21 | 19.2 | 18 | 17 | 15 | 17 | 17 |
| 2157 | MS | L | 40 | 60 | 7.97 | 10.00 | 9.15 | 22 | 22 | 20 | 19 | 18 | 18 |
| 2158 | MS | H | 99 | 1 | 5.00 | 10.00 | 8.67 | 32.7 |  |  | 31.9 |  |  |
| 2188 | MS | H | 70 | 30 | 5.59 | 10.00 | 8.84 | 27 | 26 | 2 | 27 | 4 | 2 |
| 2195 | MS | L | 50 | 50 | 8.25 | 10.00 | 9.76 | 27.3 | 27.3 |  | 26.7 | 19.7 |  |
| 2203 | RS | L | 50 | 50 | 7.22 | 10.00 | 9.58 | 9 | 8 | 7 | 5 | 9 | 4 |
| 2238 | MS | H | 65 | 35 | 7.54 | 10.00 | 9.23 | 28.09 | 28.09 |  | 28.01 | 27.77 |  |
| 2263 | RS | H | 55 | 45 | 6.60 | 10.00 | 9.26 | 1.2 | 1.2 | 1.2 | 0.3 | 0.3 | 0.7 |
| 2385D | RS | H | 100 | 0 | 8.40 | 9.47 | 9.15 | 1 |  |  | 1 |  |  |
| 2385N | RS | H | 99 | 1 | 4.16 | 9.70 | 7.81 | 0.1 |  |  | 0.1 |  |  |
| 2385S | RS | L | 50 | 50 | 7.24 | 10.00 | 8.85 |  | 1 |  |  | 1 |  |
| 2536 | MS | H | 70 | 30 | 6.39 | 9.74 | 8.35 | 21 | 21 | 17 | 8 | 11 | 15 |
| 2731 | MS | H | 70 | 30 | 6.54 | 10.00 | 9.32 | 31.3 | 30 | 11.3 | 11.8 | 18 | 14 |
| 2739 | MS | L | 40 | 60 | 8.91 | 10.00 | 9.57 | 30 |  |  | 33 |  |  |
| 2766 | MS | L | 20 | 80 | 9.50 | 10.00 | 9.89 | 30 | 30 | 30 | 33 |  |  |
| 2771 | MS | L | 30 | 70 | 8.70 | 10.00 | 9.57 | 30 | 31 | 23 | 33 | 33 | 32 |
| 2772 | RS | H | 80 | 20 | 7.01 | 10.00 | 9.17 |  | 8 | 0.4 |  | 11 | 0.3 |
| 2783 | RS | H | 70 | 30 | 6.60 | 8.95 | 7.88 | 23 | 10 |  | 13 | 2 |  |
| 2787 | MS | L | 20 | 80 | 8.02 | 10.00 | 9.87 | 33 |  |  | 33 |  |  |
| 2792 | MS | L | 50 | 50 | 7.43 | 10.00 | 9.42 | 25 | 25 | 25 | 24 | 24 | 25 |
| 2801 | MS | L | 50 | 50 | 6.55 | 10.00 | 8.97 | 31 |  |  | 29 |  |  |
| 2829 | MS | L | 30 | 70 | 8.95 | 10.00 | 9.62 | 11 |  |  | 26 |  |  |
| 2838 | MS | L | 20 | 80 | 8.22 | 10.00 | 9.42 | 27 | 26 | 17 | 22 | 22 | 17 |
| 2904 | MS | L | 10 | 90 | 8.21 | 10.00 | 9.49 | 31 | 31 | 29 | 28 | 25 | 21 |
| 2932E | MS | H | 95 | 5 | 6.52 | 9.57 | 8.79 |  |  |  | 5 | 20 | 12 |
| 2932W | MS | L | 1 | 99 | 8.20 | 10.00 | 9.65 | 35 | 35 | 28 | 19 | 27 | 24 |
| 2935 | MS | L | 1 | 99 | 7.20 | 10.00 | 9.83 | 20 | 7 | 9 | 24 | 5 | 11 |
| 2938 | RS | H | 99 | 1 | 6.30 | 9.95 | 8.96 | 35 |  |  | 21 | 23 | 25 |
| 2940I | MS | H | 90 | 10 | 5.84 | 10.00 | 8.21 | 30 | 6 | 26 | 27 | 30 | 28 |
| 2942E | MS | H | 98 | 2 | 6.87 | 8.93 | 8.41 | 25 | 20 | 23 | 29 | 21 | 21 |
| 2942W | MS | H | 85 | 15 | 7.82 | 10.00 | 8.63 | 28 | 26 | 24 |  | 24 | 25 |
| 2950 | MS | L | 1 | 99 | 8.00 | 10.00 | 9.62 | 32 | 31 | 13 | 33 | 26 | 17 |
| 2963 | MS | L | 0 | 100 | 8.05 | 10.00 | 9.26 | 32 | 31 | 28 | 31 | 30 | 30 |
| 2964 | MS | L | 20 | 80 | 8.40 | 9.97 | 9.09 | 31 | 36 | 37 | 38 | 38 | 35 |
| 2973 | RS | H | 99 | 1 | 8.04 | 9.98 | 9.25 | 0.28 | 0.28 | 1.6 |  |  |  |
| 2976 | MS | L | 10 | 90 | 8.21 | 9.98 | 9.36 | 35 | 35 | 3 | 22 | 2 |  |
| 2977 | MS | L | 25 | 75 | 8.40 | 10.00 | 9.52 |  |  | 35 |  |  |  |
| 2980 | RS | H | 97 | 3 | 6.44 | 9.90 | 8.53 | 13 | 14 | 5 | 7 | 8 | 10 |
| 2981 | MS | H | 70 | 30 | 8.20 | 9.90 | 9.16 |  |  |  |  |  |  |
| 2987N | MS | H | 85 | 15 |  |  |  | 28 |  |  |  |  |  |
| 2987S | MS | H | 98 | 2 | 7.21 | 9.75 | 8.67 | 24 | 25 | 23 | 23 | 25 | 25 |

| Site | Influence | Type | % High (est.) | % Low (est.) | Wet Index min | Wet Index max | Wet Index mean | Sal. High BR | Sal. High CM | Sal. High UP | Sal. Low BR | Sal. Low CM | Sal. Low UP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2987I | MS | H | 95 | 5 | 8.35 | 10.00 | 9.36 | 35 | 31 | 31 | 25 | 30 | 30 |
| 2994 | MS | H | 97 | 3 | 7.38 | 9.80 | 9.08 | 29 | 27 | 23 | 20 | 28 | 28 |
| 3033E | MS | L | 45 | 55 | 8.02 | 9.75 | 8.68 | 31 | 30 | | | | |
| 3033W | MS | H | 60 | 40 | 7.20 | 10.00 | 8.87 | | 30 | 0.9 | | 5.2 | 0.3 |
| 3060 | MS | H | 85 | 15 | 8.27 | 10.00 | 9.14 | 34 | | | 29 | | |
| 3070 | MS | L | 20 | 80 | 8.27 | 10.00 | 9.50 | 32 | 32 | 17 | 31 | 26 | 0.16 |
| 3086 | MS | L | 25 | 75 | 8.21 | 10.00 | 9.33 | 26 | 24 | 2 | 24 | 13 | 2 |
| 3103 | RS | H | 95 | 5 | 7.40 | 10.00 | 9.32 | | 7 | 4 | | | |
| 3113 | MS | H | 65 | 35 | 7.77 | 10.00 | 9.10 | 30 | 28 | 3 | 13 | 2 | 0.1 |
| 3128E | MS | L | 10 | 90 | 6.20 | 10.00 | 9.49 | 28 | 28 | 28 | 24.2 | 24.1 | 25.4 |
| 3128N | MS | H | 100 | 0 | 8.00 | 9.98 | 8.86 | | | | 22 | 20 | 8 |
| 3140 | MS | L | 35 | 60 | 8.15 | 10.00 | 9.39 | 21 | 31 | 4 | 12 | 14 | 5 |
| 3141H | MS | H | 95 | 5 | 7.25 | 10.00 | 9.27 | 11 | 12 | 13 | 7 | 9 | 23 |
| 3141P | MS | L | 40 | 60 | 8.00 | 10.00 | 9.82 | | | | | | |
| 3145 | MS | H | 98 | 2 | 7.86 | 10.00 | 8.83 | 2 | 4 | 4 | 2 | 7 | 2 |
| 3149 | RS | H | 95 | 5 | 7.32 | 10.00 | 9.25 | 9 | 9 | 2 | 1.79 | 1.26 | 0.2 |
| 3154 | RS | H | 100 | 0 | 5.55 | 10.00 | 9.05 | | 0.09 | 0.08 | | 4 | 0.09 |
| 3170 | MS | L | 45 | 55 | 8.21 | 10.00 | 9.38 | 13 | 10 | 10 | 10 | 10 | 11 |
| 3250 | RS | H | 99 | 1 | 7.50 | 9.70 | 8.18 | | | | | | |
| 3425 | MS | H | 80 | 20 | 5.39 | 9.93 | 8.69 | 29 | 28 | | | | |
| 3451 | MS | H | 90 | 10 | 6.99 | 9.99 | 8.99 | 34 | 32 | 26 | 20 | 26 | 30 |
| 3729 | MS | H | 80 | 20 | 1.29 | 9.99 | 8.03 | 10 | 5 | | 4 | 3 | 19.83 |
| 3944 | RS | L | 35 | 65 | 5.69 | 10.00 | 9.35 | | 0.1 | | | 0.1 | |

Influence: MS = predominantly marine-sourced, RS = predominantly river-sourced
Type: H = predominantly high marsh, L = predominantly low marsh, based on visual assessment
% High, % Low: visually estimated % of the assessed area that may be high (H) or low (L) marsh
Wet Indexscoring range is 0 (driest) to 10 (wettest). Based on percent cover of plant species categorized by their wetland status. Based on values for plants found in quadrats along marsh transects (not in channels).
Salinity (Sal.) (in ppt). Precision is greater for some values because a different meter was used
High = measured nearest the time of daytime high tide. Low = nearest to low tide
BR = measured in adjoining bay or river. CM = at mouth of a tidal channel exiting the marsh
UP = at farthest upstream point of an internal tidal channel

## 3.4 Rationales for Scoring Models (Combination Rules)

### 3.4.1 Scoring Models for Risk

All approaches to assessing risks to wetland integrity must face one thorny challenge: how best to combine information on different *types* of stressors (Bryce et al. 1999, Hennessey 2005)? For example, are plants and animals in a wetland with a breached dike exposed to as much stress (and suffer as much loss of recruitment) as those in a wetland adjoined by a parking lot or a wastewater outfall? Under which situations (spatial and extent) are these equivalent? Although generally to be avoided, combination of information on such disparate themes may be desirable in some instances, e.g., to identify which wetlands best represent “least-altered condition” overall, as required to anchor the upper range of the scoring models that comprise a rapid assessment method (see next section).

As explained in section 2.5, this HGM project used three approaches to assessing risk. Because the first approach was quite detailed and specific, it resulted in a large number (20) of risk indices, described below. A second approach, which assessed many of the same variables but was more general, eventually was incorporated into the rapid-assessment method in Part 1. The third approach was the simplest and consisted of designating a site as potentially least altered, less altered, or neither.

With the first approach, the 20 risk indices were computed as follows:

1. For each risk theme group (Hydro, Sediment, Nutrients, etc.), the mean (Av) and maximum (Mx) among-stressor rating was calculated. For example, in the Hydro theme group, the mean and maximum scores were computed among four individual stressors (Dikes, Ditching/Excavation, Paved Roads, Dams/Weirs). Although some individual stressors affect multiple themes (e.g., dikes affect soil, nutrients, sediment, and vegetation as well as hydrology), each stressor was associated with only one most-closely associated theme. For each wetland, the calculations by theme were done for each of the two spatial domains and two time periods, yielding four means and four maximums, like this:

| SITE # 45 GROUP: Hydro | Dikes | Ditching | Paved Roads | Dams | AVERAGES | MX |
|---|---|---|---|---|---|---|
| Onsite_Present | 1 | 1 | not applicable | not applicable | AV1 = 1.00 | MX1 = 1 |
| Onsite_Historic | 2 | 1 | not applicable | not applicable | AV2 = 1.50 | MX2 = 2 |
| Offsite_Present | 2 | 1 | 0 | 2 | AV3 = 1.25 | MX3 = 2 |
| Offsite_Historic | 2 | 1 | 0 | 1 | AV4 = 1.00 | MX4 = 2 |

2. Next, five alternative formulas were used independently for combining the average (AV) risk ratings for the spatial and temporal domains of each risk theme group (Hydro, Sediment, Nutrients, etc.):

Unweighted: (a) Average of (AV1, AV2, AV3, AV4)
(b) Maximum of (AV1, AV2, AV3, AV4)
Weighted: (c) Average of all four domains: [ (AV1*4), (AV2*3), (AV3*2), (AV4) ]
(d) Average of present domain only: [ (AV1*4), (AV3) ]
(e) Average of onsite domain only: [ (AV1*2), (AV2) ]

Results:

| SITE # 45 GROUP: Hydro | AVERAGES (from above) | (a) | (b) | (c) | (d) | (e) |
|---|---|---|---|---|---|---|
| Onsite_Present | AV1 = 1.00 | 1.19 | 1.50 | 3.00 | 2.63 | 1.75 |
| Onsite_Historic | AV2 = 1.50 | | | | | |
| Offsite_Present | AV3 = 1.25 | | | | | |
| Offsite_Historic | AV4 = 1.00 | | | | | |

There is no strong theoretical basis for suggesting any one of these is better than the others. Note that (a) through (e) above were named correspondingly *H1, H2, H3, H4,* and *H5* for hydrologic risks (Figure 7), and similarly according to the other risk themes.

3. The same formulas were then applied to the values in the MX column (i.e., substituting MX1 for AV1, MX2 for AV2, etc.), yielding these results.

| SITE # 45<br>GROUP: Hydro | MAXIMA (from above) | (a) | (b) | (c) | (d) | (e) |
|---|---|---|---|---|---|---|
| Onsite_Present | MX1 = 1 | 1.75 | 2.00 | 4.00 | 3.00 | 2.00 |
| Onsite_Historic | MX2 = 2 | | | | | |
| Offsite_Present | MX3 = 2 | | | | | |
| Offsite_Historic | MX4 = 2 | | | | | |

These steps were repeated for each of the four other theme groups (Sediment, Nutrients, Chemical, Vegetation).

4. Next, the risk themes were integrated by using the averages and the maximums of their components.
Risk1: AVG (H1 + C1+ S1 + N1 + V1 + Visits + BufCov + Instabil)
Risk2: AVG (H2 + C2+ S2 + N2 + V2 + Visits + BufCov + Instabil)
etc.

MX1 = MAX(H2 + C2+ S2 + N2 + V2 + Visits + BufCov + Instabil)
MX2 = MAX(H2 + C2+ S2 + N2 + V2 + Visits + BufCov + Instabil)
etc.

Again, there is no strong theoretical basis for suggesting either of these ways of combining is better than the other. Results are shown in Figure 6.

6. Steps 4 and 5 yielded a total of 20 risk indices per wetland site, most of them correlated with others, but suitable for further examination in the analysis.

Note that the occurrences of non-native plants (and other direct measures of ecological condition) were *not* used to indicate the potential exposure of a wetland to preconceived stressors. That is because non-native plant variables are primarily response variables, and their inclusion as indicators of wetland alteration would have led to undesirable autocorrelation (circularity) in subsequent data analyses. The occurrence of non-native plants is expressed more directly by their inclusion in the scoring model for botanical condition (*BotC*).

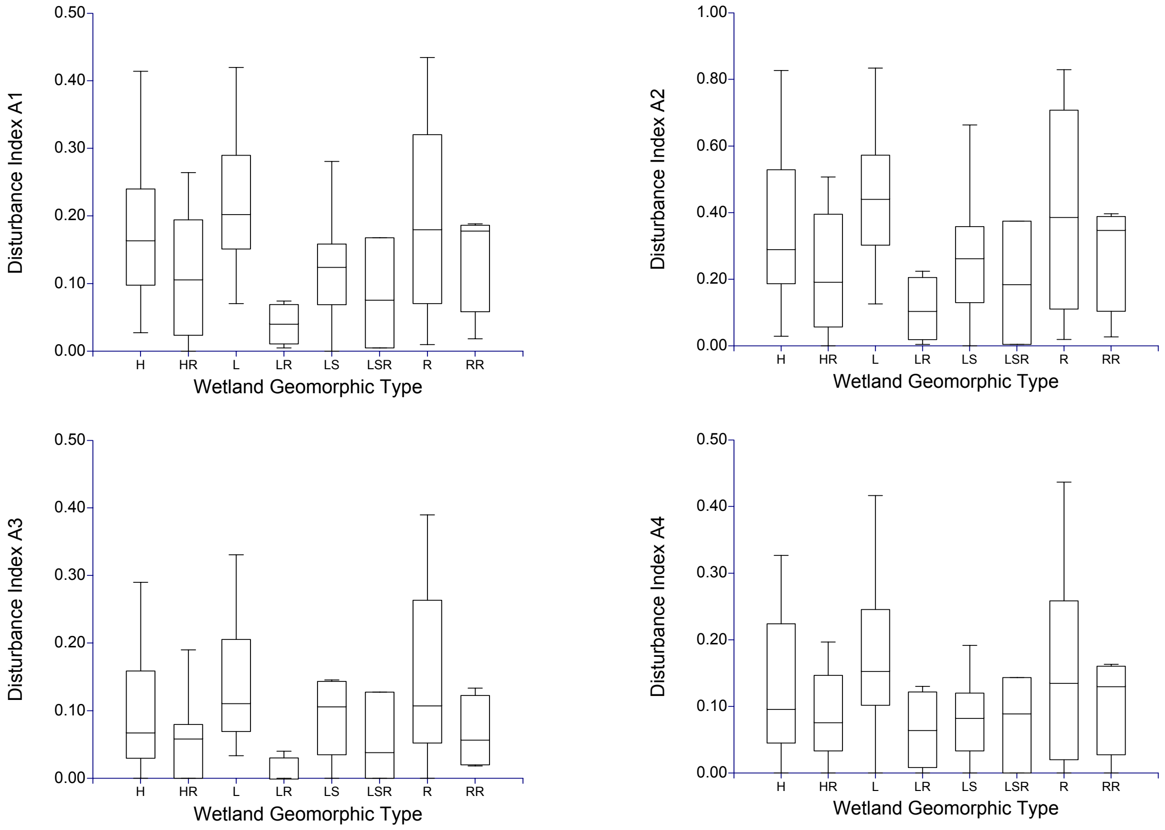

**Figure 6. Distributions of scores for the combined risk indices, *Risk1-4*, by HGM subclass, for tidal marshes of the Oregon coast**

*Note:* “Disturbance Index A1” was later renamed *Risk1*, “Disturbance Index A2” is the same as *Risk2*, etc.

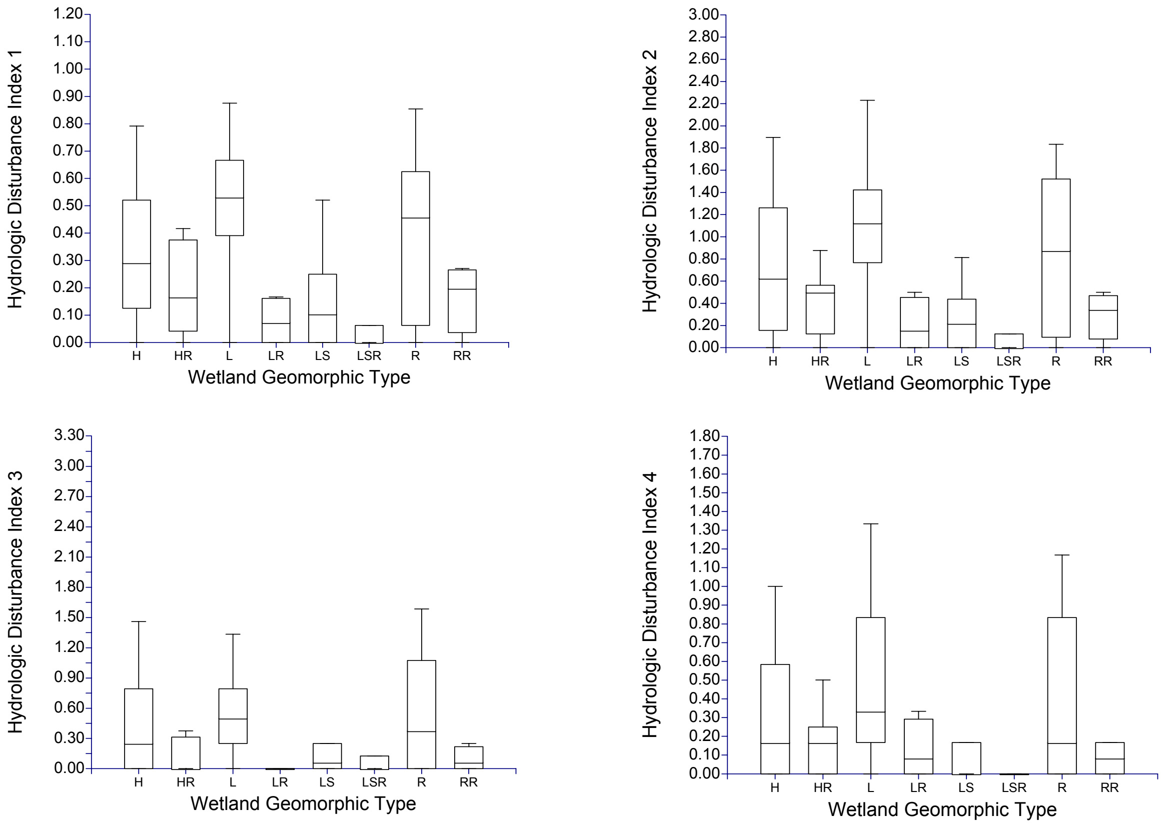

**Figure 7. Distributions of scores for the hydrologic risk indices, *H1–H4*, by HGM subclass, for tidal marshes of the Oregon coast**

H = high marsh, HR = high marsh reference sites, L = low marsh (excluding sandspits), LR = low marsh reference sites (excluding sandspits), LS = low marsh on sandspits, LSR = low marsh reference sites on sandspits, R = river-sourced tidal wetlands, RR = river-sourced tidal wetland reference sites.

### 3.4.2 Scoring Models for Wetland Integrity

Deciding an appropriate way to combine the direct indicators of tidal wetland integrity (i.e., RatioC and the adjusted botanical indicators) into a single meaningful number is no less problematic than combining the different potential *stressors* into a single index of *risk*, as described above. Lacking any theoretical basis for combining them in a particular way, we simply took their mean, resulting in the following wetland integrity index:
AVG (RatioC, SpDeficit, DomDef, NN20def, AnnDef, TapPCdef, StolPCdef, TuftPCdef)

In other words, tidal wetland integrity (or "condition") was assumed to be greatest under the following measurable conditions, in some combination:

- Tidal channel topwidth-depth ratios are close to ones measured in channels of less-altered wetlands, after accounting statistically for differences in substrate type and other factors (*RatioC*).
- Plant species richness per quadrat is higher than predicted, after accounting statistically for differences in marsh elevation, position in estuary, substrate type, and other factors (*SpDeficit*).
- The proportion of quadrats that is dominated strongly (>90% cover) by any plant species is much smaller than what is predicted based on marsh elevation, position in estuary, substrate type, and other factors (*DomDef*).
- The proportion of quadrats that contains more than 19% cover by all non-native plant species combined is much smaller than what is predicted based on marsh elevation, position in estuary, substrate type, and other factors (*NN20def*).
- The proportion of quadrats that contains an annual plant species is much smaller than what is predicted based on marsh elevation, position in estuary, substrate type, and other factors (*AnnDef*).
- The percent cover of tap-rooted plant species (mean among quadrats) is much greater than what is predicted based on marsh elevation, position in estuary, substrate type, and other factors (*TapPCdef*).
- The percent cover of stoloniferous plant species (mean among quadrats) is much smaller than what is predicted based on marsh elevation, position in estuary, substrate type, and other factors (*StolPCdef*).
- The percent cover of tuft-rooted plant species (mean among quadrats) is much greater than what is predicted based on marsh elevation, position in estuary, substrate type, and other factors (*TuftPCdef*).

Conceivably the use of a different operator (e.g., MAX or MIN rather than AVG), different nested groupings, or use of a smaller subset of these indicators might distinguish differences in condition more clearly among wetlands, but such optimization would be confounded by the lack of a single good representation of wetland condition or risk (i.e., combined stressors) with which correlation of the integrity index might be sought. Thus, optimization was not explored. Correlations of this index with risk indices and other variables are shown in Table 29.

### 3.4.3 Scoring Models for Functions

This section begins (3.4.3.1) by describing how “operators” are chosen to integrate indicators into scoring models. It then describes each of the scoring models used to assess functions of Oregon tidal wetlands, showing the rules by which individual indicators were combined. Reasons why particular indicators were used to assess a function were described in the preceding section. Text below (“Indicators Used Elsewhere”) explains why particular indicators and model formulations proposed in some other rapid-assessment methods for tidal wetlands (Shafer and Yozzo 1998, Shafer et al. 2002, Collins et al. 2004, others) were or were not used for the same function in this method. It also describes additional indicators considered but rejected for use by this HGM method, and reasons for rejection.

#### *3.4.3.1 Introduction to Scoring Operators*

A characteristic of nearly all rapid-assessment methods is the use of scoring models that combine data on measured or estimated variables (indicators) into indices of wetland integrity or relative capacity to perform individual functions. Limitations of these models and the indicators that comprise them were described in Part 1, section 3.0. Although developers of rapid-assessment methods often focus on which indicators to use and how to assess them, ultimately the accuracy and sensitivity of a rapid-assessment method may be governed as much or more by how those indicators are combined into indices, that is, the types of decision rules or mathematical operators that are used, and how they’re used. Formulations of the scoring models proposed in this HGM method were based broadly on the following considerations, which were applied after all indicator data had been converted to a common 0-to-1 scale:

*Addition* was used in scoring models to combine scores of distinctly different processes or factors that contribute cumulatively to a function, especially if the indicators of these processes or factors were uncorrelated.

*Subtraction* was used in instances where an indicator’s scale for one function was the inverse of that indicator’s scale as applied to another function, e.g., *NutrIn*, which was considered beneficial to some functions and detrimental to others. Subtraction also was used where an indicator was known to be negatively associated with a function and this had not been reflected in its scale.

*Averaging* was used when multiple indicators of the same general theme (for example, indicators of channel complexity) were correlated and:
(a) assessment “certainty” for one of the indicators is anticipated to often be low, e.g., due to the difficulty in assessing it well during a single visit, or
(b) data for one of the indicators is likely to sometimes be unavailable, or,
(c) the indicators were partially compensating, that is, when the condition of one indicator was less than optimal to support the function, and the condition of a correlated indicator was expected to be a minimally acceptable surrogate.
Averaging also was used when it seemed that one set of indicators (the averaged group) should be considered equally influential on a function as another indicator or averaged indicator group.

The *maximum* of a series of scores was used where indicators were believed to be more fully compensating than (c) above with regard to a function. That is, when the condition of one indicator was expected to be less than optimal to support the function, and the condition of a correlated indicator was expected to be almost as good.

*Multiplication* was used where one or a few indicators were believed to be controlling of function capacity, such that if a specified condition was not met for these indicators, information on all other indicators was essentially moot. An example is marsh flooding as a controller of fish access to tidal marshes.

*Division* was used to convert the numeric outputs of all models to a common 0-to-1 scale. This was necessary because different models have different numbers of indicators, leading to different hypothetical maximum scores.

*To convert raw output from a function's model to the 0-to-1 scale, the function's minimum score (among all surveyed sites) was subtracted from the raw scores of all sites, and then all the resulting scores were divided by the maximum among the sites after the minimum had been subtracted.*

### *3.4.3.2 Produce Aboveground Organic Matter (AProd)*

The scoring model[1] for this function is:

NutrIn + (MAX: Fresh, FreshSpot) + Pform - Bare - SoilX - Shade

Natural levels of aboveground production were considered by the model to be positively influenced by nutrients (*NutrIn*) and inputs of fresh water (*Fresh, FreshSpot*). From this, negative indicators or influences were subtracted, i.e., the extent of *Bare* area, soil disturbance (*SoilX*), and *Shade*.

The use of this particular model resulted in correlations between scores of this function and scores of the following functions, listed from most to least statistically significant. Non-significant correlates ($p>0.05$) are parenthesized: *Xpt, WQ, Inv, Afish, Rfish, Dux, BotC, (NFW, Mfish, LbirdM, Sbird).* All correlations were positive, that is, wetlands predicted to have high capacity for producing organic matter also were predicted to be good for all other functions considered.

#### *Indicators Used Elsewhere*

This function is not included explicitly in the national guidebook for HGM assessment of tidal fringe marshes (Shafer and Yozzo 1998), but is included as "Plant Biomass Production" in the Gulf of Mexico tidal fringe marsh guidebook (Shafer et al. 2002). That guidebook proposed only a single indicator of this function: *Mean vegetative cover* and *height*. This was not included in our HGM method because it is impractical in the context of a rapid-assessment method to assess it representatively for an entire wetland. It is most similar to the inverse of our indicator *Bare*.

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[1] Abbreviations of indicator variables in this and other scoring models in this section are defined in Appendix C.

*Rejected Indicators*

*Direct measurement of production*. This requires multiple visits to collect and weigh plant material from hundreds of points within a wetland, making it impractical to use in a rapid assessment context. Moreover, belowground production of plants (e.g., root development), which is much more difficult to measure repeatably, has been shown to be a better predictor (than aboveground production) of reduced wetland integrity and geomorphic stability (Turner et al. 2004).

*Duration of inundation.* In some marshes, production tends to be less where there are high rates of water exchange (Findlay et al. 2002), but in others, elevated production on the banks of internal tidal channels may at least partly offset this condition (Gallagher and Kibby 1981). This indicator was not included due to this ambiguity.

*Species of plant.* Marsh plants differ in their productive capacity, and consequently several efforts have been made to compare relative productivities by species or communities (e.g., Kibby et al. 1980). However, species-level differences in productivity are not well documented and often are overshadowed by abiotic factors, such as nutrient supply and flooding duration. Data are insufficient to support any one particular marsh plant being consistently much more productive. Methods of measuring and representing production also vary greatly, making comparisons difficult (Mitsch and Gosselink 2000).

*Hydromodification of the estuary*: Jetties, channel dredging and realignment, causeways, upriver dams, and other major physical alterations can result in aberrant tidal patterns, altered storm surges and summertime low-tide levels, and changed sediment and salinity regimes in at least part of an estuary (Simenstad 1983). These, in turn, can interfere with the ability of some individual marshes to support characteristically high levels of vascular plant production. However, it also is possible that production might increase or be unaffected by such changes, depending on engineering design, location, estuary type, and other factors.

*Annual solar input*: Solar radiation available for photosynthesis varies geographically along the Oregon coast, due to differences in the annual number of days with overcast or fog conditions, and slight differences in latitude. However, no suitable data are available that cover the entire coast.

*Summertime dew* and *precipitation*. Exposure of tidal marshes for long periods (e.g., high marshes) typically increases interstitial soil salinity, which in turn can reduce production or at least cause shifts in community composition (Bertness and Pennings 2000). Fresher water from precipitation, fog, and dew can somewhat alleviate this condition. However, coastwide data cover only precipitation, and probably do not have enough geographic specificity to be useful.

*Mean annual temperature*. Although freezing conditions are rare in Oregon tidal marshes, slight geographic differences exist in mean annual temperatures, and this in turn may increase annual productivity of algae and marsh plants. However, warmer temperatures also mean increasing salt toxicity associated with increased evapotranspiration (Bertness and Pennings 2000), and this can reduce productivity. Also, some benthic microalgae in Oregon estuaries do not appear to be strongly influenced by temperature (Davis and McIntire 1983). In addition, temperature data available coastwide probably do not have enough geographic specificity to be useful.

*Contaminants*. Although data on sediment chemical parameters important to marsh plant germination and survival may be available for some marshes, the data cannot be used to make meaningful comparisons among marshes unless such data are collected in a standardized and simultaneous manner from all marshes being compared. In addition, one southeastern tidal marsh study (Pennings et al. 2002) reported no significant association between measured levels of some contaminants and respiration or production of the dominant marsh plant, *Spartina alterniflora*. In other regions, this species actually has been shown to mobilize some contaminants from tidal marsh sediments.

### *3.4.3.3 Export Aboveground Plant and Animal Production (Xpt)*

The scoring model for this function is:

APro d + (AVG: BlindL, Jcts, Exits, Flood, TribL, (1- Width)

For organic matter to be exported, it obviously must first be produced. Accordingly, the scoring model includes output from the previous model that estimated the relative level of aboveground production (*AProd*). This is added to the average of several variables assumed to indicate the wetland's hydraulic export capacity — *BlindL, Jcts, Exits, Flood, TribL*, and the inverse of *Width* (i.e., narrower marshes are assumed more capable of having their production exported).

The use of this particular model resulted in correlations between scores of this function and the following functions, listed from most to least statistically significant. Non-significant correlates (p>0.05) are parenthesized: *AProd, WQ, Inv, Rfish, Afish, Dux, NFW, Mfish, (Sbird, BotC, LbirdM*). All correlations were positive.

#### *Indicators Used Elsewhere*

This function is included under the function "Nutrient and Organic Carbon Exchange," modeled by both the national guidebook for HGM assessment of tidal fringe marshes (Shafer and Yozzo 1998) and the Gulf of Mexico tidal fringe marsh guidebook (Shafer et al. 2002).
The national guidebook proposes regional calibration of the following indicators of this function.

*Flooding duration*: Similar conceptually to our *Flood.*
*Total percent vegetative cover*: Similar to the inverse of *Bare* in our *AProd* model.
*Mean plant density* and *height*: Similar to the inverse of *Bare* in our *AProd* model.

In its model, the national guidebook considers the first of these indicators to be equal in weight to the other two. The Gulf of Mexico guidebook uses the same indicators and model, with slightly different terminology.

#### *Rejected Indicators*

*Observed outwelling of plants* and *animals*: Observations (or absence of observations) of wrack or living animals emigrating during a single visit to a marsh are virtually meaningless because the quantity and fate of the material cannot be determined in the context of a rapid-assessment method, especially if not standardized by month, tidal phase, and sampling gear.

*Morphology of the estuarine entrance (*SeaJoin*)*: Outwelled organic matter might potentially provide a greater benefit to coastal food webs if it is dispersed widely, including dispersal into marine waters. However, the presence or lack of a year-round connection of the *estuary* to the ocean, which would permit such dispersal, is not likely to affect the extent of outwelling from the *marsh* to immediately adjoining subtidal waters (which is how this function is defined).

*Windward fetch*: Marshes that experience substantial wind and wave energy, in addition to tidal currents, might be more subject to having their organic matter physically removed. However, in such situations waves might just as easily introduce and confine foreign organic matter (wrack), depending on wind direction and coincidence of storms with spring high tides.

### *3.4.3.4 Stabilize and Accrete Sediment; Process Carbon, Nutrients, and Metals (WQ)*

The scoring model for this function is:

> *AProd* + (AVG: BlindL, Jcts, Exits, Flood) + Width + UpEdge + SoilFine -
> [AVG: TranAng, RatioC, Fetch, SoilX]

Output from the model for marsh production (*AProd*), which is assumed to reflect plant filtering and uptake of various substances, is added to the average of indicators of channel complexity and wetness (*BlindL, Jcts, Exits, Flood*) because greater vegetation-water edge generally facilitates processing. It also is added to marsh *Width* (longer pollutant flow path), complexity of the upland edge (*UpEdge*) (more interface between aerobic and anaerobic conditions), and presence of more-retentive soils (*SoilFine*). From this, the model subtracts the average of several possible indicators of substrate instability (*TranAng, RatioC, Fetch, SoilX*).

A less direct approach to estimating capacity for sediment retention is to estimate the ability of wetland vegetation to filter sediment from runoff and/or the water column and trap it, or at least stabilize sediments already in place so they do not erode and become resuspended. This is represented indirectly by our indicator *AProd*. At a microscale, marsh vegetation potentially acts as a physical filter or baffle, reducing current velocity and thus allowing sediment and organic matter to be deposited. Roots of tidal marsh plants bind the otherwise unstable underlying sediments and protect the substrate from tidal scour and resuspension. Thus, the more extensive and productive the mats of protective vegetation, the less will be the degree of resuspension of deposited sediments (Boorman et al. 1998, Brown et al. 1998). Of at least equal importance, the gradual accumulation of slowly decaying organic matter produced by the plants themselves contributes to the buildup of the marsh surface (Frenkel and Morlan 1990). For example, in Kunz Marsh at South Slough NERR, vertical accretion of sediment and organic matter was 0.70 cm/yr in a densely vegetated marsh but only 0.19 cm/yr in a sparsely vegetated marsh (Cornu and Sadro 2002). Moreover, marsh plants also alter the belowground oxygen regime, with potentially significant effects on cycling of many substances. Thus an extensive plant cover implies the potential for significant seasonal uptake of soluble substances and, in the case of nitrogen, cycling or conversion to gaseous ($N_2$, from denitrification) or organic forms.

The use of this particular model resulted in correlations between scores of this function and the following functions, listed from most to least statistically significant. Non-significant correlates ($p>0.05$) are parenthesized: *Dux, Xpt, NFW, Mfish, Afish, Sbird, AProd, Rfish, Inv, (LbirdM, BotC*). All correlations were positive.

*Indicators Used Elsewhere*

This function is partly similar to the function "Sediment Deposition," modeled by the national guidebooks for HGM assessment of tidal fringe marshes (Shafer and Yozzo 1998), and the functions "Sediment Deposition" and "Sediment Stabilization," modeled by the Gulf of Mexico tidal fringe marsh guidebook (Shafer et al. 2002). The national guidebook proposes regional calibration of the following indicators of this function, combined in an unweighted linear model.

*Surface roughness*: Some of our indicators — *BlindL, Exits*, and *Jcts* — are intended to represent the same
*Flooding duration*: Similar conceptually to our *Flood*
*Proximity to source channel*: Not included because Oregon's HGM method is intended to assess the entire marsh as a unit, not a point within the marsh. Also, this variable merely indicates opportunity to perform the function, not function capacity.

The Gulf of Mexico guidebook proposes regional calibration of the following indicators of the Sediment Deposition function, combined in an unweighted linear model:

*Surface roughness*: See above
*Hydroperiod*: Similar to *Flooding Duration* in the national guidebook and to our *Flood*

For the Sediment Stabilization function, the Gulf of Mexico guidebook proposes regional calibration of the following indicators, combined in an unweighted linear model:

*Surface roughness*: See above
*Mean marsh width*: Similar to our *Width*
*Wave exposure*: Similar to our *Fetch*
*Shoreline slope*: Somewhat similar to our *TranAng*
*Soil texture*: Similar to our *SoilFine*

This function also is included under the function "Nutrient and Organic Carbon Exchange," modeled by both the national guidebook for HGM assessment of tidal fringe marshes (Shafer and Yozzo 1998) and the Gulf of Mexico tidal fringe marsh guidebook (Shafer et al. 2002). The national guidebook proposes regional calibration of the following indicators of this function.

*Flooding duration*: Similar to our *Flood*
*Total percent vegetative cover*: The inverse of *Bare* in our *AProd* model
*Mean plant density* and *height*: Somewhat like the inverse of *Bare* in our *AProd* model

In its model, the national guidebook considers the first of these indicators to be equal in weight to the other two. The Gulf of Mexico guidebook uses the same indicators and model, with slightly different terminology.

*Rejected Indicators*

*Accumulation rates*: Sediment accumulation can be measured directly in the field, but doing so requires use of precise coring equipment, or physical markers, repeat visits, and weighing of samples. This is beyond the realm of rapid-assessment methods. Moreover, measuring accumulation without also measuring simultaneous subsidence of the marsh surface can confound the interpretation of resulting data.

*Invertebrate density*: Marsh invertebrates clearly play a significant role both in removing fine sediments from the water column (e.g., filter-feeding clams) and in stabilizing sediments via excretion of heavier consolidated pellets and secretion of adhesive substances. They also influence nutrient fluxes both by processing substances directly (e.g., conversion of particulate to dissolved organic matter) and by oxygenating underlying sediments via their burrowing (bioturbation) activities. However, it is impractical to assess the contribution of these processes in the context of a rapid-assessment method.

*Extent of drift logs*: By intercepting waves and upland runoff, with associated suspended sediment and organic matter, drift logs and other debris can facilitate sediment deposition (Gonor et al. 1988, Maser and Sedell 1994). As logs decay, they also can serve as substrates for colonization by marsh plants that further intercept and stabilize sediment. However, during storms and extreme tides, logs can focus the energy of currents and cause local scouring. Also, the chance of drift logs being stranded in a given marsh is a function of supply and delivery processes. Thus, they are an ambiguous indicator of the capacity of a marsh to stabilize and accrete sediment.

*Presence of natural levees or presence of sediment on plants*: In many marshes, mounds of sediment are apparent along tidal channels and near the external marsh edge. These often are the result of natural accumulation of sediment, thus implying a high capacity of the marsh for this function. However, in other instances they simply are remnants of former dikes or fills. Determining which situation is real is often too difficult, especially in the context of a rapid-assessment method. Also, fine sediment is often observed attached to plant foliage, but this alone does not imply meaningful sediment retention, because such sediment easily can be washed off and transported out of the marsh during the next high tide.

*Surface water salinity in winter/spring*: Compared to other sediment types, clay sediments are the slowest to settle yet sometimes comprise a significant amount of the suspended sediment potentially subject to interception and stabilization by marsh vegetation. Clay particles flocculate and settle out disproportionately at the salt/fresh water interface, particularly in the range 2 to 5 ppt (Rochford 1953). However, surface-water salinity varies too much spatially and temporally within a marsh or marsh channel to be practical as a rapid indicator. Surface-water salinity can be influenced more by the flows from freshwater tributaries and occurrence of spring tides than by relative daily amplitude of the tide at the location (Kistritz and Yesaki 1979).

*Proximity to mudflats, clearcuts, other sediment sources*: Marshes located next to mudflats or other sediment sources have greater *opportunity* to stabilize and accrete sediment. However, this is not relevant to this guidebook, which defines the function solely in terms of the quantity of sediment accreted *per volumetric unit of sediment imported.*

*Position in estuary*: In most estuaries, there exists a zone called the “turbidity maximum” or “null zone” where incoming bottom tidal currents counterbalance outgoing river discharge during slack water periods of each tidal cycle. As the name implies, suspended sediments tend to concentrate and be deposited in this zone. Consequently, tidal marshes situated there should have greater opportunity — but not necessarily greater capacity — to intercept and retain sediments. Moreover, this zone moves daily and seasonally, so predicting its location is not practical in the context of a rapid-assessment method.

*Tributary riparian and drainage area characteristics*: When dams and channelization on freshwater tributaries rob tidal marshes of sediments that otherwise might help sustain them, the marshes can gradually erode, rather than stabilizing and accreting sediment. However, few such disturbances were found on streams feeding tidal marshes in Oregon.

*Hydromodification of the estuary*: Jetties, channel dredging and realignment, causeways, upriver dams, and other major physical alterations can result in aberrant tidal patterns, altered storm surges and summertime low tide levels, and changed sediment regimes in at least part of an estuary (Simenstad 1983). However, depending partly on location and design, such infrastructure can either increase or decrease the ability of tidal wetlands to trap sediment. This indicator is not included because of difficulties in assessing rapidly which effect is more likely.

*Plant stature*: Tall, robust plants such as bulrush provide more resistance to current (i.e., hydraulic roughness) than short, flexible plants such as pickleweed. This would seem to suggest they might be better for entraining and causing deposition of suspended sediments. However, that may depend as much or more on their rooting characteristics and hydrologic setting. Short plants such as creeping bentgrass may stabilize deposited sediments more effectively, and may be exposed to tidal inundation at least as often as some more-robust plants, thus giving them more opportunity to interact with suspended sediment and associated substances.

*Water and sediment chemical data*: Although data on nutrients and organic carbon are available for some marshes, the data cannot be used to make meaningful comparisons among marshes unless such data are collected in a standardized and simultaneous manner from all marshes being compared. Even then, simultaneous measurements of tidal water exchange volumes are needed before attempting to determine whether a marsh is a source, sink, or converter for a particular substance.

#### *3.4.3.5 Maintain Habitat for Native Invertebrates (Inv)*

The scoring model for this function is:
*AProd* + (AVG: BlindL, Jcts, Exits) + (AVG: Pform, FormDiv, SpPerQd) + (MAX: Eelg, Alder) + (AVG: Fetch, LWDchan, LWDline, Pannes, UpEdge) + (AVG: Fresh, FreshSpot, TribL) - Invas - ChemIn - SedShed - Instabil - (1-Island)

Because the "Invertebrate" function includes such a large and diverse group of species, outputs from this scoring model are not intended to represent accurately the needs of every one. In particular, the needs of marine invertebrates often differ from those of marsh insects, but both are included in this function.

In this model, five indicators representing conditions usually detrimental to this function are subtracted from six indicators or averaged groups of indicators that tend to be supportive. The first of the supportive indicators is marsh production. Although most marsh invertebrates do not graze directly on live vascular plants, decaying plant materials and the microbial communities they support provide a rich energy source for many invertebrates. Moreover, plants shelter invertebrates from predation and temperature extremes. Taller plants can serve as refugia for some insect species during rising tides (Boyer and Zedler 1996). Accumulations of soil organic matter associated with high levels of plant production help retain moisture during low tide conditions, and this is important to survival of some invertebrates (Van Dolah 1978). Thus, animal production in tidal marshes probably correlates with plant production in the same marshes, so the output from the *AProd* scoring model is used as an indicator.

To this, the model adds the average of several indicators suggestive of increased marsh topographic complexity (*BlindL, Jcts, Exits*), and then adds the average of some indicators of plant structural and species diversity (*Pform, FormDiv, SpPerQd*). Because of their importance, two indicators (*Eelg, Alder*) are kept in a separate group — implicitly giving them more weight — and their maximum is used. This is added to the average of several indicators of structurally favorable microhabitats (*Fetch, LWDchan, LWDline, Pannes*) as well as to the average of indicators of less-saline conditions that may be favorable to marsh insects (*Fresh, FreshSpot, TribL*). The five indicators of presumably detrimental conditions — *Invas, ChemIn, SedShed, Instabil, Island* — then are subtracted individually (the inverse of *Island* is used due to the direction of its scale).

