Chapter 8

Vegetation of the Elwha River Estuary

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Abstract

The Elwha River estuary supports one of the most diverse coastal wetland complexes yet described in the Salish Sea region, in terms of vegetation types and plant species richness. Using a combination of aerial imagery and vegetation plot sampling, we identified 6 primary vegetation types and 121 plant species in a 39.7 ha area. Most of the estuary is dominated by woody vegetation types, with mixed riparian forest being the most abundant (20 ha), followed by riparian shrub (6.3 ha) and willow-alder forest (3.9 ha). The shrub-emergent marsh transition vegetation type was fourth most abundant (2.2 ha), followed by minor amounts of dunegrass (1.75 ha) and emergent marsh (0.2 ha). This chapter documents the abundance, distribution, and floristics of these six vegetation types, including plant species richness, life form, species origin (native or introduced), and species wetland indicator status. These data will serve as a baseline to which future changes can be compared, following the impending removal of Glines Canyon and Elwha Dams upstream on the Elwha River. Dam removals may alter many of the processes, materials, and biotic interactions that influence the estuary plant communities, including hydrology, salinity, sediment and wood transport, nutrients, and plant-microbe interactions.

Introduction

Unique wetland complexes occur where river mouths meet the sea. The vegetation of these areas ranges from riparian habitats that differ little from habitats associated with the river upstream to salt marshes that have a distribution limited to tidally influenced areas with elevated water salinity. The processes that drive the distribution and dynamics of plant communities in river estuary wetland complexes are also varied, ranging from fluvial-dominated processes such as flooding and channel migration to marine processes such as tidally driven water-level fluctuations. Patterns of seawater intrusion influence salinity levels in estuarine water and soils and can be a strong determinant of plant distributions (Mitsch and Gosselink, 1993; Keddy, 2000). At the scale of an entire river-mouth wetland complex, these conditions and processes can produce multiple plant communities with high beta diversity and high species richness (Keddy, 2000).

River mouth wetland complexes of the Salish Sea region (which extends from Olympia, Washington, to Canada's Desolation Sound) are relatively uncommon and small in area (Collins and Sheikh, 2005; Todd and others, 2006). Many of these systems have been modified by human activities such as channelization, large wood removal, and levee and dike construction, which typically reduce wetland extent and alter key processes such as tidal inundation (Thom and others, 2002; Todd and others, 2006; Brennan, 2007). By one estimate, Puget Sound tidal wetlands have been reduced to about 19 percent of their historical area, from approximately 29,500 ha to approximately 5,650 ha (Collins and Sheikh, 2005).

The Elwha River delta and estuary are relatively small and have been subject to alteration by the construction and operation of two large dams upstream that have significantly reduced sediment and wood transport through the estuary. Dike and levee construction also have constrained channel migration (Kloehn and others, 2008; Draut and others, 2011; Warrick and others, 2011, chapter 4, this report) and reduced the tidally influenced area (Duda and others, 2011, chapter 1, this report; Magirl and others, 2011, chapter 4, this report).

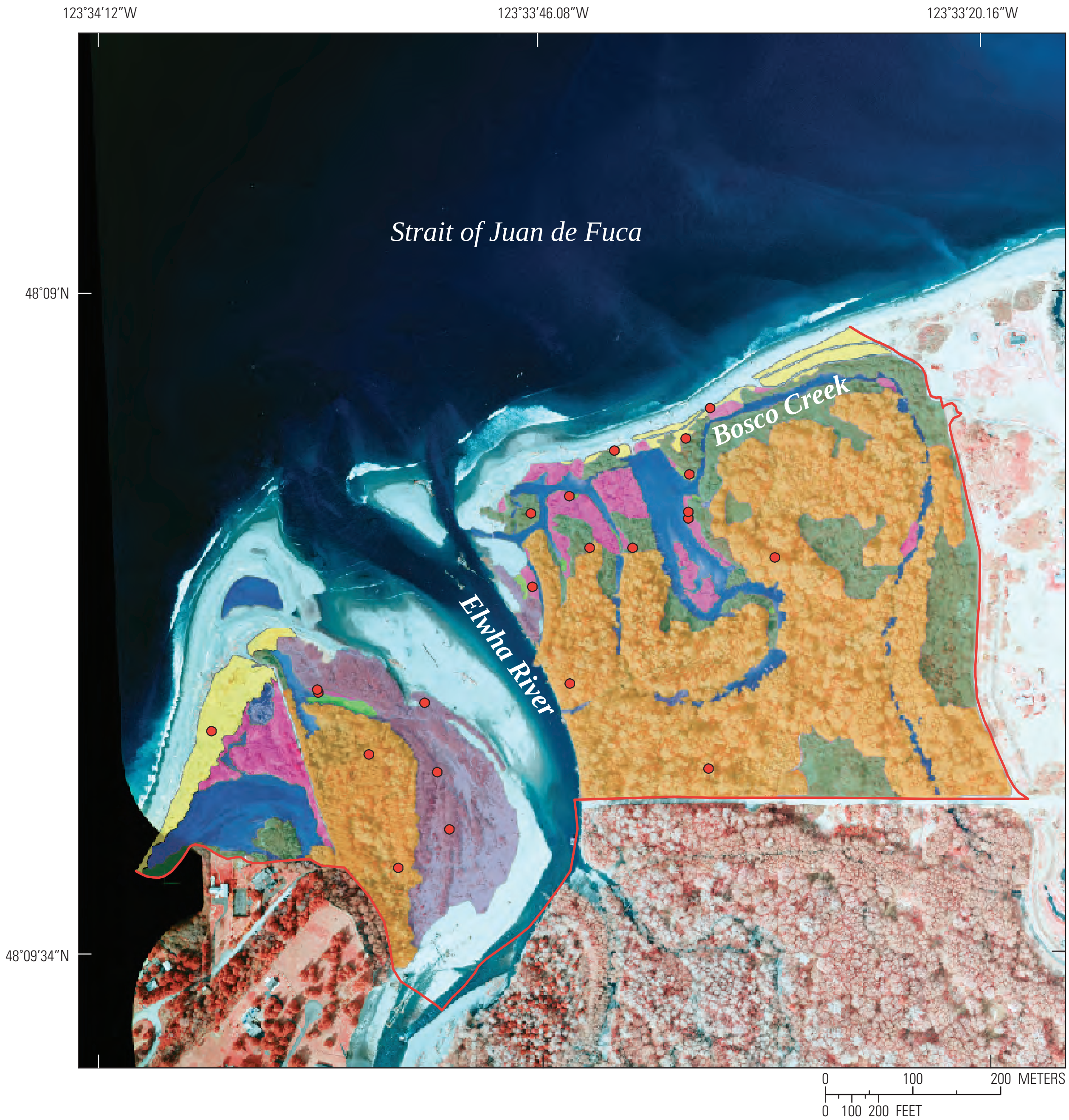
Removal of the two dams upstream on the Elwha River, anticipated to begin in 2011, will release and transport coarse woody debris and much of the approximately 19 million m^3 of sediment stored behind the dams (Bountry and others, 2010; Czuba and others, 2011, chapter 2, this report). This influx of sediment might directly influence estuarine plant communities through deposition of fine sediments, for example, or might indirectly affect these areas by inducing higher rates of channel change (Shafroth and others, 2002; Hood, 2010) and by altering the transport of sediment in the Strait of Juan de Fuca and adjacent beaches and beach berms (Warrick and others, 2011, chapter 3, this report).

