CHAPTER 11

Rapid Shoreline Inventory

A Citizen-based Approach to Identifying and Prioritizing Marine Shoreline Conservation and Restoration Projects

Philip L. Bloch, Jessemine Fung, Tom Dean, Lisa Younger, and Jacques White

Abstract

Development along marine and estuarine shorelines, coupled with the uncertain status of many species that use nearshore habitats, has generated a strong interest in both describing nearshore resources and understanding how to restore them. Advances in GIS technology and the wide availability of GIS software and inexpensive and powerful computers are improving our ability to manage complex natural and disturbed systems by helping us to understand the relationship between natural resources, habitat quality, and human uses. In this chapter, we discuss an innovative approach towards collecting, organizing, and analyzing shoreline data using volunteers known as the Rapid Shoreline Inventory. The Rapid Shoreline Inventory (RSI) is a project created with the assistance of regional experts ~~from~~ the Seattle, Washington based non-profit organization, People For Puget Sound ~~and~~ links the information needs of resource managers and restoration practitioners to well-trained volunteer stewards who collect detailed data about marine and estuarine shorelines. ~~The~~ RSI consists of six key components: (1) the

Philip L. Bloch, Jessemine Fung, Tom Dean, Lisa Younger, and **Jacques White**[3]
People For Puget Sound, 911 Western Avenue, Suite 580; Seattle, WA 98104

Philip L. Bloch
Washington Department of Natural Resources, 1111 Washington St. SE, PO Box 47027; Olympia, WA 98504
Corresponding author: philip.bloch@wadnr.gov

Tom Dean
Vashon Island Land Trust, PO Box 2031,Vashon, WA 98070

Lisa Younger and **Jacques White**
The Nature Conservancy, 217 Pine St., Suite 1100, Seattle, WA 98101

identification of resource information needs; (2) permission to access shorelines from property owners; (3) careful classroom and field training of volunteers; (4) a rapid inventory of contiguous 45-m (150-ft.) sections of Puget Sound shoreline; (5) creation and maintenance of the associated GIS database and ~~W~~eb site; and (6) analysis and recommendations for specific conservation and restoration actions. RSI data are valuable both for describing the resources found on the shoreline and for developing predictive models of shoreline health. People For Puget Sound has developed a series of models that use RSI data to describe shoreline health and uses these models to identify restoration and conservation opportunities. Combining RSI data with aerial photos and broader scale nearshore characterizations can provide a comprehensive view of shorelines conditions, and provide data that can be used for a number of purposes. In addition to targeting restoration and conservation actions, RSI data can also be used to support several coastal and estuarine management activities, including identification of marine protected areas, regional and site land-use planning, research, monitoring, and oil-spill response.

Introduction

Environmental degradation attributable to anthropogenic sources has led to significant declines in a wide variety of coastal habitats and species (Vitousek et al., 1997). Development trends have been concentrated on coastal regions with 37% of the global population (more than two billion people) living within 100 km of the coast (Cohen et al., 1997). Coastal development has led to losses of wetlands, the straightening of rivers, and the armoring of shoreline banks. It is becoming increasingly clear that in addition to conservation of existing high-quality habitat, significant restoration actions ~~are~~ necessary ensure the continued survival of coastal marine wildlife and flora (Sinclair et al., 1995).

Many of these problems are caused by anthropogenic development and artificially imposed geographic stasis in an otherwise dynamic environment. Important ecosystem functions, including hydrology and sediment dynamics, are being more or less permanently disrupted, while historic development continues to impact habitat. Nearshore habitats are essential for prey resource production, refugia and reproduction of a variety of fish, shellfish and shoreline-dependent wildlife species (Nightingale and Simenstad, 2001). The impacts of historic habitat losses are compounded ~~by the fact that we~~ have reacted slowly or failed to recognize the severity of habitat and species losses (McMurray and Bailey, 1998). Restoration and rehabilitation of nearshore habitats and natural processes have been advanced as necessary for the continued viability of many coastal ecosystems (Restore America's Estuaries, 2002).

Most restoration assessments are designed to maintain the existing or near existing amount of habitat, species population level or ecosystem service (e.g., Fonseca et al., 2000), however in many urban and other severely impacted ecosystems, there is a need to restore habitat to a former, higher level in order to support sustainable populations or communities of desired species. For example, the urbanizing Puget Sound basin appears to have already lost more functional habitat and ecosystem processes than are required to maintain viable populations of many species, including forage fish, salmon and killer whales, all of which have been recently reviewed or listed under the Endangered Species Act in the region (Federal Register, 1999, 2001).