The use of this particular model resulted in correlations between scores of this function and scores of the following functions, listed from most to least statistically significant (all were statistically significant and positive): *Mfish, Xpt, LbirdM, Sbird, NFW, Rfish, AProd, WQ, Dux, Afish, BotC.*

*Indicators Used Elsewhere*

This function is included under "Nekton Prey Pool," modeled by the national guidebook for HGM assessment of tidal fringe marshes (Shafer and Yozzo 1998), and under "Invertebrate Prey Pool," modeled by the Gulf of Mexico tidal fringe marsh guidebook (Shafer et al. 2002).
The national guidebook proposes regional calibration of the following indicators of this function.

> *Flooding duration*: Not used in our scoring model because evidence is inadequate to support the premise that a particular duration of tidal flooding is optimal for invertebrate community richness and density. Increased tidal inundation increases the marine invertebrate component, but at the expense of many freshwater invertebrates, including terrestrial insects.
> *Total percent vegetative cover*: Similar to the inverse of *Bare* in our *AProd* model
> *Aquatic edge*: Similar to the inverse of *UpEdge*

In its model, the national guidebook considers these indicators to be equal in weight. The Gulf of Mexico guidebook uses essentially the same indicators and model, with slightly different terminology.

*Rejected Indicators*

*Invertebrate samples or observations*: Observations (or absence of observations) or samples of insects and other invertebrates during a single visit to a marsh are virtually meaningless because many invertebrates are highly mobile and have short life spans, causing them to be present or absent through chance alone. For example, whereas an observation of burrows might suggest a marsh is supporting invertebrates, in another marsh that lacks burrows, invertebrates might be far more diverse and prolific, but because of their small size, cryptic habits, or mobility, they simply may be undetected. Thus, comparisons of marshes based only on anecdotal observations — especially if not comprehensive and standardized by month, tidal phase, and sampling gear — are too biased to be useful. A potential alternative — using an "index of biological integrity" (IBI) featuring marsh invertebrates as has been done for other estuarine habitats (see Appendix A)—has not yet been developed for Oregon, nor is it likely to be very rapid.

*Salinity*: Invertebrate richness and density may peak within particular salinity and/or depth ranges. For example, individual samples from deep marine or brackish waters often have greater benthic macrofaunal richness than those from shallower, fresher tidal waters (Hewitt 1993). However, too many other factors confound this relationship. Incursions of high-salinity waters into an estuary can deoxygenate marsh sediments, mobilize phosphorus, and diminish invertebrates (Simenstad et al. 2000). A goal of maintaining the full assemblage of species expected in an estuary is best fostered by maintaining in that estuary a full suite of marshes and other habitats, each representing a different salinity regime. In any case, surface water salinity in tidal marshes varies too often and too rapidly to be practical for use as an indicator (Garofalo 1980).

*Substrate diversity*: Logically, it would seem that a variety of substrate types would support a greater diversity of invertebrates. However, most tidal habitat studies so far have failed to find a strong relationship between these variables. Apparently, other factors have greater influence on invertebrates. Moreover, substrate diversity is notoriously difficult to quantify.

*Soil or sediment organic matter*: Although undoubtedly important to many marsh invertebrates (Levin and Talley 2002), this indicator may be impractical to measure meaningfully within the context of a rapid-assessment method. Lack of adequate soil organic matter has been implicated for reduced invertebrate densities in some constructed marshes (Moy and Levin 1991). Many Oregon tidal marshes once served as commercial storage areas for logs that were intentionally floated down rivers, leaving a large layer of residual bark and other material (Gonor et al. 1988, Maser and Sedell 1994). A preliminary study of such deposits in parts of the Coos Bay estuary with good tidal circulation found no year-round association with benthic invertebrate diversity or density, and possibly a slight elevation of benthic diversity during summer (Walker 1974). Shifts in community composition were associated with organic deposits. Effects specifically in tidal marshes have not been investigated.

*Predation*: When invertebrate habitat becomes accessible to predatory fish, invertebrate densities can decrease over limited times and in very localized areas. However, predation cannot be estimated by rapid assessment methods.

*Duration of inundation*: Evidence is inadequate to support the premise that a particular duration of tidal flooding is optimal for invertebrate community richness and density. Increased tidal inundation increases the marine invertebrate component, but at the expense of many freshwater invertebrates, including terrestrial insects. In Oregon, invertebrates only recently have been sampled systematically in restored Oregon tidal marshes (Gray et al. 2002). Recovery of invertebrate habitat function following the restoration of circulation to a diked marsh can take years to decades (Simenstad and Thom 1996, Warren et al. 2002). The recovery rate depends on the invertebrate species assemblages being considered, the local environment, type of breaching, and how this function is measured (species similarity index, Shannon diversity, density, etc.).

*Width*: Water levels in wider marshes are assumed to change more slowly within a tidal cycle (because water has farther to travel across the marsh surface), thus allowing time for the more sessile invertebrates to shift into spatial positions favorable for their survival. Also, wider marshes tend to provide more “core area” where invertebrates are less likely to be preyed upon by fish. However, narrow marshes are likely to have a proportionately large component of terrestrial insects due to their average proximity to uplands, and this could compensate for loss of the aquatic invertebrate component.

### *3.4.3.6 Maintain Fish Habitat (Afish, Mfish, Rfish)*

Three fish groups are discussed in this one section, although the three have slightly different scoring models. The models of all share the following:
(1)Flood * {AVG [Inv, Estu%WL, (AVG: BlindL, Jcts, Exits), (1-ChemIn)] }

That is, regardless of the species, the most important determinant of fish use of tidal wetlands is access ("opportunity"), as represented by the indicator *Flood*. Because access is potentially controlling, the score for this indicator is multiplied rather than just added to scores of other indicators. To further ensure that the influence of access is not overshadowed by other indicators, those indicators are averaged before multiplying by *Flood*. Even before that happens, the indicators of internal channel complexity (*BlindL, Jcts, Exits*) are averaged because they are correlated and somewhat redundant. Food sources for all fish groups are represented by the score from the invertebrate model (Inv), and Estu%WL is used as an indicator of the estuary-wide dominance of tidal wetlands. Chemical pollution is represented by the indicator *ChemIn*, whose inverse is used to represent relatively low pollution risk. Evidence for effects of chemical pollution on estuarine salmon in the Pacific Northwest is presented by Arkoosh et al. (2001).

Continuing now with the model for just the anadromous group (Afish), the following indicators are then added just before the last parenthesis of equation (1):
(2)+ (MAX: Eelg, LWDchan) + (MAX: TribL, Fresh, FreshSpot) + EstuSal + ShadeLM

The first group of added indicators (*LWDchan, Eelg*) are both suitable as cover for anadromous fish, so their maximum is taken. To this, three indicators of onsite freshwater availability (*TribL, Fresh, FreshSpot*) are averaged. The distribution of tidal wetlands relative to the estuary's salinity gradients (*EstuSal*) is then added, as is the availability of shade in the low marsh and its channels (*ShadeLM*). In addition, *SeaJoin* is added to the core model (1) just after *Flood*, and the average of the two is taken before multiplying by the averaged indicators to their right. The indicator *SeaJoin* is relevant primarily to anadromous and marine fish.

For the function, "Visiting Marine Fish" (Mfish), just the core model (1) is used. One indicator (*Eelg*) is substituted for another (*Estu%WL*) in the core model (1). Again, *SeaJoin* is added to the core model (1) just after *Flood*, and the average of the two is taken before multiplying by the averaged indicators to their right.

For the function, "Other Visiting and Resident Fish" (Rfish), the following indicators or averaged indicator groups are added to the core ones in the core model (1), just before the last parenthesis:
(3)+ (MAX: LWDchan, Eelg) + (MAX: TribL, Fresh, FreshSpot) + Pannes

That is, the indicator *Pannes* is added to the model while removing *EstuSal* and *ShadeLM*, which may not be as important as they were to anadromous fish. In addition, *SeaJoin* is dropped from the first group of the core model, inasmuch as connectedness of an estuary to the ocean is less important to resident fish than to anadromous and marine fish.

The use of these particular models resulted in correlations between scores of these functions and the following ones, listed from most to least statistically significant. All were positive. Non-significant correlates ($p>0.05$) are parenthesized:

*Afish* model: *Dux, Xpt, NFW, Mfish, Afish, Sbird, AProd, Rfish, Inv, (LbirdM, BotC)*
*Mfish* model: *NFW, Afish, Inv, Rfish, Sbird, WQ, Dux, Xpt, LbirdM, (BotC, AProd)*
*Rfish* model: *Afish, NFW, Mfish, Xpt, Sbird, Inv, DB, WQ, AProd, (BotC, LbirdM)*

*Indicators Used Elsewhere*
The Anadromous and Marine fish groups are included under "Nonresident Nekton Utilization" in the national and Gulf of Mexico guidebooks for HGM assessment of tidal fringe marshes (Shafer and Yozzo 1998, Shafer et al. 2002). The national guidebook suggests the following as indicators of this function.

*Flooding duration*: Similar to our *Flood*
*Aquatic edge*: Similar to the inverse of our channel complexity indicators
*Nekton habitat complexity*: Similar to our *LWDchan* and *Eelg*
*Opportunity for marsh access:* Similar to our *Flood*

In its model, the national guidebook considers the last of these indicators to be equal in weight to the first three, and if either that variable or all of the other three are absent, the assessed unit is scored "0." The model is exponential. The Gulf of Mexico guidebook uses essentially the same indicators, with slightly different terminology. Its model is structured similarly, except that, among the first three indicators, it weights the indicators by 2, 1, and 0.5 respectively.

In the national and Gulf of Mexico guidebooks, the Resident Fish group is included under "Resident Nekton Utilization." In both of those guidebooks, the indicators and model formulations are basically the same as above, except *Opportunity for marsh access* is not included.

*Rejected Indicators*

*Observations (or absence of observations) of anadromous fish*: Observations during a single visit to a marsh are virtually meaningless because fish are highly mobile and may be present or absent through chance alone. Comparisons of marshes based on existing data, especially if involving different observers using different sampling gear and non-uniform effort at different times, creates data that are too biased to use.

*Predation*: When fish become vulnerable to avian or mammalian predators, declines may occur in very localized areas over limited time periods. However, predation cannot be estimated by rapid-assessment methods.

*Predominant invertebrate families*: An increasing number of studies are documenting salmon use of particular invertebrate groups (e.g., Gray et al. 2002). Indeed, analyses of gut contents have been used as an indicator of restored marsh development in Connecticut (Warren et al. 2002). However, fish selectivity for particular invertebrates is difficult to document because of the enormous difficulty of adequately quantifying that part of the invertebrate community that can be accessed by fish. Moreover, invertebrate community composition can change rapidly from month to month, and many fish simply may feed opportunistically. Thus, this indicator is impractical to use in a rapid-assessment method.

*Relative importance to marsh-using salmonids of the associated watershed*: Various studies have attempted to categorize or rank Oregon's coastal watersheds according to their potential and/or realized capacity for supporting particular anadromous species. Factors such as watershed land cover, channel types, river flows, and historic escapements are sometimes used. Reports from such studies might be used as one indicator of the opportunity for a particular marsh within the rated watershed to support anadromous fish.

### *3.4.3.7 Maintain Habitat for Nekton-feeding Wildlife (NFW)*

The scoring model for this function is:
(MAX: Rfish, Afish, Mfish) + (AVG: TribL, BlindL, Exits, Jcts) + (MAX: Bare, MudW, Pannes) + (AVG: WetField%, Fresh, FreshSpot) + [AVG: BuffCov, (1-FootVis), (1-Boats)]

The likely availability of fish — as represented by the output scores from the fish groups described in section 3.2.5 — is of course of major importance to fish-eating wildlife. Most fish-eating animals are not consistently selective in the particular fish prey they seek, so the scoring model takes the maximum of the three groups whose habitat previously was assessed (*Rfish, Afish, Mfish*). For the purpose of predicting fish habitat suitability, all those scoring models include measures of the extent and complexity of a wetland's internal channel network, and some include as well the occurrence of freshwater within and near the wetland. Nonetheless, indicators *TribL, BlindL, Exits, Jcts* are repeated separately in this model not only because of their role predicting occurrence of prey foods (fish), but also for their role in predicting wildlife access to those foods. To their average, the model adds the maximum of *Bare, MudW,* and *Pannes* because for some nekton-feeders, access to fish and other nekton may be fostered by the presence of pannes and mudflats within or adjoining the marsh (Burger et al. 1982). Nearby freshwater habitat (*Fresh, FreshSpot*, *WetField%*) additionally can provide a different and complementary array of foods than what nekton-feeding birds find in tidal marshes, and these foods sometimes might be available during parts of the season when preferred tidal marsh foods are scarce. To that average is added the average of three indicators of human presence — *BuffCov, FootVis, Boats*. The inverse is taken of the latter two of these to reflect their negative effect. Many fish predators (e.g., otter, herons) included in this function are very sensitive to disturbance from humans. Although individual birds sometimes acclimate locally to disturbances, most wading birds (excluding some gulls) are wary of humans, especially humans on foot or with unleashed dogs. Thus, marshes with heavy foot and boat traffic within or near their edges during the season of expected wading-bird presence often experience less persistent use by certain wading birds.

The use of this particular model resulted in correlations between scores of this function and the following functions, listed from most to least statistically significant. Non-significant correlates ($p>0.05$) are parenthesized: *Sbird, Rfish, Mfish, DB, Afish, WQ, Inv, Xpt, LbirdM, (BotC, AProd*). All correlations were positive.

#### *Indicators Used Elsewhere*

This function presumably is included (but not mentioned explicitly) under the "Wildlife Habitat Utilization" function as modeled by the national guidebook, and under "Provide Wildlife Habitat" in the Gulf of Mexico guidebook for HGM assessment of tidal fringe marshes (Shafer and Yozzo 1998, Shafer et al. 2002). The national guidebook proposes regional calibration of the following indicators of this function.

- *Wildlife habitat complexity*: Several of our indicators (*TribL, BlindL, Exits, Jcts, Bare, Pannes)* contribute to habitat complexity

- *Aquatic edge*: Similar to our indicators of channel complexity (*TribL, BlindL, Exits, Jcts)* but more inclusive
- *Upland edge quantity* and *quality*: Similar to our *BuffCov* but more inclusive

In its model, the national guidebook considers these indicators to be equal in weight and combines them linearly.

The Gulf of Mexico guidebook shares the first indicator, but uses the following three in place of *Aquatic edge* and *Upland edge*:

- *Mean percent vegetative cover*: Similar to the inverse of our *Bare*.
- *Percent cover by typical vegetation*: Similar to the inverse of our *Bare*.
- *Total effective patch size*: Our *Width* and *WetField%* indicators accomplish much of the same. Many Oregon tidal marshes do not occur in discrete "patches."

The model used by the Gulf of Mexico guidebook adds the last of the above indicators to the minimum of the first two, and then to the *Wildlife habitat complexity* indicator mentioned earlier.

*Rejected Indicators*

*Nekton-feeders detected during the site visit*: Observations (or absence of observations) of herons and other nekton-feeders during a single visit to a marsh are virtually meaningless because these birds are highly mobile and may be present or absent through chance alone. Comparison of marshes based on non-uniform survey efforts, especially if involving different observers at different times, creates data that are too biased to use.

*Windward fetch*: Marshes that are adjoined by wide, open-water areas are more subject to strong wind and waves. This diminishes water clarity and can discourage use by some nekton-feeders, which rely on vision to find prey. However, because the response is highly species-specific (e.g., loons seem less influenced by fetch than kingfishers), this is not proposed as an indicator under this function.

### *3.4.3.8 Maintain Habitat for Ducks and Geese (Dux)*

The scoring model for this function is:
(AVG: BlindL, Exits, Jcts, Flood) + (AVG: Eelg, Bare, MudW, NutrIn, Pform) + (AVG: Fresh, FreshSpot, TribL) + WetField% + (1 - Fetch) + {[MAX: (Width, 1 - Island)] - [AVG: FootVis, Boats] }

This model basically says that tidal marsh habitat for waterfowl is defined about equally by marsh flooding (*BlindL, Exits, Jcts, Flood*), access to abundant and diverse foods (implied by *Eelg, Bare, MudW, NutrIn, Pform*), freshwater availability (*Fresh, FreshSpot, TribL*), local land cover (*WetField%),* shelter from stormy conditions, and minimal human intrusion (*FootVis, Boats*) unless buffered by wetland *Width* or the wetland being an *Island*.

The use of this particular model resulted in correlations between scores of this function and the following functions, listed from most to least statistically significant. Non-significant correlates ($p>0.05$) are parenthesized: *WQ, NFW, Sbird, Mfish, Xpt, Rfish, Inv, Afish, AProd, (LbirdM, BotC)* All correlations were positive.

*Indicators Used Elsewhere*

See narrative under this subheading in section 3.4.3.7 above.

*Rejected Indicators*

*Ducks* and *geese detected during the site visit*: Observations (or absence of observations) during a single visit to a marsh are virtually meaningless because waterfowl are highly mobile and may be present or absent through chance alone. Comparisons of marshes based on non-uniform survey efforts, especially if involving different observers at different times, create data that are too biased to use.

*Food value of the dominant plant species*: Anecdotal information is profuse regarding plant species consumed by waterfowl (e.g., Vermeer and Levings 1977). However, without simultaneous measurements of seasonal availability of foods, waterfowl selectivity for (or metabolic benefits from) particular plant species cannot be determined objectively.

*Predation*: When ducks and geese are preyed upon by raptors, hunters, or other vertebrate predators, declines may occur in very localized areas over limited time periods. However, predation cannot be estimated by rapid-assessment methods.

### *3.4.3.9 Maintain Habitat for Shorebirds (Sbird)*

The scoring model for this function is:
Inv + (MAX: Bare, Pannes, Flood) + [(MAX: Roost, MudW, WetField%) - FootVis - (AVG: FormDiv, UpEdge) - (1-Width)

This model postulates that tidal marsh habitat for shorebirds is defined about equally by three positive and three negative factors. The positives are the invertebrate function (*Inv*) predicted from a preceding model, an onsite habitat component (*Bare, Pannes, Flood*), and an offsite habitat component (*Roost, MudW, WetField%*). The negatives include disturbance by people and pets (*FootVis*), the encirclement of the marsh by upland cover rather than water (*UpEdge, FormDiv*), and narrowness of the marsh (the inverse of *Width*).

The use of this particular model resulted in correlations between scores of this function and the following functions, listed from most to least statistically significant. Non-significant correlates (p>0.05) are parenthesized: *NFW, Mfish, Dux, Rfish, WQ, Inv, Afish, BotC, (Xpt, LbirdM, AProd)* All correlations were positive.

*Indicators Used Elsewhere*

See narrative under this subheading in section 3.4.3.7 above.

*Rejected Indicators*

See narrative under this subheading in section 3.4.3.8 above.

### *3.4.3.10 Maintain Habitat for Native Landbirds, Small Mammals, and Their Predators (LBM)*

The scoring model for this function is:
[UpEdge + (AVG: Pform, BuffCov) + (AVG: SpPerQd, Inv) + (AVG: TribL, FreshW, FreshSpot) + (AVG: LWDmarsh, LWDline) - HomeDis - RoadX - Flood] * Island

This model first considers five factors that normally influence this function positively. These are the proportion of wetland edge that is upland (*UpEdge*), the naturalness and structural diversity of the landscape near the wetland (*Pform, BuffCov*), the diversity and amount of potential food sources (as suggested by *SpPerQd, Inv*), availability of freshwater (*TribL, FreshW, FreshSpot*), and downed wood important to small mammals (*LWDline*) and raptors (*LWDmarsh*). From these five factors the model then subtracts three that sometimes influence this function negatively (*HomeDis, RoadX, Flood*). Finally, the net sum of all five positive and three negative factors is multiplied by *Island,* meaning that if a low marsh exists only as an island with no contiguous upland, its suitability as habitat for landbirds, small mammals, and their predators is so low that this trumps all other considerations.

The use of this particular model resulted in correlations between scores of this function and the following functions, listed from most to least statistically significant. Non-significant correlates ($p>0.05$) are parenthesized: *Inv, Mfish, BotC, NFW, (WQ, Rfish, Dux, Sbird, Afish, Xpt, AProd*. All correlations were positive.

#### *Indicators Used Elsewhere*

See narrative under this subheading in section 3.4.3.7 above.

#### *Rejected Indicators*

*Area-weighted distance to other marshes (tidal or not):* Preliminary data from San Francisco Bay tidal marshes suggest that small, fragmented, geographically isolated marshes may be occupied less often by some nesting songbird species. In contrast, large, contiguous marshes — or smaller marshes that are located very close to larges ones — probably are more capable of supporting the variety of resources individual animals need, without requiring excessive expenditure of energy for travel to reach these. Thus, they have greater capacity to support this function. However, isolated sites might be individually of greater *value*, which is considered separately. In any case, the applicability of such preliminary data to Oregon's very different conditions at this point is inadvisable. See also the narrative under this subheading in section 3.4.3.8 above.

### *3.4.3.11 Maintain Native Botanical Conditions (BotC)*

The scoring model for this function is:
SpPerQd - NN20PC

Such a simple model is used because the botanical attributes considered to define this function (plant species richness, non-native species cover) can be measured directly, rather than relying on surrogates as was the case with the other function models. Richness is given the same weight as non-native species cover. The two are negatively correlated, although in some cases both may increase (at least temporarily) in response to low-intensity artificial disturbances. Also, both are included because sometimes the response of plant richness lags behind the introduction of non-native species at a site.

*Indicators Used Elsewhere*

This function is similar to the function "Maintain Characteristic Plant Community Composition" modeled by the national and Gulf of Mexico guidebooks for HGM assessment of tidal fringe marshes (Shafer and Yozzo 1998, Shafer et al. 2002). Both of those guidebooks propose regional calibration of just two indicators of this function, combined in an unweighted linear model:

> *Total percent vegetative cover*: Not used in our scoring model because it includes both non-native and non-wetland species, and because region-scale diversity of wetland plants (a key component of this function as we have defined it) does not necessarily correlate with percent vegetative cover.
>
> *Percent vegetative cover by exotic or nuisance species*. Similar to our *NN20PC*

*Rejected Indicators*

*Zonation of marsh vegetation*: Some studies suggest that plant communities in the more mature marshes, if relatively undisturbed by human alterations, may develop into distinct, internally homogeneous patches or zones (Frenkel and Morlan 1990). Further support for this is provided by Wigand et al. (2001) and Emery et al. (2001) who found zonation (the number of recognizable plant zones in a marsh) is reduced with nutrient increases, as tested both experimentally and with correlation with the proportion of residential land use in the nitrogen-contributing area above Rhode Island tidal marshes. Nutrients clearly can influence competitive outcomes among tidal marsh species (Levine et al. 1998, van Wijnen and Bakker 1999, Emery et al. 2001), including perhaps the competition between native and non-native marsh species. However, we do not include zonation as an indicator because of difficulty in defining it spatially in an objective and rapid manner.

*Species present at atypical elevations or in atypical associations with other species*: Existing data (e.g., Jefferson 1975, Frenkel and Eilers 1976), as well as data collected by this study from least-altered reference wetlands, can be used to define the expected elevation ranges of particular plant species, relative to tidal datum. If, within a particular site, a species is found consistently to be well outside its elevation range in unaltered marshes, this might be interpreted as meaning the site is new or recently has been altered or degraded. Similarly, atypical assemblages of species — all within the same elevation zone — can suggest recent alteration. For example, when Frenkel and Eilers (1976) found *Salicornia virginica* (a typical low-marsh species) associating closely with *Potentilla anserina v. pacifica* (a typical high-marsh species), they interpreted this as meaning the marsh was of recent origin. However, (a) elevational ranges of species are difficult to define precisely and universally, (b) some species are quite plastic with regard to elevational ranges, (c) species' elevational ranges can vary among sites as a result of differences in tidal range among the sites, and (d) local seeps of fresher groundwater or saltier pannes can cause unusual juxtapositions naturally within a zone.

*Soil fertility*: Soil fertility is undoubtedly important to marsh plants, and differences exist among marsh soils with regard to their intrinsic fertility, e.g., typical concentrations of geologically derived N, P, and K. Differences also exist due to effects of human activities on marsh soil fertility. These include volatilization of organics from artificial drainage, inputs of fertilizer and septic runoff, and watershed land-cover changes that result in increased prevalence of red alder, scotch broom, and other N-fixing shrubs. Waterfowl also can transfer nutrients into wetlands. However, relationships between nutrients and vascular plant species richness have not been well studied in Oregon tidal marshes, and many other factors potentially confound these relationships. Moreover, consistent data on soil fertility are not available for Oregon tidal marshes, and fertility cannot be measured meaningfully within the constraints of a rapid assessment.

*Contaminants*. Although data on sediment chemical parameters important to marsh plant germination and survival may be available for some marshes, the data cannot be used to make meaningful comparisons among marshes unless such data are collected in a standardized and simultaneous manner from all marshes being compared.

*Soil texture*: Oregon tidal marshes on sand substrates sometimes have fewer species (Jefferson 1975) and in California, marshes planted on sandy nutrient-poor soil require more than 4 years to develop canopy architecture similar to that of relatively unaltered marshes (Keer and Zedler 2002). However, species that inhabit sandy marshes are no less characteristic of tidal marshes than species present in marshes underlain by other soil textures. This guidebook's models use soil texture only secondarily, to adjust expectations for species richness.

*Similarity coefficients*: A variety of statistical approaches (e.g., canonical correlation analysis, multidimensional scaling) and indices (e.g., Jaccard coefficient) have been proposed to quantify the differences between sites containing partly different lists of plants. However, the effects of marsh size and other factors can be difficult to factor out, thus confounding interpretation of results. Moreover, the sensitivity of some indices might be limited, due to the relatively depauperate floras of most tidal marshes.

# 4.0 Analysis Results

## 4.1 Function Scores for the Surveyed Sites

The scoring models described in section 3.4.3 were applied to the data recorded on the field forms during visits to each of the 120 tidal wetlands, and capacity scores were generated for each wetland's functions (Table 26–28). These scores should be used as reference points when interpreting scores from assessments of tidal wetlands not included in that data set.

### Table 26. Function capacity scores for tidal wetlands that are considered to be predominantly in the Marine-sourced High Marsh subclass

"Least altered" wetlands were prejudged, based on risk factors, to be the least likely to have sustained lasting damage from human activities. "Less altered" wetlands were prejudged to have experienced potentially somewhat more (but still minimal) disturbance from humans. Scores are all relative and have no absolute meaning with regard to function capacity. Wetland size has not been explicitly accounted for. Abbreviations for the functions are shown in Table of Contents.

| Site# | Least altered? | Less altered? | Risk Index | AProd | Xpt | WQ | INV | AFish | Mfish | RFish | NFW | Dux | Sbird | LBM | BotC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1236 | yes | yes | 0.14 | 0.49 | 0.57 | 0.51 | 0.98 | 0.50 | 0.63 | 0.47 | 0.75 | 0.45 | 0.68 | 1.00 | 0.72 |
| 2987I | yes | yes | 0.15 | 0.35 | 0.43 | 0.57 | 0.61 | 0.43 | 0.59 | 0.28 | 0.73 | 0.56 | 0.99 | 0.63 | 0.55 |
| 883 | yes | yes | 0.15 | 0.25 | 0.41 | 0.65 | 0.68 | 0.58 | 0.80 | 0.42 | 0.80 | 0.71 | 0.96 | 0.53 | 0.55 |
| 2932E | yes | yes | 0.17 | 0.61 | 0.68 | 0.75 | 0.92 | 0.43 | 0.62 | 0.24 | 0.57 | 0.71 | 0.81 | 0.59 | 0.83 |
| 2188 | yes | yes | 0.17 | 0.51 | 0.46 | 0.37 | 0.59 | 0.74 | 0.38 | 0.36 | 0.61 | 0.35 | 0.39 | 0.90 | 0.27 |
| 3113 | yes | yes | 0.19 | 0.51 | 0.41 | 0.50 | 0.66 | 0.68 | 0.72 | 0.37 | 0.33 | 0.53 | 0.53 | 0.74 | 0.83 |
| 2942E | yes | yes | 0.22 | 0.75 | 0.80 | 0.69 | 0.93 | 0.51 | 0.56 | 0.14 | 0.46 | 0.47 | 0.58 | 0.65 | 0.72 |
| 2152 | yes | yes | 0.22 | 0.28 | 0.25 | 0.45 | 0.29 | 0.68 | 0.41 | 0.57 | 0.57 | 0.38 | 0.86 | 0.38 | 0.44 |
| 1494 | yes | yes | 0.25 | 0.57 | 0.44 | 0.68 | 0.61 | 0.51 | 0.56 | 0.19 | 0.37 | 0.67 | 0.61 | 0.53 | 0.66 |
| 3425 | yes | yes | 0.25 | 0.71 | 0.60 | 0.53 | 0.99 | 0.57 | 0.74 | 0.31 | 0.51 | 0.64 | 0.86 | 0.59 | 0.66 |
| 2994 | yes | yes | 0.26 | 0.63 | 0.59 | 0.61 | 0.87 | 0.56 | 0.79 | 0.31 | 0.56 | 0.50 | 0.64 | 0.62 | 0.66 |
| 2148W | yes | yes | 0.40 | 0.47 | 0.53 | 0.64 | 0.41 | 0.60 | 0.45 | 0.45 | 0.44 | 0.42 | 0.48 | 0.41 | 0.78 |
| 3729 | no | yes | 0.08 | 0.63 | 0.50 | 0.23 | 0.72 | 0.11 | 0.17 | 0.27 | 0.22 | 0.41 | 0.49 | 0.76 | 0.66 |
| 2940I | no | yes | 0.15 | 0.39 | 0.45 | 0.45 | 0.45 | 0.40 | 0.37 | 0.28 | 0.60 | 0.52 | 0.81 | 0.45 | 0.66 |
| 2987S | no | yes | 0.17 | 0.23 | 0.28 | 0.31 | 0.61 | 0.39 | 0.58 | 0.38 | 0.64 | 0.43 | 0.71 | 0.75 | 1.00 |
| 2942W | no | yes | 0.17 | 0.68 | 0.72 | 0.67 | 0.72 | 0.44 | 0.61 | 0.07 | 0.48 | 0.64 | 0.81 | 0.47 | 0.78 |
| 2079 | no | yes | 0.21 | 0.34 | 0.37 | 0.51 | 0.62 | 0.71 | 0.80 | 0.43 | 0.49 | 0.48 | 0.86 | 0.48 | 0.39 |
| 3060 | no | yes | 0.21 | 0.25 | 0.18 | 0.04 | 0.37 | 0.28 | 0.37 | 0.07 | 0.13 | 0.16 | 0.23 | 0.57 | 0.11 |
| 2149 | no | yes | 0.23 | 0.43 | 0.44 | 0.45 | 0.69 | 0.66 | 0.74 | 0.48 | 0.57 | 0.31 | 0.72 | 0.55 | 0.50 |
| 1048S | no | yes | 0.23 | 0.57 | 0.46 | 0.48 | 0.54 | 0.31 | 0.41 | 0.27 | 0.52 | 0.55 | 0.73 | 0.68 | 0.50 |
| 2158 | no | yes | 0.23 | 0.03 | 0.00 | 0.28 | 0.18 | 0.26 | 0.23 | 0.01 | 0.17 | 0.09 | 0.28 | 0.75 | 0.55 |
| 832 | no | yes | 0.25 | 0.48 | 0.39 | 0.27 | 0.84 | 0.23 | 0.44 | 0.14 | 0.07 | 0.11 | 0.28 | 0.40 | 0.39 |
| 787 | no | yes | 0.26 | 0.64 | 0.56 | 0.46 | 0.66 | 0.48 | 0.28 | 0.22 | 0.27 | 0.42 | 0.49 | 0.39 | 0.44 |
| 1182 | no | yes | 0.27 | 0.48 | 0.55 | 0.55 | 0.66 | 0.16 | 0.38 | 0.07 | 0.41 | 0.61 | 0.65 | 0.49 | 0.66 |
| 773 | no | yes | 0.28 | 0.40 | 0.27 | 0.32 | 0.67 | 0.31 | 0.35 | 0.02 | 0.00 | 0.16 | 0.22 | 0.22 | 0.78 |
| 1129 | no | yes | 0.29 | 0.45 | 0.60 | 0.75 | 0.94 | 0.47 | 0.69 | 1.00 | 1.00 | 1.00 | 1.00 | 0.71 | 0.44 |
| 964S | no | yes | 0.30 | 0.69 | 0.61 | 0.64 | 0.19 | 0.52 | 0.44 | 0.17 | 0.60 | 0.85 | 0.70 | 0.34 | 0.61 |
| 3145 | no | yes | 0.32 | 0.45 | 0.38 | 0.34 | 0.22 | 0.40 | 0.33 | 0.31 | 0.36 | 0.44 | 0.35 | 0.49 | 0.50 |
| 3033W | no | yes | 0.32 | 0.64 | 0.67 | 0.69 | 0.55 | 0.79 | 0.53 | 0.49 | 0.47 | 0.63 | 0.50 | 0.49 | 0.61 |
| 3128N | no | yes | 0.34 | 0.45 | 0.49 | 0.56 | 0.37 | 0.22 | 0.33 | 0.15 | 0.58 | 0.37 | 0.62 | 0.43 | 0.66 |
| 2536 | no | yes | 0.35 | 0.20 | 0.35 | 0.47 | 0.67 | 0.66 | 0.82 | 0.38 | 0.56 | 0.55 | 0.48 | 0.43 | 0.66 |

| Site# | Least altered? | Less altered? | Risk Index | AProd | Xpt | WQ | INV | AFish | Mfish | RFish | NFW | Dux | Sbird | LBM | BotC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 965 | no | yes | 0.41 | 0.74 | 0.81 | 0.84 | 0.67 | 1.00 | 1.00 | 0.82 | 0.87 | 0.81 | 0.69 | 0.62 | 0.44 |
| 2987N | no | yes |  | 0.66 | 0.56 | 0.39 | 0.53 | 0.55 | 0.41 | 0.36 | 0.61 | 0.38 | 0.45 | 0.62 |  |
| 2981 | no | no | 0.19 | 0.27 | 0.35 | 0.36 | 0.57 | 0.36 | 0.42 | 0.21 | 0.52 | 0.40 | 0.55 | 0.53 | 0.61 |
| 3141H | no | no | 0.25 | 0.59 | 0.42 | 0.59 | 0.54 | 0.51 | 0.59 | 0.31 | 0.25 | 0.43 | 0.33 | 0.72 | 0.44 |
| 3451 | no | no | 0.30 | 0.18 | 0.17 | 0.35 | 0.33 | 0.36 | 0.36 | 0.27 | 0.17 | 0.36 | 0.32 | 0.74 | 0.44 |
| 2731 | no | no | 0.33 | 0.45 | 0.36 | 0.31 | 0.56 | 0.62 | 0.64 | 0.31 | 0.47 | 0.15 | 0.56 | 0.44 | 0.61 |
| 791 | no | no | 0.34 | 0.54 | 0.43 | 0.53 | 0.51 | 0.56 | 0.39 | 0.29 | 0.20 | 0.44 | 0.30 | 0.37 | 0.44 |
| 488 | no | no | 0.41 | 0.51 | 0.44 | 0.27 | 0.39 | 0.06 | 0.25 | 0.01 | 0.05 | 0.32 | 0.15 | 0.23 | 0.05 |
| 869N | no | no | 0.43 | 0.75 | 0.62 | 0.33 | 0.45 | 0.45 | 0.40 | 0.18 | 0.31 | 0.62 | 0.26 | 0.57 | 0.39 |
| 2146 | no | no | 0.45 | 0.24 | 0.19 | 0.32 | 0.09 | 0.25 | 0.00 | 0.04 | 0.22 | 0.28 | 0.24 | 0.24 | 0.61 |
| 2238 | no | no | 0.65 | 0.93 | 0.85 | 0.69 | 0.19 | 0.60 | 0.05 | 0.29 | 0.25 | 0.46 | 0.10 | 0.26 | 0.39 |

## Table 27. Function capacity scores for tidal wetlands that are considered to be predominantly in the Marine-sourced Low Marsh subclass

See note above the preceding table.

| Site# | Least altered? | Less altered? | Risk Index | AProd | Xpt | WQ | INV | AFish | Mfish | RFish | NFW | Dux | Sbird | LBM | BotC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2792 | yes | yes | 0.19 | 0.19 | 0.41 | 0.63 | 0.66 | 0.66 | 0.92 | 0.43 | 0.71 | 0.67 | 0.82 | 0.49 | 0.39 |
| 1048N | yes | yes | 0.19 | 0.54 | 0.58 | 0.40 | 0.62 | 0.19 | 0.45 | 0.45 | 0.62 | 0.49 | 0.71 | 0.65 | 0.55 |
| 1532 | yes | yes | 0.18 | 0.34 | 0.46 | 0.58 | 0.48 | 0.62 | 0.70 | 0.21 | 0.57 | 0.67 | 0.76 | 0.37 | 0.44 |
| 2964 | yes | yes | 0.25 | 0.13 | 0.31 | 0.55 | 0.46 | 0.42 | 0.57 | 0.00 | 0.54 | 0.56 | 0.71 | 0.42 | 0.78 |
| 938 | yes | yes | 0.29 | 0.48 | 0.37 | 0.33 | 0.33 | 0.63 | 0.41 | 0.57 | 0.53 | 0.34 | 0.58 | 0.64 | 0.33 |
| 2195 | yes | yes | 0.18 | 0.22 | 0.23 | 0.36 | 0.46 | 0.76 | 0.32 | 0.27 | 0.56 | 0.32 | 0.34 | 0.81 | 0.33 |
| 2932W | no | yes | 0.24 | 0.64 | 0.72 | 0.83 | 0.99 | 0.83 | 0.82 | 0.71 | 0.70 | 0.71 | 0.88 | 0.42 | 0.05 |
| 3033E | no | yes | 0.45 | 0.49 | 0.60 | 0.65 | 0.56 | 0.82 | 0.87 | 0.66 | 0.60 | 0.69 | 0.63 | 0.20 | 0.78 |
| 2935 | no | yes | 0.21 | 0.38 | 0.58 | 0.66 | 0.79 | 0.82 | 0.78 | 0.60 | 0.71 | 0.62 | 0.76 | 0.60 | 0.00 |
| 1240W | no | yes | 0.18 | 0.80 | 0.64 | 0.80 | 0.68 | 0.31 | 0.54 | 0.12 | 0.59 | 0.70 | 0.82 | 0.52 | 0.44 |
| 2963 | no | yes | 0.39 | 0.56 | 0.66 | 0.75 | 0.54 | 0.77 | 0.56 | 0.55 | 0.60 | 0.63 | 0.39 | 0.53 | 0.44 |
| 889 | no | yes | 0.31 | 0.29 | 0.49 | 0.74 | 0.53 | 0.93 | 0.87 | 0.50 | 0.64 | 0.64 | 0.43 | 0.73 | 0.16 |
| 761 | no | yes | 0.22 | 0.62 | 0.57 | 0.31 | 0.78 | 0.54 | 0.49 | 0.57 | 0.53 | 0.32 | 0.46 | 0.58 | 0.89 |
| 1240N | no | yes | 0.20 | 0.45 | 0.39 | 0.61 | 0.77 | 0.53 | 0.52 | 0.31 | 0.54 | 0.57 | 0.72 | 0.54 | 0.61 |
| 1474L | no | yes | 0.17 | 0.48 | 0.44 | 0.64 | 0.40 | 0.56 | 0.44 | 0.36 | 0.63 | 0.67 | 0.90 | 0.37 | 0.44 |
| 2105 | no | yes | 0.27 | 0.69 | 0.51 | 0.31 | 0.65 | 0.59 | 0.59 | 0.47 | 0.56 | 0.22 | 0.61 | 0.73 | 0.33 |
| 964N | no | yes | 0.28 | 0.33 | 0.44 | 0.61 | 0.07 | 0.58 | 0.51 | 0.54 | 0.75 | 0.85 | 0.78 | 0.27 | 0.34 |
| 3070 | no | yes | 0.25 | 0.37 | 0.34 | 0.41 | 0.50 | 0.67 | 0.72 | 0.37 | 0.46 | 0.55 | 0.51 | 0.66 | 0.39 |
| 1410 | no | yes | 0.29 | 0.43 | 0.38 | 0.66 | 0.45 | 0.53 | 0.46 | 0.50 | 0.60 | 0.59 | 0.78 | 0.11 | 0.44 |
| 2094 | no | yes | 0.28 | 0.42 | 0.38 | 0.58 | 0.52 | 0.50 | 0.61 | 0.19 | 0.35 | 0.30 | 0.30 | 0.68 | 0.78 |
| 1474U | no | yes | 0.22 | 0.45 | 0.52 | 0.46 | 0.31 | 0.75 | 0.49 | 0.33 | 0.45 | 0.56 | 0.53 | 0.31 | 0.33 |
| 980 | no | yes | 0.42 | 0.36 | 0.39 | 0.47 | 0.23 | 0.56 | 0.31 | 0.60 | 0.75 | 0.65 | 0.56 | 0.01 | 0.00 |
| 2157 | no | yes | 0.33 | 0.45 | 0.34 | 0.35 | 0.37 | 0.60 | 0.27 | 0.37 | 0.30 | 0.24 | 0.59 | 0.34 | 0.50 |
| 2771 | no | yes | 0.33 | 0.31 | 0.35 | 0.08 | 0.52 | 0.63 | 0.69 | 0.31 | 0.41 | 0.15 | 0.17 | 0.73 | 0.16 |
| 1172 | no | yes | 0.22 | 0.47 | 0.36 | 0.27 | 0.57 | 0.16 | 0.24 | 0.18 | 0.28 | 0.37 | 0.45 | 0.57 | 0.44 |
| 941 | no | yes | 0.37 | 0.44 | 0.35 | 0.36 | 0.16 | 0.35 | 0.23 | 0.50 | 0.51 | 0.31 | 0.46 | 0.51 | 0.27 |
| 2976 | no | yes | 0.41 | 0.33 | 0.27 | 0.36 | 0.35 | 0.48 | 0.28 | 0.40 | 0.47 | 0.35 | 0.59 | 0.20 | 0.27 |
| 1188 | no | yes | 0.12 | 0.43 | 0.31 | 0.19 | 0.47 | 0.11 | 0.26 | 0.34 | 0.41 | 0.21 | 0.61 | 0.44 | 0.44 |
| 2739 | no | yes | 0.42 | 0.22 | 0.16 | 0.00 | 0.31 | 0.39 | 0.35 | 0.08 | 0.20 | 0.01 | 0.00 | 0.47 | 0.11 |
| 2766 | no | yes | 0.37 | 0.36 | 0.28 | 0.02 | 0.11 | 0.23 | 0.25 | 0.02 | 0.20 | 0.00 | 0.12 | 0.38 | 0.11 |
| 2838 | no | no | 0.43 | 1.00 | 0.97 | 1.00 | 0.75 | 0.66 | 0.69 | 0.45 | 0.72 | 0.94 | 0.62 | 0.75 | 0.39 |
| 767 | no | no | 0.39 | 0.73 | 0.78 | 0.53 | 0.84 | 0.74 | 0.50 | 0.50 | 0.76 | 0.63 | 0.41 | 0.65 | 0.55 |
| 3086 | no | no | 0.33 | 0.72 | 0.55 | 0.67 | 0.68 | 0.71 | 0.64 | 0.57 | 0.55 | 0.65 | 0.55 | 0.83 | 0.50 |
| 3140 | no | no | 0.31 | 0.28 | 0.36 | 0.33 | 0.52 | 0.73 | 0.73 | 0.43 | 0.54 | 0.54 | 0.40 | 0.55 | 0.44 |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1545E | no | no | 0.53 | 0.93 | 0.76 | 0.34 | 0.60 | 0.70 | 0.26 | 0.34 | 0.39 | 0.32 | 0.22 | 0.38 | 0.55 |
| 1462 | no | no | 0.44 | 0.31 | 0.26 | 0.72 | 0.33 | 0.38 | 0.34 | 0.04 | 0.61 | 0.83 | 0.66 | 0.36 | 0.72 |
| 3128E | no | no | 0.55 | 0.55 | 0.57 | 0.49 | 0.34 | 0.87 | 0.38 | 0.67 | 0.46 | 0.48 | 0.19 | 0.27 | 0.27 |
| 2950 | no | no | 0.46 | 0.48 | 0.40 | 0.22 | 0.45 | 0.57 | 0.44 | 0.60 | 0.40 | 0.20 | 0.55 | 0.38 | 0.44 |
| 1545W | no | no | 0.57 | 0.84 | 0.70 | 0.30 | 0.37 | 0.62 | 0.10 | 0.43 | 0.41 | 0.29 | 0.16 | 0.22 | 0.66 |
| 3170 | no | no | 0.45 | 0.51 | 0.33 | 0.45 | 0.43 | 0.40 | 0.34 | 0.19 | 0.20 | 0.47 | 0.28 | 0.36 | 0.72 |
| 2904 | no | no | 0.49 | 0.49 | 0.31 | 0.59 | 0.22 | 0.62 | 0.25 | 0.45 | 0.23 | 0.45 | 0.49 | 0.25 | 0.22 |
| 2801 | no | no | 0.27 | 0.51 | 0.37 | 0.06 | 0.38 | 0.41 | 0.51 | 0.19 | 0.40 | 0.20 | 0.53 | 0.58 | 0.39 |
| 3141P | no | no | 0.30 | 0.28 | 0.22 | 0.51 | 0.27 | 0.31 | 0.33 | 0.09 | 0.47 | 0.48 | 0.44 | 0.63 | 0.39 |
| 2977 | no | no | 0.53 | 0.33 | 0.38 | 0.29 | 0.41 | 0.40 | 0.37 | 0.38 | 0.46 | 0.45 | 0.38 | 0.12 | 0.27 |
| 2787 | no | no | 0.20 | 0.58 | 0.44 | 0.00 | 0.22 | 0.43 | 0.39 | 0.24 | 0.42 | 0.37 | 0.45 | 0.39 | 0.05 |
| 1403 | no | no | 0.67 | 0.52 | 0.45 | 0.29 | 0.00 | 0.59 | 0.19 | 0.34 | 0.18 | 0.35 | 0.06 | 0.10 | 0.27 |
| 2829 | no | no | 0.34 | 0.30 | 0.25 | 0.11 | 0.11 | 0.34 | 0.26 | 0.00 | 0.41 | 0.29 | 0.52 | 0.21 | 0.27 |

## Table 28. Function capacity scores for tidal wetlands that are considered to be predominantly in the River-sourced subclass

See note above the preceding table.