This study is part of a U.S. Geological Survey (USGS) and Lower Elwha Klallam Tribe multi-disciplinary effort to characterize the ecosystems of the Elwha River estuary before dam removal. Our objectives were to identify the principal vegetation types within the estuary, estimate their areal extent, and characterize their structure and species composition, including species richness. We further elucidate floristic patterns by comparing the distribution of life forms, native versus introduced species, and the wetland indicator status among the primary vegetation types in the Elwha River mouth/estuary wetland complex.

Methods

Patch Delineation and Vegetation Plot Selection

In August 2007, polygons were delineated representing distinct vegetation patches visible on 1 m resolution, 2006 National Agriculture Imagery Program (NAIP) imagery within the study area. The study area was then ground-truthed to refine the polygon boundaries and to classify each polygon as one of six vegetation types: mixed riparian forest (labeled "Riparian forest" in figures), willow-alder forest, riparian shrub, shrub-emergent marsh transition (shrub-marsh transition), emergent marsh, and dunegrass (fig. 8.1, table 8.1). Figure 8.1 shows the polygons and plot locations, overlayed on a more recent aerial photograph (April 2008), which better depicts current conditions. Table 8.1 also provides the classification of these vegetation types according to Cowardin and others (1979). Next, random x-y coordinates were generated to identify plot locations. At least three plots were sampled in each of our original six vegetation types. For two of the more extensive vegetation types (riparian forest and riparian shrub) five plots were sampled. A total of 22 plots were sampled.



EXPLANATION

Vegetation Type

- Riparian forest
- Willow-alder forest
- Riparian shrub
- Shrub-marsh transition
- Emergent marsh
- Dunegrass
- **Open water**
- **Study area**
- **Vegetation plots**

Figure 8.1. Study area showing six vegetation patch types, gravel bars, open water, and vegetation plot locations, Elwha River estuary, Washington.

Table 8.1. Vegetation types named in this study in relation to the Cowardin and others (1979) classification used by the U.S. Fish and Wildlife National Wetlands Inventory (NWI).

Elwha vegetation type (this study)	Cowardin classification	Comments
Mixed riparian forest	PFO1A, Palustrine, Forested, Broad-leaved deciduous, Temporarily flooded	Many of these areas appear to be classified as non-wetland by the NWI. Areas classified as wetland that overlap this vegetation type in our study typically fall into the PFO1A category.
Willow-alder forest	E2USP, Estuarine, Intertidal, Unconsolidated shore, Regularly flooded	These early successional areas conform to areas currently mapped as estuarine, intertidal by the NWI, but due to vegetation encroachment would likely now be classified as an estuarine or palustrine forested, depending on the amount of tidal influence.
Riparian shrub; Shrub-emergent marsh transition	PSS1C, PSS1Ch, PSS1R, Palustrine, Scrub shrub, Broad-leaved deciduous, Seasonally flooded, Seasonally-flooded-impounded or Seasonal-tidal flooded or PF01A (see above)	Much of the area classified as riparian shrub is not classified by the NWI. Classified areas that do overlap with these vegetation types typically fall into the palustrine, scrub-shrub, broad-leaved deciduous categories with variable flooding regimes. Some areas are also classified as palustrine, forested, broad- leaved deciduous.
Emergent marsh	PEM1A, Palustrine, Emergent, Persistent, Temporarily flooded	These areas are often found in the ecotone from open water (estuarine or palustrine) to drier areas (riparian shrub and mixed riparian forest)
Dunegrass	M2USN, Marine, Intertidal, Unconsolidated shore, Regularly flooded	Dunegrass dominated berms adjacent to the shore either fall into this category or are considered “upland” and not mapped by the NWI.

Vegetation Plot Sampling

At each plot location, a 100 m^2 plot was established. Each vascular plant present in a plot was assigned to 1 of 10 cover classes: trace, 0–1 percent, 1–2 percent, 2–5 percent, 5–10 percent, 10–25 percent, 25–50 percent, 50–75 percent, 75–95 percent, and 95–100 percent. Because individual plants and vegetation strata commonly overlapped, total plant cover values within a plot commonly exceeded 100 percent. In most cases, plot dimensions were 10 × 10 m, but where the vegetation patch was narrow, plot dimensions were sometimes 4 × 25 m or 5 × 20 m. With these data, the total number of species across all of our plots were tallied (estuary-scale species richness), as were the total number of species per vegetation type (community-scale species richness), and the average number of species per vegetation type (plot-scale species richness).

In August 2008, the mixed riparian forest and willow-alder plots were revisited, and tree cover by species and the diameter of all trees (stems greater than 2.5 cm at breast height) were measured in 0.1 ha (for mixed riparian forest) or 0.01 ha (for willow-alder forest) plots. Tree stem density and basal area were calculated with the diameter data.

Floristic Categories

Each species was identified by its life form (or habit): graminoid, forb, shrub, or tree, and whether it was native or introduced was noted (per the U.S. Department of Agriculture [USDA] Plants database, http://plants.usda.gov/; and the University of Washington Herbarium, Washington Flora Checklist, http://biology.burke.washington.edu/herbarium/waflora/checklist.php). If the USDA Plants database indicated that a species can have multiple growth forms (for example, a tree or shrub form), the species was categorized as having the larger of the two forms (for example, a tree rather than a shrub). Species richness patterns are summarized by life form, species origin (native or introduced), and wetland indicator status (for those species for which this information was available per the USDA Plants database; http://plants.usda.gov/). Wetland indicator status is a five-point scale that estimates the probability that a plant occurs in wetlands: Obligate wetland species = 1; Facultative wetland species = 2; Facultative = 3; Facultative upland species = 4; Upland = 5. The relative cover of plants by life form and native versus introduced status are also summarized, and wetland indicator status weighted by the relative cover of each species is examined.

Vegetation Plot Classification

To assess the extent to which the plant community data from the plots was consistent with the subjective classification of the six vegetation types (based on the aerial photography and ground-truthing, above), a nonmetric multidimensional scaling (nMDS) ordination of the vegetation plot data was run using Primer, version 6.0 (Clarke and Gorley, 2006). The ordination was derived from a Bray-Curtis similarity matrix generated from square-root transformed percent cover (mid-point of cover class, by species) values for each species in each plot.

Vegetation Plot Elevation Surveys

To explore the relation between plot elevation and vegetation type, the elevation (above sea level) of each plot was estimated using two methods. In September 2009, 18 of the plot locations were surveyed with a Magellan ProMark 3 Differential Global Positioning System operating in Real-Time Kinematic mode (RTK-DGPS), mounted on a survey pole, receiving corrections from a base station on a permanent survey monument. The estimated systematic and random error (combined) in the vertical and horizontal dimensions was ±10 cm. Points could not be captured with the RTK-DGPS system for four of the plots due to canopy density. For these, plot elevations were estimated from a digital elevation model produced from a lidar flight in April 2009, which had an estimated absolute vertical error of ±30 cm (Entrix, Inc., 2009).