While there is a growing consensus that habitat protection and restoration are necessary strategies for preserving ecosystem integrity, the understanding of coastal systems is often regarded as insufficient to identify appropriate restoration sites and procedures. Ecological performance of coastal and estuarine restoration projects is not yet predictable with great certainty (Thom, 1997). Failures of restoration projects reflect our inability to accurately predict the trajectory of restoration processes in many instances, or perhaps, that we picked the wrong project in the wrong place.

One major factor limiting the development of successful conservation planning tools for nearshore areas in Washington State is the lack of cohesive, complete, and spatially detailed datasets focused on this ecological edge that functionally includes a combination of uplands, wetlands, and submerged habitats. Management of the nearshore area is fractured between several state, local, and tribal government agencies in the state, with no single entity having jurisdiction or the incentive to collect and maintain complete biological and physical datasets. For us to develop a tool to effectively prioritize preservation and conservation actions in the nearshore, it was first necessary to develop a tool to collect spatially explicit physical and biological information across a landscape that varied in space, type, ownership, and access.

Using new citizen-collected data describing a variety of shoreline characteristics, we developed site-specific indices to describe ecosystem preservation and restoration value for five targets. Targets include a mix of species guilds (forage fish, juvenile salmonids, and marine dependent wildlife), habitat (aquatic vegetation), and ecosystem processes (sediment transport). By combining these targets into a single index we have created a systematic mechanism for ranking sites based on their restoration or preservation value to the ecosystem. These indices prioritize sites that appear to be functioning, but are also measurably impacted by anthropogenic development. Restoration indices are based on characteristics intrinsic to a particular point along the shoreline, and do not incorporate characteristics of adjacent areas in the valuation process. However, viewing the spatial relationships of "scores" derived using these indices in GIS formats allows mangers to see groupings of high-priority sites. These indices have a variety of potential uses including: testing our understanding of species-habitat relationships, prioritizing sites for preservation or restoration, and creating monitoring sites for future research.

Methods

Study Area

This study focuses on a portion of the marine nearshore zone that includes the entire intertidal, parts of the shallow subtidal, and uplands immediately adjacent to shorelines. Indices were developed specifically for ecosystem components found in the inland marine waters of Washington State, including Puget Sound, Hood Canal, the Strait of Juan de Fuca, and the San Juan Archipelago. The inland marine waters are a series of interconnected, glacially scoured channels and have a total area of approximately 7,275 km^2 and a total of 3,973 km of shoreline (Washington Department of Natural Resources, 2001). In Whatcom, Skagit, San Juan, and King Counties, 40 km of shoreline have been inventoried using a high-resolution, volunteer-based inventory called the Rapid Shoreline Inventory (RSI).

Shoreline Inventory

Stretches of shoreline are selected for inventory in cooperation with local resource managers and citizens groups based on a review of wildlife and habitat distribution data. Once stretches of shoreline are identified, and landowner access permission is obtained, the shoreline is divided into 45-m linear sections that serve as the survey unit. Groups of trained volunteers work with "experts" to inventory shorelines during low tides. Volunteers receive 10 hours of training in the classroom and field before being allowed to collect data, and all data sheets are checked on-site by staff or volunteers that have received 40 or more hours of training before volunteers move to the next 45-m section. All data are collected during extreme low summer tide windows, with tide levels of 0 m Mean Lower Low or below. Data recorded for each 45-m shoreline section describe:

1. Beach location
2. Intertidal and backshore vegetation
3. Invasive species
4. Beach substrate
5. Bluff ecology
6. Streams, outfalls and signs of pollution
7. Shoreline structures
8. Adjacent land use
9. Wildlife sightings
10. Public access

Data are entered by volunteers and staff into a Microsoft Access database, and every 20th sheet is checked for accuracy by program managers. Errors in data entry have characteristically been less than

(a)