| Site# | Least altered? | Less altered? | Risk Index | AProd | Xpt | WQ | INV | AFish | Mfish | RFish | NFW | Dux | Sbird | LBM | BotC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2980 | yes | yes | 0.24 | 0.64 | 0.76 | 0.56 | 0.67 | 0.62 | 0.64 | 0.40 | 0.54 | 0.71 | 0.64 | 0.74 | 0.72 |
| 675 | yes | yes | 0.25 | 0.32 | 0.40 | 0.73 | 0.56 | 0.44 | 0.48 | 0.19 | 0.44 | 0.58 | 0.34 | 0.63 | 0.72 |
| 543 | yes | yes | 0.13 | 0.41 | 0.45 | 0.41 | 0.66 | 0.66 | 0.45 | 0.40 | 0.46 | 0.33 | 0.35 | 0.43 | 0.55 |
| 620 | yes | yes | 0.27 | 0.61 | 0.55 | 0.58 | 0.70 | 0.37 | 0.46 | 0.12 | 0.28 | 0.30 | 0.32 | 0.60 | 0.61 |
| 1465 | yes | yes | 0.23 | 0.27 | 0.23 | 0.52 | 0.25 | 0.48 | 0.30 | 0.19 | 0.27 | 0.39 | 0.18 | 0.72 | 0.61 |
| 3944 | yes | yes | 0.17 | 0.39 | 0.22 | 0.46 | 0.39 | 0.05 | 0.05 | 0.04 | 0.36 | 0.71 | 0.50 | 0.80 | 0.27 |
| 865 | yes | yes | 0.21 | 0.40 | 0.34 | 0.25 | 0.45 | 0.35 | 0.35 | 0.12 | 0.20 | 0.52 | 0.49 | 0.31 | 0.33 |
| 3103 | no | yes | 0.19 | 0.96 | 1.00 | 0.69 | 1.00 | 0.81 | 0.95 | 0.67 | 0.82 | 0.75 | 0.54 | 0.84 | 0.44 |
| 2148E | no | yes | 0.43 | 0.48 | 0.60 | 0.54 | 0.52 | 0.96 | 0.44 | 1.00 | 0.82 | 0.60 | 0.49 | 0.67 | 0.83 |
| 2973 | no | yes | 0.16 | 0.66 | 0.66 | 0.72 | 0.86 | 0.50 | 0.50 | 0.28 | 0.53 | 0.88 | 0.67 | 0.66 | 0.27 |
| 3154 | no | yes | 0.37 | 0.68 | 0.59 | 0.50 | 0.58 | 0.52 | 0.35 | 0.28 | 0.28 | 0.47 | 0.21 | 0.73 | 0.39 |
| 1723 | no | yes | 0.11 | 0.36 | 0.17 | 0.24 | 0.66 | 0.13 | 0.32 | 0.08 | 0.37 | 0.47 | 0.61 | 0.88 | 0.72 |
| 222 | no | yes | 0.35 | 0.31 | 0.24 | 0.26 | 0.35 | 0.07 | 0.10 | 0.20 | 0.38 | 0.73 | 0.58 | 0.33 | 0.78 |
| 380 | no | yes | 0.17 | 0.29 | 0.18 | 0.24 | 0.29 | 0.17 | 0.27 | 0.06 | 0.16 | 0.42 | 0.46 | 0.31 | 0.44 |
| 2385N | no | yes | 0.12 | 0.24 | 0.15 | 0.05 | 0.37 | 0.02 | 0.04 | 0.08 | 0.25 | 0.38 | 0.27 | 0.62 | 0.78 |
| 3250 | no | no | 0.41 | 0.70 | 0.47 | 0.88 | 0.51 | 0.47 | 0.36 | 0.36 | 0.46 | 0.85 | 0.47 | 0.40 | 0.50 |
| 2203 | no | no | 0.26 | 0.49 | 0.41 | 0.43 | 0.65 | 0.76 | 0.72 | 0.37 | 0.37 | 0.49 | 0.61 | 0.37 | 0.33 |
| 2089 | no | no | 0.42 | 0.36 | 0.40 | 0.81 | 0.32 | 0.50 | 0.50 | 0.17 | 0.46 | 0.73 | 0.55 | 0.39 | 0.61 |
| 964E | no | no | 0.37 | 0.48 | 0.51 | 0.72 | 0.41 | 0.35 | 0.43 | 0.12 | 0.44 | 0.75 | 0.51 | 0.57 | 0.27 |
| 2783 | no | no | 0.42 | 0.73 | 0.62 | 0.40 | 0.46 | 0.46 | 0.38 | 0.26 | 0.35 | 0.50 | 0.24 | 0.37 | 0.78 |
| 2772 | no | no | 0.54 | 0.82 | 0.64 | 0.57 | 0.42 | 0.42 | 0.11 | 0.29 | 0.24 | 0.60 | 0.34 | 0.37 | 0.66 |
| 2938 | no | no | 0.40 | 0.55 | 0.34 | 0.65 | 0.27 | 0.43 | 0.19 | 0.14 | 0.30 | 0.61 | 0.46 | 0.67 | 0.61 |
| 692 | no | no | | 0.75 | 0.65 | 0.47 | 0.45 | 0.59 | 0.31 | 0.47 | 0.28 | 0.46 | 0.10 | 0.47 | |
| 542 | no | no | 0.34 | 0.36 | 0.34 | 0.47 | 0.50 | 0.39 | 0.27 | 0.10 | 0.25 | 0.27 | 0.13 | 0.70 | 0.88 |
| 3149 | no | no | 0.30 | 0.32 | 0.24 | 0.38 | 0.33 | 0.45 | 0.36 | 0.27 | 0.34 | 0.49 | 0.34 | 0.64 | 0.39 |
| 307 | no | no | 0.29 | 0.44 | 0.49 | 0.24 | 0.55 | 0.13 | 0.19 | 0.35 | 0.39 | 0.52 | 0.26 | 0.56 | 0.27 |
| 2385S | no | no | 0.13 | 0.15 | 0.22 | 0.22 | 0.63 | 0.04 | 0.14 | 0.13 | 0.38 | 0.52 | 0.43 | 0.85 | 0.61 |
| 610 | no | no | 0.53 | 0.10 | 0.07 | 0.45 | 0.25 | 0.29 | 0.26 | 0.07 | 0.32 | 0.43 | 0.22 | 0.58 | 0.61 |
| 2385D | no | no | 0.12 | 0.20 | 0.12 | 0.22 | 0.34 | 0.00 | 0.04 | 0.01 | 0.13 | 0.40 | 0.29 | 0.81 | 0.61 |
| 388 | no | no | 0.21 | 0.31 | 0.20 | 0.25 | 0.40 | 0.11 | 0.27 | 0.00 | 0.03 | 0.28 | 0.26 | 0.37 | 0.39 |
| 405 | no | no | 0.44 | 0.00 | 0.01 | 0.06 | 0.07 | 0.11 | 0.15 | 0.02 | 0.07 | 0.28 | 0.26 | 0.00 | 0.55 |

## 4.2 Relationship of Modeled Wetland Functions to Presumed Wetland Condition

### 4.2.1 Why Important

One potential purpose of wetland rapid-assessment methods is to estimate how degraded or healthy a wetland is, i.e., the wetland's condition. "Condition" of a wetland can be defined by the relative capacities of its functions, by the composition of its biological communities (plants are used most often), or by some combination of these. This guidebook applies these differing perspectives separately.

Confusing the matter further, some assessment methods consider "risk" and the potential stressors that comprise risk to be synonymous with "condition." This is based partly on research showing that wetlands potentially exposed to potential stressors (such as nutrient runoff) tend to have biologically degraded conditions and reduced capacity to function. However, *potential* exposure is not always *actual* exposure, and *potential* stressors are not always *actual* stressors. Therefore, "risk" (the combination of stressors and exposure) is not the same as condition, although varying degrees of correlation may exist.

Using our field estimates, we searched for correlations between indices of risk (that were based on qualitative estimates of stressors, combined in various ways), indices of function, and indices of biological condition. The fact that none of these three components could be measured directly — all being based on indices — considerably complicates any interpretation of the results. We expected that indices of biological condition and function might track similarly, declining as the indices of risk increased. Statistical results are compiled in Table 29 using multiple approaches that addressed the following questions for each variable considered to be a potential indicator of function capacity or condition:

1. Were scores or numeric values from the marshes that were judged beforehand as being "*least* altered" significantly less than those from marshes that were not? If so, the variable might be assumed to increase as wetlands become more degraded ("SM" or "smaller" in column 3 of Table 29, Mann-Whitney test for difference of means) or decrease as wetlands become more degraded ("BIG" or "bigger" in column 3).
2. Were scores or numeric values from the marshes that were judged beforehand as being "*less* altered" significantly less than those from marshes that were not? If so, the variable might be assumed to increase as wetlands become more degraded ("SM" or "smaller" in column 4 of Table 29, Mann-Whitney test for difference of means) or decrease as wetlands become more degraded ("BIG" or "bigger" in column 3).
3. With how many *risk indices* was the variable correlated positively vs. negatively? Variables that have more positive correlations might be assumed to increase as wetlands become more degraded (Spearman rank-correlation, columns 6–9 of Table 29).
4. With how many individual *stressors* (which comprise the risk indices) was the variable correlated positively vs. negatively? Again, variables that have more positive correlations might be assumed to increase as wetlands become more degraded (columns 10–13 of Table 29).
5. With how many individual *non-native plant* variables (which were not included in any of the risk indices) was the variable correlated positively vs. negatively? Again, variables that have more positive correlations increase as wetlands become more degraded,

assuming non-native plants are an acceptable surrogate for “degradation” (last four columns of Table 29).

## Table 29. Comparisons of indicators and functions with risk indices

Abbreviations for the variables shown in the table below are defined in Appendix C. Variable names ending in "Sc" are scores, not raw data.
"Type" is the type of variable:
B = botanical, C = channel dimensions, D = disturbance, F = function score, R = risk index, V = other
"Least-altered vs. others" is the result of the Mann-Whitney test for difference between means of sites designated as least-altered and those not so designated. "Less-altered" is similar but more inclusive (see p. 15):

"same" = no significant difference
"bigger" = least/less altered sites have somewhat higher scores
"BIG" = least/less altered sites have significantly higher scores
"smaller" = least/less altered sites have somewhat lower scores
"SM" = least/less altered sites have significantly lower scores

"Stats" indicates whether the correlations were based on unadjusted data or scores (U) or on data/scores that first had been statistically adjusted (A) to minimize the influence of HGM subclass (i.e., by "partialling out" such effects by including the variables *WetIndexAv* and *MarQdPct* as covariates). Calculations were performed on the file CALCMASTER (see Appendix C).

"Risk Indices" (columns 6–9) are described on p. 88, and the columns are:

"# Neg sig corr" = the number of risk indices for which correlation with the variable was negative and statistically significant
"Neg corr" = the number of risk indices for which correlation with the variable was negative but not statistically significant
(similar for Pos = Positive correlations)
When there are more negative than positive correlations, it means the variable tends to decrease with increased exposure to potential risks. When more are positive than negative, the variable tends to increase with increased risk.

"Component Stressors" are the stressor variables used to construct the risk indices (p. 14)
"Non-native Plants" are variables related to the frequency and percent cover of non-native plants

| Variable | Type | Least-altered vs. others | Less-altered vs. others | Stats | Risk Indices | | | | Component Stressors | | | | Non-native Plants | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | # Neg sig corr | Neg corr | # Pos sig corr | Pos corr | # Neg sig corr | Neg corr | # Pos sig corr | Pos corr | # Neg sig corr | Neg corr | # Pos sig corr | Pos corr |
| AllGT90 | B | | | A | 0 | 3 | 0 | 9 | 0 | 39 | 3 | 38 | 1 | 4 | 0 | 2 |
| AllGT90 | B | same | same | U | 0 | 0 | 0 | 12 | 1 | 18 | 5 | 56 | 1 | 4 | 0 | 2 |
| AllGT90sc | B | | | A | 0 | 9 | 0 | 3 | 3 | 42 | 3 | 32 | 0 | 3 | 1 | 3 |
| AllGT90sc | B | bigger | same | U | 0 | 11 | 0 | 1 | 3 | 48 | 3 | 26 | 0 | 2 | 1 | 4 |
| AnnAvgPC | B | | | A | 0 | 9 | 0 | 3 | 0 | 46 | 2 | 32 | 0 | 2 | 0 | 5 |
| AnnAvgPC | B | same | same | U | 0 | 10 | 0 | 2 | 0 | 48 | 3 | 29 | 0 | 2 | 0 | 5 |
| AnnDefSc | B | | | A | 0 | 2 | 1 | 9 | 0 | 30 | 4 | 46 | 0 | 3 | 0 | 4 |
| AnnDefSc | B | same | same | U | 0 | 3 | 1 | 8 | 0 | 32 | 4 | 44 | 0 | 2 | 0 | 5 |
| AnnFq | B | | | A | 0 | 8 | 0 | 4 | 0 | 41 | 2 | 37 | 0 | 1 | 2 | 4 |
| AnnFq | B | same | same | U | 2 | 7 | 0 | 3 | 1 | 44 | 1 | 34 | 0 | 2 | 4 | 1 |
| AnnMxPC | B | | | A | 0 | 11 | 0 | 1 | 0 | 60 | 2 | 18 | 0 | 1 | 0 | 6 |
| AnnMxPC | B | same | same | U | 0 | 11 | 0 | 1 | 0 | 60 | 2 | 18 | 0 | 2 | 4 | 1 |
| AnnPct | B | | | A | 0 | 1 | 0 | 11 | 0 | 26 | 2 | 52 | 0 | 2 | 0 | 5 |
| AnnPct | B | smaller | same | U | 0 | 1 | 0 | 11 | 0 | 25 | 2 | 53 | 0 | 3 | 0 | 4 |
| DomDefSc | B | | | A | 2 | 9 | 0 | 1 | 4 | 47 | 1 | 28 | 0 | 4 | 0 | 3 |
| DomDefSc | B | same | BIG | U | 2 | 9 | 0 | 1 | 5 | 49 | 1 | 25 | 0 | 2 | 0 | 5 |
| FreshAvgPC | B | | | A | 0 | 8 | 0 | 4 | 1 | 49 | 2 | 28 | 0 | 6 | 0 | 1 |
| FreshAvgPC | B | same | same | U | 0 | 6 | 0 | 6 | 1 | 46 | 1 | 32 | 1 | 5 | 0 | 1 |
| FreshQdPct | B | | | A | 0 | 8 | 0 | 4 | 2 | 49 | 1 | 28 | 0 | 5 | 0 | 2 |
| FreshQdPct | B | same | SM | U | 0 | 5 | 0 | 7 | 0 | 54 | 0 | 26 | 4 | 2 | 1 | 0 |
| MarPC | B | | | A | 0 | 12 | 0 | 0 | 0 | 45 | 1 | 34 | 1 | 1 | 0 | 5 |
| MarPC | B | same | bigger | U | 0 | 10 | 0 | 2 | 1 | 51 | 4 | 24 | 1 | 1 | 4 | 1 |
| MarQdpct | B | | | A | 0 | 12 | 0 | 0 | 0 | 80 | 0 | 0 | 0 | 7 | 0 | 0 |

| Variable | Type | **Least-** altered vs. others | **Less-** altered vs. others | Stats | **Risk Indices** | | | | **Component Stressors** | | | | **Non-native Plants** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | # Neg sig corr | Neg corr | # Pos sig corr | Pos corr | # Neg sig corr | Neg corr | # Pos sig corr | Pos corr | # Neg sig corr | Neg corr | # Pos sig corr | Pos corr |
| MarQdpct | B | same | bigger | U | 0 | 10 | 0 | 2 | 1 | 48 | 3 | 28 | 1 | 1 | 4 | 1 |
| NNavgPC | B | | | A | 8 | 4 | 0 | 0 | 16 | 43 | 3 | 18 | | | | |
| NNavgPC | B | same | same | U | 5 | 5 | 0 | 2 | 17 | 41 | 3 | 19 | | | | |
| NNdefSc | B | | | A | 0 | 8 | 0 | 4 | 2 | 46 | 2 | 30 | | | | |
| NNdefSc | B | same | same | U | 0 | 8 | 0 | 4 | 1 | 47 | 2 | 30 | | | | |
| NNfq | B | | | A | 0 | 11 | 0 | 1 | 1 | 51 | 0 | 28 | | | | |
| NNfq | B | same | same | U | 0 | 12 | 0 | 0 | 1 | 53 | 0 | 26 | | | | |
| NN20PC | B | | | A | 0 | 1 | 0 | 11 | 2 | 23 | 2 | 53 | | | | |
| NN20PC | B | same | same | U | 0 | 2 | 0 | 10 | 2 | 34 | 2 | 42 | | | | |
| NN20PCsc | B | | | A | 4 | 6 | 0 | 2 | 13 | 45 | 3 | 19 | | | | |
| NN20PCsc | B | same | same | U | 5 | 5 | 0 | 2 | 14 | 44 | 4 | 18 | | | | |
| NNmxPC | B | | | A | 6 | 5 | 1 | 0 | 14 | 40 | 1 | 25 | | | | |
| NNmxPC | B | same | same | U | 7 | 3 | 1 | 1 | 14 | 40 | 0 | 26 | | | | |
| ResAllgt90 | B | | | A | 0 | 4 | 0 | 8 | 1 | 34 | 0 | 45 | 0 | 6 | 0 | 1 |
| ResAllgt90 | B | same | same | U | 0 | 3 | 0 | 9 | 1 | 35 | 0 | 44 | 0 | 5 | 0 | 2 |
| ResAnnPct | B | | | A | 0 | 6 | 0 | 6 | 0 | 36 | 4 | 40 | 0 | 2 | 1 | 4 |
| ResAnnPct | B | same | same | U | 0 | 1 | 0 | 11 | 2 | 26 | 1 | 51 | 1 | 3 | 1 | 2 |
| ResNN20 | B | | | A | 0 | 0 | 3 | 9 | 2 | 15 | 7 | 56 | 4 | 1 | 1 | 1 |
| ResNN20 | B | same | same | U | 0 | 0 | 2 | 10 | 2 | 15 | 3 | 60 | 3 | 2 | 1 | 1 |
| ResStolPC | B | | | A | 0 | 3 | 0 | 9 | 0 | 31 | 4 | 45 | 3 | 2 | 1 | 1 |
| ResStolPC | B | same | same | U | 0 | 3 | 1 | 8 | 0 | 28 | 4 | 48 | 2 | 2 | 0 | 3 |
| ResTapPC | B | | | A | 0 | 9 | 0 | 3 | 0 | 49 | 0 | 31 | 0 | 3 | 0 | 4 |
| ResTapPC | B | same | same | U | 0 | 10 | 0 | 2 | 1 | 54 | 0 | 25 | 0 | 5 | 0 | 2 |
| ResTuftPC | B | | | A | 0 | 11 | 0 | 1 | 1 | 66 | 0 | 13 | 1 | 1 | 4 | 1 |
| ResTuftPC | B | same | same | U | 0 | 10 | 0 | 2 | 2 | 65 | 0 | 13 | 1 | 1 | 4 | 1 |
| RhizAvgPC | B | | | A | 3 | 6 | 0 | 3 | 10 | 49 | 4 | 17 | 0 | 3 | 3 | 1 |
| RhizAvgPC | B | same | same | U | 2 | 7 | 0 | 3 | 8 | 43 | 6 | 23 | 1 | 2 | 4 | 0 |
| RhizFq | B | | | A | 0 | 12 | 0 | 0 | 2 | 67 | 1 | 10 | 0 | 2 | 1 | 4 |
| RhizFq | B | same | same | U | 0 | 12 | 0 | 0 | 1 | 63 | 3 | 13 | 0 | 2 | 3 | 2 |
| RhizMxPC | B | | | A | 0 | 10 | 0 | 2 | 8 | 34 | 5 | 33 | 0 | 2 | 4 | 1 |
| RhizMxPC | B | same | same | U | 0 | 9 | 1 | 2 | 8 | 27 | 5 | 40 | 1 | 1 | 4 | 1 |
| SpDefSc | B | | | A | 4 | 8 | 0 | 0 | 9 | 55 | 2 | 14 | 1 | 2 | 0 | 4 |
| SpDefSc | B | same | BIG | U | 3 | 9 | 0 | 0 | 9 | 58 | 1 | 12 | 2 | 0 | 3 | 2 |
| SpPerQdSc | B | | | A | 0 | 11 | 0 | 1 | 2 | 46 | 3 | 29 | 0 | 2 | 2 | 3 |
| SpPerQdSc | B | BIG | same | U | 0 | 12 | 0 | 0 | 2 | 50 | 2 | 26 | 0 | 2 | 3 | 2 |
| SpPerQd | B | | | A | 0 | 11 | 0 | 1 | 2 | 59 | 1 | 18 | 0 | 2 | 2 | 3 |
| SpPerQd | B | same | same | U | 0 | 11 | 0 | 1 | 4 | 56 | 1 | 19 | 0 | 2 | 3 | 2 |
| StolAvgPC | B | | | A | 0 | 4 | 1 | 7 | 2 | 22 | 4 | 52 | 3 | 1 | 1 | 2 |
| StolAvgPC | B | same | same | U | 0 | 5 | 1 | 6 | 2 | 33 | 5 | 40 | 4 | 0 | 1 | 2 |
| StolDefSc | B | | | A | 0 | 1 | 3 | 8 | 0 | 9 | 7 | 64 | 0 | 1 | 0 | 6 |
| StolDefSc | B | same | smaller | U | 0 | 1 | 3 | 8 | 0 | 9 | 9 | 62 | 0 | 1 | 0 | 6 |
| StolFq | B | | | A | 0 | 3 | 0 | 9 | 2 | 24 | 1 | 53 | 3 | 1 | 1 | 2 |
| StolFq | B | same | same | U | 0 | 4 | 0 | 8 | 3 | 29 | 1 | 47 | 3 | 2 | 1 | 1 |
| StolMxPC | B | | | A | 0 | 0 | 2 | 10 | 2 | 10 | 8 | 60 | 3 | 0 | 0 | 4 |
| StolMxPC | B | same | same | U | 0 | 1 | 0 | 11 | 2 | 11 | 7 | 60 | 3 | 1 | 1 | 2 |
| StolPct | B | | | A | 0 | 3 | 0 | 9 | 0 | 32 | 5 | 43 | 0 | 5 | 0 | 2 |
| StolPct | B | BIG | BIG | U | 0 | 6 | 0 | 6 | 0 | 36 | 5 | 39 | 0 | 5 | 0 | 2 |
| TapDefSc | B | | | A | 0 | 11 | 0 | 1 | 1 | 53 | 2 | 24 | 0 | 2 | 0 | 5 |
| TapDefSc | B | same | BIG | U | 0 | 11 | 0 | 1 | 1 | 57 | 2 | 20 | 0 | 2 | 0 | 5 |
| TapFq | B | | | A | 0 | 5 | 0 | 7 | 1 | 18 | 4 | 57 | 1 | 2 | 4 | 0 |
| TapFq | B | same | same | U | 0 | 8 | 0 | 4 | 0 | 43 | 3 | 34 | 0 | 3 | 4 | 0 |
| TapMxPC | B | | | A | 0 | 10 | 0 | 2 | 3 | 46 | 2 | 29 | 0 | 3 | 3 | 1 |
| TapMxPC | B | same | same | U | 0 | 11 | 0 | 1 | 6 | 46 | 2 | 26 | 0 | 2 | 4 | 1 |
| TapPCav | B | | | A | 0 | 7 | 0 | 5 | 1 | 38 | 2 | 39 | 1 | 2 | 0 | 4 |

| Variable | Type | **Least-** altered vs. others | **Less-** altered vs. others | Stats | **Risk Indices** | | | | **Component Stressors** | | | | **Non-native Plants** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | # Neg sig corr | Neg corr | # Pos sig corr | Pos corr | # Neg sig corr | Neg corr | # Pos sig corr | Pos corr | # Neg sig corr | Neg corr | # Pos sig corr | Pos corr |
| TapPCav | B | same | same | U | 0 | 11 | 0 | 1 | 0 | 49 | 0 | 31 | 1 | 2 | 2 | 2 |
| TuftDefSc | B | | | A | 0 | 11 | 0 | 1 | 0 | 49 | 2 | 29 | 1 | 1 | 0 | 5 |
| TuftDefSc | B | same | same | U | 0 | 11 | 0 | 1 | 1 | 43 | 2 | 34 | 1 | 1 | 0 | 5 |
| TuftFq | B | | | A | 0 | 9 | 0 | 3 | 13 | 18 | 4 | 45 | 1 | 0 | 3 | 3 |
| TuftFq | B | bigger | same | U | 0 | 11 | 0 | 1 | 14 | 23 | 2 | 41 | 1 | 0 | 3 | 3 |
| TuftMxPC | B | | | A | 0 | 7 | 0 | 5 | 2 | 51 | 0 | 27 | 1 | 0 | 5 | 1 |
| TuftMxPC | B | same | same | U | 0 | 8 | 0 | 4 | 2 | 50 | 0 | 28 | 1 | 0 | 4 | 2 |
| TuftPCav | B | | | A | 0 | 9 | 0 | 3 | 0 | 46 | 0 | 34 | 1 | 0 | 4 | 2 |
| TuftPCav | B | same | same | U | 0 | 11 | 0 | 1 | 0 | 60 | 0 | 20 | 1 | 0 | 3 | 3 |
| TuftPct | B | | | A | 0 | 9 | 0 | 3 | 2 | 43 | 2 | 33 | 0 | 1 | 0 | 6 |
| TuftPct | B | same | bigger | U | 0 | 11 | 0 | 1 | 2 | 50 | 1 | 27 | 0 | 2 | 0 | 5 |
| CRresabAv | C | | | A | 0 | 0 | 0 | 12 | 0 | 31 | 1 | 48 | 0 | 3 | 0 | 4 |
| CRresabAv | C | same | same | U | 0 | 0 | 0 | 12 | 0 | 30 | 2 | 48 | 0 | 3 | 2 | 2 |
| IncisAv | C | | | A | 0 | 0 | 3 | 9 | 1 | 21 | 8 | 50 | 0 | 5 | 0 | 2 |
| IncisAv | C | same | same | U | 0 | 0 | 2 | 10 | 1 | 20 | 8 | 51 | 0 | 5 | 0 | 2 |
| IncisMax | C | | | A | 0 | 0 | 3 | 9 | 1 | 23 | 13 | 43 | 0 | 5 | 0 | 2 |
| IncisMax | C | same | same | U | 0 | 0 | 2 | 10 | 1 | 23 | 12 | 44 | 0 | 5 | 0 | 2 |
| LogRatioAv | C | | | A | 0 | 11 | 0 | 1 | 6 | 45 | 0 | 29 | 0 | 2 | 2 | 3 |
| LogRatioAv | C | same | same | U | 0 | 9 | 0 | 3 | 5 | 40 | 0 | 35 | 1 | 1 | 3 | 2 |
| LogRatioMx | C | | | A | 0 | 11 | 0 | 1 | 6 | 57 | 0 | 17 | 0 | 3 | 3 | 1 |
| LogRatioMx | C | same | same | U | 0 | 10 | 0 | 2 | 7 | 56 | 0 | 17 | 0 | 2 | 3 | 2 |
| RatioC | C | | | A | 0 | 1 | 0 | 11 | 0 | 34 | 1 | 45 | 0 | 2 | 0 | 5 |
| RatioC | C | same | same | U | 0 | 1 | 0 | 11 | 1 | 32 | 1 | 46 | 0 | 2 | 2 | 3 |
| TopwAv | C | | | A | 0 | 8 | 0 | 4 | 1 | 41 | 2 | 36 | 0 | 4 | 0 | 3 |
| TopwAv | C | same | same | U | 0 | 7 | 0 | 5 | 1 | 42 | 2 | 35 | 0 | 3 | 0 | 4 |
| TopwMax | C | | | A | 0 | 12 | 0 | 0 | 2 | 48 | 1 | 29 | 0 | 4 | 0 | 3 |
| TopwMax | C | same | same | U | 0 | 12 | 0 | 0 | 0 | 50 | 1 | 29 | 0 | 3 | 0 | 4 |
| Atv | D | same | same | | | | | | | | | | | | | |
| Bdg | D | bigger | BIG | | | | | | | | | | | | | |
| Boats | D | same | same | | | | | | | | | | | | | |
| BuffAlt | D | smaller | SM | | | | | | | | | | | | | |
| BuffCov | D | bigger | BIG | | | | | | | | | | | | | |
| Bulldoze | D | same | smaller | | | | | | | | | | | | | |
| C1 | D | smaller | SM | | | | | | | | | | | | | |
| C10 | D | same | SM | | | | | | | | | | | | | |
| C2 | D | same | SM | | | | | | | | | | | | | |
| C3 | D | same | SM | | | | | | | | | | | | | |
| C4 | D | same | SM | | | | | | | | | | | | | |
| C5 | D | same | SM | | | | | | | | | | | | | |
| C6 | D | same | SM | | | | | | | | | | | | | |
| C7 | D | same | SM | | | | | | | | | | | | | |
| C8 | D | same | SM | | | | | | | | | | | | | |
| C9 | D | same | SM | | | | | | | | | | | | | |
| Chemin | D | same | SM | | | | | | | | | | | | | |
| DikeDry | D | same | SM | | | | | | | | | | | | | |
| Dikes | D | smaller | SM | | | | | | | | | | | | | |
| DikeWet | D | smaller | SM | | | | | | | | | | | | | |
| Ditchexcav | D | same | SM | | | | | | | | | | | | | |
| Eroding | D | same | SM | | | | | | | | | | | | | |
| Footvis | D | smaller | SM | | | | | | | | | | | | | |
| Grazing | D | same | same | | | | | | | | | | | | | |
| H1 | D | smaller | SM | | | | | | | | | | | | | |
| H10 | D | smaller | SM | | | | | | | | | | | | | |
| H2 | D | smaller | SM | | | | | | | | | | | | | |

| Variable | Type | Least-altered vs. others | Less-altered vs. others | Stats | Risk Indices | | | | Component Stressors | | | | Non-native Plants | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | # Neg sig corr | Neg corr | # Pos sig corr | Pos corr | # Neg sig corr | Neg corr | # Pos sig corr | Pos corr | # Neg sig corr | Neg corr | # Pos sig corr | Pos corr |
| H3 | D | smaller | SM | | | | | | | | | | | | | |
| H4 | D | smaller | SM | | | | | | | | | | | | | |
| H5 | D | smaller | SM | | | | | | | | | | | | | |
| H6 | D | smaller | SM | | | | | | | | | | | | | |
| H7 | D | smaller | SM | | | | | | | | | | | | | |
| H8 | D | smaller | SM | | | | | | | | | | | | | |
| H9 | D | smaller | SM | | | | | | | | | | | | | |
| HomeDis | D | same | SM | | | | | | | | | | | | | |
| Instabil | D | smaller | SM | | | | | | | | | | | | | |
| Invas | D | same | same | | | | | | | | | | | | | |
| N1 | D | same | SM | | | | | | | | | | | | | |
| N10 | D | same | same | | | | | | | | | | | | | |
| N2 | D | same | smaller | | | | | | | | | | | | | |
| N3 | D | same | SM | | | | | | | | | | | | | |
| N4 | D | same | same | | | | | | | | | | | | | |
| N5 | D | same | SM | | | | | | | | | | | | | |
| N6 | D | same | smaller | | | | | | | | | | | | | |
| N7 | D | same | same | | | | | | | | | | | | | |
| N8 | D | same | SM | | | | | | | | | | | | | |
| N9 | D | same | same | | | | | | | | | | | | | |
| Nutrin | D | smaller | SM | | | | | | | | | | | | | |
| Pilings | D | same | same | | | | | | | | | | | | | |
| Pipes | D | same | smaller | | | | | | | | | | | | | |
| Resseptic | D | same | same | | | | | | | | | | | | | |
| Riprap | D | same | SM | | | | | | | | | | | | | |
| Road | D | smaller | SM | | | | | | | | | | | | | |
| S1 | D | smaller | SM | | | | | | | | | | | | | |
| S10 | D | same | same | | | | | | | | | | | | | |
| S2 | D | smaller | SM | | | | | | | | | | | | | |
| S3 | D | smaller | SM | | | | | | | | | | | | | |
| S4 | D | smaller | smaller | | | | | | | | | | | | | |
| S5 | D | smaller | SM | | | | | | | | | | | | | |
| S6 | D | smaller | smaller | | | | | | | | | | | | | |
| S7 | D | smaller | SM | | | | | | | | | | | | | |
| S8 | D | smaller | SM | | | | | | | | | | | | | |
| S9 | D | smaller | smaller | | | | | | | | | | | | | |
| Sedshed | D | smaller | same | | | | | | | | | | | | | |
| Utilityove | D | same | same | | | | | | | | | | | | | |
| V1 | D | same | same | | | | | | | | | | | | | |
| V10 | D | same | same | | | | | | | | | | | | | |
| V2 | D | same | same | | | | | | | | | | | | | |
| V3 | D | smaller | same | | | | | | | | | | | | | |
| V4 | D | same | same | | | | | | | | | | | | | |
| V5 | D | same | same | | | | | | | | | | | | | |
| V6 | D | same | same | | | | | | | | | | | | | |
| V7 | D | same | same | | | | | | | | | | | | | |
| V8 | D | same | same | | | | | | | | | | | | | |
| V9 | D | same | same | | | | | | | | | | | | | |
| Visits | D | smaller | SM | | | | | | | | | | | | | |
| AF | F | same | same | | | | | | | | | | | | | |
| AF_x | F | | | A | 0 | 4 | 2 | 6 | 4 | 22 | 12 | 42 | 0 | 1 | 1 | 5 |
| AF_x | F | same | same | U | 0 | 4 | 2 | 6 | 2 | 29 | 13 | 36 | 0 | 1 | 1 | 5 |
| AProd | F | same | same | | | | | | | | | | | | | |
| AProd_x | F | | | A | 1 | 1 | 5 | 5 | 2 | 11 | 14 | 53 | 0 | 2 | 0 | 5 |

| Variable | Type | **Least-** altered vs. others | **Less-** altered vs. others | Stats | **Risk Indices** | | | | **Component Stressors** | | | | **Non-native Plants** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | # Neg sig corr | Neg corr | # Pos sig corr | Pos corr | # Neg sig corr | Neg corr | # Pos sig corr | Pos corr | # Neg sig corr | Neg corr | # Pos sig corr | Pos corr |
| AProd_x | F | same | same | U | 1 | 1 | 6 | 4 | 1 | 12 | 13 | 54 | 0 | 2 | 0 | 5 |
| BotC | F | BIG | same | | | | | | | | | | | | | |
| BotC_x | F | | | A | 0 | 1 | 1 | 10 | 0 | 34 | 1 | 45 | 3 | 1 | 1 | 2 |
| BotC_x | F | BIG | same | U | 0 | 3 | 0 | 9 | 6 | 31 | 1 | 42 | 3 | 2 | 1 | 1 |
| Dux | F | same | same | | | | | | | | | | | | | |
| Dux_x | F | | | A | 0 | 2 | 6 | 4 | 11 | 25 | 31 | 13 | 0 | 5 | 1 | 1 |
| Dux_x | F | same | same | U | 0 | 2 | 6 | 4 | 11 | 23 | 31 | 15 | 0 | 4 | 1 | 2 |
| INV | F | BIG | BIG | | | | | | | | | | | | | |
| INV_x | F | | | A | 0 | 4 | 0 | 8 | 3 | 25 | 6 | 46 | 0 | 1 | 1 | 5 |
| INV_x | F | same | same | U | 0 | 5 | 0 | 7 | 1 | 29 | 2 | 48 | 0 | 1 | 2 | 4 |
| LBM | F | BIG | BIG | | | | | | | | | | | | | |
| LBM_x | F | | | A | 0 | 1 | 0 | 11 | 0 | 25 | 4 | 51 | 0 | 4 | 1 | 2 |
| LBM_x | F | same | same | U | 0 | 4 | 0 | 8 | 0 | 31 | 4 | 45 | 0 | 4 | 1 | 2 |
| MFish | F | BIG | BIG | | | | | | | | | | | | | |
| MFish_x | F | | | A | 1 | 5 | 0 | 6 | 9 | 31 | 5 | 35 | 0 | 0 | 1 | 6 |
| MFish_x | F | bigger | BIG | U | 1 | 6 | 1 | 4 | 7 | 34 | 5 | 34 | 0 | 1 | 2 | 4 |
| NFW | F | BIG | BIG | | | | | | | | | | | | | |
| NFW_x | F | | | A | 0 | 9 | 0 | 3 | 15 | 24 | 2 | 39 | 0 | 0 | 0 | 7 |
| NFW_x | F | same | BIG | U | 0 | 9 | 1 | 2 | 14 | 22 | 4 | 40 | 1 | 0 | 3 | 3 |
| RFish | F | same | BIG | | | | | | | | | | | | | |
| RFish_x | F | | | A | 1 | 8 | 0 | 3 | 7 | 27 | 4 | 42 | 0 | 1 | 0 | 6 |
| RFish_x | F | same | BIG | U | 1 | 5 | 1 | 5 | 0 | 32 | 4 | 44 | 1 | 0 | 3 | 3 |
| SBird | F | BIG | BIG | | | | | | | | | | | | | |
| SBird_x | F | | | A | 0 | 8 | 0 | 4 | 13 | 25 | 8 | 34 | 0 | 1 | 1 | 5 |
| SBird_x | F | same | BIG | U | 0 | 8 | 0 | 4 | 12 | 25 | 3 | 40 | 0 | 1 | 3 | 3 |
| WQ | F | same | same | | | | | | | | | | | | | |
| WQ_x | F | | | A | 1 | 1 | 6 | 4 | 15 | 20 | 31 | 14 | 1 | 3 | 1 | 2 |
| WQ_x | F | same | same | U | 1 | 1 | 6 | 4 | 15 | 20 | 31 | 14 | 0 | 3 | 1 | 3 |
| Xpt | F | same | same | | | | | | | | | | | | | |
| Xpt_x | F | | | A | 0 | 1 | 6 | 5 | 1 | 17 | 23 | 39 | 0 | 2 | 0 | 5 |
| Xpt_x | F | same | same | U | 0 | 1 | 6 | 5 | 1 | 19 | 21 | 39 | 1 | 1 | 1 | 4 |
| IntegMax | I | | | A | 0 | 4 | 0 | 8 | 0 | 28 | 1 | 48 | | | | |
| IntegMax | I | same | same | U | 0 | 5 | 0 | 7 | 0 | 33 | 1 | 43 | | | | |
| IntegMean | I | | | A | 0 | 11 | 0 | 1 | 1 | 62 | 0 | 14 | | | | |
| IntegMean | I | same | same | U | 0 | 12 | 0 | 0 | 1 | 62 | 0 | 14 | | | | |
| IntegMin | I | | | A | 0 | 7 | 0 | 5 | 0 | 38 | 0 | 39 | | | | |
| IntegMin | I | BIG | same | U | 0 | 7 | 0 | 5 | 6 | 34 | 0 | 37 | | | | |
| Risk1 | R | smaller | SM | | | | | | | | | | | | | |
| Risk2 | R | smaller | SM | | | | | | | | | | | | | |
| Risk3 | R | smaller | SM | | | | | | | | | | | | | |
| Risk4 | R | smaller | SM | | | | | | | | | | | | | |
| Risk5 | R | smaller | SM | | | | | | | | | | | | | |
| Mx1 | R | smaller | SM | | | | | | | | | | | | | |
| Mx2 | R | smaller | SM | | | | | | | | | | | | | |
| Mx3 | R | smaller | SM | | | | | | | | | | | | | |
| Mx4 | R | smaller | smaller | | | | | | | | | | | | | |
| Mx5 | R | smaller | SM | | | | | | | | | | | | | |
| Alder | V | | | A | 0 | 2 | 0 | 10 | 4 | 21 | 0 | 55 | 0 | 2 | 0 | 5 |
| Alder | V | same | same | U | 0 | 2 | 0 | 10 | 4 | 21 | 0 | 55 | 0 | 1 | 0 | 6 |
| Area | V | | | A | 2 | 2 | 1 | 7 | 15 | 31 | 18 | 16 | 0 | 2 | 0 | 5 |
| Area | V | BIG | BIG | U | 2 | 2 | 1 | 7 | 15 | 31 | 18 | 16 | 0 | 2 | 0 | 5 |
| Bare | V | | | A | 0 | 3 | 0 | 9 | 2 | 28 | 3 | 47 | 0 | 3 | 0 | 4 |
| Bare | V | same | same | U | 0 | 5 | 0 | 7 | 0 | 28 | 2 | 50 | 0 | 4 | 0 | 3 |
| BlindL | V | | | A | 2 | 5 | 0 | 5 | 16 | 29 | 10 | 25 | 0 | 3 | 1 | 3 |

| Variable | Type | **Least-** altered vs. others | **Less-** altered vs. others | Stats | **Risk Indices** | | | | **Component Stressors** | | | | **Non-native Plants** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | # Neg sig corr | Neg corr | # Pos sig corr | Pos corr | # Neg sig corr | Neg corr | # Pos sig corr | Pos corr | # Neg sig corr | Neg corr | # Pos sig corr | Pos corr |
| BlindL | V | BIG | BIG | U | 2 | 6 | 0 | 4 | 14 | 30 | 8 | 28 | 0 | 3 | 1 | 3 |
| Dunal | V | | | A | 1 | 8 | 0 | 3 | 14 | 24 | 6 | 36 | 0 | 3 | 0 | 4 |
| Dunal | V | same | same | U | 1 | 9 | 0 | 2 | 16 | 23 | 4 | 37 | 1 | 1 | 1 | 4 |
| Eelgrass | V | | | A | 7 | 4 | 1 | 0 | 11 | 54 | 4 | 11 | 0 | 2 | 0 | 5 |
| Eelgrass | V | same | same | U | 8 | 3 | 1 | 0 | 12 | 51 | 4 | 13 | 0 | 2 | 4 | 1 |
| Estu_WL | V | | | A | 0 | 8 | 0 | 4 | 1 | 33 | 5 | 41 | 0 | 3 | 1 | 3 |
| Estu_WL | V | BIG | same | U | 0 | 8 | 0 | 4 | 1 | 31 | 5 | 43 | 0 | 3 | 0 | 4 |
| EstuSal | V | | | A | 0 | 0 | 1 | 11 | 3 | 29 | 3 | 45 | 3 | 1 | 1 | 2 |
| EstuSal | V | same | same | U | 0 | 0 | 1 | 11 | 3 | 28 | 3 | 46 | 3 | 2 | 1 | 1 |
| Exits | V | | | A | 0 | 3 | 1 | 8 | 15 | 15 | 14 | 36 | 0 | 4 | 0 | 3 |
| Exits | V | BIG | BIG | U | 0 | 3 | 1 | 8 | 15 | 14 | 15 | 36 | 0 | 3 | 0 | 4 |
| Fetch | V | | | A | 7 | 5 | 0 | 0 | 24 | 43 | 2 | 11 | 1 | 0 | 1 | 5 |
| Fetch | V | BIG | BIG | U | 6 | 6 | 0 | 0 | 25 | 39 | 3 | 13 | 1 | 0 | 2 | 4 |
| Flood | V | | | A | 0 | 6 | 1 | 5 | 5 | 21 | 14 | 40 | 0 | 1 | 1 | 5 |
| Flood | V | same | same | U | 0 | 6 | 1 | 5 | 5 | 23 | 12 | 40 | 1 | 0 | 1 | 5 |
| FormDiv | V | | | A | 1 | 0 | 4 | 7 | 2 | 14 | 27 | 37 | 0 | 4 | 0 | 3 |
| FormDiv | V | same | same | U | 1 | 1 | 3 | 7 | 1 | 15 | 27 | 37 | 0 | 4 | 0 | 3 |
| Fresh | V | | | A | 0 | 1 | 7 | 4 | 2 | 15 | 31 | 32 | 1 | 3 | 1 | 2 |
| Fresh | V | same | same | U | 0 | 0 | 7 | 5 | 2 | 15 | 31 | 32 | 1 | 4 | 1 | 1 |
| FreshSpot | V | | | A | 0 | 8 | 0 | 4 | 5 | 29 | 10 | 36 | 0 | 1 | 0 | 6 |
| FreshSpot | V | same | same | U | 0 | 7 | 0 | 5 | 5 | 25 | 11 | 39 | 1 | 0 | 4 | 2 |
| HOTdis | V | | | A | 1 | 6 | 0 | 5 | 19 | 26 | 7 | 28 | 1 | 2 | 1 | 3 |
| HOTdis | V | BIG | same | U | 1 | 6 | 0 | 5 | 16 | 29 | 9 | 26 | 1 | 2 | 0 | 4 |
| Island | V | | | A | 1 | 0 | 4 | 7 | 1 | 13 | 28 | 38 | 0 | 5 | 0 | 2 |
| Island | V | same | smaller | U | 1 | 0 | 4 | 7 | 1 | 14 | 28 | 37 | 0 | 5 | 0 | 2 |
| Jcts | V | | | A | 0 | 4 | 0 | 8 | 2 | 45 | 3 | 30 | 0 | 0 | 1 | 6 |
| Jcts | V | same | same | U | 0 | 4 | 0 | 8 | 2 | 45 | 3 | 30 | 0 | 0 | 1 | 6 |
| JuncMax | V | | | A | 0 | 5 | 0 | 7 | 13 | 29 | 17 | 21 | 0 | 4 | 1 | 2 |
| JuncMax | V | BIG | BIG | U | 0 | 5 | 1 | 6 | 11 | 31 | 18 | 20 | 0 | 3 | 1 | 3 |
| Lwdchan | V | | | A | 0 | 1 | 0 | 11 | 2 | 29 | 6 | 43 | 4 | 1 | 0 | 2 |
| Lwdchan | V | same | BIG | U | 0 | 0 | 0 | 12 | 1 | 26 | 4 | 49 | 4 | 1 | 0 | 2 |
| Lwdline | V | | | A | 8 | 3 | 1 | 0 | 26 | 21 | 1 | 32 | 1 | 0 | 0 | 6 |
| Lwdline | V | same | same | U | 8 | 3 | 1 | 0 | 26 | 23 | 1 | 30 | 1 | 0 | 0 | 6 |
| Lwdmarsh | V | | | A | 6 | 6 | 0 | 0 | 18 | 50 | 4 | 8 | 0 | 5 | 0 | 2 |
| Lwdmarsh | V | same | same | U | 6 | 6 | 0 | 0 | 17 | 51 | 3 | 9 | 0 | 5 | 0 | 2 |
| MarDis | V | | | A | 0 | 0 | 6 | 6 | 3 | 21 | 17 | 39 | 5 | 0 | 2 | 0 |
| MarDis | V | same | same | U | 0 | 0 | 6 | 6 | 2 | 14 | 18 | 46 | 5 | 0 | 2 | 0 |
| MedVrel | V | | | A | 7 | 3 | 0 | 2 | 14 | 52 | 2 | 12 | 0 | 6 | 0 | 1 |
| MedVrel | V | same | same | U | 6 | 4 | 0 | 2 | 14 | 51 | 2 | 13 | 0 | 6 | 0 | 1 |
| MudW | V | | | A | 8 | 4 | 0 | 0 | 24 | 47 | 1 | 8 | 1 | 1 | 3 | 2 |
| MudW | V | same | BIG | U | 9 | 3 | 0 | 0 | 27 | 42 | 3 | 8 | 2 | 0 | 5 | 0 |
| Panne | V | | | A | 8 | 4 | 0 | 0 | 7 | 61 | 0 | 12 | 0 | 2 | 0 | 5 |
| Panne | V | same | BIG | U | 8 | 4 | 0 | 0 | 8 | 61 | 0 | 11 | 0 | 2 | 1 | 4 |
| Pform | V | | | A | 1 | 10 | 0 | 1 | 4 | 44 | 3 | 29 | 0 | 4 | 0 | 3 |
| Pform | V | bigger | same | U | 1 | 10 | 0 | 1 | 4 | 51 | 3 | 22 | 0 | 5 | 0 | 2 |
| Positn | V | | | A | 0 | 3 | 2 | 7 | 1 | 31 | 12 | 36 | 0 | 4 | 0 | 3 |
| Positn | V | same | SM | U | 0 | 2 | 3 | 7 | 2 | 27 | 12 | 39 | 1 | 4 | 2 | 0 |
| Roost | V | | | A | 2 | 7 | 0 | 3 | 12 | 41 | 0 | 27 | 0 | 2 | 2 | 3 |
| Roost | V | same | bigger | U | 2 | 6 | 0 | 4 | 12 | 42 | 0 | 26 | 0 | 2 | 1 | 4 |
| SalSoilMx | V | | | A | 0 | 7 | 2 | 3 | 4 | 34 | 4 | 38 | 0 | 2 | 4 | 1 |
| SalSoilMx | V | same | same | U | 0 | 8 | 2 | 2 | 2 | 37 | 5 | 36 | 1 | 1 | 5 | 0 |
| SalWatMx | V | | | A | 0 | 10 | 0 | 2 | 3 | 49 | 2 | 26 | 0 | 2 | 5 | 0 |
| SalWatMx | V | same | same | U | 0 | 10 | 0 | 2 | 2 | 54 | 2 | 22 | 0 | 2 | 5 | 0 |
| SeaJoin | V | | | A | 0 | 0 | 2 | 10 | 2 | 21 | 6 | 51 | 0 | 4 | 0 | 3 |

| Variable | Type | Least-altered vs. others | Less-altered vs. others | Stats | Risk Indices | | | | Component Stressors | | | | Non-native Plants | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | # Neg sig corr | Neg corr | # Pos sig corr | Pos corr | # Neg sig corr | Neg corr | # Pos sig corr | Pos corr | # Neg sig corr | Neg corr | # Pos sig corr | Pos corr |
| SeaJoin | V | same | same | U | 0 | 0 | 4 | 8 | 2 | 16 | 8 | 54 | 0 | 5 | 0 | 2 |
| Shade | V | | | A | 3 | 8 | 0 | 1 | 2 | 42 | 1 | 35 | 0 | 3 | 0 | 4 |
| Shade | V | bigger | same | U | 3 | 8 | 0 | 1 | 5 | 40 | 0 | 35 | 2 | 3 | 0 | 2 |
| ShadeLM | V | | | A | 0 | 5 | 0 | 7 | 1 | 39 | 1 | 39 | 1 | 3 | 0 | 3 |
| ShadeLM | V | same | same | U | 0 | 5 | 0 | 7 | 0 | 38 | 1 | 41 | 1 | 5 | 0 | 1 |
| SoilTex | V | | | A | 1 | 1 | 3 | 7 | 17 | 16 | 26 | 21 | 3 | 1 | 0 | 3 |
| SoilTex | V | same | same | U | 1 | 1 | 3 | 7 | 17 | 15 | 25 | 23 | 3 | 2 | 1 | 1 |
| SoilX | V | | | A | 1 | 0 | 10 | 1 | 5 | 8 | 56 | 11 | 1 | 3 | 1 | 2 |
| SoilX | V | smaller | SM | U | 1 | 0 | 10 | 1 | 5 | 7 | 56 | 12 | 1 | 3 | 1 | 2 |
| TranAng | V | | | A | 0 | 4 | 0 | 8 | 1 | 34 | 7 | 38 | 0 | 3 | 0 | 4 |
| TranAng | V | same | same | U | 0 | 3 | 0 | 9 | 0 | 29 | 8 | 43 | 0 | 3 | 0 | 4 |
| TransLength | V | | | A | 3 | 8 | 0 | 1 | 5 | 52 | 0 | 23 | 0 | 1 | 0 | 6 |
| TransLength | V | same | bigger | U | 3 | 8 | 0 | 1 | 7 | 49 | 0 | 24 | 0 | 3 | 0 | 4 |
| Trib | V | | | A | 0 | 1 | 0 | 11 | 0 | 14 | 16 | 50 | 0 | 6 | 1 | 0 |
| Trib | V | same | same | U | 0 | 1 | 0 | 11 | 0 | 15 | 16 | 49 | 0 | 6 | 1 | 0 |
| TribL | V | | | A | 0 | 1 | 5 | 6 | 2 | 22 | 25 | 31 | 1 | 3 | 1 | 2 |
| TribL | V | same | same | U | 0 | 0 | 4 | 8 | 1 | 24 | 25 | 30 | 1 | 4 | 1 | 1 |
| UpEdge | V | | | A | 1 | 0 | 6 | 5 | 1 | 12 | 17 | 50 | 0 | 5 | 0 | 2 |
| UpEdge | V | same | SM | U | 1 | 0 | 6 | 5 | 1 | 12 | 17 | 50 | 0 | 5 | 0 | 2 |
| Wetfield_ | V | | | A | 0 | 1 | 8 | 3 | 3 | 31 | 22 | 24 | 1 | 2 | 1 | 3 |
| Wetfield_ | V | same | same | U | 0 | 0 | 10 | 2 | 2 | 29 | 25 | 24 | 1 | 3 | 1 | 2 |
| WetIndexAvg | V | | | A | 0 | 12 | 0 | 0 | 0 | 80 | 0 | 0 | 0 | 7 | 0 | 0 |
| WetIndexAvg | V | same | same | U | 0 | 1 | 2 | 9 | 2 | 26 | 6 | 46 | 1 | 0 | 4 | 2 |
| Width | V | | | A | 2 | 3 | 3 | 4 | 11 | 29 | 28 | 12 | 0 | 3 | 1 | 3 |
| Width | V | bigger | BIG | U | 2 | 3 | 3 | 4 | 11 | 30 | 28 | 11 | 0 | 2 | 1 | 4 |