Elwha Estuary Vegetation Sampling Results

Vegetation Plot Classification

The six vegetation types that were identified to initially stratify the vegetation of the Elwha estuary (fig. 8.1) corresponded well to plot groupings revealed by the non-metric multi-dimensional scaling ordination (fig. 8.2). The final stress value for the two-dimensional analysis was 0.16, a value sufficiently low (that is, less than 0.2) to indicate a useful summary of multivariate pattern (Clarke and Warwick, 2001). Given the consistency between the classifications based on plot data and field mapping, these six vegetation types were retained for both the estuary-scale and community- and plot-scale descriptions. Here, the vegetation types are briefly described, and then compared with respect to various floristic metrics.

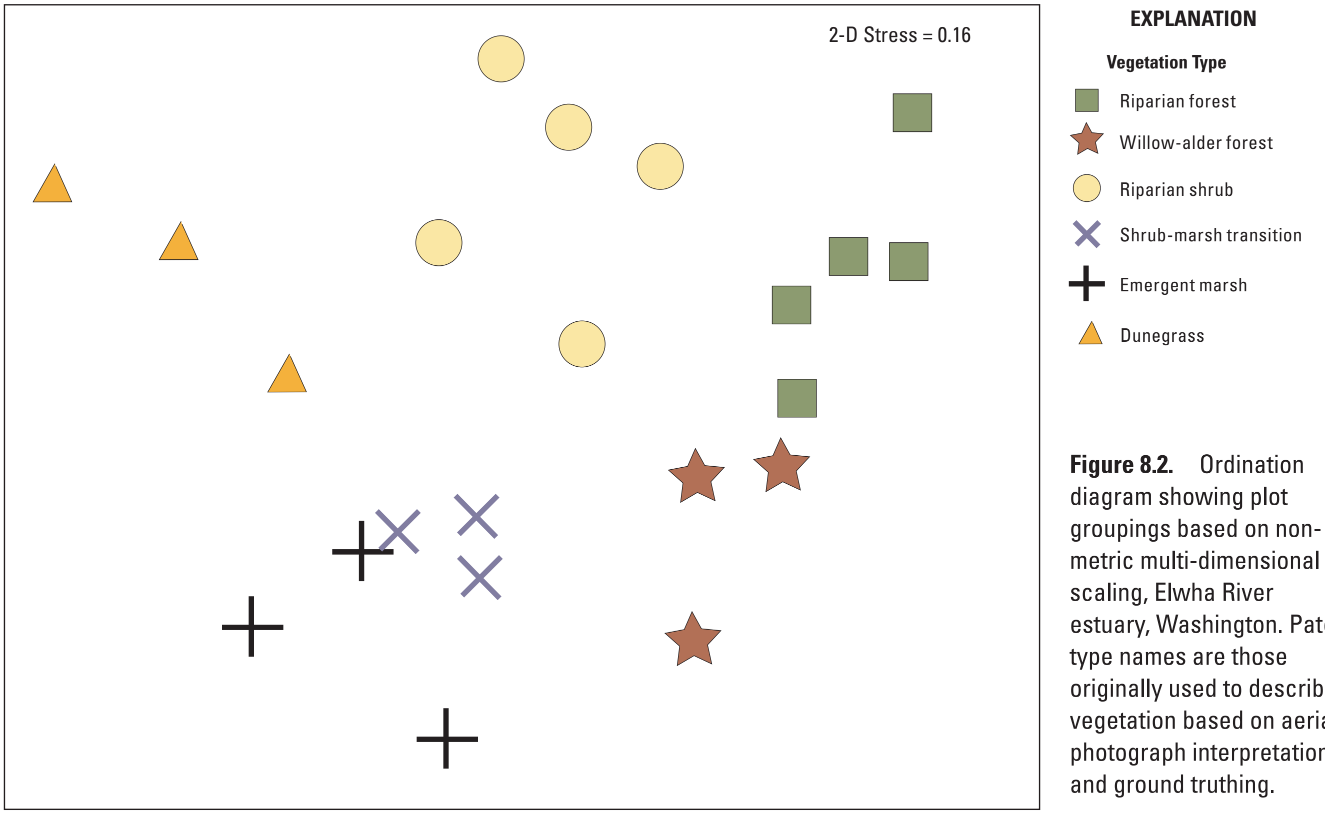


Figure 8.2. Ordination diagram showing plot groupings based on non-metric multi-dimensional scaling, Elwha River estuary, Washington. Patch type names are those originally used to describe vegetation based on aerial photograph interpretation and ground truthing.

Mixed Riparian Forest

The mixed riparian forest vegetation type is the most extensive in the study area, occupying approximately 20 ha in April 2008 (fig. 8.1). In the Elwha River estuary, mixed riparian forests can be dominated by various deciduous species, such as *Acer macrophyllum* (bigleaf maple), *Populus balsamifera* ssp. *trichocarpa* (black cottonwood), *Alnus rubra* (red alder) in the overstory, with *Sambucus racemosa* (red elderberry), *Rubus spectabilis* (salmonberry), and *Oemleria cerasiformis* (Indian plum) common in the understory (fig. 8.3). One conifer stand was sampled with *Pseudotsuga menziesii* (Douglas-fir) in the overstory. *Thuja plicata* (western redcedar), *Abies grandis* (grand fir) and *Picea sitchensis* (Sitka spruce) are other conifer species that occur within the study area. Some of these mixed riparian forest patches are relatively old (probably more than100 years) and often contain large trees (up to 163.5 cm in diameter within our sample plots). Mean ± standard deviation of tree stem density, basal area, and total percent cover of vascular plants were 676±125 stems/ha; 33.6±20.4 m^2/ha, and total percent cover was 192.4±36.7, respectively.

Figure 8.3. Mixed riparian forest vegetation type in the Elwha River estuary, Washington. (Photograph taken by Thomas O. Bates, formerly with ASRC Management Services, July 9, 2006.)

Willow-Alder Forest

Young willow-alder forests are early successional communities that occupy recently deposited gravel bars, typically close to the active river channel (fig 8.4). River channel migration over the past seven decades eroded many of the willow-alder forests on the east side of the channel but also deposited new gravel bars on the west side where several patches of this vegetation type existed during our study (Draut and others, 2008; fig. 8.1), occupying approximately 3.9 ha in April 2008 (fig. 8.1). *Alnus rubra* had the highest mean cover (61.5 percent) across the three plots sampled in this patch type. *Salix sitchensis* (Sitka willow; 23.3 percent mean cover) dominated one of the three plots, and *S. hookeriana* (Hooker's willow; 6.3 percent mean cover) was subdominant in one of the plots. Mean ± standard deviation of tree stem density in willow-alder stands was 2,767±2,450 stems/ha, mean ± standard deviation of basal area was 24.0±19.6 m^2/ha, total plant cover was 114.8±43.3 percent.

Figure 8.4. Willow-alder forest vegetation type growing on a gravel bar in the Elwha River estuary, Washington. (Photograph taken by Patrick B. Shafroth, U.S. Geological Survey, July 16, 2006.)