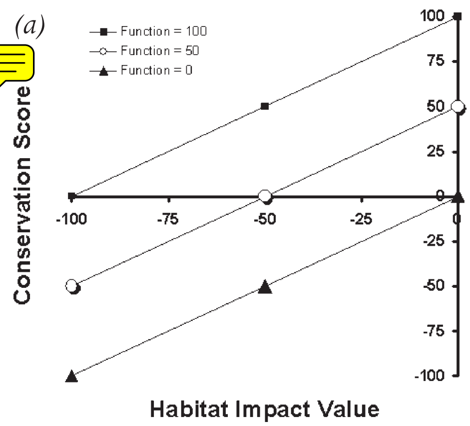
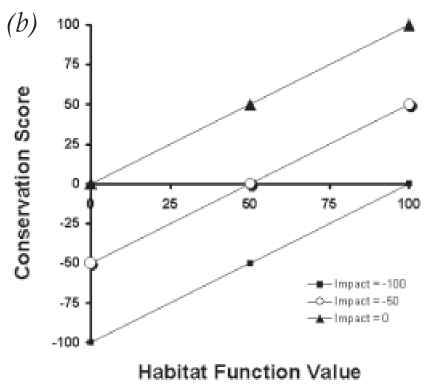
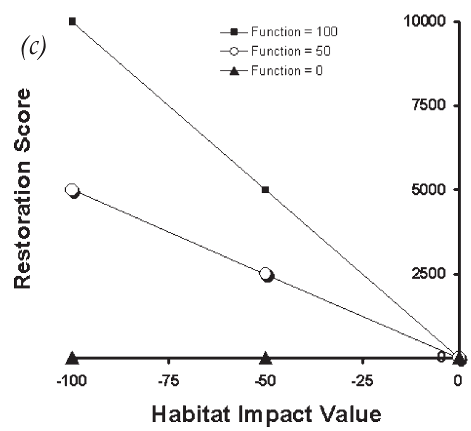


Figure 11.1 Relationship between conservation and restoration scores and habitat function and impact values (idealized for presentation, see Table 11.1). (a) Conservation score versus Habitat impact value, constant Habitat functions; (b) Conservation score versus Habitat impact value, constant Habitat impacts; (c) Restoration score versus Habitat impact value, constant Habitat functions; (d) Restoration score versus Habitat impact value, constant Habitat impacts.

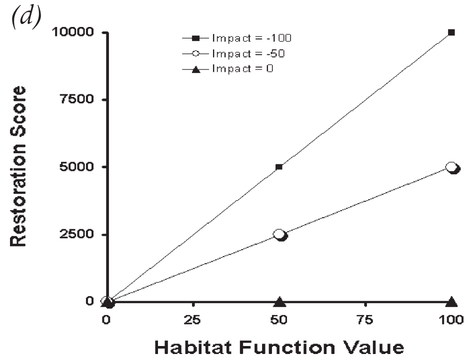
(b)



(c)



(d)



0.05 %. Once data are collected, entered, and checked for accuracy, the geographic information system (GIS) is developed. Spatial coverages are created in ArcGIS using exported Access records and combined with spatial location data collected in the field with a Trimble GeoExplorer III GPS unit.

Index Development

Conservation and restoration planning begins with the development of clear goals. The three primary types of goals that have been identified relate to: (1) species; (2) ecosystem functions; and (3) ecosystem services

(Ehrenfeld, 2000). Five ecosystem features of interest were identified that fit into these goal categories and appear to be tightly coupled to nearshore habitat conditions along sand and gravel beaches that dominate most of Puget Sound's shorelines. These features include: juvenile salmonids, forage fish, marine shoreline-dependent wildlife (especially birds), aquatic vegetation, and nearshore sediment supply and transport. For each of these targets, we developed semi-quantitative sub-indices using data collected during the RSI.

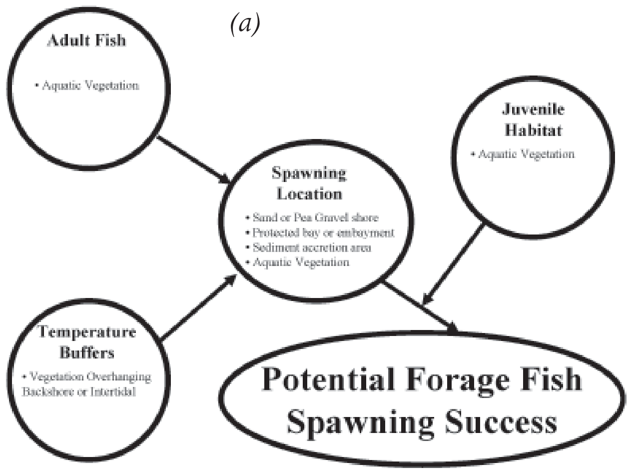
For conservation scores, each sub-index is the simple sum value of all positive attributes and all negative impacts. Conservation scores have a potential range of 0 to 100 with higher scores representing better conservation opportunities (Fig. 11.1a and b; Table 11.1). Restoration indices are calculated differently, reflecting the need to identify the "restorability" of a given site, balancing impacts with existing habitat value. For restoration, each sub-index is the absolute value of the product of all positive attributes multiplied by all negative impacts. Restoration scores have a potential range of 0 to 10,000 with higher scores representing better restoration opportunities (Fig.11.1c and d; Table 11.1).