### 4.2.2 Function Scores vs. Classification of Sites as Least- or Less-altered

Function capacity scores were computed two ways: (a) with risk variables included (i.e., the scoring models as described in section 3.4.3 and as they currently exist in the spreadsheet), and (b) with the risk variables deleted from the scoring models. The latter computation was done to avoid autocorrelation when examining potential correlations of function capacity scores with wetland condition or risk.

As anticipated, when the unaltered scoring models were used, the wetlands chosen subjectively as “least-altered” scored significantly higher (six functions) or the same (six functions) as more-altered wetlands (Table 29). Similar results were obtained with the wetlands chosen subjectively as “*less*-altered.” However, when indicators related to disturbance or risk were removed from the scoring models, only two functions (*BotC and MFish*) scored higher in least-altered wetlands; none scored lower. When the comparison was broadened to include wetlands categorized only as less (not least) altered, 4 of the 12 functions (*Rfish, Mfish, NFW, SBird*) scored higher in the less-altered wetlands; none scored lower.

### 4.2.3 Modeled Wetland Function vs. Risk Indicators

Correlations were next examined between the scores from the altered models and the risk indices. That analysis suggested that increased risk to wetlands (at least in the manner in which it was estimated) actually might be associated with increased capacity scores for 8 of the 12 functions — *AProd, Afish, BotC, Dux, Inv, LBM, WQ, Xpt* — as indicated by there being more positive than negative correlations with the various risk indices. When correlations between the potential *stressors* that comprise the risk indices were similarly compared with function scores, results were similar. Functions whose scores decreased the most consistently with increases in potential stressors were *BotC, Mfish, NFW, Rfish, and Sbird*. Note that some results might have differed had the correlations been examined within HGM subclass rather than for all sites together.

### 4.2.4 Function Scores vs. Wetland Integrity Indices

When correlations were examined between the function scores (from **un**altered models) and the three indices of wetland integrity (as we devised them: *IntegMean, IntegMax, IntegMin*), the only functions whose decrease with decreasing wetland integrity was statistically significant were *AProd, Inv*, and *Mfish*. None increased significantly with decreasing integrity. Finally, when correlations were examined between the function scores (from altered models stripped of their risk indicators) and the indices of wetland integrity, scores of the following functions increased significantly with our index of integrity: *AProd, BotC, Inv, LBM, WQ,* and *Xpt*. None increased significantly with decreasing integrity. As expected, the three wetland integrity indices showed a decline with increasing environmental risk, but the negative correlation was not statistically significant for any of the risk indices.

In summary, from the above, one can infer that:

- This HGM guidebook's function-scoring models do reflect potential negative alterations (or at least potential risks) to many functions of Oregon's tidal wetlands.
- The strength of the risk vs. functional correlation depends on the scoring models one uses to assess risk and function, as well as how each function is defined. Different model formulations and definitions for assessing risk give somewhat different results.
- Of the three indices of wetland integrity that were considered, the one that correlated with the largest number of indices of risk was *IntegMean*. This is the average of one geomorphic variable (*RatioC*) and seven botanical variables, after applying robust regression to all to minimize the influence of variation from natural factors such as salinity and substrate.

### 4.2.5 The Importance of Wetland Size to Wetland Scores

In many instances, small tidal wetlands, on a per-unit-area basis, function at the same or greater level as large wetlands. Nonetheless, as a general principle, larger wetlands, because of their size, tend to be capable of delivering more services to society, and also tend to be more stable over time (Shreffler and Thom 1993). However, the relationship between wetland size and overall functional capacity cannot easily be quantified, with small increments in size probably having a bigger effect on functions of small than large wetlands. Much depends on wetland shape, subclass, and the particular combination of other factors (as defined partly by this guidebook's indicators) that interact at a given location. For that reason, and because of the intended uses of this method, "wetland size" was not included directly as an indicator of any function. In this particular set of 120 tidal wetlands, model-based scores of the following indicators of function tended to increase the most consistently (and were statistically significant) with increasing wetland size: *Width, BlindL, Jcts, Exits, Pform, SoilFine, TranAng, LWDmarsh, Panne, Roost,* and *LWDchan.* Others increased with increasing marsh size just among wetlands of a particular HGM subclass. Ultimately, scores of only one function (Sbird) showed a statistically significant increase among the survey wetlands of increasing size, but some other functions showed non-significant increases: Dux, WQ, NFW, Mfish, Inv, Rfish, Xpt, and Afish. No indicators of risk to wetland integrity showed a statistically significant increase with increasing wetland size, and two diminished significantly among the larger surveyed wetlands: *BuffAlt* and *FootVis*.

One consequence of size bias in the indicators and scoring models is that when an assessment unit is defined to include only part of a marsh, or any time a small wetland is compared with a larger one, the just-named indicators and functions will tend artificially to score low. In the case of the botanical indicators used in this method to assess integrity across wetlands of various sizes, the final scoring models automatically adjust for area differences based on results from an earlier application of robust regression. That was not an option for most other variables because most were based on categorical rather than continuous numeric data. Moreover, if an indicator is completely absent from a wetland, simply multiplying the function score by some area-adjusting coefficient does not remedy the bias. The only indicators that *de*creased significantly with increasing wetland size were *UpEdge* and *Island.*

### 4.2.6 Environmental Correlates of Selected Plant Indices, Groups, and Species

Key factors that influence tidal marsh plants typically include elevation (flood duration), salinity, substrate type, soil oxygen, and competition. Plants sometimes respond to these by gradually forming distinctive associations of species. These may be defined at multiple scales. In the Pacific Northwest, several botanists have attempted to define such associations, e.g., Disraeli and Fonda 1978; Jefferson 1975; Liverman 1981; Hutchinson 1982, 1988; Burg et al. 1980; Ewing 1983; Brophy 2000, 2002; and in some cases to define the tidal elevations within which they or individual species occur, e.g., Taylor 1980, Frenkel and Eilers 1976, Frenkel et al. 1981, Hood et al. 2003, Elliott 2004. This project was not intended to define plant associations associated with each of the HGM subclasses. Nonetheless, correlations between individual plant species and a host of environmental variables (as well as with other plant species) were examined. Before doing so, species richness was examined (section 4.2.6.1) and species data were pooled (section 4.2.6.2) according to the species functions and values groups defined earlier. The “functions groups” were defined primarily by characteristic root structures. Most correlations were run two ways: unadjusted and adjusted (Spearman rank correlation, 0.05 significance level). Adjusted correlations were ones where the relationship between two variables was analyzed only after attempting to statistically “partial out” the confounding effects of salinity and wetness (flooding duration). If either type of correlation was found to be statistically significant, the correlation is reported below. In most cases, partialling out the potentially confounding variables did not qualitatively change the statistical significance (or lack of it) between two variables, and in any case was very approximate due to the coarse indirectness with which the potentially confounding variables were assessed. The correlation analysis was done using data from all 120 tidal wetlands. Additional correlations and/or different results might result if data within each tidal wetland subclass were analyzed separately. As with all correlation analyses, presence of significant correlation should not be interpreted as evidence of causation.

### *4.2.6.1 Species Richness and Dominance*

Plant species richness was represented in two ways: (a) number of wetland species per site, and (b) number of wetland species averaged by number of quadrats surveyed per site (*SpPerQd*). The latter is expected to be a less-biased representation because it attempts to adjust for slight differences among sites in number of quadrats surveyed. As expected, these two representations of richness were significantly and positively correlated. Only "wetland" species (those considered FAC, FAC+, FACW, or OBL) were included in the tallies (Figure 8). The total number of wetland species per marsh averaged 15.4 (range = 7–27), using the dual marsh transect method described in Part 1. Species we found only along a marsh's internal channel network are not included in this. Among all sites, the number of species per quadrat along the marsh transects averaged 3.84 (range = 1.37–7.45). Percentiles are shown in Table 18.

Our data indicated that richness of wetland plants, as represented by wetland species per quadrat (*SpPerQd*), was significantly greater in tidal wetlands that had the following characteristics:

- long wetland transects (e.g., wider marshes, with quadrats spaced further apart)
- closer to the estuary's mouth (*MarDis, Positn*)
- drier conditions, as implied by less cover of wetland obligate species (*WetIndexAv*)
- high channel complexity (*Jcts, Exits*)
- less boat traffic
- less risk of excessive nutrient inputs (risk indices *N3* and *N8*)
- adjoined by sand dunes (surprisingly)
- lower percent cover and frequency of non-native plant species

The correlation between marsh area and species richness was positive but was not statistically significant for either representation of richness. This is perhaps because (a) most of the surveyed marshes were large and thus relatively immune to detectable species-area effects, (c) all wetland species were included (rather than just the wetland species having a minimum percent cover), or (d) marsh boundaries were ill-defined in functional terms, thus confounding the computations. Similarly, the number of wetland plant species per site correlated positively but not significantly with transect length.

Based on floristic data from a few small urban tidal marshes, the following regression model was proposed by Shreffler and Thom (1993):

$$y = -36.392 + 19.596*\mathrm{LOG}(A)$$

where $y$ equals the number of wetland plant species and $A$ is site area in square meters.

Our data suggest the following model for predicting the same variables:

$$y = 12.381 + 0.590*\mathrm{LOG}(A)$$

When total transect length ($L$, in ft) rather than area is used, the model is:

$$y = 13.468 + 0.764*\mathrm{LOG}(L)$$

Our model for predicting the alternative variable (*SpPerQd*) from area is:

$$2.666 + 0.256*\mathrm{LOG}(A)$$

And the model for predicting it from transect length (x, in ft) is:

$$2.293 + 0.676*\mathrm{LOG}(L)$$

*However*, the coefficient of determination for all of our models shown above was less than 0.06, indicating that neither marsh area nor total transect length alone explained more than 6% of the variation in tidal plant species richness.

Contrary to expectations, our data did not show any significant correlation between tidal plant richness (mean per quadrat) and either salinity or elevation. The lack of correlation might have been due to the coarseness with which these abiotic variables were measured.

With regard to species dominance, analysis of our data showed that tidal marshes with the following characteristics tended to have the greatest proportion of their quadrats dominated strongly (>90 percent cover) by a single plant species:

- farther from the estuary's mouth (*MarDis, Positn*)
- longer-duration flooding as implied by greater cover of wetland obligate species (*WetIndexAv*)
- greater boat traffic and presence of pilings near the marsh
- not adjoined by sand dunes
- presence of freshwater tributaries
- presence of many logs on the marsh surface
- marshes with lower proportion of quadrats containing non-native plant species

In an average marsh, 21% of the marsh quadrats were so strongly dominated by a single species (range = 0 to 79%). Species dominance, as defined by this variable, did not show a statistically strong relationship with any of the risk indices.

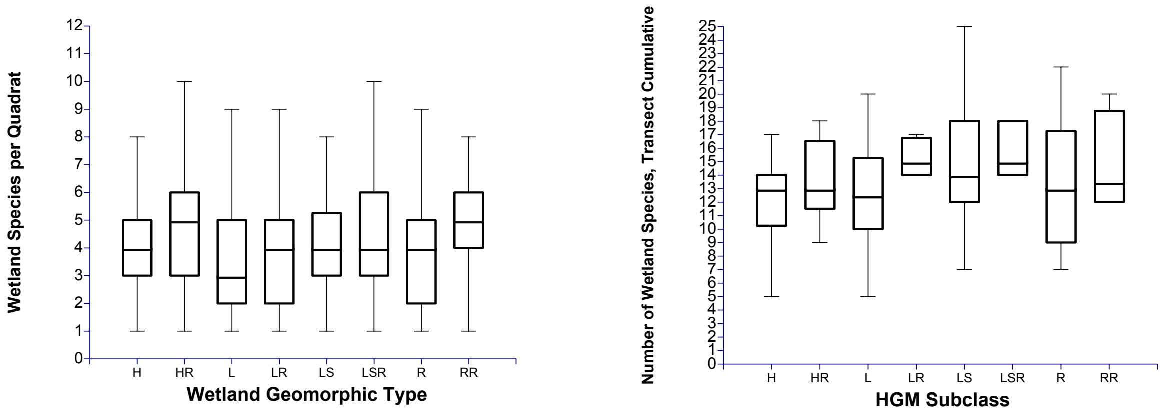

**Figure 8. Plant species richness comparisons of Oregon tidal marshes of different HGM subclasses**

H = high marsh, HR = high marsh reference sites, L = low marsh (excluding sandspits), LR = low marsh reference sites (excluding sandspits), LS = low marsh on sandspits, LSR = low marsh reference sites on sandspits, R = river-sourced tidal wetlands, RR = river-sourced tidal wetland reference sites. Comparisons are not between subclasses within the same wetland (e.g., high vs. low marsh), but rather among separate wetlands that have varied proportions of the different subclasses.

#### *4.2.6.2 Plant Functional and Value Groups*

**Non-native Species**

Non-native plants (a "value" group) typically were present in 98% of the quadrats in a marsh (range = 55–100%) and where present, their percent cover within the surveyed quadrats averaged 81% (Figure 9). The most prevalent non-native plant species were *Agrostis stolonifera, Phalaris arundinacea, Cotula coronopifolia,* and *Lotus corniculatus*. A total of 35 non-native species were found among the 120 surveyed marshes. Non-natives as a group were significantly more prevalent in tidal marshes that had the following characteristics:

- higher soil and water salinity, and closer to the estuary mouth, with less shade and no or few freshwater tributaries
- less woody debris in internal marsh channels
- larger open-water distance (fetch) and/or mudflat adjoining the marsh
- new and/or relatively unstable substrates
- not located along coastal spits
- more complexity of internal marsh channel networks (*Jcts*)
- relatively wet substrate (as suggested by proportionally more cover of obligate wetland plants)

Frequency and percent cover of non-native plants did not show a significant positive correlation with estimated risk of excessive nutrient inputs or upland buffer width, even after using the regression procedures (described in section 2.6) to minimize the influence of confounding factors such as salinity and substrate. Contrary to expectations, a few of the non-native plant variables actually decreased, coincident with increased risk of excessive nutrient inputs.

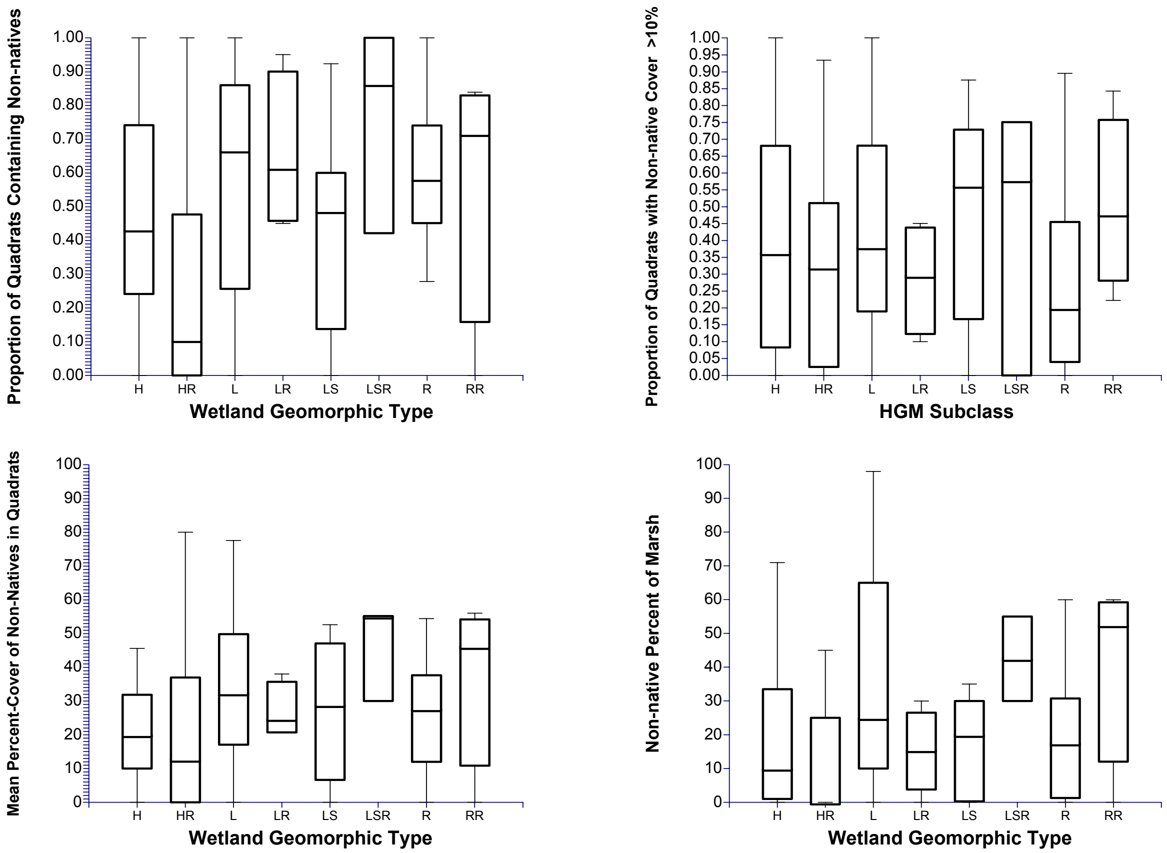

**Figure 9. Comparisons of the non-native plant component of Oregon tidal marshes of different HGM subclasses**

H = high marsh, HR = high marsh reference sites, L = low marsh (excluding sandspits), LR = low marsh reference sites (excluding sandspits), LS = low marsh on sandspits, LSR = low marsh reference sites on sandspits, R = river-sourced tidal wetlands, RR = river-sourced tidal wetland reference sites. The chart at the lower right is based on visual estimates across the entire expanse of each marsh, and so is influenced by marsh size, with estimates from larger or less accessible marshes being much less accurate.

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## Annual Species

In most tidal marshes, perennial rather than annual species comprise a larger proportion of the flora. Annual species were present in an average of 26% of the quadrats in a marsh (range = 1–83%). Where present, their percent cover within quadrats averaged 9% (range = 1–75%). Data are depicted in Figure 10 and percentiles are given in Table 18. The most prevalent annual plant species were *Atriplex patula, Eleocharis palustris*, and *Cuscuta salina*. Analysis of our data showed that annual species were significantly more prevalent (present in a greater proportion of quadrats and/or averaged greater percent cover in quadrats) in tidal marshes that had higher soil and water salinity, larger values for the sediment risk index, and less woody debris in tidal channels.

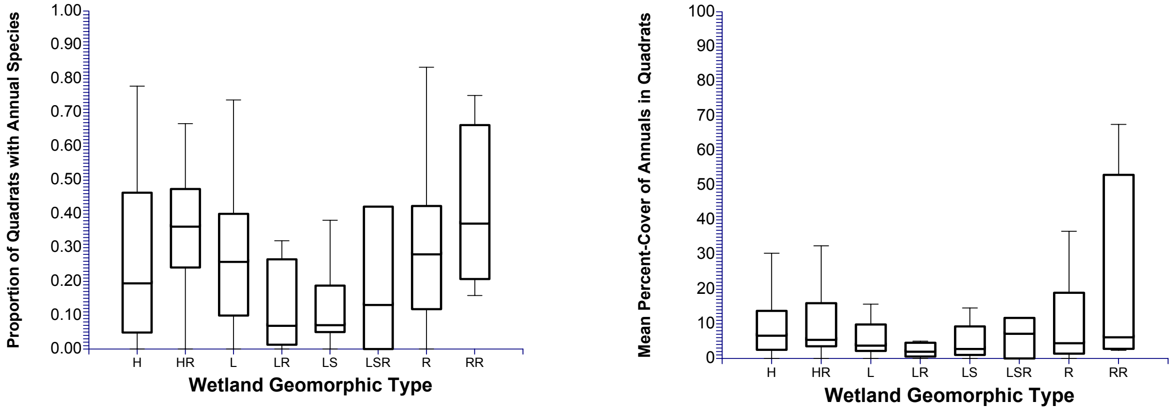

**Figure 10. Comparisons of the annual plant component of Oregon tidal marshes of different HGM subclasses**

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### Rhizotomous Species

Species that expand over a marsh at least partly with rhizomes were present in an average of 96% of the quadrats per marsh. Where present, their percent cover within quadrats averaged 66%. The most prevalent rhizotomous plant species were *Carex lyngbyei, Juncus balticus, Triglochin maritimum,* and *Salicornia virginica*. Rhizotomous species were significantly more prevalent (present in a greater proportion of quadrats and/or averaged greater percent cover in quadrats) in tidal marshes that had one or more of the following characteristics:

- several pannes
- greater soil and water salinity
- greater distance from head-of-tide
- larger open-water distance (fetch) and/or more extensive adjoining mudflats
- potentially unstable substrates
- decreased overall risk from human-related disturbances (indices *Mx1, Mx2, Mx5*), especially reduced risks from overenrichment and vegetation-disturbing activities, but increased proximity to boat traffic and areas used by off-road vehicles
- relatively wet substrate (as suggested by proportionally more cover of obligate wetland plants)
- smaller marsh area

### Stoloniferous Species

Species that spread across a marsh primarily with stolons were present in an average of 74% of the quadrats per marsh, and where present, their percent cover within quadrats averaged 37%. Data are summarized in Figure 12 and percentiles are shown in Table 18. The most prevalent stoloniferous species were *Argentina egedii* (which also can have fibrous roots), *Agrostis stolonifera*, and *Distichlis spicata* (which also can be rhizotomous). Stoloniferous species were significantly more prevalent (present in a greater proportion of quadrats and/or averaged greater percent cover in quadrats) in tidal marshes that had one or more of the following characteristics:

- larger marsh width and area
- greater channel network complexity (*Exits, Jcts*) with more wood (*LWDchan*)
- less nearby boat traffic and less alteration of adjoining upland buffer

- closer to head-of-tide
- less shade
- higher risk of potential ongoing or historical disturbance (indices *Risk4, Risk5*), especially hydrologic (indices *H1–2, 4–7, 9–10*), nutrient (indices *N4, 9*), and vegetation (*V1–5*) disturbance
- relatively dry substrate (as suggested by proportionally less cover of obligate wetland plants)

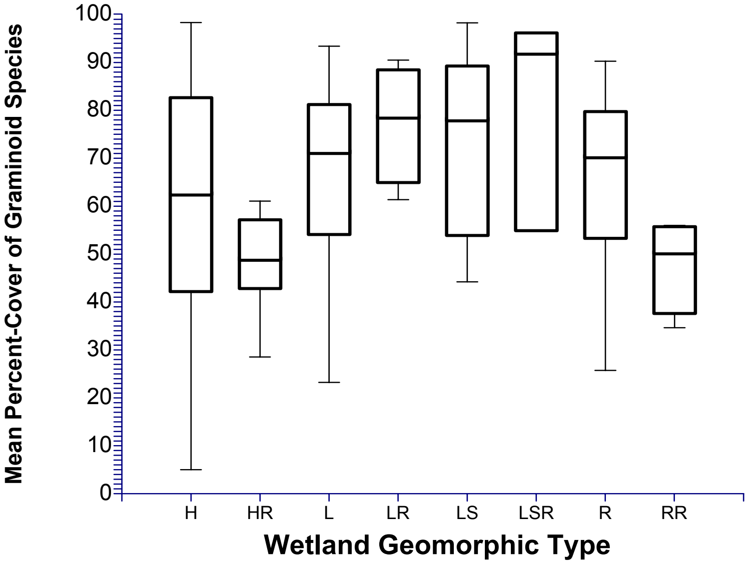

**Figure 11. Comparisons of the graminoid (grasslike taxa) component of Oregon tidal marshes of different HGM subclasses**

### Tap-rooted Species

Species that characteristically are rooted only with a taproot were present in an average of 36% of the quadrats per marsh, and where present, their percent cover within quadrats averaged 10% (range 1–56%). Percentiles are shown in Table 18. The most prevalent tap-rooted species were *Atriplex patula, Grindelia stricta*, and *Plantago maritima*. Taprooted species were significantly more prevalent (present in a greater proportion of quadrats and/or averaged greater percent cover in quadrats) in tidal marshes that had one or more of the following characteristics:

- more-extensive alterations of their upland buffers
- closer to the estuary mouth, especially on or near coastal sand spits
- less channel network complexity (*Jcts*) and less wood (*LWDchan*)
- higher risk of potential ongoing or historical disturbance (indices *Mx1, 2, 4, 5, Risk4*), but less risk specifically from potential sources of overenrichment (*N1, 2, 4, 6, 7, 9*).
- relatively dry substrate (as suggested by proportionally less cover of obligate wetland plants)

### Tuft-rooted Species

Tuft-rooted species were present in an average of 36% of the quadrats per marsh, and where present, their percent cover within quadrats averaged 15% (range = 1–76%). Data are summarized in Figure 12 and percentiles are given in Table 18. The most prevalent tuft-rooted species were *Deschampsia caespitosa* and *Hordeum brachyantherum*. Tuft-rooted species were significantly more prevalent (present in a greater proportion of quadrats and/or averaged greater percent cover in quadrats) in tidal marshes that had one or more of the following characteristics:

- larger marsh area
- greater channel network complexity (*Exits*)
- higher salinity in adjoining tidal waters, and closer to the estuary mouth
- higher risk of ongoing or historical contaminant inputs (indices *C4, 5*) and external inputs of sediments, but lesser risk of internal soil disturbance (indices *S3, S6–9*)
- lesser risk of ongoing or historical hydrologic disruption (indices *H1, H5*)
- relatively dry substrate (as suggested by proportionally less cover of obligate wetland plants)

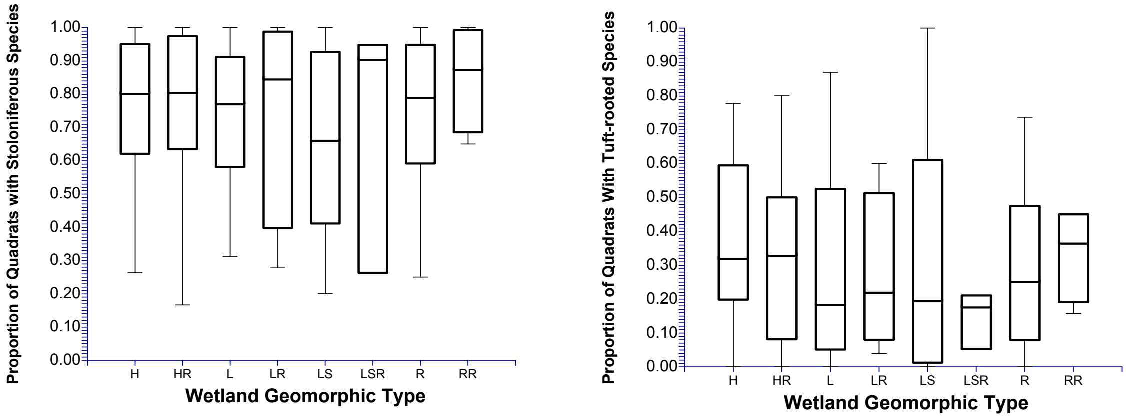

**Figure 12. Comparisons of the stolon- and tuft-rooted plant components of Oregon tidal marshes of different HGM subclasses**

*4.2.6.3 Species-level Correlations*

Species-level data on frequency and percent cover are presented in Table 30 and Table 31. Positive and negative associations among particular species are shown in Table 32 and Table 33. Species correlations with environmental variables are presented in Table 34. These data should prove useful for defining Oregon's tidal wetland plant associations, and for suggesting targets for restoration projects.

## Table 30. Frequency, percent cover, and associated relative elevation and relative distance from tidal water of plant species along marsh transects

| Species | # of wetlands | % of quadrats where present | # of quads where >1% cover | # of quads where >10% cover | # of quads where >20% cover | # of quads where >50% cover | # of quads where >90% cover | Maximum percent cover | Mean percent cover where present | Maximum proportion of quadrats in any marsh | Elevation relative to deepest point on transect | Elevation relative to deepest vegetated point on transect | Distance (%) relative to bay /river |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Achillea millefolium* | 28 | 2.47 | 29 | 18 | 7 | 0 | 0 | 40 | 7.16 | 0.46 | 0.96 | 0.53 | 57.16 |
| *Agrostis stolonifera* | 94 | 34.80 | 207 | 196 | 174 | 122 | 41 | 100 | 32.90 | 1.00 | 0.83 | 0.59 | 53.89 |
| *Ammophila arenaria* | 17 | 1.10 | 17 | 10 | 7 | 3 | 0 | 70 | 14.86 | 0.24 | 0.91 | 0.87 | 68.59 |
| *Angelica lucida* | 17 | 1.22 | 12 | 4 | 1 | 0 | 0 | 20 | 3.68 | 0.32 | 1.11 | 0.87 | 61.87 |
| *Argentina egedii* | 100 | 33.27 | 200 | 178 | 146 | 78 | 11 | 100 | 23.24 | 1.00 | 0.86 | 0.61 | 55.28 |
| *Athyrium filix-femina* | 2 | 0.27 | 5 | 5 | 4 | 2 | 1 | 90 | 35.29 | 0.20 | 0.61 | 0.61 | 74.08 |
| *Atriplex patula* | 72 | 11.10 | 84 | 45 | 22 | 4 | 0 | 60 | 6.02 | 0.71 | 0.77 | 0.52 | 54.93 |
| *Bidens cernua* | 2 | 0.59 | 14 | 14 | 11 | 5 | 2 | 95 | 41.54 | 0.68 | 0.66 | 0.66 | 51.57 |
| *Carex lyngbyei* | 88 | 31.54 | 224 | 205 | 194 | 169 | 113 | 100 | 43.99 | 1.00 | 0.72 | 0.49 | 46.39 |
| *Carex obnupta* | 61 | 15.69 | 133 | 127 | 112 | 78 | 39 | 100 | 41.80 | 0.95 | 0.76 | 0.55 | 58.06 |
| *Castilleja ambigua* | 2 | 0.20 | 5 | 1 | 1 | 0 | 0 | 20 | 8.00 | 0.25 | 0.83 | 0.65 | 40.14 |
| *Cicuta douglasii* | 1 | 0.04 | 0 | 0 | 0 | 0 | 0 | 1 | 1.00 | 0.05 | 0.84 | 0.38 | 1.56 |
| *Cirsium arvense* | 7 | 0.51 | 8 | 4 | 2 | 1 | 0 | 60 | 13.00 | 0.30 | 1.31 | 1.09 | 55.02 |
| *Cirsium vulgare* | 2 | 0.16 | 0 | 0 | 0 | 0 | 0 | 1 | 1.00 | 0.30 | 0.69 | 0.69 | 30.10 |
| *Cordylanthus maritimus v. palustris* | 6 | 0.63 | 6 | 3 | 2 | 1 | 0 | 75 | 11.07 | 0.21 | 0.58 | 0.54 | 62.45 |
| *Cotula coronopifolia* | 27 | 2.71 | 39 | 19 | 11 | 0 | 0 | 45 | 8.97 | 0.75 | 0.42 | 0.35 | 36.60 |
| *Cuscuta salina* | 29 | 5.73 | 48 | 13 | 0 | 0 | 0 | 15 | 3.20 | 0.55 | 0.80 | 0.57 | 47.24 |
| *Cytisus scoparius* | 3 | 0.04 | 1 | 0 | 0 | 0 | 0 | 5 | 5.00 | 0.06 | 1.17 | 1.17 | 16.62 |
| *Deschampsia caespitosa* | 92 | 21.54 | 161 | 141 | 108 | 41 | 1 | 90 | 16.81 | 0.83 | 0.85 | 0.58 | 48.80 |
| *Distichlis spicata* | 71 | 26.40 | 179 | 165 | 140 | 93 | 17 | 100 | 27.76 | 1.00 | 0.71 | 0.50 | 45.74 |
| *Eleocharis palustris* | 42 | 6.98 | 88 | 71 | 52 | 35 | 8 | 95 | 29.22 | 0.64 | 0.45 | 0.30 | 48.92 |
| *Eleocharis parvula* | 47 | 4.32 | 69 | 56 | 37 | 17 | 3 | 100 | 25.04 | 0.77 | 0.51 | 0.44 | 44.42 |
| *Eleocharis sp.* | 2 | 0.16 | 3 | 2 | 0 | 0 | 0 | 15 | 8.67 | 0.10 | 0.66 | 0.66 | 39.30 |
| *Epilobium ciliatum var. watsonii* | 5 | 0.47 | 5 | 3 | 1 | 0 | 0 | 30 | 5.64 | 0.21 | 0.83 | 0.70 | 45.23 |
| *Epilobium sp.* | 2 | 0.08 | 1 | 0 | 0 | 0 | 0 | 5 | 3.00 | 0.06 | 0.78 | 0.68 | 32.32 |
| *Equisetum arvense* | 1 | 0.08 | 2 | 2 | 0 | 0 | 0 |  |  | 0.07 | 0.52 | 0.52 | 17.39 |

| Species | # of wetlands | % of quadrats where present | # of quads where >1% cover | # of quads where >10% cover | # of quads where >20% cover | # of quads where >50% cover | # of quads where >90% cover | Maximum percent cover | Mean percent cover where present | Maximum proportion of quadrats in any marsh | Elevation relative to deepest point on transect | Elevation relative to deepest vegetated point on transect | Distance (%) relative to bay /river |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Equisetum hyemale* | 1 | 0.08 | 1 | 0 | 0 | 0 | 0 | 5 | 3.00 | 0.07 | 0.64 | 0.63 | 11.88 |
| *Equisetum sp.* | 4 | 0.20 | 2 | 1 | 0 | 0 | 0 | 15 | 5.50 | 0.10 | 0.81 | 0.81 | 40.07 |
| *Erechtites glomerata* | 6 | 0.63 | 9 | 4 | 3 | 0 | 0 | 20 | 6.38 | 0.45 | 0.82 | 0.71 | 58.90 |
| *Festuca arundinacea* | 1 | 0.43 | 7 | 3 | 0 | 0 | 0 | 15 | 5.40 | 0.55 | 0.82 | 0.82 | 55.23 |
| *Festuca rubra* | 31 | 4.04 | 68 | 59 | 48 | 31 | 6 | 99 | 33.54 | 0.82 | 0.92 | 0.82 | 61.84 |
| *Galium aparine* | 14 | 2.63 | 15 | 7 | 2 | 0 | 0 | 40 | 3.84 | 0.76 | 0.90 | 0.62 | 57.35 |
| *Galium trifidum* | 10 | 1.29 | 13 | 1 | 1 | 0 | 0 | 20 | 3.27 | 0.48 | 0.92 | 0.66 | 55.80 |
| *Gaultheria shallon* | 4 | 0.04 | 1 | 1 | 1 | 0 | 0 | 40 | 40.00 | 0.05 | 1.04 | 0.81 | 81.04 |
| *Glaux maritima* | 37 | 5.45 | 52 | 18 | 6 | 0 | 0 | 40 | 4.54 | 0.55 | 0.87 | 0.53 | 54.40 |
| *Grindelia stricta* | 51 | 10.40 | 105 | 77 | 52 | 11 | 1 | 90 | 12.32 | 0.70 | 0.87 | 0.61 | 52.12 |
| *Heracleum lanatum* | 10 | 0.43 | 4 | 2 | 0 | 0 | 0 | 5 | 1.89 | 0.11 | 1.08 | 0.75 | 52.09 |
| *Holcus lanatus* | 17 | 1.57 | 23 | 12 | 7 | 2 | 1 | 90 | 10.00 | 0.25 | 0.98 | 0.79 | 56.22 |
| *Hordeum brachyantherum* | 55 | 6.63 | 58 | 25 | 7 | 1 | 0 | 55 | 4.79 | 0.70 | 0.86 | 0.59 | 47.25 |
| *Hordeum jubatum* | 3 | 0.16 | 1 | 0 | 0 | 0 | 0 | 5 | 2.33 | 0.08 | 0.72 | 0.72 | 64.60 |
| *Hypochaeris radicata* | 5 | 0.71 | 9 | 5 | 2 | 1 | 0 | 50 | 8.13 | 0.65 | 0.78 | 0.76 | 53.00 |
| *Jaumea carnosa* | 44 | 14.24 | 128 | 119 | 106 | 38 | 4 | 95 | 25.72 | 1.00 | 0.72 | 0.58 | 43.91 |
| *Juncus balticus* | 87 | 24.79 | 192 | 178 | 144 | 88 | 9 | 95 | 26.41 | 0.95 | 0.85 | 0.54 | 55.03 |
| *Juncus bufonius* | 6 | 0.31 | 6 | 2 | 1 | 1 | 0 | 65 | 15.42 | 0.30 | 0.92 | 0.88 | 30.28 |
| *Juncus effusus* | 21 | 1.96 | 36 | 30 | 22 | 7 | 0 | 75 | 22.33 | 0.64 | 1.01 | 0.90 | 56.16 |
| *Juncus gerardii* | 8 | 0.94 | 18 | 14 | 9 | 9 | 2 | 90 | 31.88 | 0.38 | 0.95 | 0.75 | 62.98 |
| *Juncus lesueurii* | 9 | 1.14 | 19 | 13 | 8 | 3 | 0 | 55 | 16.83 | 0.35 | 0.69 | 0.64 | 64.69 |
| *Juncus sp.* | 6 | 0.31 | 6 | 2 | 2 | 0 | 0 | 25 | 9.50 | 0.10 | 1.11 | 0.81 | 69.01 |
| *Juncus tenuis* | 2 | 0.08 | 1 | 1 | 1 | 0 | 0 | 30 | 15.50 | 0.10 | 0.56 | 0.56 | 56.67 |
| *Lathyrus palustris* | 5 | 0.43 | 4 | 3 | 1 | 0 | 0 | 40 | 7.00 | 0.14 | 0.93 | 0.66 | 76.36 |
| *Lilaeopsis occidentalis* | 31 | 2.82 | 47 | 32 | 19 | 9 | 2 | 100 | 18.81 | 0.50 | 0.35 | 0.26 | 42.68 |
| *Limonium californicum* | 6 | 1.06 | 20 | 16 | 13 | 4 | 1 | 100 | 24.79 | 0.33 | 0.63 | 0.61 | 61.61 |
| *Limosella aquatica* | 1 | 0.04 | 1 | 0 | 0 | 0 | 0 |  |  | 0.05 | 0.00 | 0.00 | 0.00 |
| *Lonicera involucrata* | 7 | 0.51 | 9 | 8 | 7 | 2 | 1 | 95 | 27.33 | 0.30 | 0.84 | 0.53 | 57.51 |
| *Lotus corniculatus* | 21 | 3.45 | 60 | 35 | 19 | 1 | 0 | 50 | 11.99 | 0.80 | 0.85 | 0.82 | 63.56 |
| *Ludwigia palustris* | 2 | 0.27 | 5 | 4 | 2 | 1 | 0 | 50 | 19.00 | 0.32 | 0.76 | 0.76 | 46.85 |
| *Lysichiton americanum* | 3 | 0.16 | 2 | 1 | 0 | 0 | 0 | 10 | 4.25 | 0.10 | 0.58 | 0.54 | 56.61 |
| *Lysimachia sp.* | 2 | 0.20 | 1 | 0 | 0 | 0 | 0 | 5 | 1.80 | 0.25 | 1.88 | 1.88 | 57.96 |