Riparian Shrub

Riparian shrub communities are characterized by high shrub cover and can occur in different contexts within the estuary. For example, along the margins of the estuarine water bodies and Bosco Creek, riparian shrub communities typically occurred either adjacent to the water or a short distance from the water if a strip of emergent vegetation was present. In places, they also occurred along a topographic gradient from water's edge to the riparian forest, between the shrub-emergent marsh transition community and the mixed riparian forest community. Finally, riparian shrub patches can be interspersed with mixed riparian forests (fig. 8.1). The riparian shrub vegetation type occupied approximately 6.3 ha in April 2008. Several shrubs were relatively abundant in the sampled plots: *Rosa nutkana* (Nutka rose), *Rosa pisocarpa* (clustered wild rose), *Crataegus douglasii* (black hawthorne; fig. 8.5), *Lonicera involucrata* (black twinberry), *Malus fusca* (Pacific crab apple), *Oemleria cerasiformis* (Indian-plum), *Rubus spectabilis* (salmonberry), and *Symphoricarpos albus* (common snowberry). Total plant cover in riparian shrub plots was 128.0±40.8 percent (mean ± standard deviation).

Figure 8.5. Riparian shrub vegetation type within the Elwha River estuary, Washington, study area. (Photograph taken by Tracy L. Fuentes, U.S. Geological Survey, August 18, 2007.)

Shrub-Emergent Marsh Transition

Shrub-emergent marsh transition vegetation usually occurs between the narrow bands of emergent marsh vegetation that are subject to regular and relatively large, tidally driven water-level fluctuations, and patches of riparian shrub or riparian forest that typically are inundated by river flooding (fig. 8.6). The shrub-emergent marsh transition zone is apparently inundated by tidal waters, but to relatively shallow depths for relatively short durations. This vegetation type occupied approximately 2.2 ha in April 2008. Vegetation is characterized by high total cover, predominantly herbaceous. The forb *Argentina egedii* (Pacific silverweed) dominated vegetative cover in the three plots sampled in this patch type (average of approximately 45 percent). Woody plant cover is comprised largely of scattered, relatively small *Salix sitchensis* and *Alnus rubra* individuals. Several emergent marsh species are also present in these plots, including *Carex* spp. (sedges), *Juncus* spp. (rushes), *Eleocharis palustris* (creeping spike-rush), and *Typha latifolia* (cattail). Total plant cover in shrub-emergent marsh transition plots was 161.0±58.4 percent (mean ± standard deviation).

Figure 8.6. Shrub-emergent marsh transition vegetation type within the Elwha River estuary, Washington, study area. (Photograph taken by Tracy L. Fuentes, U.S. Geological Survey, August 17, 2007.)

Emergent Marsh

In the Elwha River estuary, patches of emergent marsh vegetation are typically limited to narrow bands (less than 5 m) along the margins of the estuarine ponds (fig. 8.7). They occupy the smallest area of any of the vegetation types—approximately 0.2 ha in April 2008 (fig. 8.1). Sediment particle size is usually fine and plants are subject to substantial tidally driven water-level fluctuations (Magirl and others, 2011, chapter 4, this report). Individual patches are often relatively species poor, with high dominance by one or two species. Abundant species in the three plots sampled within this vegetation type included *Juncus arcticus* (arctic rush), *Argentina egedii*, *Carex obnupta* (slough sedge), *Rumex salicifolius* (willow dock), *Eleocharis palustris*, and *Typha latifolia*. Total plant cover was 118.7±30.6 in the emergent marsh plots (mean ± standard deviation).

Figure 8.7. Emergent marsh vegetation bordering open water in the Elwha River estuary, Washington. (Photograph taken by Patrick B. Shafroth, U.S. Geological Survey, July 20, 2006.)

Dunegrass

Dunegrass communities occur at relatively high topographic positions on or adjacent to beach berms. They occupied approximately 1.75 ha in April 2008 (fig. 8.1). These communities are strongly dominated by *Leymus mollis* (American dunegrass), which averaged more than 75 percent cover in the three plots sampled (fig. 8.8). Forb diversity was high in the dunegrass communities (see below), and some forbs had relatively high cover, such as *Ambrosia chamissonis* (silver bur ragweed), *Lathyrus japonicus* (beach pea), *Rumex salicifolius*, *Senecio sylvaticus* (woodland ragwort), and *Solidago canadensis* (Canada goldenrod). Total plant cover in the three plots sampled was 162.4 ± 89.8 percent (mean ± standard deviation).

Figure 8.8. Dunegrass vegetation type in the Elwha River estuary, Washington. (Photograph taken by Tracy L. Fuentes, U.S. Geological Survey, August 17, 2007.)

Floristics and Species Richness

A total of 121 unique vascular plant taxa in 46 families were identified within our 22 sample plots (table 8.2). Six of these taxa were identifiable only to the genus level, but were distinct from all other plants we identified. Given this, these taxa are considered "species" in the context of calculating richness values hereafter. The riparian shrub and shrub-emergent marsh transition vegetation types had the highest total richness (52 species), while the emergent marsh vegetation type had the lowest total richness (31 species; fig. 8.9). Plot-scale species richness differed in similar ways as total richness across the six vegetation types (fig. 8.9). The shrub-emergent marsh transition and mixed riparian forest vegetation types contained the most unique species (not found in any other vegetation type; 12 and 13 species, respectively); the willow-alder forest vegetation type contained only one unique species (fig. 8.9). The greater number of plots in the mixed riparian forest and riparian shrub vegetation types could bias the comparisons of total species richness and number of unique species.