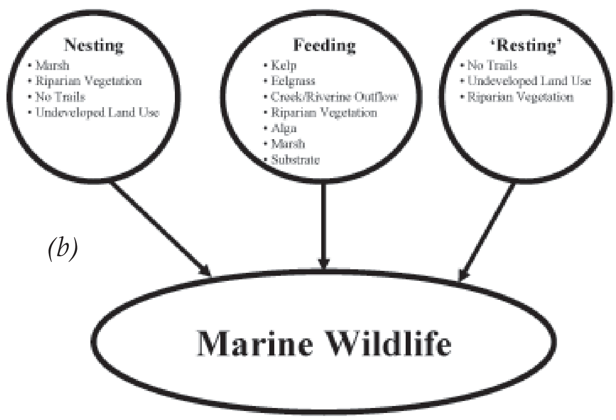
Since these conservation and restoration indices are semi-quantitative, the value assigned to a single site may have limited meaning relative to sites outside the study area, but in the context of a given study area, the relative value of a site is meaningful. The final conservation and restoration index value for each 45-m section is the average of the normalized rank order rankings for individual sub-indices. Therefore, conservation or restoration sites are ~~ultimately~~ ranked against others in the study area and ~~ultimately~~ have a score somewhere between the 1st and 99th percentile. Depending on regional conservation and restoration goals, it may be useful to examine different combinations of sub-indices rather than all five indices combined.

Table 11.1. Idealized habitat function and impact values for corresponding conservation and restoration scores (for demonstration purposes only, see Fig. 11.1a-d).

Function	*Impact*	*Conservation*	*Restoration*
100	-100	0	10000
100	-50	50	5000
100	0	100	0
50	-100	-50	5000
50	-50	0	2500
50	0	50	0
0	-100	-100	0
0	-50	-50	0
0	0	0	0

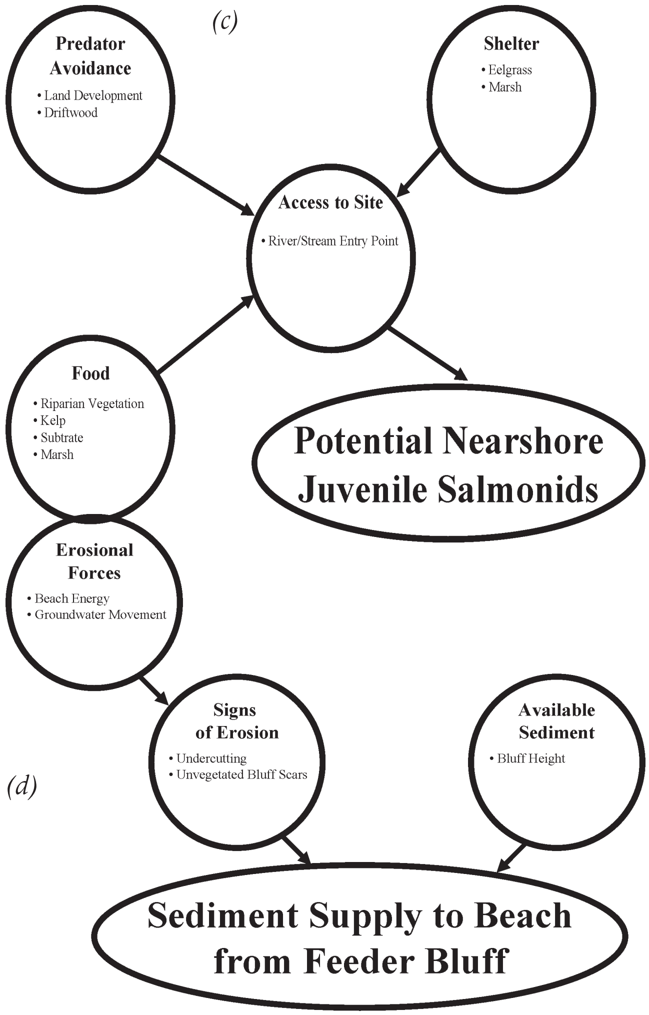
Figure 11.2. Causal models describing the relationship between shoreline characteristics and ecosystem target indices for: (a) potential forage fish spawning success.; (b) marine wildlife; (c) potential nearshore juvenile salmonids; (d) sediment supply to beach from feeder bluff; (e) aquatic vegetation.