| Species | # of wetlands | % of quadrats where present | # of quads where >1% cover | # of quads where >10% cover | # of quads where >20% cover | # of quads where >50% cover | # of quads where >90% cover | Maximum percent cover | Mean percent cover where present | Maximum proportion of quadrats in any marsh | Elevation relative to deepest point on transect | Elevation relative to deepest vegetated point on transect | Distance (%) relative to bay /river |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Lythrum salicaria* | 5 | 0.90 | 17 | 9 | 5 | 1 | 0 | 50 | 10.91 | 0.58 | 0.68 | 0.64 | 58.89 |
| *Melilotus albus* | 3 | 0.27 | 5 | 3 | 0 | 0 | 0 | 1 | 1.00 | 0.17 | 0.71 | 0.71 | 68.83 |
| *Melilotus sp.* | 2 | 0.16 | 3 | 1 | 0 | 0 | 0 | 1 | 1.00 | 0.17 | 0.69 | 0.68 | 69.40 |
| *Mentha pulegium* | 4 | 0.20 | 4 | 1 | 0 | 0 | 0 | 5 | 5.00 | 0.07 | 0.53 | 0.53 | 46.68 |
| *Oenanthe sarmentosa* | 17 | 2.94 | 33 | 25 | 12 | 4 | 1 | 90 | 12.84 | 0.80 | 0.80 | 0.59 | 52.44 |
| *Parentucellia viscosa* | 2 | 0.82 | 10 | 10 | 10 | 9 | 1 | 95 | 32.35 | 0.69 | 0.73 | 0.39 | 49.04 |
| *Phalaris arundinacea* | 41 | 6.98 | 92 | 87 | 80 | 62 | 41 | 100 | 48.19 | 1.00 | 0.86 | 0.66 | 53.74 |
| *Phleum pratense* | 2 | 0.59 | 10 | 3 | 1 | 0 | 0 | 20 | 5.33 | 0.65 | 0.72 | 0.72 | 53.82 |
| *Plantago lanceolata* | 3 | 0.24 | 5 | 1 | 0 | 0 | 0 | 10 | 10.00 | 0.28 | 1.03 | 1.03 | 61.94 |
| *Plantago major* | 1 | 0.04 | 1 | 0 | 0 | 0 | 0 | 5 | 5.00 | 0.05 | 0.27 | 0.27 | 10.00 |
| *Plantago maritima* | 32 | 3.73 | 48 | 36 | 18 | 0 | 0 | 45 | 10.92 | 0.75 | 0.67 | 0.60 | 50.50 |
| *Plectritis congesta* | 1 | 0.12 | 0 | 0 | 0 | 0 | 0 | 1 | 1.00 | 0.14 | 1.36 | 1.36 | 59.26 |
| *Polygonum hydropiperoides* | 6 | 0.35 | 7 | 5 | 2 | 1 | 0 | 20 | 9.20 | 0.11 | 0.46 | 0.46 | 39.36 |
| *Polystichum munitum* | 1 | 0.04 | 1 | 0 | 0 | 0 | 0 | 5 | 5.00 | 0.10 |  |  |  |
| *Puccinellia pumila* | 18 | 1.29 | 21 | 9 | 6 | 3 | 0 | 85 | 16.38 | 0.19 | 0.64 | 0.53 | 50.48 |
| *Ranunculus orthorhynchus* | 1 | 0.08 | 1 | 1 | 0 | 0 | 0 | 10 | 10.00 | 0.17 | 0.81 | 0.81 | 76.30 |
| *Ranunculus repens* | 3 | 0.35 | 7 | 6 | 5 | 2 | 0 | 55 | 20.78 | 0.25 | 1.24 | 1.24 | 31.23 |
| *Ranunculus sp.* | 2 | 0.16 | 3 | 0 | 0 | 0 | 0 | 5 | 3.67 | 0.15 | 1.02 | 1.02 | 38.24 |
| *Rhamnus purshiana* | 1 | 0.04 | 0 | 0 | 0 | 0 | 0 | 1 | 1.00 | 0.05 | 2.08 | 2.08 | 100.00 |
| *Rorippa nasturtium-aquaticum* | 1 | 0.08 | 0 | 0 | 0 | 0 | 0 | 1 | 1.00 | 0.08 | 1.03 | 0.82 | 60.66 |
| *Rubus discolor* | 7 | 0.08 | 0 | 0 | 0 | 0 | 0 | 1 | 1.00 | 0.05 | 1.15 | 0.87 | 73.81 |
| *Rubus spectabilis* | 3 | 0.20 | 3 | 0 | 0 | 0 | 0 | 5 | 3.40 | 0.20 | 0.86 | 0.77 | 67.20 |
| *Rubus ursinus* | 2 | 0.12 | 3 | 1 | 0 | 0 | 0 | 15 | 8.33 | 0.20 | 1.22 | 0.88 | 100.00 |
| *Rumex acetosella* | 1 | 0.16 | 3 | 3 | 0 | 0 | 0 | 15 | 8.67 | 0.20 | 0.95 | 0.95 | 58.33 |
| *Rumex aquaticus* | 8 | 0.71 | 5 | 1 | 0 | 0 | 0 | 10 | 2.47 | 0.40 | 1.36 | 1.31 | 62.32 |
| *Rumex conglomeratus* | 4 | 0.12 | 1 | 0 | 0 | 0 | 0 | 5 | 2.33 | 0.05 | 0.96 | 0.87 | 80.79 |
| *Rumex crispus* | 12 | 0.39 | 4 | 3 | 0 | 0 | 0 | 15 | 3.25 | 0.11 | 0.83 | 0.66 | 49.14 |
| *Rumex sp.* | 7 | 0.27 | 1 | 0 | 0 | 0 | 0 | 5 | 1.80 | 0.10 | 0.99 | 0.76 | 54.28 |
| *Ruppia maritima* | 2 | 0.04 | 0 | 0 | 0 | 0 | 0 |  |  | 0.05 | 0.29 | 0.14 | 40.00 |
| *Sagittaria latifolia* | 1 | 0.16 | 4 | 4 | 2 | 0 | 0 | 15 | 12.50 | 0.21 | 0.80 | 0.80 | 76.28 |
| *Salicornia virginica* | 63 | 26.68 | 171 | 153 | 142 | 88 | 32 | 100 | 33.42 | 1.00 | 0.65 | 0.49 | 43.42 |
| *Salix hookeriana* | 1 | 0.08 | 2 | 1 | 1 | 0 | 0 | 30 | 17.50 | 0.10 | 1.03 | 0.52 | 63.33 |

| Species | # of wetlands | % of quadrats where present | # of quads where >1% cover | # of quads where >10% cover | # of quads where >20% cover | # of quads where >50% cover | # of quads where >90% cover | Maximum percent cover | Mean percent cover where present | Maximum proportion of quadrats in any marsh | Elevation relative to deepest point on transect | Elevation relative to deepest vegetated point on transect | Distance (%) relative to bay /river |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Salix sp.* | 8 | 0.27 | 4 | 1 | 0 | 0 | 0 | 10 | 3.83 | 0.14 | 0.69 | 0.58 | 74.88 |
| *Schoenoplectus (Scirpus) americanus* | 26 | 5.37 | 67 | 51 | 38 | 28 | 10 | 100 | 22.58 | 0.67 | 0.39 | 0.30 | 39.03 |
| *Isolepis (Scirpus) cernuus* | 10 | 0.90 | 19 | 10 | 4 | 1 | 0 | 60 | 12.74 | 0.26 | 0.64 | 0.48 | 44.54 |
| *Schoenoplectus (Scirpus) maritimus* | 26 | 2.20 | 35 | 21 | 12 | 7 | 0 | 75 | 10.52 | 0.38 | 0.59 | 0.40 | 58.29 |
| *Schoenoplectus (Scirpus) microcarpus* | 8 | 0.63 | 8 | 5 | 4 | 4 | 2 | 95 | 22.53 | 0.19 | 0.87 | 0.64 | 67.03 |
| *Schoenoplectus (Scirpus) acutus* | 20 | 5.22 | 74 | 64 | 59 | 38 | 15 | 100 | 34.13 | 0.83 | 0.86 | 0.60 | 46.57 |
| *Sium suave* | 1 | 0.04 | 0 | 0 | 0 | 0 | 0 | 1 | 1.00 | 0.06 | 0.72 | 0.72 | 51.11 |
| *Solanum dulcamara* | 2 | 0.08 | 1 | 1 | 0 | 0 | 0 | 15 | 8.00 | 0.05 | 1.39 | 1.39 | 50.00 |
| *Sonchus asper* | 1 | 0.04 | 0 | 0 | 0 | 0 | 0 | 1 | 1.00 | 0.25 | 0.70 | 0.70 | 66.67 |
| *Sparganium sp.* | 2 | 0.31 | 6 | 2 | 1 | 0 | 0 | 20 | 7.13 | 0.30 | 0.33 | 0.33 | 48.02 |
| *Spergularia canadensis* | 6 | 0.55 | 13 | 8 | 4 | 2 | 0 | 60 | 18.83 | 0.33 | 0.25 | 0.23 | 32.94 |
| *Spergularia macrotheca* | 14 | 1.37 | 26 | 17 | 12 | 4 | 0 | 40 | 9.74 | 0.42 | 0.52 | 0.33 | 40.11 |
| *Spergularia salina* | 17 | 1.57 | 28 | 18 | 11 | 2 | 0 | 55 | 11.69 | 0.32 | 0.37 | 0.33 | 40.41 |
| *Spiraea douglasii* | 1 | 0.12 | 2 | 2 | 2 | 2 | 1 | 95 | 48.00 | 0.15 | 0.75 | 0.30 | 65.89 |
| *Stellaria humifusa* | 9 | 0.86 | 10 | 4 | 1 | 0 | 0 | 20 | 4.41 | 0.30 | 1.03 | 0.81 | 71.27 |
| *Symphoricarpos alba* | 1 | 0.04 | 0 | 0 | 0 | 0 | 0 |  |  | 0.05 | 0.77 | 0.32 | 100.00 |
| *Symphyotrichum (Aster) subspicatus* | 51 | 5.49 | 64 | 44 | 24 | 4 | 0 | 80 | 11.27 | 0.67 | 1.06 | 0.71 | 58.83 |
| *Trifolium repens* | 4 | 0.43 | 6 | 1 | 1 | 0 | 0 | 40 | 6.90 | 0.40 | 0.77 | 0.77 | 60.37 |
| *Trifolium wormskioldii* | 20 | 1.22 | 13 | 6 | 2 | 0 | 0 | 45 | 5.83 | 0.16 | 0.82 | 0.53 | 53.26 |
| *Triglochin concinnum* | 2 | 0.04 | 1 | 1 | 1 | 0 | 0 | 40 | 40.00 | 0.05 | 0.99 | 0.99 | 100.00 |
| *Triglochin maritimum* | 79 | 20.87 | 156 | 123 | 98 | 42 | 5 | 100 | 14.80 | 0.85 | 0.72 | 0.44 | 49.09 |
| *Typha latifolia* | 19 | 2.63 | 44 | 35 | 22 | 6 | 0 | 75 | 14.64 | 0.82 | 0.55 | 0.48 | 60.69 |
| *Ulex europaeus* | 2 | 0.16 | 4 | 3 | 1 | 1 | 0 | 60 | 60.00 | 0.17 | 1.10 | 1.09 | 73.88 |
| *Urtica dioica* | 2 | 0.12 | 1 | 1 | 0 | 0 | 0 | 10 | 5.50 | 0.10 | 1.20 | 0.90 | 97.92 |
| *Veronica americana* | 3 | 0.24 | 4 | 4 | 2 | 0 | 0 | 40 | 19.20 | 0.15 | 1.08 | 1.09 | 38.31 |
| *Vicia americana* | 12 | 0.94 | 8 | 2 | 1 | 1 | 0 | 60 | 4.93 | 0.38 | 1.33 | 1.05 | 59.20 |
| *Vicia gigantea* | 1 | 0.24 | 1 | 1 | 0 | 0 | 0 | 10 | 2.50 | 0.32 | 0.71 | 0.37 | 49.18 |

| Species | # of wetlands | % of quadrats where present | # of quads where >1% cover | # of quads where >10% cover | # of quads where >20% cover | # of quads where >50% cover | # of quads where >90% cover | Maximum percent cover | Mean percent cover where present | Maximum proportion of quadrats in any marsh | Elevation relative to deepest point on transect | Elevation relative to deepest vegetated point on transect | Distance (%) relative to bay /river |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Vicia sp.* | 11 | 1.06 | 10 | 4 | 0 | 0 | 0 | 15 | 3.60 | 0.29 | 0.80 | 0.75 | 69.46 |

## Table 31. Frequency of plant species along channel cross-sectional transects, by geomorphic position

Numbers in the last nine columns are the proportion of points in that category in which the species occurred. "Lowest channel" pertains to the tidal channel cross-section located closest to the bay or river; "highest channel" refers to the one closest to upland (i.e., usually first order).

| Species | # of points | # of sites | In Channel | Channel Edge | Bank Top | Marsh Plain | Lowest Channel | Low Channel | Mid Order | High Channel | Highest Channel |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Achillea millefolium* | 53 | 26 | 0.0000 | 0.0031 | 0.0215 | 0.0312 | 0.0208 | 0.0213 | 0.0187 | 0.0185 | 0.0153 |
| *Agrostis stolonifera* | 615 | 70 | 0.0039 | 0.1636 | 0.3175 | 0.2712 | 0.1557 | 0.2016 | 0.2755 | 0.3105 | 0.2527 |
| *Alnus rubra* | 2 | 1 | 0.0000 | 0.0000 | 0.0000 | 0.0020 | 0.0000 | 0.0033 | 0.0000 | 0.0000 | 0.0000 |
| *Ammophila arenaria* | 21 | 9 | 0.0000 | 0.0000 | 0.0034 | 0.0176 | 0.0087 | 0.0016 | 0.0102 | 0.0185 | 0.0044 |
| *Angelica lucida* | 32 | 10 | 0.0020 | 0.0031 | 0.0147 | 0.0166 | 0.0138 | 0.0098 | 0.0119 | 0.0111 | 0.0109 |
| *Anthemis cotula* | 1 | 1 | 0.0000 | 0.0000 | 0.0000 | 0.0010 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0022 |
| *Argentina egedii* | 541 | 76 | 0.0079 | 0.1204 | 0.2520 | 0.2663 | 0.1263 | 0.2049 | 0.1837 | 0.2421 | 0.3115 |
| *Athyrium filix-femina* | 6 | 3 | 0.0000 | 0.0062 | 0.0011 | 0.0029 | 0.0000 | 0.0000 | 0.0034 | 0.0037 | 0.0044 |
| *Atriplex patula* | 135 | 47 | 0.0039 | 0.0370 | 0.0520 | 0.0732 | 0.0502 | 0.0852 | 0.0748 | 0.0536 | 0.0632 |
| *Carex lyngbyei* | 774 | 84 | 0.0727 | 0.4475 | 0.3390 | 0.2849 | 0.2993 | 0.3148 | 0.2840 | 0.2847 | 0.2898 |
| *Carex obnupta* | 223 | 35 | 0.0020 | 0.0432 | 0.0949 | 0.1190 | 0.0692 | 0.0639 | 0.1020 | 0.1035 | 0.1089 |
| *Cicuta douglasii* | 1 | 1 | 0.0000 | 0.0000 | 0.0000 | 0.0010 | 0.0000 | 0.0016 | 0.0000 | 0.0000 | 0.0000 |
| *Cirsium arvense* | 24 | 10 | 0.0000 | 0.0031 | 0.0090 | 0.0146 | 0.0087 | 0.0033 | 0.0204 | 0.0037 | 0.0065 |
| *Convolvulus sp.* | 1 | 1 | 0.0000 | 0.0000 | 0.0011 | 0.0000 | 0.0000 | 0.0000 | 0.0017 | 0.0000 | 0.0000 |
| *Cotula coronopifolia* | 67 | 29 | 0.0138 | 0.0741 | 0.0158 | 0.0215 | 0.0467 | 0.0279 | 0.0374 | 0.0148 | 0.0065 |
| *Cuscuta salina* | 43 | 14 | 0.0039 | 0.0000 | 0.0203 | 0.0224 | 0.0173 | 0.0164 | 0.0408 | 0.0351 | 0.0240 |
| *Deschampsia caespitosa* | 532 | 80 | 0.0079 | 0.1049 | 0.2847 | 0.2351 | 0.1384 | 0.1934 | 0.2126 | 0.2218 | 0.2745 |
| *Distichlis spicata* | 358 | 51 | 0.0098 | 0.1204 | 0.1548 | 0.1727 | 0.1419 | 0.1607 | 0.1905 | 0.1811 | 0.1176 |
| *Eleocharis palustris* | 97 | 22 | 0.0039 | 0.1019 | 0.0339 | 0.0312 | 0.0381 | 0.0443 | 0.0255 | 0.0388 | 0.0327 |
| *Eleocharis parvula* | 90 | 35 | 0.0275 | 0.0988 | 0.0136 | 0.0312 | 0.0363 | 0.0557 | 0.0408 | 0.0869 | 0.0153 |
| *Eleocharis sp.* | 2 | 2 | 0.0000 | 0.0000 | 0.0000 | 0.0020 | 0.0052 | 0.0000 | 0.0051 | 0.0000 | 0.0000 |
| *Epilobium ciliatum var. watsonii* | 1 | 1 | 0.0000 | 0.0031 | 0.0000 | 0.0000 | 0.0017 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| *Equisetum arvense* | 1 | 1 | 0.0000 | 0.0000 | 0.0011 | 0.0000 | 0.0017 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| *Equisetum hyemale* | 4 | 3 | 0.0000 | 0.0031 | 0.0034 | 0.0000 | 0.0017 | 0.0000 | 0.0017 | 0.0018 | 0.0022 |
| *Equisetum sp.* | 10 | 5 | 0.0000 | 0.0000 | 0.0056 | 0.0049 | 0.0017 | 0.0000 | 0.0085 | 0.0055 | 0.0022 |
| *Erechtites glomerata* | 12 | 5 | 0.0000 | 0.0000 | 0.0011 | 0.0107 | 0.0017 | 0.0033 | 0.0034 | 0.0018 | 0.0131 |
| *Festuca rubra* | 49 | 19 | 0.0000 | 0.0062 | 0.0169 | 0.0293 | 0.0225 | 0.0213 | 0.0187 | 0.0111 | 0.0131 |
| *Galium aparine* | 12 | 5 | 0.0000 | 0.0000 | 0.0068 | 0.0059 | 0.0017 | 0.0000 | 0.0085 | 0.0055 | 0.0065 |
| *Galium trifidum* | 17 | 3 | 0.0000 | 0.0031 | 0.0102 | 0.0068 | 0.0069 | 0.0016 | 0.0068 | 0.0074 | 0.0087 |
| *Glaux maritima* | 18 | 10 | 0.0000 | 0.0062 | 0.0056 | 0.0107 | 0.0035 | 0.0016 | 0.0034 | 0.0092 | 0.0174 |
| *Grindelia stricta* | 169 | 33 | 0.0000 | 0.0123 | 0.0927 | 0.0810 | 0.0657 | 0.0607 | 0.0714 | 0.0758 | 0.0545 |
| *Heracleum* | 19 | 11 | 0.0000 | 0.0062 | 0.0068 | 0.0107 | 0.0069 | 0.0098 | 0.0051 | 0.0092 | 0.0022 |

| Species | # of points | # of sites | In Channel | Channel Edge | Bank Top | Marsh Plain | Lowest Channel | Low Channel | Mid Order | High Channel | Highest Channel |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *lanatum* | | | | | | | | | | | |
| *Holcus lanatus* | 27 | 10 | 0.0000 | 0.0031 | 0.0102 | 0.0156 | 0.0069 | 0.0082 | 0.0085 | 0.0148 | 0.0174 |
| *Hordeum brachyantherum* | 94 | 40 | 0.0020 | 0.0093 | 0.0463 | 0.0468 | 0.0311 | 0.0393 | 0.0357 | 0.0407 | 0.0370 |
| *Hordeum jubatum* | 11 | 6 | 0.0000 | 0.0000 | 0.0045 | 0.0068 | 0.0052 | 0.0180 | 0.0000 | 0.0000 | 0.0022 |
| *Hypochaeris radicata* | 11 | 2 | 0.0000 | 0.0000 | 0.0034 | 0.0078 | 0.0000 | 0.0016 | 0.0051 | 0.0074 | 0.0065 |
| *Iris pseudocorus* | 1 | 1 | 0.0000 | 0.0000 | 0.0000 | 0.0010 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0022 |
| *Jaumea carnosa* | 198 | 34 | 0.0059 | 0.0802 | 0.1028 | 0.0761 | 0.0865 | 0.0787 | 0.0697 | 0.0610 | 0.0763 |
| *Juncus acuminatus* | 2 | 1 | 0.0000 | 0.0000 | 0.0011 | 0.0010 | 0.0000 | 0.0033 | 0.0000 | 0.0000 | 0.0000 |
| *Juncus balticus* | 317 | 59 | 0.0039 | 0.0463 | 0.1107 | 0.1932 | 0.0606 | 0.0803 | 0.1293 | 0.1682 | 0.2222 |
| *Juncus bufonius* | 8 | 4 | 0.0000 | 0.0154 | 0.0023 | 0.0000 | 0.0017 | 0.0049 | 0.0034 | 0.0037 | 0.0000 |
| *Juncus effusus* | 28 | 8 | 0.0000 | 0.0000 | 0.0102 | 0.0185 | 0.0035 | 0.0082 | 0.0102 | 0.0129 | 0.0174 |
| *Juncus gerardii* | 17 | 3 | 0.0020 | 0.0123 | 0.0034 | 0.0088 | 0.0035 | 0.0033 | 0.0051 | 0.0092 | 0.0131 |
| *Juncus lesueurii* | 3 | 3 | 0.0000 | 0.0000 | 0.0000 | 0.0020 | 0.0000 | 0.0000 | 0.0000 | 0.0037 | 0.0022 |
| *Juncus sp.* | 2 | 1 | 0.0000 | 0.0000 | 0.0000 | 0.0020 | 0.0000 | 0.0000 | 0.0017 | 0.0000 | 0.0022 |
| *Lathyrus palustris* | 3 | 3 | 0.0000 | 0.0000 | 0.0000 | 0.0029 | 0.0000 | 0.0000 | 0.0017 | 0.0037 | 0.0000 |
| *Lilaeopsis occidentalis* | 64 | 26 | 0.0432 | 0.0833 | 0.0079 | 0.0078 | 0.0242 | 0.0295 | 0.0221 | 0.0296 | 0.0174 |
| *Lonicera involucrata* | 12 | 6 | 0.0000 | 0.0000 | 0.0000 | 0.0117 | 0.0017 | 0.0098 | 0.0034 | 0.0037 | 0.0022 |
| *Lotus corniculatus* | 46 | 8 | 0.0000 | 0.0185 | 0.0215 | 0.0205 | 0.0087 | 0.0213 | 0.0187 | 0.0222 | 0.0109 |
| *Lysichiton americanum* | 2 | 1 | 0.0000 | 0.0000 | 0.0000 | 0.0020 | 0.0000 | 0.0000 | 0.0000 | 0.0037 | 0.0000 |
| *Lythrum salicaria* | 16 | 4 | 0.0000 | 0.0000 | 0.0045 | 0.0117 | 0.0087 | 0.0098 | 0.0068 | 0.0000 | 0.0022 |
| *Melilotus albus* | 1 | 1 | 0.0000 | 0.0000 | 0.0000 | 0.0010 | 0.0017 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| *Mentha pulegium* | 15 | 7 | 0.0000 | 0.0031 | 0.0079 | 0.0068 | 0.0069 | 0.0066 | 0.0017 | 0.0074 | 0.0044 |
| *Mimulus guttatus* | 1 | 1 | 0.0020 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0022 |
| *Nuphar lutea v. polysepala* | 1 | 1 | 0.0020 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0017 | 0.0000 | 0.0000 |
| *Oenanthe sarmentosa* | 45 | 13 | 0.0000 | 0.0123 | 0.0181 | 0.0234 | 0.0121 | 0.0164 | 0.0187 | 0.0203 | 0.0153 |
| *Parentucellia viscosa* | 1 | 1 | 0.0000 | 0.0000 | 0.0000 | 0.0010 | 0.0000 | 0.0000 | 0.0000 | 0.0018 | 0.0000 |
| *Phalaris arundinacea* | 176 | 29 | 0.0059 | 0.0802 | 0.0712 | 0.0820 | 0.0588 | 0.0623 | 0.0765 | 0.0518 | 0.0741 |
| *Picea sitchensis* | 1 | 1 | 0.0000 | 0.0000 | 0.0000 | 0.0010 | 0.0000 | 0.0016 | 0.0000 | 0.0000 | 0.0000 |
| *Plantago lanceolata* | 34 | 18 | 0.0039 | 0.0062 | 0.0090 | 0.0215 | 0.0381 | 0.0131 | 0.0119 | 0.0055 | 0.0174 |
| *Plantago maritima* | 1 | 1 | 0.0000 | 0.0000 | 0.0011 | 0.0000 | 0.0000 | 0.0016 | 0.0000 | 0.0000 | 0.0000 |
| *Polygonum hydropiperoides* | 1 | 1 | 0.0000 | 0.0031 | 0.0000 | 0.0000 | 0.0017 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| *Polystichum munitum* | 2 | 2 | 0.0000 | 0.0000 | 0.0000 | 0.0020 | 0.0000 | 0.0000 | 0.0017 | 0.0000 | 0.0022 |
| *Puccinellia pumila* | 8 | 4 | 0.0000 | 0.0062 | 0.0023 | 0.0029 | 0.0052 | 0.0066 | 0.0017 | 0.0018 | 0.0022 |

| Species | # of points | # of sites | In Channel | Channel Edge | Bank Top | Marsh Plain | Lowest Channel | Low Channel | Mid Order | High Channel | Highest Channel |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Pyrus sp.* | 1 | 1 | 0.0000 | 0.0000 | 0.0000 | 0.0010 | 0.0000 | 0.0016 | 0.0000 | 0.0000 | 0.0000 |
| *Ranunculus repens* | 8 | 3 | 0.0000 | 0.0123 | 0.0045 | 0.0000 | 0.0017 | 0.0000 | 0.0000 | 0.0055 | 0.0087 |
| *Ranunculus sp.* | 2 | 2 | 0.0000 | 0.0000 | 0.0000 | 0.0020 | 0.0017 | 0.0000 | 0.0017 | 0.0000 | 0.0000 |
| *Rubus discolor* | 13 | 8 | 0.0000 | 0.0000 | 0.0034 | 0.0098 | 0.0087 | 0.0049 | 0.0000 | 0.0055 | 0.0065 |
| *Rubus laciniatus* | 5 | 3 | 0.0000 | 0.0000 | 0.0000 | 0.0049 | 0.0035 | 0.0049 | 0.0000 | 0.0000 | 0.0000 |
| *Rubus parviflorus* | 1 | 1 | 0.0020 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0018 | 0.0000 |
| *Rubus spectabilis* | 2 | 2 | 0.0000 | 0.0000 | 0.0011 | 0.0010 | 0.0000 | 0.0000 | 0.0000 | 0.0018 | 0.0022 |
| *Rubus ursinus* | 2 | 1 | 0.0000 | 0.0031 | 0.0000 | 0.0010 | 0.0000 | 0.0016 | 0.0017 | 0.0000 | 0.0000 |
| *Rumex acetosella* | 1 | 1 | 0.0000 | 0.0000 | 0.0000 | 0.0010 | 0.0000 | 0.0000 | 0.0000 | 0.0018 | 0.0000 |
| *Rumex aquaticus* | 24 | 7 | 0.0000 | 0.0062 | 0.0102 | 0.0127 | 0.0104 | 0.0098 | 0.0051 | 0.0055 | 0.0131 |
| *Rumex conglomeratus* | 4 | 2 | 0.0000 | 0.0031 | 0.0011 | 0.0020 | 0.0017 | 0.0000 | 0.0034 | 0.0000 | 0.0022 |
| *Rumex crispus* | 13 | 10 | 0.0039 | 0.0000 | 0.0023 | 0.0088 | 0.0035 | 0.0033 | 0.0034 | 0.0092 | 0.0044 |
| *Rumex maritimus* | 1 | 1 | 0.0000 | 0.0000 | 0.0011 | 0.0000 | 0.0000 | 0.0016 | 0.0000 | 0.0000 | 0.0000 |
| *Rumex sp.* | 10 | 5 | 0.0000 | 0.0000 | 0.0056 | 0.0049 | 0.0017 | 0.0016 | 0.0000 | 0.0055 | 0.0109 |
| *Ruppia maritima* | 20 | 12 | 0.0393 | 0.0000 | 0.0000 | 0.0000 | 0.0069 | 0.0082 | 0.0085 | 0.0111 | 0.0000 |
| *Salicornia virginica* | 466 | 52 | 0.0098 | 0.1790 | 0.2249 | 0.1980 | 0.2318 | 0.2213 | 0.2007 | 0.1275 | 0.1438 |
| *Salix hookeriana* | 4 | 2 | 0.0000 | 0.0000 | 0.0023 | 0.0020 | 0.0017 | 0.0016 | 0.0034 | 0.0000 | 0.0000 |
| *Salix sp.* | 4 | 3 | 0.0000 | 0.0000 | 0.0000 | 0.0039 | 0.0052 | 0.0000 | 0.0017 | 0.0000 | 0.0000 |
| *Schoenoplectus (Scirpus) americanus* | 61 | 15 | 0.0177 | 0.0062 | 0.0249 | 0.0273 | 0.0502 | 0.0230 | 0.0153 | 0.0092 | 0.0131 |
| *Isolepis (Scirpus) cernuus* | 7 | 4 | 0.0000 | 0.0000 | 0.0011 | 0.0059 | 0.0017 | 0.0016 | 0.0000 | 0.0055 | 0.0044 |
| *Schoenoplectus (Scirpus) maritimus* | 17 | 8 | 0.0000 | 0.0000 | 0.0011 | 0.0156 | 0.0017 | 0.0082 | 0.0085 | 0.0166 | 0.0022 |
| *Schoenoplectus (Scirpus) microcarpus* | 19 | 6 | 0.0000 | 0.0000 | 0.0079 | 0.0117 | 0.0087 | 0.0066 | 0.0085 | 0.0018 | 0.0109 |
| *Schoenoplectus (Scirpus) acutus* | 126 | 14 | 0.0157 | 0.0370 | 0.0508 | 0.0595 | 0.0450 | 0.0492 | 0.0408 | 0.0444 | 0.0566 |
| *Solanum dulcamara* | 1 | 1 | 0.0000 | 0.0000 | 0.0000 | 0.0010 | 0.0000 | 0.0000 | 0.0017 | 0.0000 | 0.0000 |
| *Sparganium sp.* | 3 | 3 | 0.0020 | 0.0031 | 0.0000 | 0.0010 | 0.0017 | 0.0016 | 0.0017 | 0.0000 | 0.0000 |
| *Spergularia canadensis* | 2 | 2 | 0.0020 | 0.0000 | 0.0011 | 0.0000 | 0.0069 | 0.0000 | 0.0017 | 0.0000 | 0.0000 |
| *Spergularia macrotheca* | 39 | 13 | 0.0079 | 0.0309 | 0.0136 | 0.0127 | 0.0208 | 0.0164 | 0.0153 | 0.0074 | 0.0087 |
| *Spergularia salina* | 8 | 7 | 0.0000 | 0.0031 | 0.0056 | 0.0020 | 0.0035 | 0.0082 | 0.0068 | 0.0018 | 0.0065 |
| *Stellaria humifusa* | 1 | 1 | 0.0000 | 0.0000 | 0.0011 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0018 | 0.0000 |
| *Symphoricarpos* | 3 | 1 | 0.0000 | 0.0031 | 0.0011 | 0.0010 | 0.0000 | 0.0000 | 0.0017 | 0.0018 | 0.0022 |

| Species | # of points | # of sites | In Channel | Channel Edge | Bank Top | Marsh Plain | Lowest Channel | Low Channel | Mid Order | High Channel | Highest Channel |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *albus* | | | | | | | | | | | |
| *Symphyotrichum (Aster) subspicatus* | 85 | 26 | 0.0000 | 0.0093 | 0.0373 | 0.0478 | 0.0173 | 0.0230 | 0.0272 | 0.0351 | 0.0588 |
| *Trifolium repens* | 9 | 3 | 0.0000 | 0.0000 | 0.0068 | 0.0029 | 0.0035 | 0.0049 | 0.0034 | 0.0037 | 0.0000 |
| *Trifolium wormskioldii* | 5 | 4 | 0.0000 | 0.0000 | 0.0011 | 0.0029 | 0.0035 | 0.0016 | 0.0017 | 0.0000 | 0.0022 |
| *Triglochin maritimum* | 225 | 46 | 0.0098 | 0.0617 | 0.0780 | 0.1268 | 0.0744 | 0.0967 | 0.0833 | 0.0980 | 0.0893 |
| *Typha latifolia* | 51 | 16 | 0.0039 | 0.0123 | 0.0192 | 0.0273 | 0.0069 | 0.0131 | 0.0238 | 0.0185 | 0.0349 |
| *Urtica dioica* | 3 | 1 | 0.0000 | 0.0000 | 0.0011 | 0.0020 | 0.0000 | 0.0033 | 0.0000 | 0.0000 | 0.0022 |
| *Vicia americana* | 13 | 7 | 0.0000 | 0.0031 | 0.0056 | 0.0068 | 0.0052 | 0.0049 | 0.0051 | 0.0037 | 0.0044 |
| *Vicia gigantea* | 2 | 1 | 0.0000 | 0.0000 | 0.0000 | 0.0020 | 0.0017 | 0.0016 | 0.0000 | 0.0000 | 0.0000 |
| *Vicia sp.* | 14 | 9 | 0.0000 | 0.0000 | 0.0023 | 0.0117 | 0.0069 | 0.0049 | 0.0102 | 0.0018 | 0.0000 |

## Table 32. Interspecies correlates at the site scale

Bold italics indicate significant (p<0.05) correlation of both frequency (% of quadrats where species was present) and percent cover (mean among quadrats). Plain italics indicate frequency correlation only. Plain font indicates percent cover correlation only.

| Species | Associated Positively: | Associated Negatively: |
|---|---|---|
| *Achillea millefolium* | *Agrostis stolonifera, Argentina egedii,* ***Juncus balticus, Oenanthe sarmentosa***, Symphyotrichum subspicatus | Salicornia virginica, *Schoenoplectus americanus* |
| *Agrostis stolonifera* | *Argentina egedii,* ***Carex lyngbyei***, *Juncus balticus,* ***Symphyotrichum subspicatus*** | *Cordylanthus maritimus, Distichlis spicata, Grindelia stricta,* ***Jaumea carnosa,*** *Plantago maritima, Salicornia virginica, Spergularia macrotheca* |
| *Argentina egedii (=Potentilla pacifica, P. anserina)* | ***Agrostis stolonifera, Eleocharis palustris, Juncus balticus, Oenanthe sarmentosa, Symphyotrichum subspicatus***, Trifolium wormskioldii | Cordylanthus maritimus, ***Distichlis spicata,*** *Grindelia stricta,* ***Jaumea carnosa,*** *Plantago maritima****, Salicornia virginica,*** *Spergularia salina, Triglochin maritimum* |
| *Atriplex patula* | ***Deschampsia caespitosa, Distichlis spicata***, *Glaux maritima, Grindelia stricta, Hordeum brachyantherum*, ***Jaumea carnosa,*** Juncus balticus, ***Salicornia virginica, Triglochin maritimum*** | Carex obnupta |
| *Castilleja ambigua* | Schoenoplectus americanus, ***Stellaria humifusa, Trifolium wormskioldii*** | —- |
| *Carex lyngbyei* | ***Agrostis stolonifera***, Deschampsia caespitosa, Spergularia salina, ***Triglochin maritimum*** | *Carex obnupta,* ***Cordylanthus maritimus*** |
| *Carex obnupta* | ***Deschampsia caespitosa, Eleocharis palustris***, Eleocharis parvula, *Oenanthe sarmentosa* | Atriplex patula, *Carex lyngbyei,* ***Distichlis spicata, Glaux maritima***, Hordeum brachyantherum, ***Jaumea carnosa,*** *Juncus balticus,* ***Salicornia virginica*** |
| *Cotula coronopifolia* | *Atriplex patula*, Carex obnupta, ***Eleocharis parvula, Juncus effusus, Spergularia salina, Triglochin maritimum,*** Symphyotrichum subspicatus | Argentina egedii, Carex lyngbyei, *Juncus balticus, Symphyotrichum subspicatus* |
| *Cordylanthus maritimus* | *Distichlis spicata,* ***Puccinellia pumila, Salicornia virginica, Spergularia macrotheca*** | ***Argentina egedii, Carex lyngbyei*** |
| *Deschampsia caespitosa* | ***Atriplex patula***, Carex lyngbyei, *Distichlis spicata*, ***Glaux maritima,*** *Grindelia stricta,* ***Hordeum brachyantherum,*** *Jaumea carnosa,* ***Juncus balticus,*** Stellaria humifusa, *Salicornia virginica,* ***Triglochin maritimum*** | ***Carex obnupta****, Eleocharis palustris, Oenanthe sarmentosa* |
| *Distichlis spicata* | ***Atriplex patula,*** *Cordylanthus maritimus, Deschampsia caespitosa,* ***Glaux maritima, Grindelia stricta***, *Hordeum brachyantherum,* ***Jaumea carnosa, Plantago maritima, Puccinellia pumila, Salicornia virginica, Spergularia macrotheca***, Stellaria humifusa, ***Triglochin maritimum*** | *Agrostis stolonifera,* ***Argentina egedii, Carex obnupta, Eleocharis palustris,*** *Oenanthe sarmentosa, Symphyotrichum subspicatus* |
| *Eleocharis palustris* | ***Argentina egedii, Carex obnupta, Lilaeopsis occidentalis, Oenanthe sarmentosa, Schoenoplectus americanus*** | *Deschampsia caespitosa,* ***Distichlis spicata, Glaux maritima, Hordeum brachyantherum, Jaumea carnosa, Salicornia virginica,*** |

| Species | Associated Positively: | Associated Negatively: |
|---|---|---|
| | | ***Spergularia macrotheca, Triglochin maritimum*** |
| *Eleocharis parvula* | Carex obnupta, ***Schoenoplectus americanus, Spergularia salina*** | —- |
| *Erechtites glomerata* | *Argentina egedii,* ***Symphyotrichum subspicatus*** | *Distichlis spicata,* ***Hordeum brachyantherum, Salicornia virginica, Triglochin maritimum*** |
| *Glaux maritima* | *Atriplex patula,* ***Distichlis spicata, Grindelia stricta, Hordeum brachyantherum, Jaumea carnosa, Juncus balticus, Plantago maritima, Puccinellia pumila, Salicornia virginica, Triglochin maritimum*** | ***Carex obnupta, Deschampsia caespitosa, Eleocharis palustris,*** *Oenanthe sarmentosa*, ***Stellaria humifusa*** |
| *Grindelia stricta* | *Atriplex patula, Deschampsia caespitosa,* ***Distichlis spicata, Glaux maritima, Hordeum brachyantherum, Jaumea carnosa,*** *Juncus balticus,* ***Plantago maritima, Salicornia virginica, Triglochin maritimum*** | —- |
| *Heracleum lanatum* | Oenanthe sarmentosa, Jaumea carnosa, *Juncus effusus, Oenanthe sarmentosa,* Salicornia virginica | *Jaumea carnosa, Salicornia virginica* |
| *Hordeum brachyantherum* | *Atriplex patula,* ***Deschampsia caespitosa***, *Distichlis spicata,* ***Glaux maritima, Grindelia stricta, Jaumea carnosa, Juncus balticus, Plantago maritima, Puccinellia pumila, Salicornia virginica,*** *Stellaria humifusa,* ***Triglochin maritimum*** | *Carex obnupta,* ***Eleocharis palustris, Lilaeopsis occidentalis, Oenanthe sarmentosa*** |
| *Jaumea carnosa* | ***Atriplex patula,*** *Deschampsia caespitosa,* ***Distichlis spicata, Glaux maritima, Grindelia stricta, Hordeum brachyantherum***, Juncus balticus, *Plantago maritima, Puccinellia pumila, Salicornia virginica, Spergularia macrotheca, Triglochin maritimum* | ***Agrostis stolonifera, Argentina egedii, Carex obnupta, Eleocharis palustris***, *Juncus effusus,* ***Lilaeopsis occidentalis, Oenanthe sarmentosa,*** *Symphyotrichum subspicatus* |
| *Juncus balticus* | *Agrostis stolonifera,* ***Argentina egedii,*** Atriplex patula, ***Deschampsia caespitosa, Glaux maritima***, *Grindelia stricta,* ***Hordeum brachyantherum***, Jaumea carnosa, ***Symphyotrichum subspicatus***, *Trifolium wormskioldii* | *Carex obnupta* |
| *Juncus effusus* | ***Oenanthe sarmentosa*** | *Jaumea carnosa* |
| *Limonium californicum* | ***Cordylanthus maritimus, Distichlis spicata, Jaumea carnosa, Plantago maritima, Salicornia virginica, Spergularia macrotheca*** | ***Agrostis stolonifera,*** *Argentina egedii,* ***Carex lyngbyei*** |
| *Lilaeopsis occidentalis* | ***Eleocharis palustris, Schoenoplectus maritimus*** | ***Hordeum brachyantherum, Jaumea carnosa,*** *Salicornia virginica* |
| *Lythrum salicaria* | ***Eleocharis palustris, Lilaeopsis occidentalis*** | ***Distichlis spicata, Salicornia virginica*** |
| *Oenanthe sarmentosa* | ***Argentina egedii,*** *Carex obnupta,* ***Eleocharis palustris, Juncus effusus, Symphyotrichum subspicatus*** | *Deschampsia caespitosa, Distichlis spicata, Glaux maritima, Grindelia stricta,* ***Hordeum brachyantherum, Jaumea carnosa, Salicornia virginica, Triglochin maritimum*** |
| *Phalaris arundinacea* | ***Carex obnupta,*** *Deschampsia caespitosa,* ***Eleocharis palustris, Juncus effusus,*** | ***Distichlis spicata, Glaux maritima, Grindelia stricta, Hordeum brachyantherum, Jaumea*** |

| Species | Associated Positively: | Associated Negatively: |
|---|---|---|
| | ***Oenanthe sarmentosa, Symphyotrichum subspicatus*** | ***carnosa,*** *Juncus balticus,* ***Plantago maritima, Salicornia virginica, Spergularia macrotheca, Spergularia salina, Triglochin maritimum*** |
| *Plantago maritima* | *Castilleja ambigua,* ***Distichlis spicata, Glaux maritima, Grindelia stricta, Hordeum brachyantherum, Jaumea carnosa, Puccinellia pumila, Salicornia virginica,*** Spergularia macrotheca | *Agrostis stolonifera, Argentina egedii* |
| *Puccinellia pumila* | ***Cordylanthus maritimus, Distichlis spicata, Glaux maritima, Hordeum brachyantherum, Jaumea carnosa, Plantago maritima, Salicornia virginica,*** Triglochin maritimum | —- |
| *Salicornia virginica* | ***Atriplex patula, Cordylanthus maritimus, Distichlis spicata, Glaux maritima, Grindelia stricta, Hordeum brachyantherum, Jaumea carnosa, Plantago maritima, Puccinellia pumila, Spergularia macrotheca, Spergularia salina, Triglochin maritimum*** | ***Agrostis stolonifera, Argentina egedii, Carex obnupta,*** *Deschampsia caespitosa,* ***Eleocharis palustris,*** *Lilaeopsis occidentalis,* ***Oenanthe sarmentosa, Symphyotrichum subspicatus*** |
| *Schoenoplectus americanus* | *Castilleja ambigua*, ***Eleocharis palustris, Eleocharis parvula, Trifolium wormskioldii*** | —- |
| *Isolepis cernua (Scirpus cernuus)* | ***Lilaeopsis occidentalis*** | Hordeum brachyantherum, Juncus balticus |
| *Schoenoplectus maritimus* | ***Lilaeopsis occidentalis*** | |
| *Schoenoplectus acutus* | *Carex lyngbyei,* ***Eleocharis palustris,*** *Oenanthe sarmentosa*, ***Symphyotrichum subspicatus*** | ***Distichlis spicata, Grindelia stricta, Hordeum brachyantherum, Jaumea carnosa, Plantago maritima, Salicornia virginica, Triglochin maritimum, Trifolium wormskioldii*** |
| *Spergularia macrotheca* | *Cordylanthus maritimus, Distichlis spicata, Jaumea carnosa, Salicornia virginica, Stellaria humifusa,* ***Triglochin maritimum*** | *Agrostis stolonifera,* ***Eleocharis palustris*** |
| *Spergularia salina* | Carex lyngbyei, ***Eleocharis parvula, Salicornia virginica, Triglochin maritimum*** | *Argentina egedii* |
| *Stellaria humifusa* | ***Castilleja ambigua***, Deschampsia caespitosa, Distichlis spicata, ***Glaux maritima***, Hordeum brachyantherum, ***Spergularia macrotheca,*** *Triglochin maritimum* | —- |
| *Symphyotrichum subspicatus* | ***Agrostis stolonifera, Argentina egedii, Juncus balticus, Oenanthe sarmentosa*** | ***Distichlis spicata,*** *Jaumea carnosa, Salicornia virginica* |
| *Triglochin maritimum* | ***Atriplex patula, Carex lyngbyei, Deschampsia caespitosa, Distichlis spicata, Glaux maritima, Grindelia stricta, Hordeum brachyantherum, Jaumea carnosa***, *Puccinellia pumila*, ***Salicornia virginica, Spergularia macrotheca, Spergularia salina,*** *Stellaria humifusa* | *Argentina egedii,* ***Eleocharis palustris, Oenanthe sarmentosa*** |

| Species | Associated Positively: | Associated Negatively: |
|---|---|---|
| *Trifolium wormskioldii* | Argentina egedii, ***Castilleja ambigua,*** *Juncus balticus,* ***Schoenoplectus americanus*** | —- |
| *Typha latifolia* | ***Eleocharis palustris, Juncus effusus*** | *Deschampsia caespitosa,* ***Distichlis spicata, Glaux maritima, Grindelia stricta, Jaumea carnosa,*** *Juncus balticus,* ***Salicornia virginica, Triglochin maritimum*** |

## Table 33. Interspecies correlates at the quadrat scale, based on percent cover

All correlations were significant at $p<0.05$, and are listed in decreasing strength of association.

