


A Spatially-Explicit Analysis of Historic Change in Puget Sound's Nearshore Ecosystems

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On behalf of the Puget Sound Nearshore Ecosystem Restoration Project's Nearshore Science Team


Abstract

The Puget Sound Nearshore Ecosystem Restoration Project's (PSNERP) Nearshore Science Team (NST) developed a spatially-explicit analysis of historic change in nearshore ecosystems along ~4,000 km of the Puget Sound shoreline. Our objective was to prioritize and strategize restoration and protection plans for degraded beaches, estuaries and deltas, and included assessing adjacent upland and watershed conditions and stressors at multiple scales. We developed a geospatial framework that incorporates geo-spatial data and analyses with a Decision Support Systems that resulted in a comprehensive ranking of impairment for the Puget Sound nearshore ecosystem. This poster presents an overview of the geospatial framework, maps of the impairment rankings at the Puget Sound sub-basin and Puget Sound-wide scales, and how the framework is being used for restoration and protection planning Puget Sound-wide.

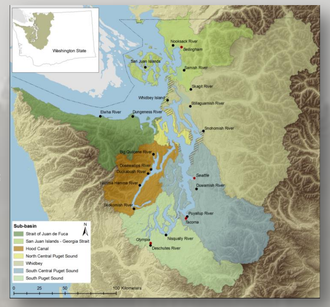


Figure 1. Puget Sound watershed and sub-basins

Approach: Data and Geospatial Framework

Based on a new classification of nearshore landforms (Shipman 2008) , we developed for the entire Puget Sound shoreline:

- a geospatial dataset of historic and current geomorphic shoreline landforms;
- delineation of geospatial historic and current wetlands areas (**Fig. 2**); and,
- two dominant nearshore ecosystem "process units" (PU; **Fig. 3**) that outline the upland drainage (catchment) area and extend from shore to the 10-m depth contour, and include two types:
  (1) **shoreline process units (SPUs)** for beaches associated with littoral drift cells that overlap with each other at the estimated sources of sediment delivery (812 SPU); and,
  (2) **delta process units (DPUs)** large river deltas and drainages organized by different seawater-freshwater mixing zone (16 DPU).

DPUs and SPUs may overlap where nearshore drift is active

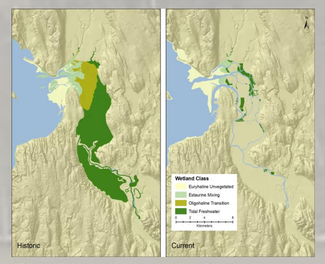


Figure 2. Historic and current wetlands

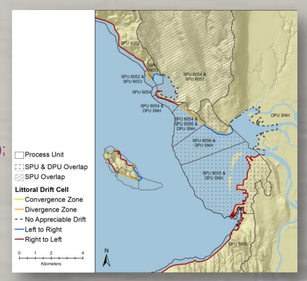


Figure 3. Process units

Methods: Change Analyses

Summary of change was organized by four hierarchical "**tiers**" for each PU (**Fig. 4**);

Tier 1

Change in natural landform types and between natural and artificial landforms

Tier 2

Quantitative change as percent of linear shoreline length for linear features area of aquatic zone for area features, in addition to changes in type and occurrence of historic to current estuarine wetlands (**Fig. 2**)

Tier 3

Land use and land cover changes within 200-m of the adjoining uplands and within the -10-m depth offshore

Tier 4

Land use and land cover changes in the watershed-area, and changes to the hydrology (i.e., extent).

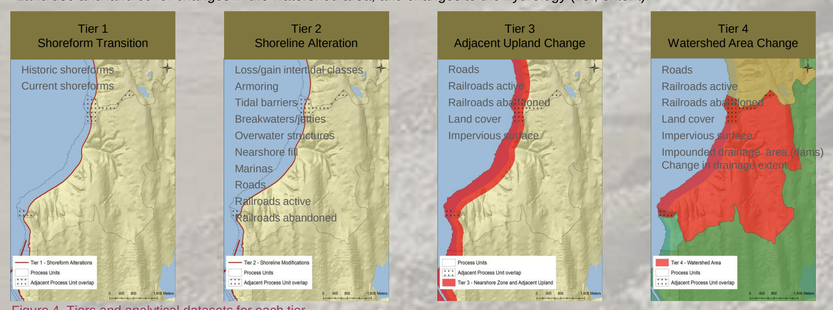
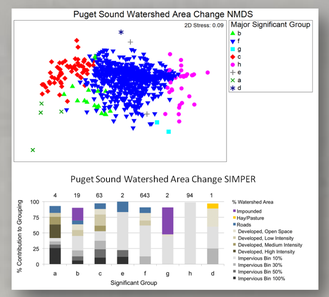