SUB-INDICES

Forage Fish. Forage fish, including populations of Pacific herring (*Clupea harengus*), surf smelt (*Hypomesus pretiosus*), and Pacific sand lance (*Ammodytes hexapterus*), are an essential component of the Puget Sound food web. Though phylogenetically unrelated, these three nearshore-dependent species comprise an essential trophic link within Puget Sound, and are a major component of the diet of many predatory species including salmonids (Bargmann, 1998). While relatively little is known about the adult life stages of forage fish, shoreline spawning preferences and requirements are generally understood. Our analysis is an important extension of existing surveys that identify actual forage fish spawning sites, because the model focuses on identifying all sites that have characteristics consistent with spawning needs, and therefore, identifies potential spawning habitat. While forage fish may use the same sites for spawning over long periods of time (Penttila, 1995), a site may be abandoned for no apparent reason only to become used again at some point in the future (Robards et al., 1999).



Shoreline surveys to identify spawning beaches have been conducted by the Washington State Department of Fish and Wildlife (formerly the Department of Fisheries) since 1972. Based on information obtained during these surveys, surf smelt and sand lance are thought to spawn selectively on shorelines that have deposits of either sand or pea-gravel sized sediment in the upper intertidal zone (Bargmann ,1998; Fig.11.2a). In addition to substrate preferences and requirements, forage fish eggs tend to have lower mortality when there is riparian vegetation adjacent to the shoreline that can shade the shoreline and moderate temperatures (Robards et al., 1999; Fig. 11.2a). Pacific herring vary slightly from smelt and sand lance in that herring spawn primarily in the lower intertidal and shallow subtidal zones, and therefore their habitat requirements are focused on vegetation such as eelgrass or algal turfs (Penttila, personal communication 2001; Fig. 11.2a).

The forage fish analysis focuses on identifying those beaches with conditions that would seem to favor forage fish spawning and spawn survival (Table 11.2). Positive attributes for shorelines include

Table 11.2. Description of model scores and justification for index targets.

Positive Attribute	*A*	*B*	*C*	*D*	*E*
Geophysical Characteristics		-	-	*NA*	-
Intertidal Substrate	-	10 to 15	10 to 20	NA	-
Upper Intertidal Substrate	5	-	-	NA	-
Sand/Pea Gravel Bed	20	-	-	NA	-
Spit or Tombolo	10	-	-	NA	10
Dune	-	-	15		-
Driftwood	-	5	-	NA	-
Creek or River Mouth	-	5	5	NA	10
Seep	5	-	-	NA	
Bluff Height	5	-	-	NA	10 to 50
Bluff Scars	-	-	-		10 to 15
Bluff Undercutting	-	-	-		10
Beach Energy	-	-	-		10
Vegetation Characteristics		-	-	*NA*	-
Eelgrass (Z. marina)	10	15	-	NA	-
Kelp and intertidal algae	10	5	-	NA	-
Overhanging Vegetation	5 to 15	-	-	NA	-
Riparian Vegetation	-	10 to 30	5 to 25	NA	-
Marsh	5	15	10	NA	-
Bluff//Bank Vegetation	-	3 to 5	3 to 5	NA	-
Anthropomorphic Group		-	-	*NA*	-
Undeveloped/Natural Landuse	5	5	5	NA	-
No intertidal structures	10	-	-	NA	-

appropriate sediment found in the upper intertidal, overhanging vegetation for shade, as well as aquatic vegetation that might be used for spawning.

Habitat impacts for this model are primarily those that interrupt or disturb potential spawning areas or the processes that form potential spawning areas. These include artificial outfalls that might supply excess nutrients or toxic chemicals to the shoreline, bulkheads that alter nearshore hydrography, or piers that shade subtidal vegetation .