| Species | Associated Positively: | Associated Negatively: |
|---|---|---|
| *Achillea millefolium* | *Symphyotrichum subspicatus, Oenanthe sarmentosa, Argentina egedii, Agrostis stolonifera, Heracleum lanatum, Erechtites glomerata, Juncus balticus, Deschampsia caespitosa* | *Distichlis spicata, Salicornia virginica, Carex lyngbyei, Jaumea carnosa, Triglochin maritimum, Glaux maritima* |
| *Agrostis stolonifera* | *Argentina egedii, Juncus balticus, Symphyotrichum subspicatus, Achillea millefolium, Erechtites glomerata, Juncus effusus, Deschampsia caespitosa, Trifolium wormskioldii, Carex lyngbyei, Atriplex patula* | *Phalaris arundinacea, Distichlis spicata, Jaumea carnosa, Salicornia virginica, Spergularia macrotheca, Eleocharis parvula, Lythrum salicaria, Triglochin maritimum, Limonium californicum, Cordylanthus maritimus, Schoenoplectus americanus, Spergularia salina, Cotula coronopifolia* |
| *Argentina egedii (=Potentilla pacifica, P. anserina)* | *Juncus balticus, Symphyotrichum subspicatus, Agrostis stolonifera, Oenanthe sarmentosa, Carex obnupta, Eleocharis palustris, Trifolium wormskioldii, Juncus effusus, Grindelia stricta, Schoenoplectus acutus, Erechtites glomerata* | *Carex lyngbyei, Plantago maritima, Achillea millefolium, Triglochin maritimum, Jaumea carnosa, Distichlis spicata, Salicornia virginica, Eleocharis parvula, Glaux maritima, Limonium californicum, Spergularia salina, Cotula coronopifolia, Cordylanthus maritimus, Lilaeopsis occidentalis, Schoenoplectus maritimus* |
| *Atriplex patula* | *Grindelia stricta, Hordeum brachyantherum, Juncus balticus, Distichlis spicata, Spergularia macrotheca, Puccinellia pumila, Glaux maritima, Cotula coronopifolia, Agrostis stolonifera* | *Carex lyngbyei, Phalaris arundinacea, Carex obnupta, Symphyotrichum subspicatus* |
| *Castilleja ambigua* | *Plantago maritima, Trifolium wormskioldii, Grindelia stricta, Jaumea carnosa, Glaux maritima, Salicornia virginica* | —- |
| *Carex lyngbyei* | *Jaumea carnosa, Schoenoplectus acutus, Limonium californicum, Trifolium wormskioldii, Agrostis stolonifera, Stellaria humifusa* | *Hordeum brachyantherum, Juncus balticus, Argentina egedii, Distichlis spicata, Phalaris arundinacea, Grindelia stricta, Salicornia virginica, Carex obnupta, Plantago maritima, Atriplex patula, Oenanthe sarmentosa, Juncus effusus, Schoenoplectus americanus, Deschampsia caespitosa, Achillea millefolium, Cotula coronopifolia, Eleocharis palustris, Cordylanthus maritimus, Spergularia salina, Spergularia macrotheca* |
| *Carex obnupta* | *Oenanthe sarmentosa, Argentina egedii, Eleocharis palustris, Phalaris arundinacea, Grindelia stricta, Juncus effusus, Heracleum lanatum, Symphyotrichum subspicatus* | *Glaux maritima, Juncus balticus, Jaumea carnosa, Distichlis spicata, Salicornia virginica, Carex lyngbyei, Hordeum brachyantherum, Plantago maritima, Deschampsia caespitosa, Triglochin maritimum, Atriplex patula* |
| *Cotula coronopifolia* | *Eleocharis parvula, Spergularia macrotheca, Triglochin maritimum, Spergularia salina, Salicornia virginica, Schoenoplectus maritimus, Atriplex patula, Puccinellia pumila* | *Juncus balticus, Argentina egedii, Carex lyngbyei, Agrostis stolonifera, Jaumea carnosa, Grindelia stricta, Hordeum brachyantherum* |

| Species | Associated Positively: | Associated Negatively: |
|---|---|---|
| *Cordylanthus maritimus* | *Limonium californicum, Puccinellia pumila, Salicornia virginica, Jaumea carnosa, Plantago maritima, Typha latifolia, Lythrum salicaria, Distichlis spicata* | *Agrostis stolonifera, Carex lyngbyei, Argentina egedii* |
| *Deschampsia caespitosa* | *Glaux maritima, Grindelia stricta, Triglochin maritimum, Juncus balticus, Hordeum brachyantherum, Jaumea carnosa, Distichlis spicata, Salicornia virginica, Achillea millefolium, Agrostis stolonifera, Puccinellia pumila, Plantago maritima, Juncus effusus, Erechtites glomerata* | *Schoenoplectus americanus, Phalaris arundinacea, Eleocharis palustris, Schoenoplectus acutus, Carex obnupta, Carex lyngbyei, Oenanthe sarmentosa, Lythrum salicaria, Spergularia macrotheca* |
| *Distichlis spicata* | *Salicornia virginica, Jaumea carnosa, Triglochin maritimum, Glaux maritima, Grindelia stricta, Plantago maritima, Deschampsia caespitosa, Hordeum brachyantherum, Puccinellia pumila, Atriplex patula, Limonium californicum, Spergularia salina, Cordylanthus maritimus* | *Typha latifolia, Oenanthe sarmentosa, Carex lyngbyei, Symphyotrichum subspicatus, Schoenoplectus acutus, Eleocharis palustris, Phalaris arundinacea, Carex obnupta, Agrostis stolonifera, Argentina egedii, Achillea millefolium, Lythrum salicaria, Trifolium wormskioldii, Erechtites glomerata* |
| *Eleocharis palustris* | *Typha latifolia, Schoenoplectus americanus, Lythrum salicaria, Argentina egedii, Schoenoplectus acutus, Carex obnupta, Oenanthe sarmentosa, Lilaeopsis occidentalis, Grindelia stricta, Eleocharis parvula, Schoenoplectus maritimus* | *Jaumea carnosa, Distichlis spicata, Salicornia virginica, Deschampsia caespitosa, Triglochin maritimum, Glaux maritima, Carex lyngbyei, Hordeum brachyantherum* |
| *Eleocharis parvula* | *Cotula coronopifolia, Triglochin maritimum, Lilaeopsis occidentalis, Salicornia virginica, Spergularia salina, Eleocharis palustris, Schoenoplectus americanus* | *Agrostis stolonifera, Argentina egedii, Juncus balticus, Grindelia stricta, Phalaris arundinacea, Jaumea carnosa,* |
| *Erechtites glomerata* | *Symphyotrichum subspicatus, Achillea millefolium, Agrostis stolonifera, Argentina egedii, Deschampsia caespitosa* | *Salicornia virginica, Distichlis spicata, Triglochin maritimum* |
| *Glaux maritima* | *Jaumea carnosa, Deschampsia caespitosa, Distichlis spicata, Juncus balticus, Hordeum brachyantherum, Triglochin maritimum, Puccinellia pumila, Salicornia virginica, Stellaria humifusa, Plantago maritima, Atriplex patula, Achillea millefolium* | *Carex obnupta, Grindelia stricta, Eleocharis palustris, Castilleja ambigua, Argentina egedii, Phalaris arundinacea, Symphyotrichum subspicatus, Schoenoplectus acutus, Schoenoplectus americanus, Oenanthe sarmentosa* |
| *Grindelia stricta* | *Jaumea carnosa, Salicornia virginica, Distichlis spicata, Deschampsia caespitosa, Hordeum brachyantherum, Glaux maritima, Juncus balticus, Atriplex patula, Plantago maritima, Castilleja ambigua* | *Argentina egedii, Carex lyngbyei, Eleocharis palustris, Phalaris arundinacea, Carex obnupta, Symphyotrichum subspicatus, Oenanthe sarmentosa, Lilaeopsis occidentalis, Eleocharis parvula, Typha latifolia, Schoenoplectus americanus, Schoenoplectus acutus, Cotula coronopifolia* |
| *Heracleum lanatum* | *Juncus effusus, Symphyotrichum subspicatus, Oenanthe sarmentosa, Hordeum brachyantherum, Carex obnupta* | —- |
| *Hordeum brachyantherum* | *Jaumea carnosa, Grindelia stricta, Glaux maritima, Deschampsia caespitosa, Juncus balticus, Atriplex patula, Salicornia virginica, Distichlis spicata, Puccinellia pumila, Juncus effusus, Plantago maritima, Heracleum lanatum* | *Carex lyngbyei, Carex obnupta, Phalaris arundinacea, Schoenoplectus americanus, Schoenoplectus acutus, Eleocharis palustris, Cotula coronopifolia* |
| *Jaumea carnosa* | *Lythrum salicaria, Salicornia virginica, Distichlis spicata, Plantago maritima, Grindelia stricta, Glaux maritima, Hordeum* | *Schoenoplectus acutus, Symphyotrichum subspicatus, Eleocharis palustris, Phalaris arundinacea, Limonium californicum, Carex* |

| Species | Associated Positively: | Associated Negatively: |
|---|---|---|
| | *brachyantherum, Deschampsia caespitosa, Puccinellia pumila, Triglochin maritimum, Castilleja ambigua, Cordylanthus maritimus, Spergularia salina* | *obnupta, Carex lyngbyei, Agrostis stolonifera, Argentina egedii, Oenanthe sarmentosa, Typha latifolia, Lilaeopsis occidentalis, Juncus effusus, Schoenoplectus maritimus, Achillea millefolium, Schoenoplectus americanus, Eleocharis parvula, Cotula coronopifolia, Lythrum salicaria* |
| *Juncus balticus* | *Argentina egedii, Glaux maritima, Agrostis stolonifera, Grindelia stricta, Deschampsia caespitosa, Hordeum brachyantherum, Symphyotrichum subspicatus, Atriplex patula, Achillea millefolium, Trifolium wormskioldii* | *Cotula coronopifolia, Schoenoplectus acutus, Carex lyngbyei, Salicornia virginica, Carex obnupta, Phalaris arundinacea, Typha latifolia, Juncus effusus, Spergularia salina, Spergularia macrotheca, Lythrum salicaria, Triglochin maritimum, Eleocharis parvula, Lilaeopsis occidentalis, Isonephs cernua (Scirpus cernuus), Schoenoplectus maritimus, Oenanthe sarmentosa, Limonium californicum, Plantago maritima* |
| *Juncus effusus* | *Oenanthe sarmentosa, Argentina egedii, Heracleum lanatum, Hordeum brachyantherum, Agrostis stolonifera, Carex obnupta, Deschampsia caespitosa* | *Salicornia virginica, Carex lyngbyei, Juncus balticus, Jaumea carnosa, Triglochin maritimum* |
| *Limonium californicum* | *Cordylanthus maritimus, Puccinellia pumila, Salicornia virginica, Jaumea carnosa, Plantago maritima, Spergularia macrotheca, Spergularia salina, Distichlis spicata* | *Argentina egedii, Agrostis stolonifera, Carex lyngbyei, Juncus balticus* |
| *Lilaeopsis occidentalis* | *Schoenoplectus americanus, Schoenoplectus maritimus, Triglochin maritimum, Isolepis cernua (Scirpus cernuus), Eleocharis parvula Eleocharis palustris, Grindelia stricta* | *Salicornia virginica, Jaumea carnosa, Juncus balticus, Argentina egedii* |
| *Lythrum salicaria* | *Eleocharis palustris, Phalaris arundinacea, Cordylanthus maritimus* | *Agrostis stolonifera, Salicornia virginica, Distichlis spicata, Juncus balticus, Deschampsia caespitosa, Triglochin maritimum, Jaumea carnosa* |
| *Oenanthe sarmentosa* | *Carex obnupta, Symphyotrichum subspicatus, Typha latifolia, Juncus effusus, Achillea millefolium, Argentina egedii, Phalaris arundinacea, Eleocharis palustris, Jaumea carnosa, Heracleum lanatum* | *Triglochin maritimum, Distichlis spicata, Salicornia virginica, Carex lyngbyei, Deschampsia caespitosa, Grindelia stricta, Juncus balticus, Glaux maritima* |
| *Phalaris arundinacea* | *Oenanthe sarmentosa, Carex obnupta, Lythrum salicaria, Typha latifolia, Schoenoplectus acutus* | *Deschampsia caespitosa, Carex lyngbyei, Agrostis stolonifera, Jaumea carnosa, Juncus balticus, Triglochin maritimum, Distichlis spicata, Salicornia virginica, Grindelia stricta, Glaux maritima, Hordeum brachyantherum, Plantago maritima, Eleocharis parvula, Atriplex patula* |
| *Plantago maritima* | *Jaumea carnosa, Salicornia virginica, Distichlis spicata, Castilleja ambigua, Limonium californicum, Grindelia stricta, Spergularia salina, Cordylanthus maritimus, Hordeum brachyantherum, Glaux maritima, Deschampsia caespitosa, Puccinellia pumila* | *Agrostis stolonifera, Argentina egedii, Carex lyngbyei, Carex obnupta, Phalaris arundinacea, Symphyotrichum subspicatus, Schoenoplectus acutus, Juncus balticus* |
| *Puccinellia pumila* | *Cordylanthus maritimus, Glaux maritima, Limonium californicum, Spergularia macrotheca, Jaumea carnosa, Salicornia virginica, Hordeum brachyantherum, Distichlis spicata, Atriplex patula,* | —- |

| Species | Associated Positively: | Associated Negatively: |
|---|---|---|
| | *Deschampsia caespitosa, Triglochin maritimum, Plantago maritima, Cotula coronopifolia* | |
| *Salicornia virginica* | *Jaumea carnosa, Distichlis spicata, Triglochin maritimum, Plantago maritima, Grindelia stricta, Spergularia macrotheca, Glaux maritima, Limonium californicum, Hordeum brachyantherum, Cotula coronopifolia, Deschampsia caespitosa, Puccinellia pumila, Cordylanthus maritimus, Spergularia salina, Eleocharis parvula, Castilleja ambigua* | *Juncus effusus, Typha latifolia, Oenanthe sarmentosa, Juncus balticus, Schoenoplectus acutus, Eleocharis palustris, Symphyotrichum subspicatus, Phalaris arundinacea, Carex obnupta, Carex lyngbyei, Agrostis stolonifera, Argentina egedii, Lilaeopsis occidentalis, Achillea millefolium, Trifolium wormskioldii, Lythrum salicaria, Erectites glomerata* |
| *Schoenoplectus americanus* | *Eleocharis palustris, Lilaeopsis occidentalis, Trifolium wormskioldii, Eleocharis parvula, Spergularia macrotheca, Grindelia stricta* | *Deschampsia caespitosa, Carex lyngbyei, Agrostis stolonifera, Hordeum brachyantherum, Jaumea carnosa, Glaux maritima, Schoenoplectus acutus* |
| *Isolepis cernua (Scirpus cernuus)* | *Triglochin maritimum, Schoenoplectus maritimus* | *Juncus balticus* |
| *Schoenoplectus maritimus* | *Lilaeopsis occidentalis, Isolepis cernua (Scirpus cernuus)* | *Jaumea carnosa, Juncus balticus, Argentina egedii* |
| *Schoenoplectus acutus* | *Typha latifolia, Eleocharis palustris, Carex lyngbyei, Symphyotrichum subspicatus, Argentina egedii, Phalaris arundinacea* | *Juncus balticus, Jaumea carnosa, Triglochin maritimum, Distichlis spicata, Salicornia virginica, Deschampsia caespitosa, Glaux maritima, Hordeum brachyantherum, Schoenoplectus americanus, Plantago maritima, Grindelia stricta* |
| *Spergularia macrotheca* | *Cotula coronopifolia, Salicornia virginica, Puccinellia pumila, Triglochin maritimum, Limonium californicum, Stellaria humifusa, Atriplex patula, Schoenoplectus americanus* | *Agrostis stolonifera, Juncus balticus, Deschampsia caespitosa, Carex lyngbyei* |
| *Spergularia salina* | *Cotula coronopifolia, Plantago maritima, Salicornia virginica, Limonium californicum, Eleocharis parvula, Jaumea carnosa, Distichlis spicata, Triglochin maritimum* | *Argentina egedii, Juncus balticus, Agrostis stolonifera, Carex lyngbyei* |
| *Stellaria humifusa* | *Glaux maritima, Spergularia macrotheca, Triglochin maritimum, Carex lyngbyei* | —- |
| *Symphyotrichum subspicatus* | *Achillea millefolium, Argentina egedii, Oenanthe sarmentosa, Agrostis stolonifera, Juncus balticus, Jaumea carnosa, Erectites glomerata, Heracleum lanatum, Schoenoplectus acutus, Carex obnupta* | *Distichlis spicata, Salicornia virginica, Triglochin maritimum, Glaux maritima, Grindelia stricta, Plantago maritima, Atriplex patula* |
| *Triglochin maritimum* | *Salicornia virginica, Distichlis spicata, Deschampsia caespitosa, Glaux maritima, Cotula coronopifolia, Eleocharis parvula, Lilaeopsis occidentalis, Isolepis cernua (Scirpus cernuus), Spergularia macrotheca, Schoenoplectus maritimus, Stellaria humifusa, Spergularia salina, Puccinellia pumila, Trifolium wormskioldii* | *Oenanthe sarmentosa, Schoenoplectus acutus, Jaumea carnosa, Phalaris arundinacea, Argentina egedii, Symphyotrichum subspicatus, Eleocharis palustris, Carex obnupta, Agrostis stolonifera, Juncus balticus, Juncus effusus, Lythrum salicaria, Typha latifolia, Achillea millefolium, Erectites glomerata* |
| *Trifolium wormskioldii* | *Argentina egedii, Castilleja ambigua, Juncus balticus, Schoenoplectus americanus, Agrostis stolonifera* | *Salicornia virginica, Distichlis spicata, Carex lyngbyei, Triglochin maritimum* |
| *Typha latifolia* | *Lythrum salicaria, Eleocharis palustris, Oenanthe sarmentosa, Schoenoplectus acutus, Jaumea carnosa, Phalaris arundinacea, Cordylanthus maritimus* | *Distichlis spicata, Salicornia virginica, Juncus balticus, Triglochin maritimum, Grindelia stricta* |

### Table 34. Species-position correlates at the quadrat scale, based on percent cover

All correlations were significant at p<0.05, and are listed in decreasing strength of association. The variables are:

RelEl = relative elevation above lowest point on the marsh transects at the surveyed site
RelVelev = similar, but measured from the lowest *vegetated* point
Dist2start = the quadrat's distance from start of transect, generally, the distance from the adjoining bay or river
PctL = the same, expressed as a percent

| Species | Associated Positively: | Associated Negatively: |
|---|---|---|
| *Achillea millefolium* | RelElev, PctL | —- |
| *Agrostis stolonifera* | RelEl, Dist2start, PctL, RelVelev | —- |
| *Argentina egedii (=Potentilla pacifica, P. anserina)* | Dist2start, PctL, RelVelev | —- |
| *Atriplex patula* | Dist2start, PctL | — |
| *Castilleja ambigua* | —- | —- |
| *Carex lyngbyei* | Dist2start | PctL |
| *Carex obnupta* | PctL, Dist2start, RelEl | —- |
| *Cotula coronopifolia*[2] | —- | RelEl, RelVelev, Dist2start, PctL |
| *Cordylanthus maritimus* | —- | —- |
| *Deschampsia caespitosa* | RelEl, RelVelev | —- |
| *Distichlis spicata* | —- | PctL RelVelev |
| *Eleocharis palustris* | —- | RelEl, RelVelev |
| *Eleocharis parvula* | —- | RelEl |
| *Erectites glomerata* | —- | —- |
| *Glaux maritima* | Dist2start, RelEl | —- |
| *Grindelia stricta* | RelEl,RelVelev | —- |
| *Heracleum lanatum* | —- | —- |
| *Hordeum brachyantherum* | RelEl,RelVelev | —- |
| *Isolepis cernua (Scirpus cernuus)* | —- | —- |
| *Jaumea carnosa* | —- | PctL, Dist2start |
| *Juncus balticus* | RelEl, Dist2start, PctL | —- |
| *Juncus effusus* | RelVelev, RelEl, Dist2start | —- |
| *Limonium californicum* | —- | Dist2start |
| *Lilaeopsis occidentalis* | —- | RelVelev, RelEl |
| *Lythrum salicaria* | —- | —- |
| *Oenanthe sarmentosa* | —- | —- |
| *Phalaris arundinacea* | RelEl, RelVelev | —- |
| *Plantago maritima* | —- | Dist2start, RelEl |
| *Puccinellia pumila* | —- | —- |
| *Salicornia virginica* | —- | RelVelev, PctL RelEl, Dist2start |
| *Schoenoplectus americanus* | —- | RelVelev, RelEl, PctL, Dist2start |
| *Schoenoplectus maritimus* | —- | RelEl, RelVelev |
| *Schoenoplectus acutus* | —- | —- |
| *Spergularia macrotheca* | —- | RelVelev, RelEl |
| *Spergularia salina* | —- | RelEl, Dist2start, RelVelev |
| *Stellaria humifusa* | PctL, RelEl, Dist2start | —- |
| *Symphyotrichum subspicatus* | RelEl, RelVelev | —- |
| *Triglochin maritimum* | Dist2start | —- |
| *Trifolium wormskioldii* | —- | —- |
| *Typha latifolia* | PctL | RelEl |

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[2] Other researchers have reported this species to often be associated with areas of high organic content, e.g., former log stoarge areas, recently flooded marshes that formerly were diked.

## Table 35. Soil salinity associated with dominant plant species in tidal wetlands of the Oregon coast

| Species | # of plots tested | Soil Salinity (mean ppt) | Soil Salinity (min ppt) | Soil Salinity (max ppt) | Usual Zone | Reputed Salt Tolerance* |
|---|---|---|---|---|---|---|
| *Achillea millefolium* | 5 | 22.60 | 14 | 28 | high | F |
| *Agrostis stolonifera* | 51 | 20.78 | 5 | 48 | high | BF |
| *Angelica lucida* | 2 | 5.50 | 2 | 9 | high | F |
| *Argentina egedii (=Potentilla pacifica, P. anserina)* | 59 | 17.90 | 1 | 48 | high | BF |
| *Atriplex patula* | 14 | 24.71 | 10 | 47 | both | BF |
| *Carex lyngbyei* | 69 | 20.62 | 3 | 39 | low | BF |
| *Carex obnupta* | 22 | 15.14 | 1 | 41 | high | F |
| *Cordylanthus maritimus v. palustris* | 2 | 38.50 | 29 | 48 | both | FBS |
| *Cotula coronopifolia* | 4 | 15.25 | 10 | 20 | low | FBS |
| *Deschampsia caespitosa* | 45 | 24.27 | 3 | 40 | high | FBS |
| *Distichlis spicata* | 42 | 29.10 | 4 | 48 | both | BS |
| *Eleocharis palustris* | 14 | 12.00 | 1 | 29 | both | BF |
| *Eleocharis parvula* | 2 | 13.50 | 11 | 16 | low | S |
| *Erechtites glomerata* | 1 | 25.00 | 25 | 25 | high | F |
| *Galium aparine* | 1 | 7.00 | 7 | 7 | upland | F |
| *Glaux maritima* | 4 | 21.00 | 10 | 32 | low | S |
| *Grindelia stricta* | 22 | 23.82 | 4 | 40 | high | FBS |
| *Hordeum brachyantherum* | 2 | 22.00 | 19 | 25 | high | BF |
| *Jaumea carnosa* | 26 | 30.96 | 4 | 48 | low | BS |
| *Juncus balticus* | 55 | 22.53 | 3 | 48 | high | BF |
| *Juncus effusus* | 3 | 13.33 | 10 | 19 | high | F |
| *Juncus gerardii* | 2 | 44.50 | 42 | 47 | high | FBS |
| *Juncus lesueurii* | 2 | 4.50 | 3 | 6 | high | FBS |
| *Lilaeopsis occidentalis* | 5 | 9.80 | 3 | 20 | low | BF |
| *Limonium californicum* | 2 | 31.50 | 29 | 34 | high | BS |
| *Lythrum salicaria* | 2 | 1.00 | 1 | 1 | high | BF |
| *Oenanthe sarmentosa* | 2 | 12.00 | 10 | 14 | high | F |
| *Phalaris arundinacea* | 12 | 11.00 | 3 | 18 | high | BF |
| *Plantago maritima* | 2 | 30.00 | 25 | 35 | both | FBS |
| *Puccinellia pumila* | 2 | 46.00 | 45 | 47 | low | BS |
| *Ranunculus repens* | 3 | 5.33 | 1 | 10 | high | F |
| *Sagittaria latifolia* | 1 | 3.00 | 3 | 3 | high | F |
| *Salicornia virginica* | 56 | 32.13 | 4 | 65 | low | S |
| *Schoenoplectus (Scirpus) americanus* | 13 | 14.62 | 1 | 37 | both | FBS |
| *Schoenoplectus (Scirpus) maritimus* | 5 | 26.00 | 15 | 36 | low | FBS |
| *Schoenoplectus (Scirpus) acutus* | 13 | 14.00 | 1 | 25 | high | FBS |
| *Spartina patens* | 1 | 30.00 | 30 | 30 | low | S |
| *Spergularia macrotheca* | 3 | 35.67 | 29 | 40 | low | BS |
| *Symphyotrichum (Aster) subspicatum* | 6 | 20.67 | 13 | 29 | high | BF |
| *Triglochin maritimum* | 40 | 26.08 | 10 | 41 | both | BS |
| *Typha latifolia* | 6 | 11.17 | 3 | 20 | high | BF |

Based on spot measurements. *F = fresh, B = brackish, S = saline

## Table 36. Frequencies of associated soil redoximorphic conditions and root densities, by dominant plant species, in tidal wetlands of the Oregon coast

| Species | # of plots checked | # with mottles | # with gley | # with sulfidic. odor | # with few roots | # with moderate roots | # with many roots |
|---|---|---|---|---|---|---|---|
| *Achillea millefolium* | 6 | 2 | 0 | 0 | 2 | 3 | 1 |
| *Agrostis stolonifera* | 57 | 43 | 7 | 1 | 17 | 23 | 14 |
| *Angelica lucida* | 2 | 0 | 0 | 0 | 0 | 1 | 0 |
| *Argentina egedii (=Potentilla pacifica, P. anserina)* | 72 | 50 | 3 | 3 | 17 | 31 | 17 |
| *Atriplex patula* | 14 | 11 | 0 | 1 | 5 | 4 | 3 |
| *Carex lyngbyei* | 72 | 63 | 20 | 9 | 14 | 30 | 21 |
| *Carex obnupta* | 25 | 19 | 6 | 5 | 5 | 9 | 6 |
| *Cordylanthus maritimus v. palustris* | 2 | 2 | 0 | 0 | 2 | 0 | 0 |
| *Cotula coronopifolia* | 4 | 4 | 1 | 1 | 3 | 1 | 0 |
| *Deschampsia caespitosa* | 50 | 41 | 7 | 1 | 13 | 22 | 13 |
| *Distichlis spicata* | 44 | 35 | 5 | 3 | 10 | 15 | 14 |
| *Eleocharis palustris* | 17 | 12 | 3 | 2 | 4 | 6 | 5 |
| *Eleocharis parvula* | 4 | 3 | 1 | 1 | 2 | 1 | 1 |
| *Erechtites glomerata* | 1 | 1 | 0 | 0 | 1 | 0 | 0 |
| *Festuca rubra* | 3 | 1 | 0 | 0 | 1 | 1 | 1 |
| *Galium aparine* | 1 | 1 | 0 | 0 | 0 | 1 | 0 |
| *Glaux maritima* | 3 | 3 | 2 | 0 | 0 | 1 | 2 |
| *Grindelia stricta* | 27 | 19 | 0 | 2 | 5 | 12 | 9 |
| *Hordeum brachyantherum* | 2 | 2 | 1 | 0 | 1 | 1 | 0 |
| *Jaumea carnosa* | 27 | 24 | 1 | 0 | 4 | 13 | 10 |
| *Juncus balticus* | 57 | 48 | 5 | 3 | 8 | 24 | 23 |
| *Juncus effusus* | 4 | 4 | 0 | 0 | 2 | 2 | 0 |
| *Juncus gerardii* | 2 | 2 | 0 | 0 | 0 | 0 | 2 |
| *Juncus lesueurii* | 3 | 2 | 1 | 0 | 0 | 2 | 1 |
| *Lilaeopsis occidentalis* | 5 | 4 | 2 | 0 | 3 | 1 | 1 |
| *Limonium californicum* | 3 | 3 | 0 | 0 | 1 | 2 | 1 |
| *Lotus corniculatus* | 6 | 1 | 0 | 0 | 1 | 3 | 2 |
| *Lythrum salicaria* | 2 | 1 | 0 | 0 | 1 | 1 | 0 |
| *Oenanthe sarmentosa* | 2 | 2 | 0 | 0 | 0 | 1 | 1 |
| *Phalaris arundinacea* | 16 | 15 | 1 | 0 | 6 | 7 | 2 |
| *Plantago maritima* | 2 | 2 | 0 | 0 | 0 | 2 | 0 |
| *Puccinellia pumila* | 2 | 1 | 0 | 0 | 0 | 2 | 0 |
| *Ranunculus repens* | 3 | 3 | 1 | 0 | 2 | 1 | 0 |
| *Sagittaria latifolia* | 1 | 1 | 1 | 0 | 0 | 1 | 0 |
| *Salicornia virginica* | 58 | 50 | 4 | 4 | 9 | 27 | 18 |
| *Schoenoplectus (Scirpus) americanus* | 16 | 11 | 2 | 4 | 10 | 3 | 1 |
| *Schoenoplectus (Scirpus) maritimus* | 5 | 3 | 1 | 1 | 0 | 1 | 2 |
| *Schoenoplectus (Scirpus) acutus* | 13 | 11 | 2 | 4 | 5 | 7 | 1 |
| *Spartina patens* | 1 | 1 | 0 | 1 | 0 | 0 | 1 |
| *Spergularia macrotheca* | 3 | 2 | 1 | 1 | 1 | 1 | 0 |
| *Symphyotrichum (Aster) subspicatum* | 3 | 2 | 2 | 0 | 1 | 3 | 3 |
| *Triglochin maritimum* | 38 | 35 | 11 | 6 | 3 | 15 | 15 |
| *Typha latifolia* | 5 | 5 | 1 | 0 | 0 | 3 | 2 |

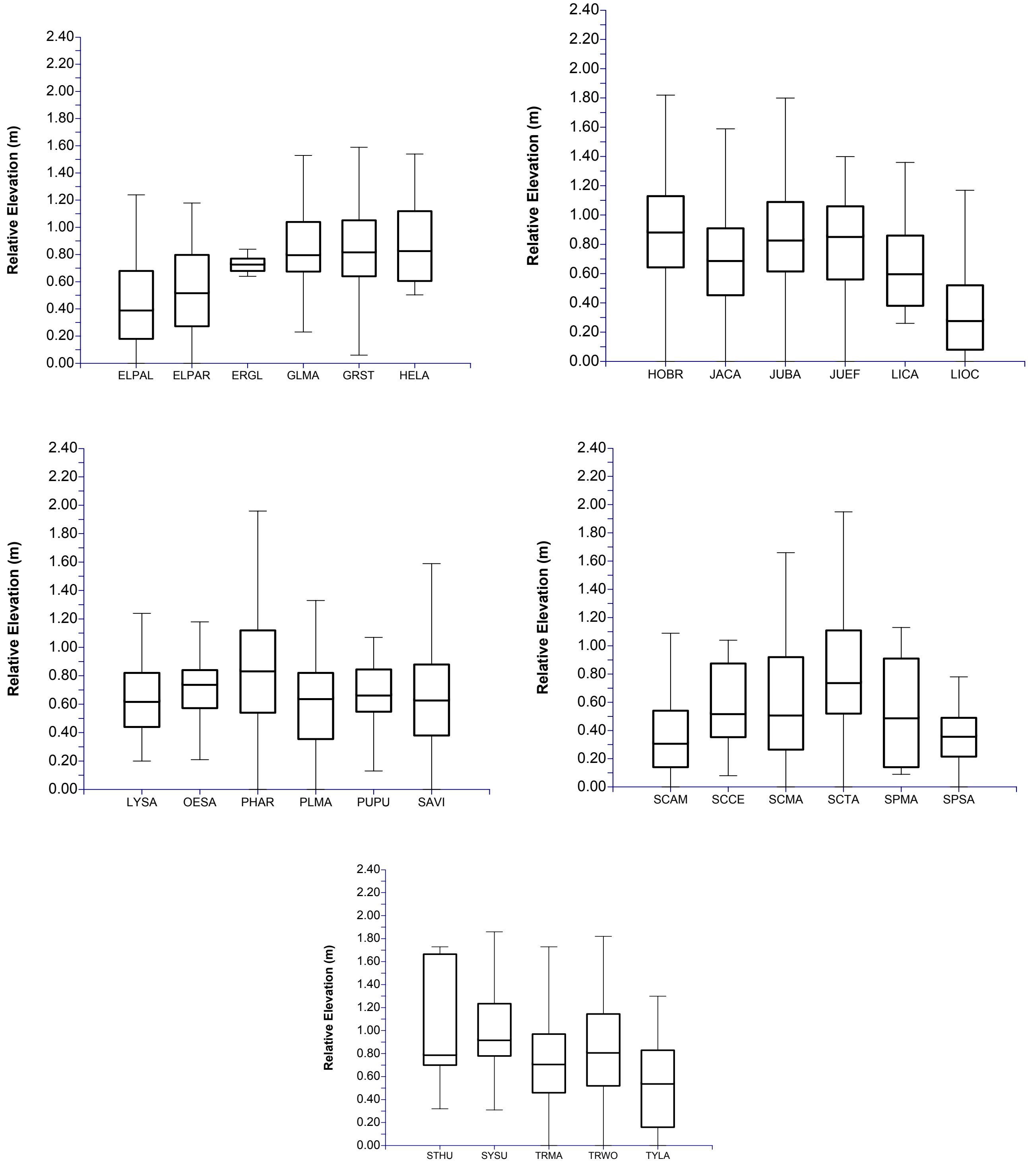

**Figure 13. Range of relative elevations of selected tidal marsh plant species surveyed on the Oregon coast**

Note: Elevations were referenced only to the lowest point surveyed in each marsh. This was often — but not always — the lowest vegetated edge.

## Table 37. Number of significant correlations with risk indicators at site scale, by species

The numbers are the number of risk indices with which the species' percent cover or frequency was significantly correlated ($p<0.05$). The risk indices are defined on p. 88. Species (in bold) with many more negative than positive correlations in both columns may be promising candidates, pending further study, as indicators of risks to the integrity of Oregon tidal marshes.

| Plant Species | Number of significant correlations of risk indices with **Percent Cover** | | Number of significant correlations of risk indices with **Frequency** | |
|---|---|---|---|---|
| | Positive | Negative | Positive | Negative |
| *Achillea millefolium* | 1 | 3 | 1 | 1 |
| *Agrostis stolonifera* | 4 | 3 | 6 | 2 |
| *Argentina egedii* | 3 | 3 | 6 | 3 |
| *Atriplex patula* | 3 | 1 | 6 | 2 |
| *Carex lyngbyei* | 1 | 0 | 3 | 1 |
| ***Carex obnupta*** | 6 | 9 | 2 | 8 |
| ***Cotula coronopifolia*** | 0 | 2 | 0 | 3 |
| *Cordylanthus maritimus* | 0 | 1 | 0 | 1 |
| *Deschampsia caespitosa* | 1 | 3 | 2 | 3 |
| ***Distichlis spicata*** | 3 | 27 | 2 | 17 |
| *Eleocharis palustris* | 3 | 2 | 3 | 3 |
| *Eleocharis parvula* | 1 | 0 | 1 | 0 |
| *Erectites glomerata* | 3 | 17 | 3 | 17 |
| *Glaux maritima* | 9 | 3 | 4 | 1 |
| *Grindelia stricta* | 1 | 2 | 1 | 2 |
| *Heracleum lanatum* | 9 | 10 | 8 | 11 |
| *Hordeum brachyantherum* | 2 | 3 | 4 | 3 |
| *Isolepis cernua (Scirpus cernuus)* | 1 | 1 | 1 | 1 |
| *Jaumea carnosa* | 2 | 2 | 3 | 2 |
| ***Juncus balticus*** | 1 | 6 | 1 | 3 |
| *Juncus effusus* | 0 | 2 | 0 | 2 |
| *Limonium californicum* | 2 | 2 | 2 | 2 |
| *Lilaeopsis occidentalis* | 3 | 0 | 3 | 0 |
| *Lythrum salicaria* | 1 | 1 | 1 | 1 |
| *Oenanthe sarmentosa* | 11 | 0 | 11 | 0 |
| *Phalaris arundinacea* | 5 | 2 | 7 | 1 |
| ***Plantago maritima*** | 1 | 27 | 1 | 25 |
| ***Puccinellia pumila*** | 4 | 11 | 4 | 7 |
| ***Salicornia virginica*** | 4 | 12 | 3 | 7 |
| ***Schoenoplectus americanus*** | 0 | 3 | 0 | 2 |
| *Schoenoplectus maritimus* | 2 | 1 | 1 | 1 |
| *Schoenoplectus acutus* | 3 | 2 | 3 | 2 |
| ***Spergularia macrotheca*** | 4 | 12 | 4 | 10 |
| *Spergularia salina* | 1 | 1 | 1 | 1 |
| ***Stellaria humifusa*** | 0 | 10 | 0 | 9 |
| *Symphyotrichum subspicatus* | 3 | 6 | 3 | 3 |
| ***Triglochin maritimum*** | 2 | 17 | 3 | 11 |
| *Typha latifolia* | 3 | 3 | 3 | 3 |

# 5.0 Future Directions

The data contained on the accompanying CD provide a rich resource for further exploration of relationships between environmental components of Oregon tidal marshes. In the limited time available to conduct this project, only the most basic of statistical techniques (e.g., Spearman rank correlation, Mann-Whitney tests) were used to explore the data. Consideration should be given to future exploration of the data using more sophisticated modeling and ordination techniques, to better define (for example):

- the clearest groupings (associations) of tidal marsh plant species
- plant-based indicators and indices that best reflect impacts of human activities on tidal marshes (or at least, potential risk)
- environmental influences on tidal marsh plant richness, functional groups, and species — particularly *within* each tidal wetland subclass

Looking beyond this particular data set, among the more pressing needs for understanding the functions of Oregon's tidal wetlands are the following, in no particular order:

- Measure the height of the highest annual high tide — at as many locations as possible in Oregon's estuaries, during both wet (high runoff volume) and dry years. Use these data to establish, with finer spatial resolution, the heads-of-tide locations in all portions of each estuary (especially in small marsh tributary channels) and along the upper fringes of all tidal wetlands.
- Establish tidal datums and permanent topographic benchmarks at many more locations than presently exist (e.g., Shalowitz 1962, 1964; Hamilton 1980).
- Determine loading levels and seasonal delivery regimes under which sediment and nutrient inputs to tidal marshes shift from being ecologically beneficial to detrimental, and develop threshold criteria for these.
- Use remote sensing to quantify with greater spatial resolution the tidal channel networks within marshes, thresholds for processes needed to sustain these networks, and their specific effects on the duration and saturation of tidal marsh flooding throughout the monthly tidal cycle.
- Determine the effects of non-native invertebrates on Oregon tidal wetland food webs and geochemical processes.
- Identify relationships between visually observed conditions in tidal wetland soils and root systems, and the biogeochemical processes important to wetland functions. Relate these to signs of degradation of the soil processes as a result of human activities.
- Quantify the chronic effects on tidal marsh functions of low levels of various chemical contaminants, especially persistent and/or relatively unmonitored substances such as perchlorate, flame retardants such as PFOA, mercury (Davis et al. 2003, Marvin-DiPasquale et al. 2003), pharmaceuticals, and plasticizers (Oros et al. 2003).
- Determine the degree to which various forms of organic matter, especially those originating from tidal wetlands, influence estuarine oxygen loads and increase or decrease the natural degradation, bioavailability, and toxicity of contaminants in the estuarine environment (e.g., Gallagher and Kibby 1980, Brown 2003).

- Determine how wildlife species use Oregon's tidal wetlands as part of the overall landscape matrix of habitat types, and quantify the effects of human activities in or near tidal wetlands on these species.
- Determine the circumstances under which plant community changes (perhaps the most easily monitored aspect of tidal marshes) reflect significant human-related changes in invertebrate communities, soils, and fundamental biogeochemical processes, and thus can serve as indicators of those changes. Identify change thresholds beyond which recovery from human impacts is unlikely.
- At regular intervals, repeat the estimates of these same indicators at this same set of tidal marshes (or a subset to which access permission is granted) and track changes over time, with appropriate consideration to the relative repeatability and spatial resolution of a particular indicator. If warranted, use the new data to recalibrate and improve the existing scoring models, and use the results to help assess cumulative effects of restoration projects and coastal development.[3]

With regard to the HGM method itself as presented in Part 1, there is a need for:

- testing its repeatability, as determined by multiple users having various levels of training and expertise and covering a variety of tidal wetland types at a variety of seasons
- testing to see whether it produces logical results in adjoining regions, i.e., Washington and northern California
- testing for correlations between the scores it assigns particular functions and variables used to quantify ecosystem processes (e.g., nitrogen cycling rate) or habitat use, provided that such variables can be considered synonymous with the functions they are intended to represent more directly
- intensified tidal monitoring and chemical testing of sediments in the wetlands that have been designated as least-altered; this ultimately may suggest that some of these reference sites have had more (or less) alteration than is apparent, requiring some adjustment in the scoring of all sites
- archiving and analysis of function scores as may be obtained by future users who assess other tidal marshes using this HGM method

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[3] For example, using an HGM approach, the state of Louisiana has begun to monitor 200 tidal wetlands annually and another 500 every three years (Steyer et al. 2003).

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Zawislanski, P.T., S. Chau, H. Mountford, H.C. Wong, and T.C. Sears. 2001. Accumulation of selenium and trace metals on plant litter in a tidal marsh. Estuarine, Coastal, and Shelf Science 52:589–603.

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Zeff, M.L. 1999. Salt marsh tidal channel morphometry: applications for wetland creation and restoration. Restoration Ecology 7:205.

Zimmerman, S.T. 1972. Seasonal succession of zooplankton populations in two dissimilar marine embayments on the Oregon coast. Thesis, Oregon State University, Corvallis.

# Appendix A. Other Rapid Methods and Sampling Protocols for Assessment of Tidal Wetlands or Estuaries

***Rapid-assessment Methods*** (generally require only a single visit to collect data and produce ratings; usually provide criteria and/or models for scoring tidal wetlands; results are relative and approximate rather than definitive):

Collins, J.N., E. Stein, and M. Sutula. 2004. California Rapid Assessment Method for Wetlands. Version 3.0.

Cook, R.A., A.J. Lindley Stone, and A.P. Ammann. 1993. Method for the evaluation and inventory of vegetated tidal marshes in New Hampshire (coastal method). Audubon Society of New Hampshire. Concord, NH.

Findlay, S.E.G., E. Kiviat, W.C. Nieder, and E.A. Blair. 2002. Functional assessment of a reference wetland set as a tool for science, management and restoration. Aquat. Sci. 64:107–117.

Louis Berger Group, Inc. 2004. Regional Guidebook for Hydrogeomorphic Assessment of Tidal Fringe Wetlands in the Hackensack Meadowlands. Report to the New Jersey Meadowlands Commission, East Rutherford, NJ.

Shafer, D.J. and D.J. Yozzo. 1998. National Guidebook for Application of Hydrogeomorphic Assessment to Tidal Fringe Wetlands. Tech. Rep. WEP-DE-16. US Army Corps of Engineers Waterway Experiment Station, Vicksburg, MS.

Shafer, D.J., B. Herczeg, D. Moulton, A. Sipocz, K. Jaynes, L. Rozas, C. Onuf, and W. Miller. 2002. Regional Guidebook for Application of Hydrogeomorphic Assessments to Northwest Gulf of Mexico Tidal Fringe Wetlands. US Army Corps of Engineers Waterway Experiment Station, Vicksburg, MS.

Tippett, J.P. 1990. A structural approach to tidal wetland evaluation. M.S. thesis, School of Forestry and Environmental Studies, Duke University, Durham, NC.

***More-intensive Protocols or General Discussions of Assessment*** (may require repeat sampling and/or sample processing; usually address fewer attributes and functions; often lack criteria or scoring models to interpret the data in a standardized manner; some are not intended for tidal wetlands specifically):

Becker, D.S. and J.W. Armstrong. 1988. Development of regionally standardized protocols for marine environmental studies. Marine Pollution Bulletin 19:310–313.

Brophy, L. 2005. Estuarine Assessment. In: Watershed Assessment Manual. Oregon Watershed Enhancement Board, Salem, OR.

Lamberson, J.O. 2002. Environmental Monitoring and Assessment Program (EMAP) national coastal assessment field operations. West Coast field sampling methods, intertidal 2002. Western Ecology Division, USEPA, Newport, OR.

Neckles, H.A. and M. Dionne (eds.). 2000. Regional standards to identify and evaluate tidal wetland restoration in the Gulf of Maine. Wells National Estuarine Research Reserve, Maine. http://www.pwrc.usgs.gov/resshow/neckles/gpac.htm

Neckles, H.A., M. Dionne, D.M. Burdick, C.T. Roman, R. Buchsbaum, and E. Hutchins. 2002. A monitoring protocol to assess tidal restoration of salt marshes on local and regional scales. Restor. Ecol. 10:556–563.

Niedowski, N. 2000. New York State Salt Marsh Restoration and Monitoring Guidelines. NY Div. of Coastal Resources and NY State Dept. of Environmental Conservation.

Pacific Estuarine Research Laboratory. 1990. A Manual for Assessing Restored and Natural Coastal Wetlands with Examples from Southern California. California Sea Grant Report No. T-CSGCP-021. Biology Dept., San Diego State University, La Jolla, CA.

Roman, C.T., M. James-Pirri, and J.F. Heltshe. 2001. Monitoring salt marsh vegetation: a protocol for the long-term coastal ecosystem monitoring program at Cape Cod National Seashore. USGS Patuxent Wildlife Research Center and National Park Service Cape Cod National Seashore. http://www.nature.nps.gov/im/monitor/protocoldb.cfm

Short, F.T., D.M. Burdick, C.A. Short, R.C. Davis, and P.A. Morgan. 2000. Developing success criteria for restored eelgreass, salt marsh, and mudflat habitats. Ecological Engineering 15:239–252.

Simenstad, C.A., C.D. Tanner, R.M. Thom, and L. Conquest. 1993. Estuarine Habitat Assessment Protocol. FRI-UW-8918. Fisheries Research Institute, University of Washington, Seattle.

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Sutula, M., J. Collins, J. Callaway, T. Parker, M. Vasey, and E. Wittner. 2002. Quality assurance project plan (QAPP) for Environmental Monitoring and Assessment Program (EMAP) West Coast pilot 2002 intertidal assessment: California intensification. USEPA, San Francisco, CA.

USEPA. 1995a. Short-term methods for estimating the chronic toxicity of effluents and receiving waters to West Coast marine and estuarine organisms. EPA 600/R-95-136. USEPA, Washington, D.C. (NTIS /PB95-261665 or NEPIS /http://www.epa.gov/clariton/).