Figure 4. Tiers and analytical datasets for each tier

Methods: Statistical Analyses

We performed four multivariate analyses using PRIMER v6 (Clarke & Gorley 2006); cluster analysis, similarity profile permutation (SIMPROF), SIMPER, and non-metric multi-dimensional scaling (NMDS) (Clarke and Gorley 2006). We used these analyses to define categories of nearshore ecosystem change (e.g., 2 groups of PU having similar shoreform compositions or types and magnitudes of change) and mapped the results (**Fig. 5**)



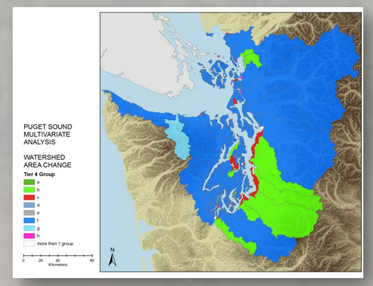


Figure 5. Example of PRIMER non-metric multi-dimensional scaling (NMDS), SIMPER groups (maximum of 9) composition, and map for the Puget Sound watershed

Methods: Assessment of Nearshore Impairment

Lacking Sound-wide historical information on shoreline functions, and actually very incomplete information for even their current contributions to the Puget Sound populace, the Nearshore Science Team ranked the level of cumulative impairment of nearshore ecosystem processes among the PUs to demonstrate how changes in nearshore ecosystems might be qualitatively associated with potential changes of ecological, social and cultural importance. The NST individually rated Ecosystem Function, Goods, and Services (EFG&S) for each change analyses attribute and used a modified Delphi process to derive a consensus EFG&S rating for each attribute. We quantified EFG&S for each PU by multiplying the value of proportional change (ranging from 0 to 1) for each attribute within each process unit with the consensus EFGS rating. EFG&S values for all attributes in a tier were summed within a PU to generate a composite impairment score (**Fig. 6**). To classify levels of impairment, the impairment scores for individual PU were assigned to one of nine bins using the Natural Breaks classification scheme (**Fig. 7**)

Independent rankings for each sub-basin were assessed as well but are not presented here

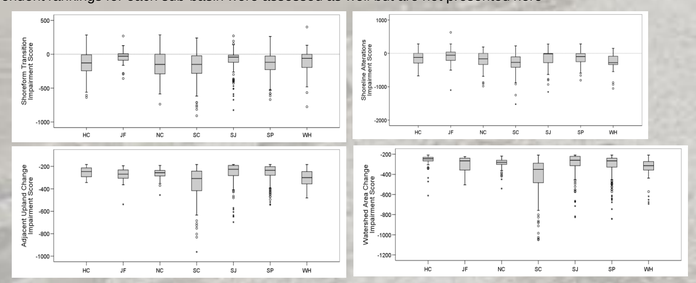


Figure 6. Distribution by tier of impairment scores for each sub-basin within the Puget Sound watershed results.

Results: Highlights of Change Analysis

Only 6.5 percent (54) process units surrounding Puget Sound lack any modification today

Tier 1 **-** The most pervasive change Sound-wide is the simplification of the shoreline, resulting in the reduction of shoreline length

The complexity of natural shoreforms declined the least in the Strait of Juan de Fuca (-7.2%) and most in South Central Puget Sound (-36.4%)

Tier 2 **-** The total area of wetlands in Puget Sound has declined dramatically in most DPUs, particularly the upper-estuary classes (tidal freshwater and oligohaline transition) where 115.2 (-90.0 percent) and 62.6 km2 (-97.8 percent) have been removed (**Fig. 2**)

Tier 3 and Tier 4 **-** The majority of the adjacent upland (Tier 3) and watershed area (Tier 4) is classified as natural land cover

The ratio of developed to natural land is consistently higher in the adjacent upland than watershed area, reflecting the concentration of human activities along the Sound's shoreline