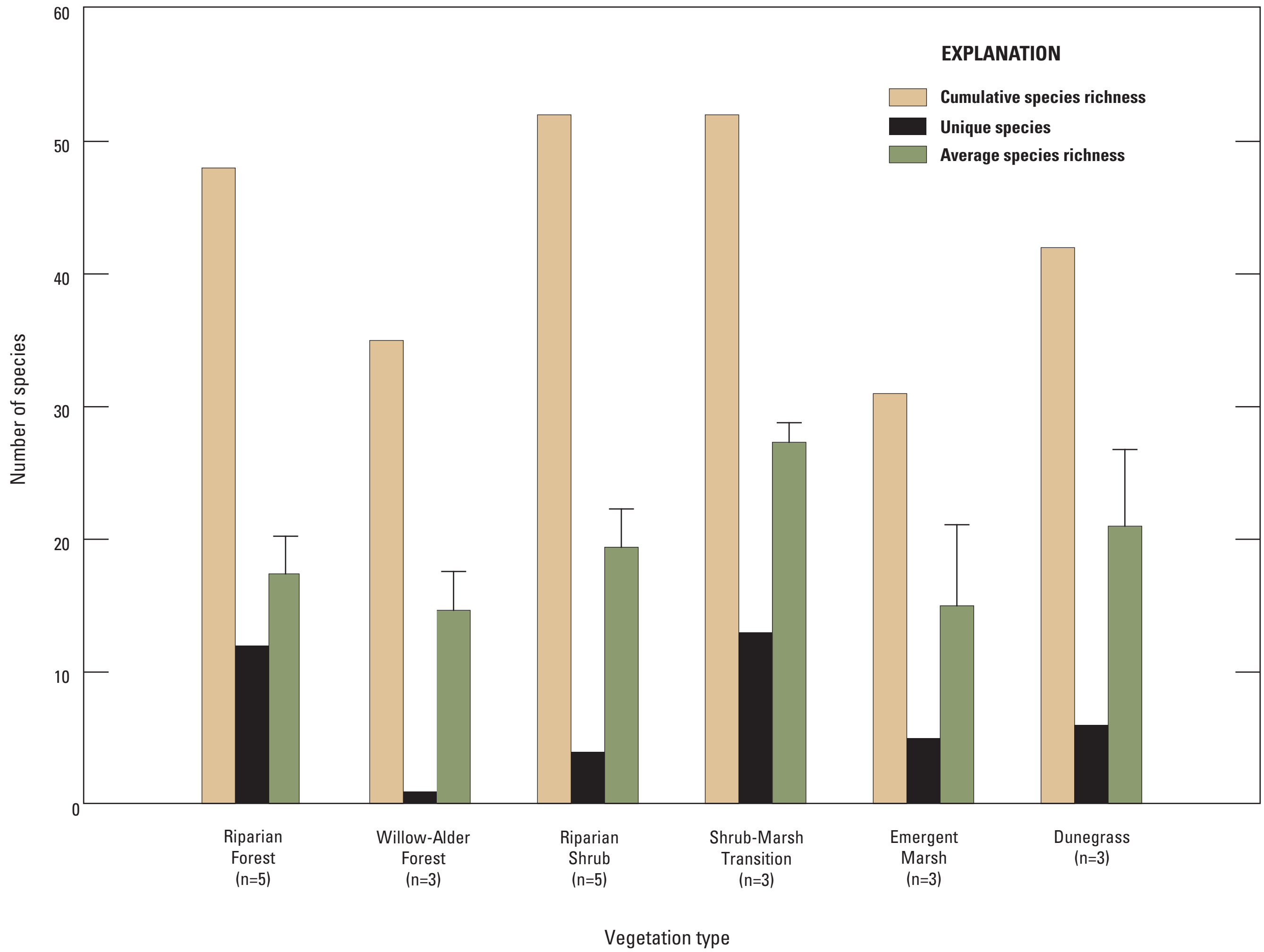


Figure 8.9. Species richness in the six vegetation types described for the Elwha River estuary, Washington. Light brown bars indicate the total number of species among all plots within a given vegetation type (cumulative species richness). Black bars indicate the number of species that are only in a given vegetation type (unique species). Green bars indicate the mean + standard error (black whisker) number of species (average species richness) per plot, by vegetation type. Number of plots sampled per vegetation type is indicated in parentheses beneath the x-axis labels. The area sampled is equal to the number of plots sampled times 100 square meters

Table 8.2. Characteristics of 121 unique plant taxa identified in 22 vegetation plots sampled in the Elwha River estuary, Washington, August 2007.

[Nomenclature for scientific names and plant family is based on the U.S. Department of Agriculture (USDA) Plants database (http://plants.usda.gov/). An "X" in a row beneath one of the six vegetation community column headings indicates that the plant was present in at least one plot sampled in that community. **Life form:** T, tree; F, forb; S, shrub; V, vine; SS, subshrub; G, graminoid. **Origin:** N, native plant; I, introduced plant; N/A, information not available **Noxious weeds:** Plants designated as noxious weeds by the Washington State Noxious Weed Board (2011) are labeled either B, (class B noxious weeds are nonnative species whose distribution is limited to parts of Washington State) or C, (Class C noxious weeds that already are widespread in Washington or are of special interest to the State's agricultural industry). **Wetland indicator status:** Based on information from USDA Plants database. Wetland indicator status is a five-point scale that estimates the probability that a plant occurs in wetlands compared to non-wetlands (OBL, obligate wetland species; FACW, faculative wetland species; FAC, FAC+, FAC-, faculative; FACU, faculative upland species; UPL, upland]

Scientific name (genus and species)	Family	Mixed riparian forest	Willow alder forest	Riparian shrub	Shrub-marsh transition	Emergent marsh	Dunegrass	Life form	Origin	Noxious weeds	Wetland indicator status
Acer macrophyllum	Aceraceae	X	X	X				T	N		FACU
Alisma plantago-aquatica	Alismataceae					X		F	I		OBL
Daucus carota	Apiaceae				X			F	I	B	N/A
Oenanthe sarmentosa	Apiaceae			X		X		F	N		OBL
Hedera helix	Araliaceae			X				S/V	I	C	N/A
Achillea millefolium	Asteraceae		X	X	X		X	F	N		FACU
Adenocaulon bicolor	Asteraceae	X						F	N		N/A
Ambrosia chamissonis	Asteraceae			X			X	F	N		N/A
Anaphalis margaritacea	Asteraceae				X			F	N		N/A
Cirsium arvense	Asteraceae				X		X	F	I	C	FACU+
Cirsium vulgare	Asteraceae				X	X	X	F	I	C	FACU
Erigeron sp.	Asteraceae				X			F	N/A		N/A
Hypochaeris radicata	Asteraceae		X	X	X		X	F	I	C	FACU
Lapsana communis	Asteraceae	X	X					F	I		FAC
Leucanthemum vulgare	Asteraceae	X	X	X	X		X	F	I	C	N/A
Mycelis muralis	Asteraceae	X	X					F	I		N/A
Senecio jacobaea	Asteraceae					X	X	F	I	B	FACU
Senecio sylvaticus	Asteraceae			X			X	F	I		N/A
Solidago canadensis	Asteraceae			X	X		X	F	N		FACU
Sonchus oleraceus	Asteraceae						X	F	I		UPL
Taraxacum officinale	Asteraceae		X	X				F	I		FACU
Alnus rubra	Betulaceae	X	X	X	X			T	N		FAC
Myosotis scorpioides	Boraginaceae				X	X		F	I		FACW
Cakile maritima	Brassicaceae						X	F	I		FACU
Lepidium campestre	Brassicaceae				X		X	F	I		N/A
Lepidium virginicum	Brassicaceae						X	F	N		FACU
Lonicera ciliosa	Caprifoliaceae	X						S	N		FAC+
Lonicera involucrata	Caprifoliaceae		X	X	X	X	X	S	N		FAC+
Sambucus racemosa	Caprifoliaceae	X						T/S	N		FACU
Symphoricarpos albus	Caprifoliaceae	X	X	X				SS/S	N		FACU
Stellaria crispa	Caryophyllaceae	X						F	N		FAC+
Chenopodium sp.	Chenopodiaceae						X	F	N/A		N/A
Convolvulus sp.	Convolvulaceae		X				X	F/V	N/A	B	N/A
Cornus stolonifera	Cornaceae	X		X				T/S	N		FACW
Thuja plicata	Cupressaceae			X				T	N		FAC
Carex deweyana var. *deweyana*	Cyperaceae	X						G	N		FACU
Carex lenticularis	Cyperaceae				X	X		G	N		FACW+