USEPA. 1995b. Environmental Monitoring and Assessment Program (EMAP) Laboratory methods manual for estuaries, volume 1: biological and physical analyses. EPA 620/R-95-008. USEPA, Washington, D.C. (NTIS /PB96-151196 or EMAP /http://www.epa.gov/emfjulte/html/pubs/docs/groupdocs/estuary/field/labman.html )

USEPA. 2000. Estuarine and coastal marine waters: bioassessment and biocriteria technical guidance. EPA 822/B-00-024. USEPA, Washington, D.C.

USEPA 2001a. Environmental Monitoring and Assessment Program (EMAP): National Coastal Assessment Quality Assurance Project Plan 2001-2004. EPA 620/R-01/002. USEPA, Gulf Breeze, FL.

USEPA 2001b. National Coastal Assessment: Field Operations Manual. EPA 620/R-01/003. USEPA, Gulf Breeze, FL.

Zedler, J.B. and R. Lindig-Cisneros. 2000. Functional equivalency of restored and natural salt marshes. pp. 569–582 in: M.P.Weinstein and D.A. Kreeger (eds.). Concepts and Controversies in Tidal Marsh Ecology. Kluwer Academic Publishers, Boston.

### ***Estuarine Integrity, Vulnerability, or Risk Indices or Analyses*** (also not rapid, usually include criteria or scoring models but focus on just one or a few taxonomic groups or features; most require taxonomic skills and sample processing; not all are intended for tidal wetlands specifically):

Carlisle, B.K., J.P. Smith, A.L. Hicks, B.G. Largay, and S.R. Garcia. 1998. Wetland Ecological Integrity: An Assessment Approach. Massachusetts Coastal Zone Management Program, Boston.

Cooper, J.A.G., A.E.L. Ramm, and T.D. Harrison. 1994. The estuarine health index: a new approach to scientific information transfer. Ocean and Coastal Management 25:103–141.

Bilyard, G.R. 1987. The value of benthic infauna in marine pollution monitoring studies. Marine Pollution Bulletin 18:581–585.

Deegan, L.A., J.T. Finn, S.G. Ayvazian, C.A. Ryder-Kieffer, and J. Buonaccorsi. 1997. Development and validation of an estuarine biotic integrity index. Estuaries 20:601–617.

Deluca, W.V., C.E. Studds, L.L. Rockwood, and P.P. Marra. 2004. Influence of land use on the integrity of marsh bird communities of Chesapeake Bay. Wetlands 24:837–847.

Diaz, R.J. 1982. Examination of Tidal Flats: Evaluation Methodology. FHWA/RD-80/183. Federal Highway Admin., Washington, D.C.

Engle, V.D , J. Summers, and G. Gaston. 1994. A benthic index of environmental condition of Gulf of Mexico estuaries. Estuaries 17:372–384.

Engle, V.D. 2000. Application of the indicator evaluation guidelines to an index of benthic condition for Gulf of Mexico Estuaries. Section 3 in: Jackson, L.E., J.C. Kurtz, and W.S. Fisher (eds.). Evaluation Guidelines for Ecological Indicators. EPA/620/R-99/005. USEPA, Washington, D.C.

Engle, V.D. and J.K. Summers. 1999. Refinement, validation, and application of a benthic condition index for Gulf of Mexico estuaries. Estuaries 22:624–635.

Ferreira, J.G. 2000. Development of an estuarine quality index based on key physical and biogeochemical features. Ocean and Coastal Management 43:99–122.

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Oviatt, C.A., S.W. Nixon, and J. Garber. 1977. Variation and evaluation of coastal salt marshes. Environmental Management 1:201–211.

Parrish, J.K., K. Bell, E. Logerwell, and C. Roegner. 2000. Indicators of West Coast estuary health. Annual Report, PNCERS, University of Washington, Seattle.

Rizzo, W.M., R.E. Berry, R.L. Wetzel, S.K. Dailey, G.J. Lackey, and R.R. Christian. 1996. A metabolism-based trophic index for comparing the ecological values of shallow-water sediment habitats. Estuaries 19:247–256.

Smith, R.W., M. Bergen, S.B. Weisberg, D. Cadien, A. Dalkey, D. Montagne, J.K. Stull, and R.G. Velarde. 2001. Benthic response index for assessing infaunal communities on the southern California mainland shelf. Ecological Applications 11:1073–1087.

Thompson, B. and S. Lowe. 2004. Assessment of macrobenthos response to sediment contamination in the San Francisco Estuary, California, USA. Environmental Toxicology and Chemistry 23:2178–2187.

Van Dolah, R.F., J.L Hyland, A.F. Holland, J.S. Rosen, and T.R. Snoots. 1999. A benthic index for assessing sediment quality in estuaries of the southeastern United Sates. Marine Environmental Research 48:269–283.

Warwick. R.M. 1986. A new method for detecting pollution effects on marine macrobenthic communities. Marine Biology 92:557–562.

Weisberg, S.B., J.A. Ranasinghe, D.M Dauer, L.C. Schaffner, R. Diaz, and J. Frithsen. 1997. An estuarine benthic index of biotic integrity (B-IBI) for Chesapeake Bay. Estuaries 20:149–156.

Wilson, J.G. and D.W. Jeffrey. 1994. Benthic biological pollution indices in estuaries. pp. 311–327 in: K.J.M. Kramer (ed.). Biomonitoring of Coastal Waters and Estuaries. CRC Press, Boca Raton, FL.

## Appendix B. Forms Used in 2003 Field Data Collection

Data collected from 120 tidal wetlands using these forms is available in the files described in Appendix C. These forms do not constitute the HGM "rapid-assessment method."

**Form MQ. Marsh Quadrats**

Site_________ Date__________________ Observer:________________
Start Time:_________ Start Latitude: ____________Start Longitude:____________ Bearing: ___________°
End Time: _________ End Latitude: _____________ End Longitude: ________________

| Point | Distance | Elev | Plant Species (% cover) (/D = dead) | Other |
|---|---|---|---|---|
| | | | | |
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Soil: indicate if no hydric evidence (NH)
Other: **B**are (%), **W**ater (%), **L**og, **L**arge **T**rash (> 2 sq.ft) **S**mall **T**rash (<2 sq.ft). Do not count the quadrat toward your required total of 16 if any of these features occupies >9% of the quadrat. In that case, record the information and then move to the nearest point where plant cover is >90% and do the official quadrat there.

## Form C. Channel Transects

Site_________ Date__________ Observer:________________ Start Time: ____________________ End Time: _________________

*This channel is*: _____ tidal channel only (blind) _____ tributary, flowing today _____ tributary, not flowing today _____ artificially fed channel/ditch only

*Take a photo of each cross-section (up and downstream views). Draw transect locations on aerial photograph.*

| Xsec # | Latitude | Longitu | Distance from previous Xsec | Bank angles since last Xsec | Vegetation since previous Xsec (on banks or within 15m, whichever is less) (and circle the predominant one) | Point feature (PF) | Distance from previous PF | Elevation of PF | Vegetation at point (and circle the predominant one) |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |
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At a minimum, take data at **B** = channel bottom, **RE, LE** = right and left edge of contiguous vegetation; **RT, LT** = right and left top of bank; **RB, LB** = right and left backside @ 15m; **VC1, 2** etc. = vegetation change at intermediate point 1, 2, etc. on right or left bank (record only the elevation)
Angles: **V**ertical (90–45°), **S**teep (45–30°), **M**oderate (5–30° **F**lat (5–1°), **U**ndercut

## Form G. Site Disturbance Checklist

Site Number: ______
Date Visited: ______
Times of Visit:________________________
Observer: ____________________________

Is at least part of the marsh accessible to fish during spring tides? _________________

Describe any artificial features within or below the site that potentially restrict passage of some fish:

| |
|---|
| |
| |
| |
| |

Visits within the marsh and extending 100 ft into the uplands:

| | **% of site** |
|---|---|
| Percent of marsh and upland visited daily or almost so by people on *foot* | % |
| Percent of marsh and upland with intermediate visitation frequency | % |
| Percent of marsh and upland visited only rarely (<10 days /yr) | ____% |
| | 100 % |

Distance to nearest residence: __________ft

Exotic Invertebrate Introduction Potential:

| | |
|---|---|
| *In same estuary:* | |
| Oyster cultivation facility? | |
| Foreign ship traffic: frequent? | |
| Foreign ship traffic: occasional? | |
| Local boat traffic: frequent? | |
| Local boat traffic: occasional? | |

Human-related Disturbances:

| If present, indicate:<br>2 = extensive<br>1 = minor | onsite | | offsite w/i 100 ft | |
|---|---|---|---|---|
| | now | hist. | now | hist. |
| ATV use | | | | |
| Bulldozing | | | | |
| Ditches/excavation | | | | |
| Dikes | | | | |
| Docks/marina | — | — | | |
| Dredging | — | — | | |
| Eroding upland | | | | |
| Facility, chemical/petro | — | — | | |
| Facility, other industrial | — | — | | |
| Feedlot/manure pit | — | — | | |
| Fill (other than dike) | | | | |
| Garbage/log dumping | | | | |
| Golf course | — | — | | |
| Gravel/sand extraction | | | | |
| Grazing/fences | | | ▨ | ▨ |
| Haying | | | — | — |
| Lawn | | | | |
| Logging, clearcut | | | | |
| Logging, other major | | | | |
| Mowing | | | — | — |
| Pilings | | | | |
| Pipes, intake | | | | |
| Pipes, outfall | | | | |
| Residence, sewered | — | — | | |
| Residence, septic | — | — | | |
| Riprap, seawalls, etc. | | | | |
| Road, dirt | | | | |
| Road, paved | — | — | | |
| Row crop/garden/tilled | — | — | | |
| Skidder trail | — | — | | |
| Utility, overhead | | | | |
| Utility, underground | | | | |
| Weir/dam | | | | |

* "now" = within 5 yrs
"hist." = historical, i.e., >5 yrs ago but likely to still be affecting functions in the marsh

**Form H. Mesoscale Indicators Assessment Form**

| **Visually assessed Indicator** | **Low Marsh** | **High Marsh** |
|---|---|---|
| Subclass as a proportion of total marsh (%) | % | % |
| Major vegetation species in subclass (list if >5% of subclass area) | | |
| 1. | % | % |
| 2. | % | % |
| 3. | % | % |
| 4. | % | % |
| 5. | % | % |
| 6. | % | % |
| 7. | % | % |
| 8. | % | % |
| 9. | % | % |
| 10. | % | % |
| 11. | % | % |
| 12. | % | % |
| 13. | % | % |
| 14. | % | % |
| 15. | % | % |
| Proportion of internal channel network (contiguous or not) that was wetted during today's *low* tide (check ONE): | | |
| 0 % | | |
| 1–10% | | |
| 10–30% | | |
| 30–60% | | |
| 60–90% | | |
| 90–99% | | |
| 100% | | |
| Proportion of marsh surface that was wetted during today's *high* tide (check ONE): | | |
| 0 % | | |
| 1–10% | | |
| 10–30% | | |
| 30–60% | | |
| 60–90% | | |
| 90–99% | | |
| 100% | | |
| Maximum proportion of marsh area that could be shaded by woody vegetation, wrack, or topography: | | |
| 0 % | | |
| 1–10% | | |
| 10–30% | | |
| >30% (give estimate) | | |
| Proportion of tidal marsh occupied by living shrubs | —- | % |
| Proportion of tidal marsh occupied by living spruce trees | —- | % |

### Mesoscale Indicators Assessment Form (continued)

| **Visually assessed Indicator** | **Low Marsh** | **High Marsh** |
|---|---|---|
| Undercut bay edge (% of total external edge length, check ONE): | | |
| 0 % | | —- |
| 1–10% | | —- |
| 10–30% | | —- |
| 30–60% | | —- |
| 60–90% | | —- |
| >90% | | —- |
| Undercut channel banks (% of total internal channel network length, both banks, check ONE): | | |
| 0 % | | |
| 1–10% | | |
| 10–30% | | |
| 30–60% | | |
| 60–90% | | |
| >90% | | |
| Transition angle from *unvegetated to vegetated* intertidal<br>(V = vertical; N = gentle but noticeable topographic break; S = smooth transition) | | —- |
| Transition angle from *low to high* marsh<br>(V = vertical; N = gentle but noticeable topographic break; S = smooth transition) | | —- |
| Length of tidal channel (m) with mudflats >2m wide at low tide: | | |
| Brackish or saline pannes, wet or dry, unconnected to channels<br>(total area, check ONE): | | |
| 0 | | |
| 1–100m$^2$ | | |
| 100–2,500m$^2$ | | |
| 2,500–10,000m$^2$ | | |
| >9,000m$^2$ | | |
| Wet pools, isolated, fresh (salinity <0.5 ppt), not recently flooded by tide, includes some remnant ditches (check ONE): | | |
| 0 | —- | |
| 1–100m$^2$ | —- | |
| 100–2500m$^2$ | —- | |
| 2,500–10,000m$^2$ | —- | |
| >9,000m$^2$ | —- | |
| Large woody debris (diameter >15 cm, length >2 m, or root wad), individually or as a pile with these dimensions, and located in tidal channel? | | |
| Isolated large root wads or fallen trees: estimate number on marsh surface: | | |
| Standing snags (estimate number): | —- | |
| Drift wood line: proportion of upland edge (check ONE): | | |
| 0 % | —- | |
| 1–10% | —- | |
| 10–30% | —- | |
| 30–60% | —- | |
| 60–90% | —- | |
| >90% | —- | |

| **External intertidal or edge habitats**<br>**(M = mudflat; E = eelgrass; S = sand flat; R = rock; RR = riprap; D = dike/levee)** | **Coverage within 300 ft** |
|---|---|
| 1. | % |
| 2. | % |
| 3. | % |
| 4. | % |
| 5. | % |

| **External land cover, aerial view, upslope within 100 ft. of upland edge** | **on flat slope** | **moderate slope** | **steep slope** |
|---|---|---|---|
| emergent non-tidal wetland, pond | | | % |
| grass-forb: unmowed ungrazed (tall) | | | % |
| grass-forb: lawn, grazed pasture, crops, or mowed (short) | | | % |
| alder, scotch broom, or sweetgale shrub | | | % |
| other short shrub (2–6 ft tall), native | | | % |
| other short shrub (2–6 ft tall), e.g., willow, blackberries, vines | | | % |
| tall shrub (6–20 ft tall) | | | % |
| upland forest (>20 ft tall) | | | % |
| buildings, other structures | | | % |
| bare dike, fill, road | | | % |
| bare sand dune, rock, riprap | | | % |
| other: ________________________________ | | | % |
| | | | 100 % |

* flat is <5%, moderate is 5–20%, steep is >20% slope

# Appendix C. Data Dictionaries for Files from the 2003 Oregon Coast Tidal Wetland Survey

FILE: **VegMesoscale**
records: 1,229
General Description: This file describes the overall percent of the high and/or low marsh zone occupied by each plant species that seemed to comprise (in most cases) more than 1 percent of either zone, as estimated visually across the entire zone by field crews.

| heading for VegMesoscale | description |
|---|---|
| Site | identifier for the site |
| Zone | H = high marsh, L = low marsh; based on coarse visual assessment rather than by measured elevations |
| ZonePct | percent of the marsh covered by the zone, estimated visually rather than by measured elevations |
| SciName | scientific name of plant species |
| MajorVeg | standardized species code associated with SciName |
| PctOfZone | percent of the zone (not the entire marsh) occupied by the major species, estimated visually; mimimum threshold generally 1 percent overall cover |

FILE: **MarshTransectData**
records: 12,576
General Description: Contains relative percent cover and relative elevation data by species from a total of 3,339 points (including 2,549 meter-square quadrats) along 261 transects (about 2 per site) in 121 marshes.

| heading for MarshTransectData | description |
|---|---|
| Site | identifier code for the site |
| Transect | identifier code for the marsh transect |
| PtSeq | sequence code for the quadrat along each marsh transect |
| InQuad | 0 = quadrat in which bare/water comprised >20%; 1 = bare/water was <20%; blank = no percent cover data available |
| Feature | T = vegetation transition noted in the field; P = panne; C = channel; D = dike; UPL = upland |
| Dis2start | distance (m) from quadrat to the beginning of the transect; usually, the distance to the main channel or bay |
| PctLength | the quadrat's relative position on the transect, where 0 = closest to the external bay or river and 1 = closest to upland |
| RelElev | elevation (m) of the quadrat relative to the lowest point measured along any marsh transect at this site |
| RelVelev | elevation (m) of the quadrat relative to the lowest **vegetated** point measured along any marsh transect at this site |
| SciName | scientific name of plant species found in the quadrat |
| SpCode | standardized code for the species used on field forms |
| PctCov | relative percent cover estimated for the species in the quadrat |

FILE: **XSvegAll**
records: 7,567

General Description: Contains occurrence and relative elevation data by species from a total of 2,865 points along 471 transects (about 5 per site) in 101 marshes.

| heading for XSvegAll | description |
|---|---|
| Site | identifier code for the site |
| Xsec | identifier code for the site’s channel cross-sectional transect |
| Geo | position of the point along the transect: B = internal marsh channel; C = other channel; RE/LE = right or left edge of internal channel; RT/LT = right or left top-of-bank of the internal channel; RB/LB = right or left end of cross-sectional transect, usually 15m perpendicular from the internal channel; RV/LV = points between RT and RB (or LT and LB) at which vegetation change was noted; UPL = upland (-R, -L for right or left) |
| SciName | scientific name of the plant species (percent cover not estimated on channel transects |
| SpCode | standardized species code |
| DomSp | D = species noted as dominant or co-dominant at this point on the transect |
| Dist | distance (m) from centerpoint of the internal channel crossed by this transect |
| ElRel_B | elevation (m) of the point relative to the lowest point measured along any channel cross-section transect at this site |
| ElRel_VE | elevation (m) of the point relative to the lowest vegetated point measured along any channel cross-section transect at this site |

FILE: **StreamsideRawData**
records: 2,264
General Description: Records of the occurrences of species in 415 segments along the banks of the internal channels of 97 tidal marshes.

| heading | description |
|---|---|
| Site | identifier code for site |
| Transect | closest transect (1 = closest to bay or river, 5 = closest to upland) |
| SpCode | standardized code for species |
| SciName | scientific name |

FILE: **Pannes**
records: 43
General Description: Salinity and relative elevation of 43 pannes noted non-systematically in 32 tidal marshes.

| heading | description |
|---|---|
| Site | identifier code for the site |
| Panne | code for an individual panne when multiple pannes were sampled |
| RelEl | elevation (m) relative to lowest point on the marsh transect |
| Salinity | water salinity (ppt) in the panne |

FILE: **SoilData**
records: 358

General Description: Soil salinity, texture, and other soil features in soils associated with the one to three most-dominant plant communities at each of 117 tidal marshes.

| heading for SoilData | description |
|---|---|
| Site | identifier code for the site |
| Sp1name | scientific name of a plant species that is dominant or co-dominant |
| Sp1code | standardized species code for the above |
| Sp2name | scientific name of an associated plant species that is dominant or co-dominant |
| Sp2code | standardized species code for the above |
| Time | approximate time (military) when soil sample was extracted |
| Relel | elevation (m) of soil sample relative to lowest point on this site's marsh transects |
| Dist | distance from bay or river (estimated visually—very rough) |
| Salin | measured soil salinity (ppt) |
| Motts | 1 = mottling present |
| Gley | 1 = gley present |
| Sulf | 1 = hydrogen sulfide odor |
| Roots | 1 = roots and fibrous organics sparse; 3 = dense; 2 = intermediate (estimated visually) |
| Peat | 1 = soil obviously peaty |
| Clay | 1 = clayey soil |
| Loam | 1 = loamy soil |
| Silt | 1 = silty soil |
| Sand | 1 = sandy soil |
| SandDepth | depth (cm) to noticeable change in soil texture, usually to sand |

FILE: **LandCovSlope**
records: 173
General Description: This describes extent of various land cover classes in the adjoining upland as estimated while at the site. "Water" is not a category because it is not upland. Sites that are islands and contain <5% upland were not assessed with regard to their land cover.

| heading for LandCovSlope | description |
|---|---|
| Site | identifier code for the site |
| Slope Class | slope class(es) of the upland within 100 ft of the wetland edge: F = flat (<5%), M = moderate (5–20%), S = steep (>20%) |
| Non-tidal Wetlnd | percent of the area within 100 ft that is within this slope class and contains non-tidal wetland |
| Tall Grass | percent of the area within 100 ft that is within this slope class and contains tall grasses and forbs |
| Short Grass | percent of the area within 100 ft that is within this slope class and contains short grasses and forbs, e.g., lawns, heavily grazed pasture, most crops |
| N-fix Shrub | percent of the area within 100 ft that is within this slope class and contains alder, scotch broom, or other shrubs known to fix nitrogen |
| Short Shrub | percent of the area within 100 ft that is within this slope class and contains other short (2–6 ft) shrubs, e.g., blackberry, vines, willow |
| Tall Shrub | percent of the area within 100 ft that is within this slope class and contains other tall (6–20 ft) shrubs |

| heading for LandCovSlope | description |
|---|---|
| Forest | percent of the area within 100 ft that is within this slope class and contains trees >20 ft tall, with or without a closed canopy |
| Bdg | percent of the area within 100 ft that is within this slope class and contains buildings or other structures |
| Road and Dike | percent of the area within 100 ft that is within this slope class and contains roads, fill, or bare dike |
| Dune and Rock | percent of the area within 100 ft that is within this slope class and contains bare sand dune, rock, riprap |

FILE: **SiteBiol**
records: 121
General Description: Contains counts and indices derived from files listed earlier. Includes species richness as well as frequency and cumulative percent cover for various functional groupings of plant species. With regard to species-level rooting and salinity tolerances, some species were assigned to multiple categories as appropriate.

| heading for SiteBiol | description |
|---|---|
| Seq | sequencing code for the site |
| Site | site identifier code |
| HGM_MR | M = predominantly marine-sourced; R = predominantly river-sourced; based on coarse visual assessment rather than on measured elevations or hydrology |
| HGM_LH | H = predominantly high marsh; L = predominantly low marsh; based on coarse visual assessment rather than on measured elevations or hydrology |
| EstHiPct | visually estimated high marsh percent; not based on measured elevations |
| EstLoPct | visually estimated low marsh percent; not based on measured elevations |
| Area | appoximate area (acres) within the assessed unit (the “site”) |
| TransectL | cumulative length of the two marsh transects |
| SpMeso | number of species covering >4% of the assessed unit, based on visual estimate (not quadrats) |
| SpNativMeso | number of native species covering >4% of the assessed unit, based on visual estimate |
| HiSpMeso | number of species covering >1% of the part of the site suspected of being high marsh, based on visual estimate |
| LoSpMeso | number of species covering >1% of the part of the site suspected of being low marsh, based on visual estimate |
| NNmesoPC | combined percent cover of non-native species over the entire assessment unit, based on visual estimates only |
| BankSpp | number of plant species found along the banks of the internal tidal channel (just the major species, searching was not limited to channel cross-sections and also was not comprehensive; lack of a standardized protocol for this component resulted in systematic differences between numbers of species recorded by south and north coast crews) |
| UnitEff | 100 x TransectL (ft)/Area (sq.ft); a measure of the relative extent of coverage of the site by the marsh transects |
| SppSite | number of plant species found in the entire wetland site, including both the marsh and channel transects |
| NumQd01 | number of quadrats at the site, including ones with >20% bare substrate |
| NumQd1 | number of quadrats at the site, excluding ones with >20% bare substrate |
| SppAll_MT | number of species found anywhere along the marsh transects |

| heading for SiteBiol | description |
|---|---|
| SppQ01 | number of species found in quadrats along the marsh transects, including quadrats with >20% bare substrate |
| SppQ1 | number of species found in quadrats along the marsh transects, excluding quadrats with >20% bare substrate |
| Spp/Qd | number of species per quadrat along the marsh transects, excluding quadrats with >20% bare substrate |
| Spp1gt1 | number of species with percent cover >1% found in quadrats along the marsh transects, excluding quadrats with >20% bare substrate |
| Pct1 | the above total as a proportion of all species found in quadrats along the marsh transects, excluding quadrats with >20% bare substrate |
| Spp1gt20 | number of species with percent cover >19% found in quadrats along the marsh transects, excluding quadrats with >20% bare substrate |
| Pct20 | the above total as a proportion of all species found in quadrats along the marsh transects, excluding quadrats with >20% bare substrate |
| Spp1gt50 | number of species with percent cover >49% found in quadrats along the marsh transects, excluding quadrats with >20% bare substrate |
| Pct50 | the above total as a proportion of all species found in quadrats along the marsh transects, excluding quadrats with >20% bare substrate |
| Spp1gt90 | number of species with percent cover >89% found in quadrats along the marsh transects, excluding quadrats with >20% bare substrate |
| Pct90 | the above total as a proportion of all species found in quadrats along the marsh transects, excluding quadrats with >20% bare substrate |
| NNspAll | number of non-native plant species found in the entire wetland site, including both the marsh and channel transects |
| NNPctAll | the above as a proportion of all species found at the site |
| NNspQ1 | number of non-native species found in quadrats along the marsh transects, excluding quadrats with >20% bare substrate |
| NN/qd | number of non-native species per quadrat along the marsh transects, excluding quadrats with >20% bare substrate |
| PctQ1 | proportion of all species found in the quadrats that were non-native |
| NnspQgt1 | number of non-native species with percent cover >1% found in quadrats along the marsh transects, excluding quadrats with >20% bare substrate |
| Pct1lNNall | the above total as a proportion of all non-native species found in quadrats along the marsh transects, excluding quadrats with >20% bare substrate |
| NnspQgt20 | number of non-native species with percent cover >19% found in quadrats along the marsh transects, excluding quadrats with >20% bare substrate |
| Pct20lNNall | the above total as a proportion of all non-native species found in quadrats along the marsh transects, excluding quadrats with >20% bare substrate |
| NnspQgt50 | number of non-native species with percent cover >49% found in quadrats along the marsh transects, excluding quadrats with >20% bare substrate |
| Pct50lNNall | the above total as a proportion of all non-native species found in quadrats along the marsh transects, excluding quadrats with >20% bare substrate |
| PctAllQd1 | proportion of all quadrat species that were both non-native and had percent cover >50% |
| NnspQgt90 | number of non-native species with percent cover >89% found in quadrats along the marsh transects, excluding quadrats with >20% bare substrate |
| Pct90lNNall | the above total as a proportion of all non-native species found in quadrats along the marsh transects, excluding quadrats with >20% bare substrate |
| AnSpAll | number of annual plant species found in the entire wetland site, including both the marsh and channel transects |

| heading for SiteBiol | description |
|---|---|
| Ann%all | the above total as a proportion of all species found at the site |
| AnSpQ1 | number of annual species found in quadrats along the marsh transects, excluding quadrats with >20% bare substrate |
| An/Qd1 | number of annual species per quadrat along the marsh transects, excluding quadrats with >20% bare substrate |
| AnQpctAllQ | proportion of all species found in the quadrats that were annual |
| AnSpgt1 | number of annual plant species with >1 percent cover |
| Pctgt1 | the above total as a proportion of all annual species found at the site |
| AnSpgt20 | number of annual plant species with >19 percent cover in the marsh quadrats |
| AnSpgt50 | number of annual plant species with >49 percent cover in the marsh quadrats |
| AnSpgt90 | number of annual plant species with >89 percent cover in the marsh quadrats |
| RtNone | number of plant species found in the marsh quadrats which are not rooted in the substrate, e.g., marsh dodder |
| pctNone | the above as a proportion of all species found on the site's marsh transects (some species with multiple rooting strategies are counted more than once) |
| RtRhiz | number of plant species found in the marsh quadrats that are rhizotomous |
| pctRhiz | the above as a proportion of all species found on the site’s marsh transects (some species with multiple rooting strategies are counted more than once) |
| RtTap | number of plant species found in the marsh quadrats that characteristically have taproots |
| PctTap | the above as a proportion of all species found on the site’s marsh transects (some species with multiple rooting strategies are counted more than once) |
| RtTuft | number of plant species found in the marsh quadrats whose roots grow in tufts |
| PctTuft | the above as a proportion of all species found on the site’s marsh transects (some species with multiple rooting strategies are counted more than once) |
| RtStol | number of plant species found in the marsh quadrats whose roots are stoloniferous |
| PctStol | the above as a proportion of all species found on the site’s marsh transects (some species with multiple rooting strategies are counted more than once) |
| RtFibr | number of plant species found in the marsh quadrats whose roots are fibrous |
| PctStol | the above as a proportion of all species found on the site’s marsh transects (some species with multiple rooting strategies are counted more than once) |
| RootSum | sum of species with root information |
| Forb_gt1 | number of other forb species with percent cover >1 in the marsh quadrats |
| ForbSucGt1 | number of succulent forb species with percent cover >1 in the marsh quadrats |
| GrassGt1 | number of other graminoid species with percent cover >1 in the marsh quadrats |
| GtallGT1 | number of tall graminoid species (e.g., *Deschampsia*) with percent cover >1 in the marsh quadrats |
| FV_gt1 | vine subtotal 1 |
| V_gt1 | vine subtotal 2 |
| VineSum1 | number of forb species that are vines and have percent cover >1 in the marsh quadrats |
| AqGt1 | number of forb species that are partly submersed aquatics and have percent cover >1 in the marsh quadrats |
| GrobusGT1 | number of robust graminoid species (e.g., bullrush) with percent cover >1 in the marsh quadrats |
| FE_gt1 | number of forb species that are ferns or horsetails and have percent cover >1 in the marsh quadrats |
| ForbSumGT1 | total number of forb species that have percent cover >1 in the marsh quadrats |
| GramSumGT1 | total number of graminoid species that have percent cover >1 in the marsh quadrats |
| Forb1Sp% | forb species that have percent cover >1 in the quadrats as a proportion of all quadrat species |
| F20 | number of other forb species with percent cover >19 in the marsh quadrats |

| heading for SiteBiol | description |
|---|---|
| FS20 | number of succulent forb species with percent cover >19 in the marsh quadrats |
| G20 | number of other graminoid species with percent cover >19 in the marsh quadrats |
| GT20 | number of tall graminoid species (e.g., *Deschampsia*) with percent cover >19 in the marsh quadrats |
| FV20 | number of forb species that are vines and have percent cover >19 in the marsh quadrats |
| GR20 | number of robust graminoid species (e.g., bullrush) with percent cover >19 in the marsh quadrats |
| FE20 | number of forb species that are ferns or horsetails and have percent cover >19 in the marsh quadrats |
| A20 | number of forb species that are partly submersed aquatics and have percent cover >19 in the marsh quadrats |
| Forb20Sum | total number of forb species that have percent cover >19 in the marsh quadrats |
| Gram20Sum | total number of graminoid species that have percent cover >19 in the marsh quadrats |
| Forb20sp% | forb species that have percent cover >19 in the quadrats as a proportion of all quadrat species |
| FS50 | number of succulent forb species with percent cover >49 in the marsh quadrats |
| GT50 | number of tall graminoid species (e.g., *Deschampsia*) with percent cover >49 in the marsh quadrats |
| F50 | number of other forb species with percent cover >49 in the marsh quadrats |
| G50 | number of other graminoid species with percent cover >49 in the marsh quadrats |
| FE50 | number of forb species that are ferns or horsetails and have percent cover >49 in the marsh quadrats |
| GR50 | number of robust graminoid species (e.g., bullrush) with percent cover >49 in the marsh quadrats |
| A50 | number of forb species that are partly submersed aquatics and have percent cover >49 in the marsh quadrats |
| FV50 | number of forb species that are vines and have percent cover >49 in the marsh quadrats |
| ForbSum50 | total number of forb species that have percent cover >49 in the marsh quadrats |
| GramSum20 | total number of graminoid species that have percent cover >49 in the marsh quadrats |
| Forb50sp% | forb species that have percent cover >49 in the quadrats as a proportion of all quadrat species |
| Forb90 | number of other forb species with percent cover >89 in the marsh quadrats |
| Grass90 | number of other graminoid species with percent cover >89 in the marsh quadrats |
| FS90 | number of succulent forb species with percent cover >89 in the marsh quadrats |
| GT90 | number of tall graminoid species (e.g., *Deschampsia*) with percent cover >89 in the marsh quadrats |
| FE90 | number of forb species that are ferns or horsetails and have percent cover >89 in the marsh quadrats |
| GR90 | number of robust graminoid species (e.g., bullrush) with percent cover >89 in the marsh quadrats |
| A90 | number of forb species that are partly submersed aquatics and have percent cover >89 in the marsh quadrats |
| GramSum90 | total number of graminoid species that have percent cover >89 in the marsh quadrats |
| ForbSum90 | total number of forb species that have percent cover >89 in the marsh quadrats |
| Forb90sp% | forb species that have percent cover >89 in the quadrats as a proportion of all quadrat species |
| WetIndMinMT | minimum value among the site’s marsh quadrats for the wetness index (10 = wettest, 0 = driest; see text) |
| WetIndMaxMT | maximum value among the site’s marsh quadrats for the wetness index (10 = wettest, 0 = driest; see text) |
| WetIndAvgMT | mean value among the site’s marsh quadrats for the wetness index (10 = wettest, 0 = driest; see text) |
| UplQds | proportion of quadrats having predominantly non-wetland species i.e., wet index score <5 |

| heading for SiteBiol | description |
|---|---|
| TotalSpC | total plant species found among the channel cross-sectional transects |
| TotNNspC | number of non-native plant species found among the channel cross-sectional transects |
| PctNNc | the above as a proportion of all species found among the channel transects |
| TotAnnSpC | number of annual plant species found among the channel cross-sectional transects |
| PctAnnC | the above as a proportion of all species found among the channel transects |
| ForbC | number of other forb species found among the channel cross-sectional transects |
| ForbSuccC | number of succulent forb species found among the channel cross-sectional transects |
| GrassC | number of other graminoid species found among the channel cross-sectional transects |
| GrassTallC | number of tall graminoid species found among the channel cross-sectional transects |
| ForbVineC | number of vine and forb species found among the channel cross-sectional transects |
| AquatC | number of forb species that are partially submersed aquatic found among the channel cross-sectional transects |
| FernC | number of forb species that are ferns or horsetails found among the channel cross-sectional transects |
| GrassRobustC | number of robust graminoid species found among the channel cross-sectional transects |
| VineC | number of forb species that are vines found among the channel cross-sectional transects |
| ForbCsum | total forb species found among the channel cross-sectional transects |
| GramCsum | total graminoid species found among the channel cross-sectional transects |
| ForbC% | forbs as a proportion of all species found among the channel cross-sectional transects |
| BrackFreshC | number of species classified as adapted to fresh or brackish salinity, among the channel cross-sectional transects |
| FreshC | number of species classified as adapted to fresh salinity, among the channel cross-sectional transects |
| BrackSalineC | number of species classified as adapted to saline or brackish conditions, among the channel cross-sectional transects |
| SalineC | number of species classified as adapted to saline conditions, among the channel cross-sectional transects |
| FBsumC | sum of BrackFreshC and FreshC |
| FB%C | species classified as adapted to fresh or brackish salinity, as a proportion of all species along the channel cross-sectional transects |
| Fresh% | species classified as adapted to fresh salinity, as a proportion of all species along the channel cross-sectional transects |
| BankSpC | number of plant species found on the top-of-bank portions of the channel cross-sectional transects |
| Bank%allC | the above as a proportion of all species found on the channel cross-sectional transects |
| BankNNspC | number of non-native plant species found on the top-of-bank portions of the channel cross-sectional transects |
| BankNN% | the above as a proportion of all species found on the channel cross-sectional transects |
| BankAnnSpC | number of annual plant species found on the top-of-bank portions of the channel cross-sectional transects |
| BankAnn% | the above as a proportion of all species found on the channel cross-sectional transects |
| TapCsp | number of plant species that characteristically have taproots and were found on the channel cross-sectional transects |
| TapC% | the above as a proportion of all species found on the site's channel transects (some species with multiple rooting strategies are counted more than once) |
| RhizCsp | number of plant species that characteristically have rhizomes and were found on the channel cross-sectional transects |
| RhizC% | the above as a proportion of all species found on the site's channel transects (some species with multiple rooting strategies are counted more than once) |

| heading for SiteBiol | description |
|---|---|
| StolonC | number of plant species that characteristically have stoloniferous roots and were found on the channel cross-sectional transects |
| StolC% | the above as a proportion of all species found on the site's channel transects (some species with multiple rooting strategies are counted more than once) |
| FibrousC | number of plant species that characteristically have fibrous roots and were found on the channel cross-sectional transects |
| FibC% | the above as a proportion of all species found on the site's channel transects (some species with multiple rooting strategies are counted more than once) |
| TuftC | number of plant species that characteristically have roots that grow as tufts, and were found on the channel cross-sectional transects |
| TufC% | the above as a proportion of all species found on the site's channel transects (some species with multiple rooting strategies are counted more than once) |
| RtNoneC | number of plant species that characteristically are not rooted in the substrate, e.g., marsh dodder |
| RtNo% | the above as a proportion of all species found on the site's channel transects (some species with multiple rooting strategies are counted more than once) |
| RtCsum | number of plant species on the cross-section that had information on rooting characteristics |
| WetIndMinC | minimum value along the channel cross-sectional transects for the wetness index (10 = wettest, 0 = driest; see text) |
| WetIndMaxC | maximum value along the channel cross-sectional transects for the wetness index (10 = wettest, 0 = driest; see text) |
| WetIndAvgC | mean value along the channel cross-sectional transects for the wetness index (10 = wettest, 0 = driest; see text) |
| WetIminBk | minimum value at the top-of-bank position of the channel cross-sectional transects for the wetness index (10 = wettest, 0 = driest; see text) |
| WetImaxBk | maximum value at the top-of-bank position of the channel cross-sectional transects for the wetness index (10 = wettest, 0 = driest; see text) |
| WetIavgBk | mean value at the top-of-bank position of the channel cross-sectional transects for the wetness index (10 = wettest, 0 = driest; see text) |
| NNavgPC | combined percent cover of non-native plant species, mean among marsh quadrats |
| NNmaxPC | combined percent cover of non-native plant species, maximum among marsh quadrats |
| AnnAvgPC | combined percent cover of annual plant species, mean among marsh quadrats |
| AnnMaxPC | combined percent cover of annual plant species, maximum among marsh quadrats |
| WoodyAvgPC | combined percent cover of woody plant species, mean among marsh quadrats |
| WoodyMaxPC | combined percent cover of woody plant species, maximum among marsh quadrats |
| FreshAvgPC | combined percent cover of plant species adapted mainly for fresh or brackish salinity, mean among marsh quadrats |
| FreshMaxPC | combined percent cover of plant species adapted mainly for fresh or brackish salinity, maximum among marsh quadrats |
| OBLavgPC | combined percent cover of wetland obligate plant species, mean among marsh quadrats |
| OBLmaxPC | combined percent cover of wetland obligate plant species, maximum among marsh quadrats |
| FibrAvgPC | combined percent cover of plant species whose roots are fibrous, mean among marsh quadrats |
| FibrMaxPC | combined percent cover of plant species whose roots are fibrous, maximum among marsh quadrats |
| RhizAvgPC | combined percent cover of rhizotomous species, mean among marsh quadrats |
| RhizMaxPC | combined percent cover of rhizotomous species, maximum among marsh quadrats |
| TapAvgPC | combined percent cover of species with taproots, mean among marsh quadrats |
| TapMaxPC | combined percent cover of species with taproots, maximum among marsh quadrats |
| StolAvgPC | combined percent cover of stoloniferous species, mean among marsh quadrats |
| StolMaxPC | combined percent cover of stoloniferous species, maximum among marsh quadrats |

| heading for SiteBiol | description |
|---|---|
| TuftAvgPC | combined percent cover of species whose roots grow in tufts, mean among marsh quadrats |
| TuftMaxPC | combined percent cover of species whose roots grow in tufts, maximum among marsh quadrats |
| NoRtAvgPC | combined percent cover of species with no obvious roots (e.g., saltmarsh dodder), mean among marsh quadrats |
| NoRtMaxPC | combined percent cover of species with no obvious roots (e.g., saltmarsh dodder), maximum among marsh quadrats |
| ForbAvgPC | combined percent cover of forbs, mean among marsh quadrats |
| ForbMaxPC | combined percent cover of forbs, maximum among marsh quadrats |
| GramAvgPC | combined percent cover of graminoids, mean among marsh quadrats |
| GramMaxPC | combined percent cover of graminoids, maximum among marsh quadrats |
| GrobustAvgPC | combined percent cover of robust graminoids, mean among marsh quadrats |
| GrobustMaxPC | combined percent cover of robust graminoids, maximum among marsh quadrats |
| NNnumQds | proportion of quadrats having non-native species |
| AnnNumQds | proportion of quadrats having annual species |
| WdyNumQds | proportion of quadrats having woody species |
| FreshumQds | proportion of quadrats having characteristically freshwater species |
| OBLnumQds | proportion of quadrats having wetland obligate species |
| FibrQdN | proportion of quadrats having species with fibrous roots |
| RhizQdN | proportion of quadrats having rhizotomous species |
| TapQdN | proportion of quadrats having species with taproots |
| StolQdN | proportion of quadrats having species with stolons or runners |
| TuftQdN | proportion of quadrats having species whose roots grow in tufts |
| NoRtQdN | proportion of quadrats having species with no obvious roots |
| ForbQdN | proportion of quadrats having forb species |
| GramQdN | proportion of quadrats having graminoid species |
| GrobustQdN | proportion of quadrats having robust graminoid species |

FILE: **MTqdWetScore**
records: 2581
General Description: By quadrat, this gives the wetness index, number and total percent cover of freshwater plant species, and relative elevation, plus the salinity measured at high and low tide at three locations at the site.

| heading for MTqdWetScore | description |
|---|---|
| Site | identifier for the site |
| Transect | identifier for the marsh transect |
| PtSeq | sequential number for the quadrat along the marsh transect |
| UPL | 1 = quadrat might be non-wetland (upland) based on its wetness score being <5 |
| SppPerQdPC | number of plant species found in the quadrat whose characteristic degree of association with wetlands had been categorized previously by USFWS |
| WetIndex | score for the wetness index (see text for formula); scores may be less reliable if SppPerQdPC (above) is low |
| FreshPC | total percent cover of species in the quadrat that had previously been known to be adapted to fresh or fresh-brackish environments |
| FreshSpp | number of species in the quadrat that had previously been known to be adapted to fresh or fresh- |

| heading for MTqdWetScore | description |
|---|---|
| | brackish environments |
| PctLength | quadrat’s position along its transect as represented by percent of transect length (0 = closest to bay or river, 1 = closest to upland) |
| RelElev | elevation (m) of the quadrat relative to the lowest point measured along any marsh transect at this site |
| RelVelev | elevation (m) of the quadrat relative to the lowest vegetated point measured along any marsh transect at this site |
| SalHiBR | salinity (ppt) nearest daytime high tide, measured in adjoining bay or river |
| SalHiCM | salinity (ppt) nearest daytime high tide, measured at mouth of a tidal channel exiting the marsh |
| SalHiUP | salinity (ppt) nearest daytime high tide, measured at farthest upstream point of an internal tidal channel |
| SalLoBR | salinity (ppt) nearest daytime low tide, measured in adjoining bay or river |
| SalLoCM | salinity (ppt) nearest daytime low tide, measured at mouth of a tidal channel exiting the marsh |
| SalLoUP | salinity (ppt) nearest daytime low tide, measured at farthest upstream point of an internal tidal channel |
| SoilSalMin | minimum of the three (usually) soil salinity measurements at the site (not in this quadrat specifically) |
| SoilSalMax | maximum of the three (usually) soil salinity measurements at the site (not in this quadrat specifically) |

FILE: **SppBySiteMT**
records: 1,839
General Description: This is a list of sites where each species was found in quadrats along the marsh transects, the number of quadrats in each site where found, and found having various percent cover classes.

| heading for SppBySiteMT | description |
|---|---|
| SciName | scientific name |
| Site | site identifier |
| NumQdsPres | number of quadrats along marsh transects at that site where species was found |
| PctQds | percent of quadrats along marsh transects at that site where species was found |
| MaxSite | 1 = species occurred more frequently at this site than at any other (based on marsh transect quadrats) |
| NumQdsGT1 | number of quadrats at this site in which the percent cover of the species exceeded 1% |
| NumQdsGT10 | number of quadrats at this site in which the percent cover of the species exceeded 9% |
| NumQdsGT20 | number of quadrats at this site in which the percent cover of the species exceeded 19% |
| NumQdsGT50 | number of quadrats at this site in which the percent cover of the species exceeded 49% |
| NumQdsGT90 | number of quadrats at this site in which the percent cover of the species exceeded 89% |
| PctCovAvgSite | mean relative percent cover of the species among all quadrats along this site’s marsh transects |
| PctCovMaxSite | maximum relative percent cover of the species among all quadrats along this site’s marsh transects |

FILE: **SppPctCovMT**
records: 113

General Description: By species and percent cover class, this describes the relative elevation and lateral position of each species on the marsh transects.