Juvenile Salmon. The salmon habitat analysis relies on the assumption that nearshore habitats provide key functions for juvenile salmon development and survival (Fig. 11.2b). Nearshore marine habitat may serve as migration corridors, feeding areas, physiological transition zones, refuge from predators, or refuge from high-energy wave

Negative Impact	*A*	*B*	*C*	*D*	*E*
Shoreline Structures					
Intertidal Structures	-10 to -30	-30	-30	-20	
Shoreline Armoring		-10 to -30	-10 to -20	-10	-10 to -40
Boat Ramp	-20				
Adjacent Landuse					
Upland Land use	-10	-10 to -30	-10 to -30	-20	
Trails			-10 to -20		
Potentially Polluted Outfalls		-10	-10		-10
Invasive Plants					
Spartina				-30	
Purple Loosestrife				-20	
Sargassum				-10	

Column A = Forage Fish; Column B = Juvenile Salmonids; Column C = Marine Wildlife; Column D = Aquatic Vegetation; Column E = Sediment Transpoty and Supply

dynamics (Mason, 1970; MacDonald et al., 1987; Levings, 1994; Thom et al., 1994; Spence et al., 1996). All juvenile salmon utilize the shallow waters of estuaries and nearshore areas as migration corridors to move from their natal streams to the ocean (Willliams and Thom, 2001). Estuarine environments provide a gradual transition area for juvenile salmon to adjust physiologically to salt water (Simenstad et al., 1982). With declines in submerged aquatic vegetation that formerly served as feeding grounds and refugia for juvenile salmonids, it is likely that juvenile salmon have shifted their distributions and now utilize shallow water as an alternate refuge habitat (Ruiz et al., 1993).

This model focuses on valuing individual sites for their capacity to serve as feeding areas, refugia, or migration corridors (Table 11.2). Emergent vegetation (*Carex lyngbyei*, *Scirpus* spp., etc.) and riparian shrubs and trees have been identified as vital components that provide detritus and habitat for chinook food organisms (Levings et al., 1991; Tanner et al., 2002), and were therefore scored.

Habitat impacts are those features that are known to or believed to displace habitat or impede habitat forming processes. These include structures that reduce shallow, nearshore refuge habitat or adjacent land uses that may impact vegetation and upland food sources.

Marine Shoreline Wildlife. A variety of terrestrial animals will spend part or all of their lives within the nearshore environment and have a great impact on the composition and functioning of the nearshore ecosystem. An essential component of the nearshore ecosystem is marine birds. Marine birds are often the dominant predators along rocky as well as sandy beaches (Hori and Noda, 2001). In addition to being a dominant consumer of animals, most birds are omnivores and therefore play a critical role in structuring assemblages of animals as well as vegetation in the nearshore ecosystem.

This analysis focuses on habitat components that contribute to the feeding, rearing, and resting of shoreline dependent wildlife (Fig. 11.2c). This analysis looks at a variety of shoreline features that are beneficial for a variety of birds that depend on marine shorelines (Table 11.2). It awards points for fine sediments where shorebirds forage, niche habitats where rivers and creeks meet salt water, and dunes where some shorebirds nest. It awards points for a variety of vegetation directly beneficial to marine waterfowl (such as black brants) and indirectly beneficial to fish-eating birds (such as great blue herons and kingfishers). This model incorporates habitat impacts in the form of sources of disturbance such as trails accessing the shoreline as well as landuse patterns associated with human use.

Aquatic Vegetation. Primary production forms the base of any food web, and in Puget Sound, the primary producers are seaweeds, seagrasses, benthic microalage, kelps, marsh macrophytes, and phytoplankton. In Puget Sound, areas of increased algae and seagrass density, or biomass, contain more species and a greater abundance of epibenthic invertebrates than do areas of lower vegetative cover or structure (Cheney et al., 1994). With the exception of estuary marsh vegetation, which was formerly widespread in and around the major bays and deltas of Puget Sound (Bortelson, 1980), benthic primary production is limited to a relatively narrow band of habitat as a result of the steep fjord-like character of Puget Sound's nearshore habitat. Any attempt to determine the suitability of a certain area as habitat for aquatic vegetation must take into consideration light and parameters that modify light (epiphytes, total suspended solids, chlorophyll concentration, nutrients; Koch, 2001). Anthropogenic nitrogen loads to shallow coastal waters have been linked to shifts from seagrass to algae-dominated communities in many regions of the world (McClelland and Valiela, 1998). Propagules of most types of aquatic vegetation are generally found to be ubiquitous, so the absence of aquatic vegetation is generally a result of either inappropriate habitat for colonization and survival or displacement by another type of aquatic vegetation (Moore et al., 1996).