Table 8.2. Characteristics of 121 unique plant taxa identified in 22 vegetation plots sampled in the Elwha River estuary, Washington, August 2007.—Continued

Scientific name (genus and species)	Family	Mixed riparian forest	Willow alder forest	Riparian shrub	Shrub-marsh transition	Emergent marsh	Dunegrass	Life form	Origin	Noxious weeds	Wetland indicator status
Carex lyngbyei	Cyperaceae				X			G	N		OBL
Carex obnupta	Cyperaceae			X	X	X		G	N		OBL
Carex stipata var. *stipata*	Cyperaceae				X	X		G	N		OBL
Eleocharis palustris	Cyperaceae				X	X		G	N		OBL
Pteridium aquilinum	Dennstaedtiaceae	X						F	N		FACU
Dipsacus fullonum	Dipsacaceae				X			F	I		FAC
Athyrium filix-femina	Dryopteridaceae	X		X	X			F	N		FAC
Polystichum munitum	Dryopteridaceae	X		X				F	N		FACU
Equisetum arvense	Equisetaceae	X		X	X	X		F	N		FAC
Equisetum hyemale var. *affine*	Equisetaceae	X						F	N		FACW
Arbutus menziesii	Ericaceae						X	T	N		N/A
Gaultheria shallon	Ericaceae	X						SS/S	N		FACU
Vaccinium parvifolium	Ericaceae	X						S	N		N/A
Cytisus scoparius	Fabaceae	X			X			S	I	C	N/A
Lathyrus japonicus	Fabaceae				X		X	F/V	N		FACU-
Lathyrus sylvestris	Fabaceae				X			F/V	I		N/A
Lotus corniculatus	Fabaceae				X	X	X	F	I		FAC
Trifolium repens	Fabaceae		X		X		X	F	I		FAC
Vicia hirsuta	Fabaceae			X			X	F/V	I		N/A
Vicia nigricans ssp. *gigantea*	Fabaceae		X	X			X	F/V	N		N/A
Geranium robertianum	Geraniaceae	X	X					F	I	B	N/A
Ribes divaricatum	Grossulariaceae	X	X	X				S	N		FAC
Myriophyllum aquaticum	Haloragaceae					X		F	I	B	OBL
Iris pseudacorus	Iridaceae					X		F	I		OBL
Juncus acuminatus	Juncaceae				X			G	N		OBL
Juncus arcticus ssp. *littoralis*	Juncaceae					X		G	N		FACW+
Juncus articulatus	Juncaceae				X			G	N		OBL
Juncus effusus	Juncaceae				X			G	N		FACW
Mentha arvensis	Lamiaceae			X	X		X	F	N		FACW-
Mentha xpiperita [aquatica+spicata]	Lamiaceae				X	X		F	N		FACW+
Prunella vulgaris	Lamiaceae			X	X	X		F	N		FACU+
Maianthemum dilatatum	Liliaceae		X	X				F	N		FAC
Chamerion angustifolium ssp. *angustifolium*	Onagraceae				X			F	N		FACU+
Circaea alpina	Onagraceae	X						F	N		FAC+
Epilobium ciliatum ssp. *watsonii*	Onagraceae					X	X	F	N		FACW-
Epipactis gigantea	Orchidaceae	X		X				F	N		OBL
Piperia elongata	Orchidaceae	X		X				F	N		N/A
Pseudotsuga menziesii	Pinaceae	X		X				T	N		FACU
Plantago lanceolata	Plantaginaceae			X	X	X		F	I		FAC
Plantago major	Plantaginaceae		X				X	F	I		FACU+
Plantago maritima	Plantaginaceae				X			F	N		FACW+
Agrostis capillaris	Poaceae	X	X	X	X	X	X	G	I		FAC

Table 8.2. Characteristics of 121 unique plant taxa identified in 22 vegetation plots sampled in the Elwha River estuary, Washington, August 2007.—Continued

Scientific name (genus and species)	Family	Mixed riparian forest	Willow alder forest	Riparian shrub	Shrub-marsh transition	Emergent marsh	Dunegrass	Life form	Origin	Noxious weeds	Wetland indicator status
Agrostis stolonifera	Poaceae	X	X	X	X			G	I		FAC
Bromus sitchensis	Poaceae	X	X					G	N		N/A
Dactylis glomerata	Poaceae	X	X		X		X	G	I		FACU
Elymus repens	Poaceae		X	X				G	I		FAC-
Festuca rubra	Poaceae			X	X			G	I		FAC+
Holcus lanatus	Poaceae	X	X	X	X		X	G	I		FAC
Leymus mollis	Poaceae			X			X	G	N		N/A
Lolium perenne ssp. *multiflorum*	Poaceae						X	G	I		FACU
Phalaris arundinacea	Poaceae			X	X	X	X	G	N	C	FACW
Phleum pratense	Poaceae				X			G	I		FAC-
Poa palustris	Poaceae			X	X			G	N		FAC
Schedonorus pratensis	Poaceae	X		X	X		X	G	I		FACU+
Polygonum sp.	Polygonaceae		X			X		F	N/A		N/A
Rumex crispus	Polygonaceae				X	X		F	I		FAC+
Rumex salicifolius var. *salicifolius*	Polygonaceae		X		X	X	X	F	N		FACW
Polypodium glycyrrhiza	Polypodiaceae	X		X				F	N		N/A
Claytonia sibirica	Portulacaceae	X						F	N		FAC
Potamogeton sp.	Potamogetonaceae					X		F	N/A		OBL
Ranunculus repens	Ranunculaceae	X	X	X			X	F	I		FACW
Argentina egedii ssp. *egedii*	Rosaceae		X	X	X	X	X	F	N		FAC-
Crataegus douglasii	Rosaceae			X				T/S	N		FAC
Crataegus monogyna	Rosaceae	X						T	I		FACU+
Holodiscus discolor	Rosaceae	X						S	N		N/A
Malus fusca	Rosaceae			X				T/S	N		FACW
Oemleria cerasiformis	Rosaceae	X	X	X				T/S	N		FACU
Rosa nutkana var. *nutkana*	Rosaceae			X			X	SS	N		FAC
Rosa pisocarpa	Rosaceae			X			X	SS	N		FAC
Rubus armeniacus	Rosaceae			X			X	SS	I	C	FACU
Rubus parviflorus	Rosaceae	X	X					SS	N		FAC-
Rubus spectabilis	Rosaceae	X	X	X	X	X		SS/V	N		FAC+
Rubus ursinus	Rosaceae	X		X			X	SS	N		FACU
Galium boreale	Rubiaceae		X	X	X	X		F	N		FAC
Galium sp.	Rubiaceae	X						F	N/A		N/A
Populus balsamifera ssp. *trichocarpa*	Salicaceae	X		X				T	N		FAC
Salix hookeriana	Salicaceae		X					T/S	N		FACW-
Salix lasiandra ssp. *lasiandra*	Salicaceae				X			T/S	N		FACW+
Salix sitchensis	Salicaceae	X	X	X	X	X	X	T/S	N		FACW
Tolmiea menziesii	Saxifragaceae	X	X					F	N		FAC
Digitalis purpurea	Scrophulariaceae	X	X					F	I		FACU
Solanum dulcamara	Solanaceae						X	SS/F/V	I		FAC+
Typha latifolia	Typhaceae				X	X		F	N		OBL
Urtica dioica	Urticaceae	X						F	N		FAC+