| heading for SppPctCovMT | definition |
|---|---|
| SciName | scientific name |
| PC1numQuads | number of quadrats along all marsh transects in which relative percent cover of the species was >1 |
| PC1minL_ | nearest location to beginning of any marsh transect at which the species had >1 percent cover in a quadrat, expressed as a percent of transect length (0 = closest to external bay or river) |
| PC1maxL_ | farthest location from beginning of any marsh transect at which the species had >1 percent cover in a quadrat, expressed as a percent of transect length (0 = closest to external bay or river) |
| PC1avgL_ | mean location from beginning of any marsh transect at which the species had >1 percent cover in a quadrat, expressed as a percent of transect length (0 = closest to external bay or river) |
| PC1minElRel | minimum relative elevation (m above lowest point on transect) at which the species was found, among all marsh transects among all sites |
| PC1maxElRel | maximum relative elevation (m above lowest point on transect) at which the species had >1 percent cover, among all marsh transects among all sites |
| PC1avgElRel | mean relative elevation (m above lowest point on transect) at which the species had >1 percent cover, among all marsh transects among all sites |
| PC1minVelRel | minimum relative elevation (m above lowest vegetated point on transect) at which the species had >1 percent cover, among all marsh transects among all sites |
| PC1maxVelRel | maximum relative elevation (m above lowest vegetated point on transect) at which the species had >1 percent cover, among all marsh transects among all sites |
| PC1avgVelRel | mean relative elevation (m above lowest vegetated point on transect) at which the species had >1 percent cover, among all marsh transects among all sites |
| PC10numQuads | number of quadrats along all marsh transects in which relative percent cover of the species was >9 |
| PC10minL_ | nearest location to beginning of any marsh transect at which the species had >9 percent cover in a quadrat, expressed as a percent of transect length (0 = closest to external bay or river) |
| PC10maxL_ | farthest location from beginning of any marsh transect at which the species had >9 percent cover in a quadrat, expressed as a percent of transect length (0 = closest to external bay or river) |
| PC10avgL_ | mean location from beginning of any marsh transect at which the species had >9 percent cover in a quadrat, expressed as a percent of transect length (0 = closest to external bay or river) |
| PC10minElRel | minimum relative elevation (m above lowest point on transect) at which the species had >9 percent cover, among all marsh transects among all sites |
| PC10maxElRel | maximum relative elevation (m above lowest point on transect) at which the species had >9 percent cover, among all marsh transects among all sites |
| PC10avgElRel | mean relative elevation (m above lowest point on transect) at which the species had >9 percent cover, among all marsh transects among all sites |
| PC10minVelRel | minimum relative elevation (m above lowest vegetated point on transect) at which the species had >9 percent cover, among all marsh transects among all sites |
| PC10maxVelRel | maximum relative elevation (m above lowest vegetated point on transect) at which the species had >9 percent cover, among all marsh transects among all sites |

| heading for SppPctCovMT | definition |
|---|---|
| PC10avgVelRel | mean relative elevation (m above lowest vegetated point on transect) at which the species had >9 percent cover, among all marsh transects among all sites |
| PC20numQds | number of quadrats along all marsh transects in which relative percent cover of the species was >19 |
| PC20minL_ | nearest location to beginning of any marsh transect at which the species had >19 percent cover in a quadrat, expressed as a percent of transect length (0 = closest to external bay or river) |
| PC20maxL_ | farthest location from beginning of any marsh transect at which the species had >19 percent cover in a quadrat, expressed as a percent of transect length (0 = closest to external bay or river) |
| PC20avgL_ | mean location from beginning of any marsh transect at which the species had >19 percent cover in a quadrat, expressed as a percent of transect length (0 = closest to external bay or river) |
| PC20minElRel | minimum relative elevation (m above lowest point on transect) at which the species had >19 percent cover, among all marsh transects among all sites |
| PC20maxElRel | maximum relative elevation (m above lowest point on transect) at which the species had >19 percent cover, among all marsh transects among all sites |
| PC20avgElRel | mean relative elevation (m above lowest point on transect) at which the species had >19 percent cover, among all marsh transects among all sites |
| PC20minVelRel | minimum relative elevation (m above lowest vegetated point on transect) at which the species had >19 percent cover, among all marsh transects among all sites |
| PC20maxVelRel | maximum relative elevation (m above lowest vegetated point on transect) at which the species had >19 percent cover, among all marsh transects among all sites |
| PC20avgVelRel | mean relative elevation (m above lowest vegetated point on transect) at which the species had >19 percent cover, among all marsh transects among all sites |
| PC50numQds | number of quadrats along all marsh transects in which relative percent cover of the species was >49 |
| PC50minL_ | nearest location to beginning of any marsh transect at which the species had >49 percent cover in a quadrat, expressed as a percent of transect length (0 = closest to external bay or river) |
| PC50maxL_ | farthest location from beginning of any marsh transect at which the species had >49 percent cover in a quadrat, expressed as a percent of transect length (0 = closest to external bay or river) |
| PC50avgL_ | mean location from beginning of any marsh transect at which the species had >49 percent cover in a quadrat, expressed as a percent of transect length (0 = closest to external bay or river) |
| PC50minElRel | minimum relative elevation (m above lowest point on transect) at which the species had >49 percent cover, among all marsh transects among all sites |
| PC50maxElRel | maximum relative elevation (m above lowest point on transect) at which the species had >49 percent cover, among all marsh transects among all sites |
| PC50avgElRel | mean relative elevation (m above lowest point on transect) at which the species had >49 percent cover, among all marsh transects among all sites |
| PC50minVelRel | minimum relative elevation (m above lowest vegetated point on transect) at which the species had >49 percent cover, among all marsh transects among all sites |
| PC50maxVelRel | maximum relative elevation (m above lowest vegetated point on transect) at which the species had >49 percent cover, among all marsh transects among all sites |
| PC50avgVelRel | mean relative elevation (m above lowest vegetated point on transect) at which the species had >49 percent cover, among all marsh transects among all sites |

FILE: **SppFreqMarshT**
records: 130
General Description: By species, this summarizes the number of marsh transect quads in which each species occurred in various percent cover categories, and the relative elevation and position of its occurrences on marsh transects.

| heading for SppPctCovMT | definition |
|---|---|
| SciName | scientific name |
| NumSites | number of sites where species was found anywhere along the marsh transects |
| NumSitesInQds | number of sites where species was found in quadrats along the marsh transects |
| NumQdsAll | number of marsh transect quadrats in which found, all sites combined, including quadrats that were >20% bare |
| NumQds | number of marsh transect quadrats in which found, all sites combined, excluding quadrats that were >20% bare |
| PctQdsAll | percent of marsh transect quadrats in which found, all sites combined, including quadrats that were >20% bare |
| NumQdsGT1 | number of marsh transect quadrats in which percent cover of the species was >1% (trace) |
| NumQdsGT10 | number of marsh transect quadrats in which percent cover of the species was >9% |
| NumQdsGT20 | number of marsh transect quadrats in which percent cover of the species was >19% |
| NumQdsGT50 | number of marsh transect quadrats in which percent cover of the species was >49% |
| NumQdsGT90 | number of marsh transect quadrats in which percent cover of the species was >89% |
| PcovMax | largest percent cover of the species found among all marsh transect quadrats among all sites |
| PcovAvg | mean percent cover of the species found among all marsh transect quadrats among all sites |
| MaxFqSite | site code of the site with the largest proportion of its quadrats containing this species |
| NumQdsPres | number of marsh transect quadrats in which the species was found at this maximum-frequency site |
| MaxPctQds | proportion of the marsh transect quadrats in which the species was found at this maximum-frequency site |
| MaxPCmxSite | maximum percent cover of the species at this maximum-frequency site |
| AvgPCmxSite | mean percent cover of the species at this maximum-frequency site |
| ElRelMin | minimum relative elevation (m above lowest point on transect) at which the species was found, among all marsh transects among all sites |
| ElRelMax | maximum relative elevation (m above lowest point on transect) at which the species was found, among all marsh transects among all sites |
| ElRelAvg | mean relative elevation (m above lowest point on transect) at which the species was found, among all marsh transects among all sites |

| heading for SppPctCovMT | definition |
|---|---|
| ElRelVmin | minimum relative elevation (m above lowest vegetated point on transect) at which the species was found, among all marsh transects among all sites |
| ElRelVmax | maximum relative elevation (m above lowest vegetated point on transect) at which the species was found, among all marsh transects among all sites |
| ElRelVavg | mean relative elevation (m above lowest vegetated point on transect) at which the species was found, among all marsh transects among all sites |
| DistRelMin | nearest location to beginning of any marsh transect at which the species was found in a quadrat, expressed as a percent of transect length (0 = closest to external bay or river) |
| DistRelMax | farthest location from beginning of any marsh transect at which the species was found in a quadrat, expressed as a percent of transect length (0 = closest to external bay or river) |
| DistRelAvg | mean location from beginning of any marsh transect at which the species was found in a quadrat, expressed as a percent of transect length (0 = closest to external bay or river) |

FILE: **ChannelMorph**
records: 423
General Description: By site and channel transect, this gives the channel top width and degree of incision.

| heading for ChannelMorph | description |
|---|---|
| Site | identifier code for the site |
| ChanTyp | type of channel where cross-sections were done: 1 = blind tidal channel only, 2 = tidal with upland input and flowing at time of visit; 3 = tidal with upland input but not flowing at time of visit, 4 = fed only via an artificial channel, pipe, or ditch |
| Xsec | identifier for internal channel cross-sectional transect (1= closest to bay or river, 5 = closest to upland) |
| Subs | 1 = sandy substrate; 2 = dike present; 0 = neither |
| Incision | elevation difference (m) between bottom of channel and the top of the higher of the channel's two banks at this point |
| TopWidth | distance (m) between tops of left and right channel banks |
| Ratio | Incision divided by TopWidth |
| Trib_ | 1 = an upland tributary flows through this marsh; 0 = internal tidal channels only, or no internal channels |
| Branched | 1 = channels in this marsh have branches visible in a 1:24,000-scale airphoto; 0 = unbranched |

FILE: **SppXsGeoFq**
records: 105
General Description: By plant species, this gives the frequency with which the species was found among sites, among all channel transect points, and at various vertical and lateral positions relative to internal tidal channels, as well as horizontally within the marsh's channel network.

| heading for SppXsGeoFq | description |
|---|---|
| SciName | scientific name of the plant |
| NumPts | total number of points found among all channel transects at all sites |

| heading for SppXsGeoFq | description |
|---|---|
| NumSites | number of sites where found |
| InChannel | proportion of data points within internal channels where found |
| ChanEdge | proportion of data points on the edge of internal channels where found |
| BankTop | proportion of data points on or near the tops of channel banks where this species was found |
| MPlain | proportion of data points on the marsh plain (i.e., interfluve) where found (number of such points surveyed varied among marshes) |
| UpEdge | proportion of data points near the marsh's upland edge where found; number of such points surveyed varied among marshes |
| LowestC | proportion of data points in the lowest of the five channel transects, generally the transect closest the bay or river, where found |
| LowC | proportion of data points in the next-to-lowest of the five channel transects, usually the transect above the first branch, where this species was found |
| MidC | proportion of data points in the middle (#3) of the five channel transects, where found |
| HighC | proportion of data points in the next-to-highest of the five channel transects, usually a transect on a second- or third-order branch, where found |
| HighestC | proportion of data points in the highest of the five channel transects, usually a transect on a first-order channel, where found |

FILE: **StreamsideVeg**
records: 67
General Description: This is a listing of the most prevalent species occurring alongside the internal tidal channel in which channel cross-sections were measured (e.g., between the lowest and next-to-lowest cross-sections), but does not include data from the cross-sections themselves.

| heading for StreamsideVeg | description |
|---|---|
| SciName | scientific name of the streamside plant species |
| Frequency | total number of streamside segments (of 491) in which it was found |
| PctLowest | proportion of this species' occurrences that were near the lowest (closest to bay or river) channel cross-section |
| PctLow | proportion of its occurrences that were near the next-to-lowest channel cross-section |
| PctMid | proportion of its occurrences that were near the middle channel cross-section |
| PctHigh | proportion of its occurrences that were near the next-to-highest channel cross-section |
| PctHighest | proportion of its occurrences that were near the highest (closest to upland boundary) channel cross-section |

FILE: **SiteGeo**
records: 121
General Description: By site, this provides data for a variety of additional variables, most with geomorphic themes, estimated or measured in the field or derived from GIS layers.

| heading for SiteGeo | description |
|---|---|
| Site | site identifier code |
| HGM_MR | predominant influence: M = predominantly marine-sourced; R = predominantly river-sourced; estimated based on position in estuary, geomorphic setting, and/or salinity |
| HGM_LH | H = predominantly high marsh; L = predominantly low marsh; based only on coarse visual assessment, not on measured elevations |
| EstHiMarshPct | % of the assessed area that may be high marsh, based only on coarse visual assessment, |

| heading for SiteGeo | description |
|---|---|
| | not on measured elevations |
| EstLoMarshPct | % of the assessed area that may be low marsh, based only on coarse visual assessment, not on measured elevations |
| MedVrelEl | median relative elevation (m) of quadrats along a site's marsh transects; averaged between the two (usually) transects; higher values sometimes indicate greater marsh slope; elevations were zeroed to the lowest vegetated point found in any quadrat in the marsh |
| CV_VreEl | coefficient of variation of quadrat relative elevations along a site's marsh transects; averaged between the two (usually) transects; a rough indicator of marsh microtopography |
| SkewVreEl | skewness statistic of quadrat relative elevations along a site's marsh transects; averaged between the two (usually) transects; negative values suggest quadrats closer to the bay/river were generally lower than those closer to uplands, whereas positive values imply they were higher |
| SkewFVreEl | same as above, but using an alternative formula (Fisher's G1) |
| WetIndexMin | scoring range is 0 (driest) to 10 (wettest); based on percent cover of plant species categorized by their wetland status; based on values for plants found in quadrats along marsh transects (not in channels); minimum among quadrats |
| WetIndexMax | same; maximum among quadrats |
| WetIndexAv | same; mean among quadrats |
| FrLoAllPC | overall cover of freshwater-adapted plant species within the low marsh zone; estimated visually |
| FrHiAllPC | overall cover of freshwater-adapted plant species within the high marsh zone; estimated visually |
| FreshSpp | number of freshwater-adapted plant species found along the marsh or channel transects |
| FreshQdPct | percent of marsh quadrats containing freshwater-adapted plant species |
| FreshAvgPC | percent cover of freshwater-adapted plant species within marsh quadrats containing any such species; averaged among quadrats |
| FreshMaxPC | percent cover of freshwater-adapted plant species within marsh quadrats containing any such species; maximum among quadrats |
| SalHiBR | salinity (ppt) nearest daytime high tide; measured in adjoining bay or river |
| SalHiCM | salinity (ppt) nearest daytime high tide; measured at mouth of a tidal channel exiting the marsh |
| SalHiUP | salinity (ppt) nearest daytime high tide; measured at farthest upstream point of an internal tidal channel. |
| SalLoBR | salinity (ppt) nearest daytime low tide; measured in adjoining bay or river |
| SalLoCM | salinity (ppt) nearest daytime low tide; measured at mouth of a tidal channel exiting the marsh |
| SalLoUP | salinity (ppt) nearest daytime low tide; measured at farthest upstream point of an internal tidal channel. |
| SalHiLoBR | change in salinity (ppt) between high and low tide in the adjoining bay or river |
| SalHiLoCM | change in salinity (ppt) between high and low tide at mouth of a tidal channel exiting the marsh |
| SalHiLoUP | change in salinity (ppt) between high and low tide at farthest upstream point of an internal tidal channel |
| SalHiBR_CM | difference in salinity between channel mouth and in the adjoining bay or river; near daily high tide |
| SalHiCM_UP | difference in salinity between channel mouth and the farthest upstream point of an internal tidal channel; near high tide |
| SalHiBR_UP | difference in salinity between adjoining bay or river and the farthest upstream point of an internal tidal channel; near high tide |
| SalLoBR_CM | difference in salinity between channel mouth and the adjoining bay or river; near daily low tide |
| SalLoCM_UP | difference in salinity between channel mouth and the farthest upstream point of an internal tidal channel; low tide |
| SalLoBR_UP | difference in salinity between adjoining bay or river and the farthest upstream point of an |

| heading for SiteGeo | description |
|---|---|
| | internal tidal channel; low tide |
| SoilSalMin | minimum of three (usually) soil salinity measurements taken on the marsh plain |
| SoilSalMax | maximum of three (usually) soil salinity measurements taken on the marsh plain |
| SalMax | the maximum of the measured water salinities (SalHiBr through SalLoUP) |
| SoilSalDiff | SoilSalMax minus LowMax; i.e., difference in soil salinity and water salinity at low tide |
| SalMarch | mean salinity (ppt) for January–March at the closest location with DEQ salinity data reported in Hamilton (1984) |
| SalJune | mean salinity (ppt) for April–June at the closest location with DEQ salinity data reported in Hamilton (1984) |
| SalSept | mean salinity (ppt) for July–September at the closest location with DEQ salinity data reported in Hamilton (1984) |
| SalDec | mean salinity (ppt) for October–December at the closest location with DEQ salinity data reported in Hamilton (1984) |
| SalHiDiff | SalHiBR minus SalSept, a measure of the possible representativeness of our salinity data |
| SalLoDiff | SalLoBR minus SalSept, a measure of the possible representativeness of our salinity data |
| HOTdistance | water-distance (ft) upriver on mainstem channel to the DSL-designated head of tide; negative values indicate polygon is above the supposed head of tide |
| MarineDist | water-distance (ft) downriver to waters classified as Marine by NWI; approximates the distance to the mouth of the estuary |
| EstPosition | approximate downriver position of the polygon; as a percent of the approximate estuary length (MarineDis x 100) divided by (HOTmain + MarineDis); small values indicate sites closer to the ocean; maximum value of 100 indicates site is at or above head of tide |
| PositClass | a categorization of EstPosition; 1 = EstPosition is <30 (low in estuary); 3 = EstPosition is >55 (high in estuary); 2 = intermediate |
| TideMLW | estimated elevation (ft) of mean low water relative to mean lower low water (MLLW) at the nearest location reported in Hamilton (1984) |
| TideMHW | estimated elevation (ft) of mean high water relative to mean lower low water (MLLW) at the nearest location reported in Hamilton (1984) |
| TideMHHW | estimated elevation (ft) of mean higher high water relative to mean lower low water (MLLW) at the nearest location reported in Hamilton (1984) |
| TideMXHW | predicted elevation (ft) of highest tide relative to mean lower low water (MLLW) at the nearest location reported in Hamilton (1984), and not accounting for storm surge effects |
| Trib | 1 = freshwater tributaries are present within the site; 0 = not |
| ChanType | type of channel where cross-sections were done: 1 = blind tidal channel only, 2 = tidal with upland input and flowing at time of visit; 3 = tidal with upland input but not flowing at time of visit, 4 = fed only via an artificial channel, pipe, or ditch |
| TribL | approximate cumulative length of all perennial freshwater tributaries to the assessment unit as shown on 1:24,000-scale topographic maps and measured with MapTech. |
| Exits | number of internal channels exiting the wetland and flowing into adjoining bay or river, as visible in a 1:24,000-scale airphoto |
| Jcts | number of junctions (confluences) between internal tidal channels as visible in a 1:24,000-scale airphoto |
| Subs | 1 = sandy substrate; 2 = dike present; 0 = neither |
| Branched | 1 = channels in this marsh have branches visible in a 1:24,000-scale airphoto; 0 = unbranched |
| MinIncis | elevation difference (m) between bottom of channel and the top of the higher of the channel's two banks; minimum of measurements made at five (usually) points spread over the channel network |
| MaxIncis | maximum of the five points |
| AvgIncis | mean of the five points |
| MinTopW | distance (m) between tops of left and right channel banks |
| MaxTopW | maximum of the five points |
| AvgTopW | mean of the five points |
| MinRatio | ratio of Incision divided by TopW, minimum of the five points |
| MaxRatio | maximum of the five points |

<table>
<tr><td>heading for SiteGeo</td><td>description</td></tr>
<tr><td>AvgRatio</td><td>mean of the five points</td></tr>
<tr><td>Aspect</td><td>azimuth of most of the upland-marsh edge (marsh = the mapped polygon; not the assessment unit associated with it); N = north; NE = northeast; etc.  X = no adjoining water body (fetch = 0); I = island</td></tr>
<tr><td>EstuSize</td><td>subjective rating of the size of the associated estuary; relative to other estuaries on the Oregon coast; 1 = small; 2 = medium; 3 = large</td></tr>
<tr><td>FetchGIS</td><td>greatest open water distance (ft) at mean low tide; NOTE: 999999 = dummy value to indicate >40,000 ft fetch. 0 = no fetch (site is almost entirely enclosed by land)</td></tr>
<tr><td>FetchClas</td><td>a categorization of FetchGIS; 1 = short: <2,330 ft; 3 = long >6,500 ft; 2 = intermediate</td></tr>
<tr><td>ChanBay</td><td>predominant type of subtidal water that adjoins the assessment unit; 1 = bay; 2 = channel</td></tr>
<tr><td>Confinemt</td><td>geomorphic confinement condition of the assessment unit; FC = channel fringe marsh; FI = island fringe marsh; P = pocket marsh</td></tr>
<tr><td>Dunal</td><td>located on a sand spit or other sandy substrate; 1 = yes</td></tr>
<tr><td>SoilMCat</td><td>a categorization of SoilMarsh; 1 = muck/peat; 2 = silt-clay; 3 = silt or alluvium; 4 = sand; 5 = fill</td></tr>
<tr><td>SoilUpCat</td><td>a similar categorization of SoilUpland</td></tr>
<tr><td>SoilMarsh</td><td>soil series that occupies the largest proportion of the assessment unit according to NRCS maps</td></tr>
<tr><td>SoilUpland</td><td>soil series that occupies the largest proportion of the upland that adjoins the assessment unit according to NRCS maps</td></tr>
<tr><td>GeoDomType</td><td>geologic stratum that occupies the largest proportion of the polygon of which the assessment unit is a part; according to USGS; 9 = Otter Point Formation; 1 = dune sand; 2 = alluvial deposits; 3 = lacustrine and fluvial sedimentary rocks; 4 = terrace; pediment; and lag gravels; 5 = Marine sedimentary rocks; 6 = Tuffaceous siltstone and sandstone; 7 = Alsea Formation; 8 = Tyee Formation</td></tr>
<tr><td colspan="2"><b>Important Notes:</b> For the following variables, the “assessment unit” is defined as the part of the marsh that was sufficiently viewable that major plant communities adjoining the marsh transects and channel cross-sections could be identified while doing the field work. Except for very large marshes, this included all of the tidal marsh shown on USGS topographic maps as a somewhat geomorphically discrete spatial unit. In contrast, the “polygon” is at least as inclusive and covers as well the areas contiguous to the assessment unit but not viewable from it during our field work. Assessment units were measured by using MapTech Terrain Navigator Pro to sketch and then measuring (on a 1:12,000-scale topo map) their approximate boundaries. Polygon measurements were made with ESRI’s Spatial Analyst GIS tool. Partly because of the scale of the spatial data and difficulty in detecting most tidal channels from imagery, the variables that describe edge lengths are severe underestimates of the true length of the wetland-water edge. Also note that measurements for sites 964 (E, S, N), 2385 (D, N, S ), 2987 (N, S), and 2942 (E, W) are repetitive overestimates because the polygon was split but not remeasured after the split.</td></tr>
<tr><td>TransectFt</td><td>sum of lengths of all plant (marsh) transects at the site, in ft</td></tr>
<tr><td>AssessAc</td><td>measured area (acres) of the approximate assessment unit; measured with MapTech; see Note at beginning of this file</td></tr>
<tr><td>GIS_ac</td><td>measured area (acres) of the wetland polygon of which the assessment unit is a part; see Note at beginning of this file</td></tr>
<tr><td>WidthMax</td><td>maximum width of marsh (perpendicular to bay or channel) divided by square root of AssessFt2; measured with MapTech</td></tr>
<tr><td>MudWidth</td><td>maximum width (ft) of the area shown as mudflat on USGS topographic map and measured perpendicular to the assessment unit using MapTech; a “1” signifies an expanse of mudflat that was too narrow to be shown on the existing topographic maps</td></tr>
<tr><td>MudWidth/Width</td><td>MudWidth divided by WidthMax</td></tr>
<tr><td>Width/AreaFt2</td><td>WidthMax divided by the square root of AssessFt2</td></tr>
<tr><td>GIS_edgeFt</td><td>measured perimeter (both water and upland) of the wetland polygon of which the assessment unit is a part, in ft</td></tr>
<tr><td>WatEdge</td><td>length (ft) of the assessment unit’s edge with external subtidal and intertidal habitats; measured with MapTech; a “1” signifies that water edge is present but could not be measured even approximately from existing topographic maps</td></tr>
<tr><td>UpEdge</td><td>length of the assessment unit’s edge with adjoining terrestrial habitats; measured with MapTech; a “1” signifies that upland edge is present but could not be measured even</td></tr>
</table>

| heading for SiteGeo | description |
|---|---|
| | approximately from existing topographic maps |
| WatEdgePct | WatEdge divided by the sum of WatEdge + UpEdge; times 100 |
| WatEdge/A | WatEdge divided by the square root of AssessFt2 |
| WedgeFtGIS | measured length (ft) of the water edge of the wetland polygon of which the assessment unit is a part |
| Wedge/AreaFt2GIS | WedgeFtGIS divided by the square root of GIS_areaFt2 |
| UpedgeFtGIS | measured length (ft) of the upland edge of the wetland polygon of which the assessment unit is a part |
| Upedge/A | UpEdgeFtGIS divided by the square root of GIS_areaFt2 |
| Gis_edge/A | GIS_edgeFt divided by the square root of GIS_areaFt2 |
| MSHft2GIS | measured area (sq. ft) of the polygon (of which the assessment unit is a part) that is classified as marine-sourced high marsh |
| MSLft2GIS | measured area (sq. ft) of the polygon (of which the assessment unit is a part) that is classified as marine-sourced low marsh |
| RSft2GIS | measured area (sq. ft) of the polygon (of which the assessment unit is a part) that is classified as river-sourced tidal marsh |
| MSHpctA | percent of the polygon area (of which the assessment unit is a part) that is classified as marine-sourced high marsh |
| MSLpctA | percent of the polygon area (of which the assessment unit is a part) that is classified as marine-sourced high marsh |
| RSpctA | percent of the polygon area (of which the assessment unit is a part) that is classified as marine-sourced high marsh |
| MSHftGIS | length (ft) of the polygon perimeter (of which the assessment unit is a part) that is classified as marine-sourced high marsh |
| MSLftGIS | length (ft) of the polygon perimeter (of which the assessment unit is a part) that is classified as marine-sourced high marsh |
| RSftGIS | length (ft) of the polygon perimeter (of which the assessment unit is a part) that is classified as marine-sourced high marsh |
| MSHpctEdge | percent of the polygon perimeter (of which the assessment unit is a part) that is classified as marine-sourced high marsh |
| MSLpctEdge | percent of the polygon perimeter (of which the assessment unit is a part) that is classified as marine-sourced high marsh |
| RSpctEdge | percent of the polygon perimeter (of which the assessment unit is a part) that is classified as marine-sourced high marsh |

FILE: **Visits**
records: 121
General Description: By site, information on the conditions under which the field data were collected in summer 2003.

| heading for Visits | description |
|---|---|
| Site | identifier for the assessed site |
| Estuary | estuary where the site is located |
| Date | date when visited during 2003 |
| HrLoHGM | time closest to daytime low tide when salinity was measured |
| HrHiHGM | time closest to daytime high tide when salinity was measured |
| TideHrLo | predicted time of daytime low tide on this date at the closest location for which predictions were available |
| TideHrHi | predicted time of daytime high tide on this date at the closest location for which predictions were available |
| HtLo | predicted height (ft) of daytime low tide on this date at the closest location for which predictions |

| heading for Visits | description |
|---|---|
| | were available |
| HtTideHi | predicted height (ft) of daytime high tide on this date at the closest location for which predictions were available |
| Crew | N = north crew (mostly Adamus and Taylor); S = south crew (mostly Scranton and DeMarzo) |

FILE: **Disturbances**
records: 122
General Description: By site, the summaries of scores calculated, using various alternative formulae, for describing potential ongoing and past human disturbance at each site. Information for calculating the scores was based mainly on site visits and review of existing GIS spatial data layers and historical aerial photographs. Data (scores of 0, 1, or 2) used to compute the index scores in this file are not contained comprehensively in the file.

| heading for Disturbances | description |
|---|---|
| Site | identifier code for the site |
| Risk1–5 | Within each stressor category [hydrologic alteration (H), sediment (S), chemical (C), nutrient (N), vegetation alteration (V)] described below, the average was determined of the scores (0, 1, or 2) of the activities comprising that stressor category, then those averages were:<br>Risk1 = combined according to rule H1 described in H1–10 below (i.e., were averaged)<br>Risk2 = combined according to rule H2 described in H1–10 below<br>Risk3 = combined according to rule H3 described in H1–10 below<br>Risk4 = combined according to rule H4 described in H1–10 below<br>Risk5 = combined according to rule H5 described in H1–10 below |
| Max1–5 | Max1 through Max5: Within each stressor category, the maximum was determined for the scores (0, 1, or 2) of the activities comprising that category (hydrologic alteration, sediment, chemical, nutrient, vegetation alteration), then the average was taken of those maximums:<br>Max1 = combined according to rule H1 described in H1–10 below (i.e., were averaged)<br>Max2 = combined according to rule H2 described in H1–10 below<br>Max3 = combined according to rule H3 described in H1–10 below<br>Max4 = combined according to rule H4 described in H1–10 below<br>Max5 = combined according to rule H5 described in H1–10 below |
| Bdg | Distance (ft) to the nearest building. If greater than 5,000 ft, it was recorded as 5,000 ft. Measured from maps and airphotos. |
| Road | Road contact with wetland. Score = 0 (none) to 2 (extensive); estimated onsite. |
| Boats | Boat traffic score = 0 (none) to 6 (much). Calculated by scoring 0 (absent) or 1 (present) in each of the following categories, then assigning weights and summing the scores:<br>ship traffic (frequent/close); weight = 4<br>ship traffic (infrequent/distant); weight = 3<br>small boat traffic (frequent/close); weight = 2<br>small boat traffic (infrequent/distant); weight = 1 |
| Visits | Visitation score = 100 (minimal) to 220 (extensive and frequent). Calculated by estimating the percents of the site that are visited by people on foot daily, moderately, or rarely (<10 days/yr). Each of the percents is multiplied by a weighting factor (3, 2.1, respectively) and then summed. |
| H1–10 | Scores in each data field range from 0 (no identified hydrologic alteration) to 1 (greatest identified potential or actual alteration). Features that were considered potential hydrologic modifiers were: dikes (including culverts, tidegates), ditches, excavations, paved roads, and weirs/dams.<br>H1: unweighted average of ratings for onsite-present (ON-P), offsite present (OFF-P), onsite-historical (ON-H), offsite historical (OFF-H) |

| heading for Disturbances | description |
|---|---|
| | H2: maximum of ratings for ON-P, OFF-P, ON-H, OFF-H<br>H3: weighted average: [ (ON-P x 4), (OFF-P x 3), (ON-H x 2), (OFF-H) ]<br>H4: average of present domain only: [ (ON-P), (OFF-P) ]<br>H5: average of onsite domain only: [ON-P, ON-H]<br>H6–10: same, but calculated using maximum values from among the various types of hydrologic alteration at the site, rather than their average<br>See report text for further explanation. |
| N1–10 | Scores in each column range from 0 (no identified potential source) to 1 (largest identified potential or actual sources). Features that were considered potential nutrient sources were: golf courses and other lawned areas, grazing, stormwater pipes, and residences with septic systems. |
| c1–10 | Scores in each column range from 0 (no identified potential contamination) to 1 (highest identified potential or actual contamination). Features that were considered potential contamination sources were: manufacturing facilites, stormwater pipes, and residences with septic systems. |
| V1–10 | Scores in each column range from 0 (no identified activity) to 1 (largest activity). Features that were considered to have a potentially direct effect on tidal marsh vegetation were: off-road vehicle tracks, grazing, haying, mowing, and overhead utilities (due to potential drift of herbicides used to control right-of-way vegetation). |
| S1–10 | Scores in each column range from 0 (no identified potential source) to 1 (largest identified potential or actual sources). Features that were considered potential sediment sources were: off-road vehicle tracks, regraded areas, underground utilities (historical source), dredging, eroding uplands, fill, upland logging, riprap, and dirt roads. |
| ATV | extent of on-site all-terrain vehicle activity in the past 5 years within the wetland (0 = none, 1 = some, 2 = extensive) |
| Ditchexcav | extent of ditching within the wetland (0 = none, 1 = some, 2 = extensive) |
| Dikes | extent of dikes within the wetland (0 = none, 1 = some, 2 = extensive) |
| Grazing | extent of recent grazing within the wetland (0 = none, 1 = some, 2 = extensive) |

FILE: **MTlatlong**
records: 246
General Description: This contains latitude and longitude of the start and ending points of each marsh transect, as determined using Garmin Rino 120 handheld GPS units (precision approximately 30 ft). At the request of landowners, the coordinates of sites on private land are not reported in the file for public distribution.

| heading for MTlatlong | description |
|---|---|
| Site | identifier for the assessed site |
| Transect | identifier for the marsh transect |
| LatStart | latitude at beginning of the transect |
| LongStart | longitude at beginning of the transect |
| LatEnd | latitude at end of the transect |
| LongEnd | longitude at end of the transect |

FILE: **ChannelxsLatlong**
records: 442
General Description: This contains latitude and longitude of the start point of each channel cross-sectional transect, as determined using Garmin Rino 120 handheld GPS units (precision approximately 30 ft). At the request of landowners, the coordinates of sites on private land are not reported in the file for public distribution.

| heading for ChannelxsLatLong | description |
|---|---|
| Site | identifier for the assessed site |
| ChanTransect | identifier for the channel cross-sectional transect |
| Lat | latitude near center of the transect |
| Long | longitude near center of the transect |

## FILE: **CalcMaster**

records: 121

General Description: This spreadsheet contains the calculations for various indices used, as well as repeating some of the original data in the file descriptions below. This was used in subsequent correlations. The listing below is alphabetical and is not in the same sequence as the data fields.

| heading for MasterCalc | Description |
|---|---|
| AF | function capacity score for anadromous fish (Afish) |
| AF_x | function capacity score for anadromous fish (Afish), excluding any risk variables |
| Alder | score reflecting the extent of alder along the wetland-upland edge |
| AllGT90 | proportion of quadrats that contain plant species with a percent cover of 90 or greater |
| AllPC90 | same as AllGT90 |
| AnnDef | the difference between the AnnFq predicted and the AnnFq found, scaled |
| AnnMxPC | maximum percent cover of annual plants among quadrats at a site |
| APRO | function capacity score for aboveground production (AProd) |
| APRO_x | same, but excluding any risk variables |
| Area | assessed wetland area in acres |
| ATV | extent of recent on-site all-terrain vehicle activity |
| Bare | score reflecting the extent of unvegetated mud within the wetland |
| BC | function capacity score for botanical condition (BotC) |
| BC_x | same, but excluding any risk variables |
| Bdg | distance (ft) to the nearest building; if greater than 5,000 ft; it was recorded as 5,000 ft; measured from maps and airphotos |
| BlindL | score reflecting increasing channel complexity |
| BuffAlt | score for buffer alteration |
| BuffCov | score for percent of the area surrounding this wetland that appears (in a 1:24,000-scale airphoto) to be developed or persistently bare |
| Bulldoze | extent of recent on-site regrading |
| C1–10 | risk index scores from 0 (no identified protential contamination) to 1 (highest identified potential or actual contamination); features that were considered potential contamination sources were: manufacturing facilites, stormwater pipes, and residences with septic systems; see H1–10 |
| Chemin | similar to C1–10, but also considered exposure potential |
| CRresabAV | absolute value of the residuals of the predicted vs. actual channel ratios, averaged among all 5 channel transects per site |
| DG | function capacity score for ducks and geese (Dux) |
| DG_x | same, but excluding any risk variables |
| DikeDry | score representing degree to which the area that is still wetland (and including its internal channels) has become **drier** (i.e., muted tidal flooding) as a result of installation of dikes, tidegates, culverts, and other artificial constrictions |
| Dikes | extent of dikes within the wetland (0 = none, 1 = some, 2 = extensive) |
| DikeWet | score representing degree to which the wetland has become **wetter** (more ponding) as a result of installation of dikes, tidegates, culverts, ditches, and other artificial constrictions or excavations, including substrate compaction and subsidence associated with these |
| Ditchexcav | extent of ditching within the wetland (0 = none, 1 = some, 2 = extensive). |
| DomDef | the difference between the AllGT90 predicted and the AllGT90 found, scaled |
| Dunal | located on a sand spit or other sandy substrate; 1 = yes |
| Eelgrass | presence of eelgrass within or near wetland; 1 = yes |
| Eroding | score representing onsite soil disturbance and compaction from human activities |

| | |
|---|---|
| Estu_WL | score for relative dominance of undiked tidal wetlands in this estuary |
| EstuSal | score for distribution and amount of tidal marsh acreage in wetland's major estuary |
| Exits | score reflecting the number of internal channels exiting the wetland and flowing into adjoining bay or river, as visible in a 1:24,000-scale airphoto |
| Exitsx | number of internal channels exiting the wetland and flowing into adjoining bay or river, as visible in a 1:24,000-scale airphoto |
| Fetch | score reflecting direction and distance of external edge's exposure to intense wave and/or river current action |
| Flood | score reflecting proportion of wetland that is accessible to anadromous fish under various conditions |
| Footvis | score representing percent of wetland visited regularly by people on foot |
| FormDiv | score reflecting number of easily recognizable vegetation forms within the wetland or *directly adjoining* its upland edge |
| Fresh | score reflecting number and types of freshwater sources that feed the wetland internally |
| FreshAvgPC | Percent cover of freshwater-adapted plant species within marsh quadrats containing any such species; averaged among quadrats at a site |
| FreshSpot | score reflecting difference in salinity within the wetland vs. outside the wetland is (maximum difference) |
| Grazing | extent of recent grazing within the wetland (0 = none, 1 = some, 2 = extensive). |
| H1–10 | Scores from 0 (no identified hydrologic alteration) to 1 (greatest identified potential or actual alteration). Features that were considered potential hydrologic modifiers were: dikes (including culverts, tidegates), ditches, excavations, paved roads, and weirs/dams.<br>H1: unweighted average of ratings for onsite-present (ON-P), offsite present (OFF-P), onsite-historical (ON-H), offsite historical (OFF-H)<br>H2: maximum of ratings for ON-P, OFF-P, ON-H, OFF-H<br>H3: weighted average: [ (ON-P x 4), (OFF-P x 3), (ON-H x 2), (OFF-H) ]<br>H4: average of present domain only: [ (ON-P), (OFF-P) ]<br>H5: average of onsite domain only: [ON-P, ON-H]<br>H6–10: same, but calculated using maximum values from among the various types of hydrologic alteration at the site, rather than their average<br>See report text for further explanation. |
| Homevis | score for proximity (ft) to the nearest inhabited structure; higher scores indicate closer distance |
| HOTdis | water-distance (ft) upriver on mainstem channel to the DSL-designated head of tide; negative values indicate polygon is above the supposed head of tide |
| IncisAv | mean channel incision depth (m) among all five channel transects per site |
| IncisMx | maximum channel incision depth (m) among all five channel transects per site |
| Instabil | score for possible instability of wetland based on past changes to substrate, tidal circulation, other factors described in Part 1 |
| IntegMax | maximum of RatioC, SpDeficit, DomDef, NNdef, AnnDef, TapPCdef, StolPCdef, TuftPCdef |
| IntegMean | average of RatioC, SpDeficit, DomDef, NNdef, AnnDef, TapPCdef, StolPCdef, TuftPCdef |
| IntegMin | minimum of RatioC, SpDeficit, DomDef, NNdef, AnnDef, TapPCdef, StolPCdef, TuftPCdef |
| INV | function capacity score for invertebrate habitat |
| INV_x | same, but excluding any risk variables |
| Invas | score for potential invasive invertebrates in the wetland's estuary |
| Island | score reflecting whether the marsh comprises all of an island in a bay or river |
| Jcts | number of junctions (confluences) between internal tidal channels as visible in a 1:24,000-scale airphoto |
| JctMax | score reflecting number of junctions (confluences) between internal tidal channels as visible in a 1:24,000-scale airphoto |
| LBM | function capacity score for landbird and mammal habitat |
| LBM_x | same, but excluding any risk variables |
| LogRatioAv | ratio of topwidth to channel incision depth (m), both log-transformed and averaged among all five channel transects per site |
| LogRatioMx | ratio of topwidth to channel incision depth (m), both log-transformed; maximum among all five channel transects per site |
| LWDchan | score reflecting number of pieces of large woody debris (LWD) in wetland's tidal channel network |
| LWDline | score reflecting driftwood line as % of wetland's upland edge length |
| LWDmarsh | score reflecting number of LWD projecting at least 1m above the wetland surface |

| | |
|---|---|
| MarDis | water-distance (ft) downriver to waters classified as Marine by NWI; approximates the distance to the mouth of the estuary |
| MedVrel | elevation of the quadrat relative to the lowest vegetated point along the marsh transect, median of all such elevations |
| MF | function capacity score for marine fish habitat |
| MF_x | same, but excluding any risk variables |
| MudW | score reflecting maximum width (ft) of largest mudflat that adjoins the wetland |
| Mx1 | see section 3.4.1 |
| Mx2 | see section 3.4.1 |
| Mx3 | see section 3.4.1 |
| Mx4 | see section 3.4.1 |
| Mx5 | see section 3.4.1 |
| N1–10 | scores from 0 (no identified potential source) to 1 (largest identified potential or actual sources); features that were considered potential nutrient sources were: golf courses and other lawned areas, grazing, stormwater pipes, and residences with septic systems; see H1–10 |
| NFW | function capacity score for nekton-feeding wildlife |
| NFW_x | same, but excluding any risk variables |
| NN20def | the difference between the NNgt20 predicted and the NNgt20 found, scaled |
| NNgt20 | proportion of quadrats containing non-native species with percent cover >19%, excluding quadrats with >20% bare substrate |
| NNmaxPC | combined percent cover of non-native plant species, maximum among marsh quadrats at a site |
| NutrIn | similar to N1–10, but also considers exposure potential |
| Panne | score reflecting area of pannes and shallow isolated pools (not mudflats) |
| Pform | score reflecting number of easily recognizable vegetation structures present within the wetland |
| Pilings | extent of pilings near the wetland (0 = none, 1 = some, 2 = extensive). |
| Pipes | extent of pipes visibly entering the wetland (0 = none, 1 = some, 2 = extensive). |
| Positn | relative position of wetland in its estuary (1 = near ocean, 2 = mid, 3 = near head of tide) |
| RatioC | score reflecting the absolute difference between predicted vs. actual channel ratio, averaged among all five channel transects per site |
| ResAllgt90 | the difference between the AllGT90 predicted and the AllGT90 found, unscaled |
| ResAnnPct | the difference between the AnnFq predicted and the AnnFq found, unscaled |
| ResNN | the difference between the NNgt20 predicted and the NNgt20 found, unscaled |
| Resseptic | extent of residences near the wetland on septic systems (0 = none, 1 = some, 2 = extensive). |
| ResStolPC | the difference between the StolPCavg predicted and the StolPCavg found, unscaled |
| ResTapPC | the difference between the TapAvgPC predicted and the TapAvgPC found, unscaled |
| ResTuftPC | the difference between the TuftPCavg predicted and the TuftPCavg found, unscaled |
| RF | function capacity score for resident fish (Rfish) |
| RF_x | same, but excluding any risk variables |
| RhizAvgPC | combined percent cover of rhizotomous species, mean among marsh quadrats |
| RhizFq | proportion of quadrats having rhizotomous species |
| RhizMxPC | maximum percent cover of rhizotomous plants among quadrats at a site |
| Riprap | extent of riprap near the wetland (0 = none, 1 = some, 2 = extensive). |
| Risk1 | (= Avg1). See section 3.4.1 |
| Risk2 | (= Avg2). See section 3.4.1 |
| Risk3 | (= Avg3). See section 3.4.1 |
| Risk4 | (= Avg4). See section 3.4.1 |
| Risk5 | (= Avg5). See section 3.4.1 |
| Road | extent of road contact along the wetland-upland edge |
| Roost | score reflecting number of types of potential shorebird roosts within 1.5 mi of the center of the wetland |
| S1–10 | scores from 0 (no identified potential source) to 1 (largest identified potential or actual sources) of sediment; features that were considered potential sediment sources were: golf courses and other lawned areas, grazing, stormwater pipes, and residences with septic systems; see H1-10 |
| SalSoilMx | maximum soil salinity (ppt) among the three soil pits checked at the site during a single visit |
| SalWatMx | maximum surface water salinity (ppt) among the three locations checked at the site during a single visit (maximum of channel mouth, channel inlet, and head of internal tidal channel), daily high and low tide |

| | |
|---|---|
| SB | function capacity score for shorebirds (Sbird) |
| SB_x | same, but excluding any risk variables |
| SeaJoin | score reflecting permanency of estuary connection with ocean |
| Sedshed | score representing incoming fine-sediment overload resulting from human activities |
| Shade | score reflecting proportion of wetland shaded at mid-day |
| ShadeLM | score reflecting proportion of tidal channel and low marsh shaded at mid-day |
| SoilTex | soil texture predominant among the three soil pits checked: 1 = loam, silt, clay; 2 = sandy soil; 3 = sand dunes, fill, dredged material, rock |
| SoilX | score reflecting extent of wetland affected by ongoing or past erosion/compaction caused directly by human activities |
| SpDeficit | the difference between the SpPerQd predicted and the SpPerQd found, scaled |
| SpPerQd | the number of plant species (richness) found per square-meter quadrat, averaged over 20 quadrats placed as shown in Figure 1 of Part 1 of this guidebook |
| StolAvgPC | combined percent cover of stoloniferous species, mean among marsh quadrats |
| StolFq | proportion of quadrats having stoloniferous species |
| StolMxPC | maximum percent cover of stoloniferous plants among quadrats at a site |
| StolPCdef | the difference between the StolPCavg predicted and the StolPCavg found, scaled |
| TapPCdef | the difference between the TapAvgPC predicted and the TapAvgPC found, scaled |
| TopwAv | mean channel topwidth (m) among all five channel transects per site |
| TopwMax | maximum channel topwidth (m) among all five channel transects per site |
| TranAng | score reflecting transition angle along most of the wetland external edge |
| TransLength | combined length (ft) of all marsh transects at the site |
| Trib | 1 = non-tidal tributary channels feed into the wetland |
| TribL | score reflecting cumulative length (miles) of fish-accessible non-tidal tributary channels that feed into the wetland |
| TuftPCdef | the difference between the TuftPCavg predicted and the TuftPCavg found, scaled |
| UpEdge | score reflecting percent of the wetland's entire *perimeter* that is upland |
| UtilityOve | extent of overhead utilities in or near the wetland |
| V1–10 | scores for features that were considered to have a potentially direct effect on tidal marsh vegetation: off-road vehicle tracks, grazing, haying, mowing, and overhead utilities (due to potential drift of herbicides used to control right-of-way vegetation) |
| Visits | visitation score = 100 (minimal) to 220 (extensive and frequent); calculated by estimating the percents of the site that are visited by people on foot daily, moderately, or rarely (<10 days/yr); each of the percents is multiplied by a weighting factor (3, 2.1, respectively) and then summed |
| Wetfield_ | score reflecting percent of land within 1.5 mi that appears (in a 1:24,000-scale airphoto) to be ponds, lakes, nontidal marsh, sewage lagoons, cropland, or pasture in flat terrain |
| WetIndexAvg | mean score for the wetness index (see section 3.3.4 for formula); scores may be less reliable if *SpPerQd* is low |
| Width | score reflecting wetland's width (ft) at its widest part |
| WQ | function capacity score for stabilizing and accreting sediment, processing carbon, nutrients, and metals |
| WQ_x | same, but excluding any risk variables |
| XPT | function capacity score for export of organic production |
| XPT_x | same, but excluding any risk variables |