The focus of this analysis is on direct observations of aquatic vegetation with individual types of aquatic vegetation valued primarily for their ecological "services" (Fig. 11.2d). Implicit in the scoring of this model is the underlying assumption that each type of aquatic vegetation typically occupies a particular zone in the nearshore environment, from the subtidal to the upper intertidal. Species and multi-species assemblage scores are largely based on the ecological services they provide and the number of zones they occupy. Factors affecting light availability and nutrient loading as well as non-native competitors are assessed as habitat impacts in this model (Table 11.2).

Nearshore Sediment Supply and Transport. Puget Sound's shorelines are composed of hundreds of littoral cells that redistribute sediment along the shoreline. In the relatively protected waters of Puget Sound, the primary sources of sediment to the shoreline are alongshore and onshore transport, bluff erosion, and beach nourishment (Fig. 11.2e; Table 11.2). Sediment is lost from the beach as a result of erosion and longshore transport or deposition on spits (Downing, 1983). Shoreline development and armoring actively impact Puget Sound beaches by altering sediment supply and transport processes on shorelines and by directly modifying and occupying critical habitats (Shipman and Canning, 1993; Shipman, 1995).

In developing a causal model to assess the local functionality of the nearshore sediment budget, we adapted the results of other models that focus on the impacts of human activity on shoreline erosion (e.g., Lawrence, 1994). The focus of this analysis is on identifying signs that the sediment budget is being filled by looking for evidence of active erosion, in particular along bluff faces, and areas of deposition that are found at the end of drift cells such as tombolos and spits.

Summary Data Presentations

Once the analyses are complete, potential nearshore conservation and restoration targets data are displayed on GIS-generated shoreline maps laid over topographic or orthophoto renderings of the adjacent water and land for perspective. Figure 11.3 (see page XXX) shows the cumulative score for potential restoration targets on Samish Island in Skagit County, Washington, in northern Puget Sound. Notice that the complete island was not surveyed, a result of failure to obtain permission from all property owners to access their shoreline, and of time available during low summer tides. By looking at the map, it is possible to identify areas that have a higher density of high scores, and thus might be of particular interest for restoration actions.

Discussion

The models are designed to assess each site for both the current condition of the site (conservation opportunities) and for the potential condition of the site (restoration opportunities). Each model employs two series of "habitat attributes." One series of attributes is valued positively for perceived benefits or indication of benefits to habitat quality. The second series of "habitat impacts" is assigned negative values for impacts on habitat forming/maintaining processes, indications of physical disturbance, or direct impact on the model's focal species group.

For conservation opportunities, the models are used to rate individual 45-m sections of shoreline on a scale of -100 to 100, with higher scores reflecting higher quality habitat. Positive scores were assigned to positive attributes such as riparian vegetation or feeder bluffs. Negative scores were assigned to habitat impacts such as bulkheads or signs of pollution. The conservation score is then simply the net difference between the sums of positive and negative values accrued for each 45-m section.

This analysis is helpful for identifying areas of highly functional habitat as well as those places that are not being directly or indirectly impacted by habitat-altering processes related to invasive organisms or anthropogenic development. While scores vary linearly on this scale, it is important to recognize that this is a semi-quantitative model that provides a relative indication of site conservation value (sites scoring higher will generally be more favorable) for areas included in this study. The precise scores achieved may have little meaning taken outside the context of this specific cross-site analysis.

On the other hand, ranking sites for restoration potential is complex and must account for both existing habitat conditions and potential future conditions should the site be restored. Since no system currently exists for evaluating nearshore restoration potential, we were forced to create a new scoring scheme. For our restoration-ranking scheme, the ultimate goal was to target high-value sites with restoration actions that produce the largest reduction in impacts. This scheme is designed to achieve the overall objective of identifying those sites with a high level of current ecosystem function or potential, and a significant degree of impairment.

We based our restoration analysis on the same scientific literature and data-driven, semi-quantitative rankings of site characteristics used in the conservation model. Our specific objective was to develop the most appropriate restoration model that would accentuate those sites scoring high in both the habitat attribute and habitat impact categories while giving relatively little value to sites that score low in either category. This objective was achieved by multiplying the habitat attribute score and the habitat impact score, and then taking the absolute value of the product of these two numbers. Thus, our restoration scores vary from zero—those sites that have either no current habitat function or no obvious habitat impacts, to 10,000—those sites that have both the maximum score in habitat attributes and impacts present. A site with high restoration potential might have multiple positive habitat attributes, such as pea gravel, a spit, eelgrass, and riparian vegetation, but also habitat impacts such as intertidal structures, a boat ramp, and several outfalls.