Life Form

Of the 121 unique taxa in our sample plots, there were 15 tree, 15 shrub, 67 forb, and 24 graminoid species. Within all of the vegetation types, species richness of forbs was higher than the other life forms. Forb richness was especially high in the shrub-emergent marsh transition and dunegrass plots. Species richness of shrubs was relatively high in the riparian shrub plots and somewhat high in the mixed riparian forest plots. Graminoid richness was relatively high in the shrub-emergent marsh plots and in the emergent marsh plots. Finally, tree species richness was notably low in the emergent marsh and dunegrass plots (fig. 8.10*A*). Relative cover of trees was high in mixed riparian forest and willow-alder forest plots (greater than 60 percent); relative cover of shrubs was highest in riparian shrub (39 percent) and mixed riparian forest (26 percent) plots; relative cover of forbs was highest in the shrub-emergent marsh transition (65 percent) and emergent marsh (42 percent) plots; relative cover of graminoids was highest in the dunegrass (64 percent) and emergent marsh (53 percent) plots (fig. 8.10*B*).

Native Compared with Introduced Species

Of the 121 unique taxa, 113 had information indicating whether they are native or introduced. Of these 113 species, 71 (63 percent) are native and 42 (37 percent) are introduced. Thirteen of the introduced species are State-listed noxious weeds (Washington State Noxious Weed Control Board, 2011). The numbers of introduced species were highest in the shrub-emergent marsh transition and dunegrass vegetation types (20 and 21 species, respectively) and lowest in the emergent marsh and riparian forest vegetation types (10 and 12 species, respectively; fig. 8.11). Differences among vegetation types were more pronounced when cover of native versus introduced species was considered. The relative cover of introduced species was highest in the shrub-emergent marsh transition and dunegrass vegetation types (33 percent and 18 percent, respectively) and lowest in the emergent marsh, riparian forest, and riparian shrub vegetation types (1.9, 3.4, and 3.6 percent, respectively; fig. 8.11).

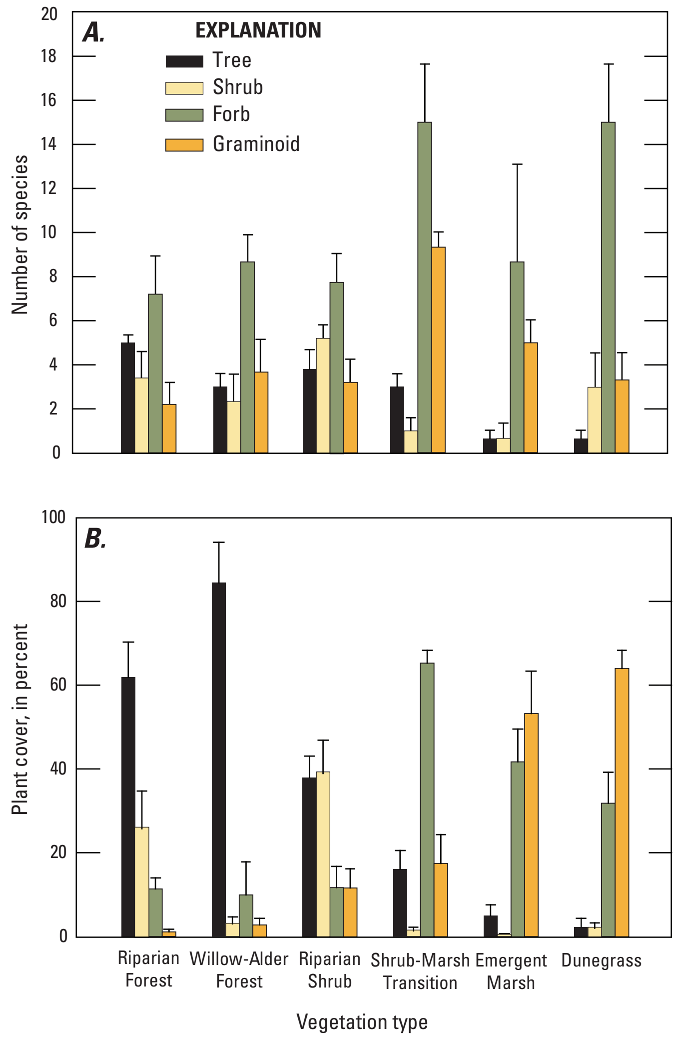


Figure 8.10. Life form composition of vegetation, Elwha River estuary, Washington. (*A*) Contribution of different life forms to species richness in the six Elwha River estuary vegetation types described in this study (plot means + standard error [black whisker]). *(B)* Relative plant cover associated with different life forms in the six Elwha River estuary vegetation types described in this study (plot means + standard error [black whisker]).

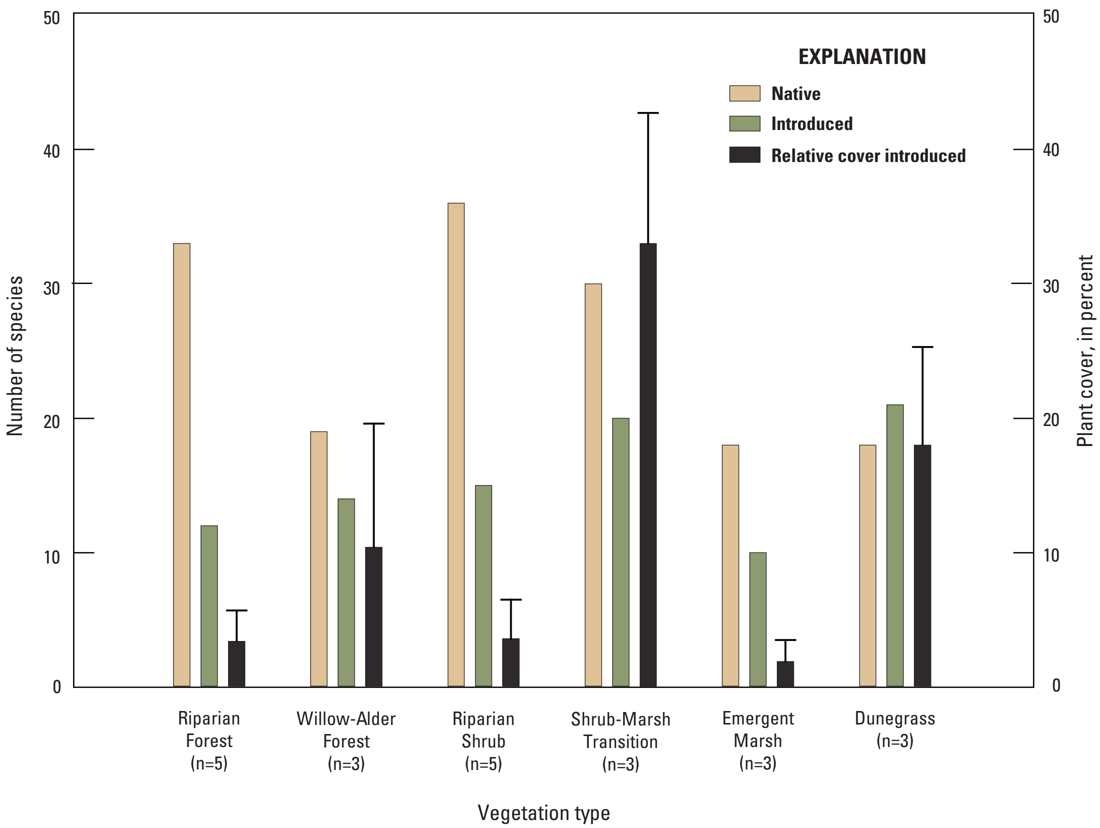


Figure 8.11. Number of native and introduced species and relative plant cover of introduced species in the six vegetation types described for the Elwha River estuary, Washington. Numbers of native and introduced species are cumulative across all plots in a particular vegetation type. Relative plant cover of introduced species is the mean + standard error (black whisker).