The upland and watershed areas of the South Central sub-basin are highly impacted, with all area measurements of human development (excluding the low intensity development and 0-10 percent impervious surface categories) exceeding that found in any other sub-basin ; conversely, the majority of the Hood Canal sub-basin remains as natural land with very little area categorized as impervious surface greater than 10 percent, despite a relatively high road density in the adjacent upland

Results: Highlights of Statistical Analyses

The most common watershed area changes within Puget Sound can be described as moderate development (including low intensity and open space development), low to moderate impervious surface coverage, and roads (group f, 643 PUs) (**Fig. 5**)

The second largest group (h), including 94 PUs, shows very little impact to the watershed and is characterized solely by the lowest level of impervious surface (**Fig. 5**)

PUs within groups b and c are mostly found in the urbanized Seattle, Tacoma, Olympia, and Bellingham regions and are distinguished from other groups by higher levels of impervious surface as well as the presence of dams (signified by the impounded area category) in group b (**Fig. 5**).

Results: Highlights of Impairment

Based on the NST's demonstration of change in EFG&S, the highest scales of impairment are associated with shoreform transitions and shoreline alterations

Tiers 1 and 2 **-** Within the Puget Sound watershed, South Central Puget Sound consistently represented the most impaired sub-basin across all tiers (**Fig. 6**)

The most impaired regions occur along the extensively developed eastern margin of the Puget Sound Basin, excluding several notable "pockets" of impairment, most notably in the urbanized/suburban areas of the eastern side of the South Central sub-basin and in southern Hood Canal (**Fig. 7**)

Strait of Juan de Fuca, San Juan Islands-Strait of Georgia, Hood Canal and often components of South Puget Sound illustrate moderate or low relative impairment (**Figs. 6 and 7**)

Tiers 3 and 4 **-** PUs along the eastern margins of the Whidbey and the western margins of the South Central (eastern shores of Kitsap Peninsula) sub-basins are moderately to highly impaired

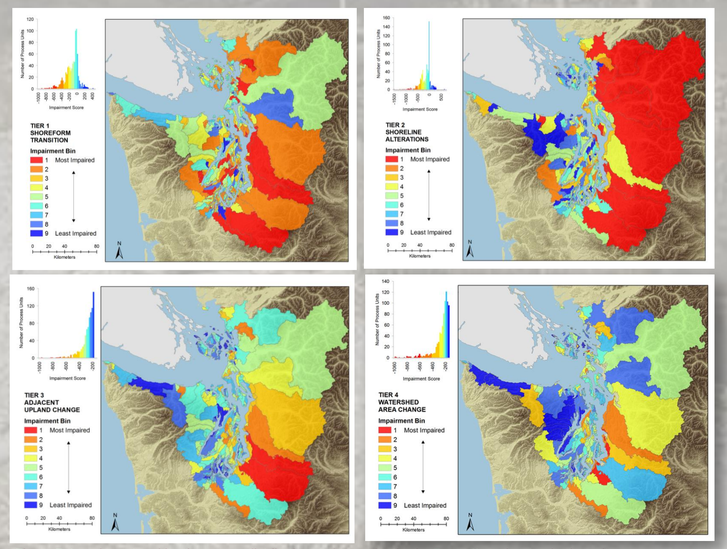


Figure 7. Impairment ranking frequency distribution and maps by tier for Puget Sound watershed results.

Conclusions

We successfully developed a spatial organization of change that represents nearshore ecosystems and the processes that structure these ecosystems, and demonstrated quantitative assessments of changes in nearshore ecosystem structure that could be related to change in ecosystem processes that could impact ecological and other nearshore functions. Using the framework of Ecosystem Functions, Goods and Services, we demonstrated how these changes can the impairment condition of nearshore ecosystems and contributing upland areas can be scaled across Puget Sound. These data and results support the development of PSNERP Strategic Needs Assessment (SNA), restoration and protection strategies that incorporate spatial principles and a landscape approach

References

Clarke, K.R., and R.N. Gorley. 2006. PRIMER v6: User Manual/Tutorial. PRIMER-E, Plymouth, United Kingdom.

Shipman, H. 2008. A geomorphic classification of Puget Sound nearshore landforms. Puget 24 Sound Nearshore Partnership Report No. 2008-01. Published by Seattle District, U.S. Army 25 Corps of Engineers, Seattle, Washington and Washington Department of Fish and Wildlife, 26 Olympia, Washington.

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