As with any model, the interpretation of scores requires care and consideration. We recommend that scores for this model be interpreted on a logarithmic scale. Since the model is semi-quantitative, the direction of scores (higher being more favorable than lower) is more important than the specific score or precise difference between scores.

One way to visualize our analyses is to plot conservation and restoration scores versus habitat function and impact values (the independent variables used to calculate the scores). Table 11.1 shows a series of idealized habitat function and impact values and the corresponding conservation and restoration scores. These values are plotted on Figures 11.1a-d. Notice that when conservation scores are plotted along lines of constant habitat function or habitat impact values, scores increase linearly with improvements in both habitat function and impact (i.e., less impact). The point of the conservation scoring system is to identify sites that have the greatest existing habitat value and the fewest negative impacts.

For the restoration analyses however, the scores increase along with increasing function and increasing intensity of impact (i.e., more impact equals a larger negative number). This results because the impact and function values are multiplied instead of added. The implication of this model is that sites with very low habitat function or very low habitat impact, are not prime targets for restoration, whereas sites that still have substantial remaining or intrinsic habitat value, but also have significant impairment, represent the best opportunity to make significant gains for the ecosystem through restoration.

Overall, we believe this ranking system reveals those restoration opportunities that would provide the highest value to the living resources—not merely those that are the cheapest or most convenient. While sites identified using this tool are likely to provide ecosystem benefits if they are protected and restored, this ranking scheme should only serve as a guide and pre-ranking tool for further detailed site inspections and analysis of site-specific circumstances.

Because the precise meaning of each individual scoring mechanism is uncertain, we believe it is best to compare sites within a given physical sampling area. In the specific examples presented later, we preferred to rank sites according to their scores and display those ranks rather than the raw scores. Those sites scoring in the highest decile (top 10%) are likely the most noteworthy sites and should be reviewed for potential conservation or restoration. Depending on the sampling area, sites in lower quantiles (the next 20%) may also be of interest for review. Overall conservation and restoration values were calculated by averaging the rank order (between 1 and 228 (the number of samples), with 228 being the highest scoring site) for the five models described here.

We should note that our conservation and restoration ranking schemes do not take into account the quality of immediately adjacent 45-m sections, or groups of adjacent sections. In this sense, the study and analysis does not explicitly account for habitat continuity along the shoreline. For example, multiple continuous sections of good to moderate quality habitat might be more important for conservation than one cell of excellent quality habitat in the middle of a larger area of very low-quality habitat. While scores for individual sections do not reflect this larger spatial context, viewing groupings of scores on the display maps can help identify important habitat "clusters," and at this point, the summary maps probably represent the appropriate tool for such integrative ranking of spatial relationships.

Finally, since this scoring system has only recently been developed, the model would benefit from further validation through: (1) taking conservation and restoration actions on sites identified by the model; (2) direct observations of target species and habitat processes at model sites; (3) further scientific inquiry into general habitat requirements of various species modeled here; and (4) review and exploration of the modeling method put forth here, incorporating newly collected information.

Results of the RSI data collection and analysis have provided support for several shoreline protection and restoration projects. While few of these projects originated as a result of these shoreline inventory efforts, the RSI provides project proponents with clear, objective information analyzing individual sites in a regional context. Restoration projects that have been supported include the restoration of a tidal channel on Samish Island, Washington, and the restoration of surf smelt spawning habitat along March Point, Washington. Protection efforts that have been supported include the acquisition of pristine shoreline habitats along Piner Point on Maury Island, Washington.

Conclusion

Restoration planning starts with the development of clear goals. The three primary types of goals that have been identified are: (1) restoration of species; (2) restoration of ecosystem functions and ecosystem management; and (3) restoration of ecosystem services (Ehrenfeld, 2000). An ecosystem approach requires an understanding of the fundamental linkages among ecosystem components, biological responses to physical and geochemical processes, rates and variability of these underlying processes, and the effects of disturbance and other modes of ecosystem change (Simenstad et al., 2000). The complexity of shoreline systems has delayed the development of assessment tools for either site specific or landscape level restoration planning.

While landscape metrics such as habitat connectivity may better describe some ecosystem components (Simenstad and Cordell, 2000), before these metrics can be applied suitable site-specific indices must be developed and examined. Therefore, the indices described here represent an early step in the development of restoration planning tools for marine shorelines.

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