Wetland Indicator Status

Wetland indicator status information was available for 94 of the 121 unique taxa. The average wetland indicator value associated with species present in plots was highest (least likely to occur in wetlands) for the dunegrass vegetation type, followed by the mixed riparian forest and riparian shrub vegetation types (fig. 8.12). As would be expected, the emergent marsh vegetation type had the lowest value, and the shrub-marsh transition vegetation types had the second lowest value (fig. 8.12). The pattern of wetland indicator values weighted by relative cover of each species was similar (fig. 8.12).

Vegetation Types Along a Topographic Gradient

Consistent with the wetland indicator status results, average plot elevation above NAVD 88 was highest for dunegrass and mixed riparian forest (fig. 8.13). Willow-alder forest and riparian shrub plots were intermediate and shrub-emergent marsh transition and marsh plots were at the lowest elevations (fig. 8.13).

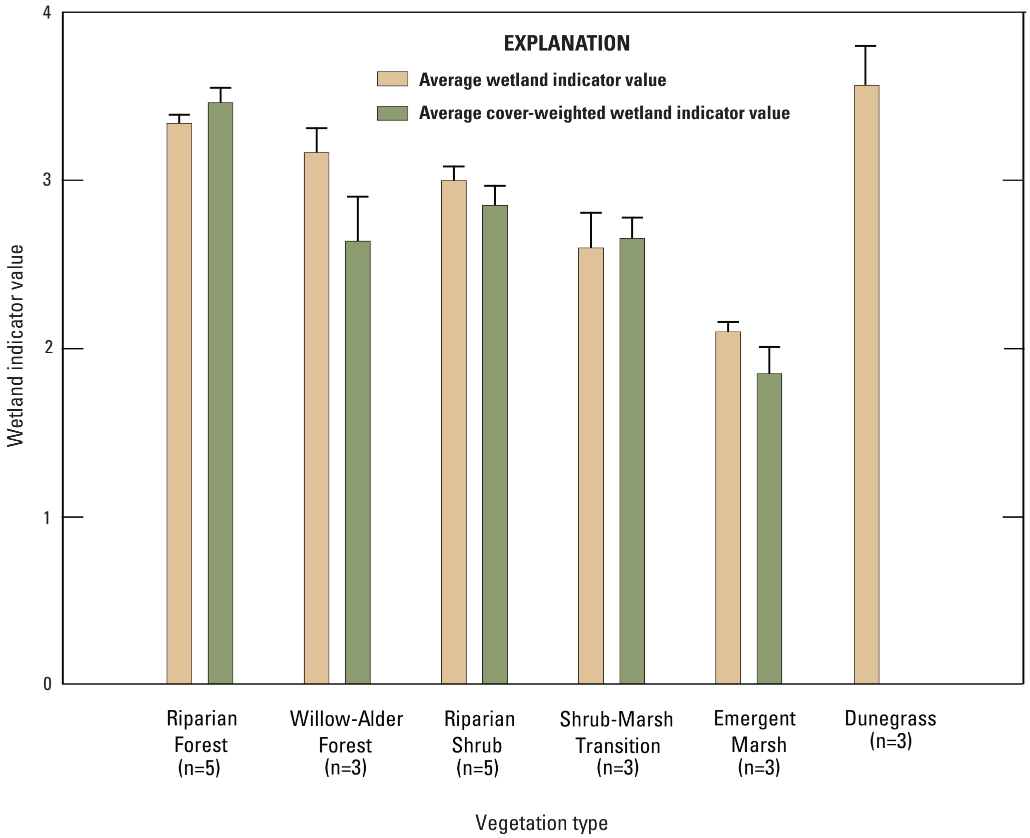


Figure 8.12. Wetland indicator values of plants in the six vegetation types described for the Elwha River estuary, Washington. Lower values indicate a greater tendency to occur in wetlands. Light brown bars indicate the average (of all plots within a vegetation type) of the average wetland indicator value of all plants for which a value was available in each plot. Green bars indicate the average (of all plots within a vegetation type) of the average wetland indicator value of plants in a plot, by vegetation type, weighted by the relative cover of those plants. Black whiskers indicate one standard error. Plots from the cover-weighted calculations were excluded if plants without a known wetland indicator value comprised greater than 20 percent of the plot's relative cover, which included all of the dunegrass plots.

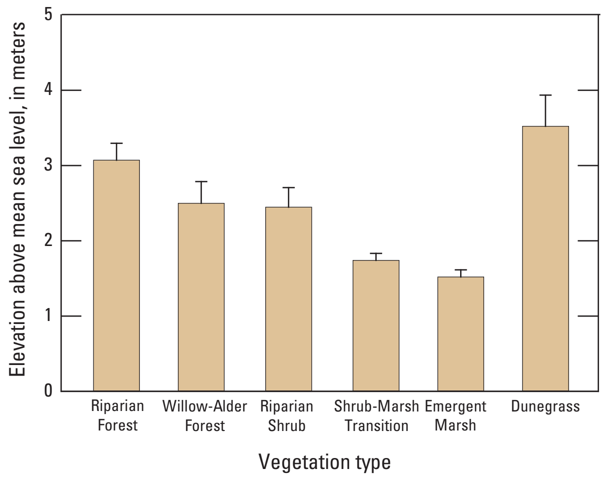


Figure 8.13. Average plus standard error (black whisker) elevation of plots within the six vegetation types described for the Elwha River estuary, Washington. See the “Methods” section for a detailed description of topographic survey data collection.

Elwha Estuary Vegetation—Discussion of Results

Species Richness and Vegetation Type Diversity

Despite its small size, the Elwha River estuary is quite diverse in terms of vegetation types present and species richness. 121 unique plant taxa in 6 vegetation types were documented in 2,200 m^2 total (twenty-two 100 m^2 plots) within 39.7 ha of land area within the Elwha estuary study area (fig. 8-1). This is the greatest plant species diversity yet documented, both in terms of total species richness and species richness within a particular vegetation type, within the admittedly sparse Pacific Northwest coastal wetland literature (MacDonald and Barbour, 1974; Brennan, 2007). Thom and others (2002) documented between 8 and 14 plant species per year in the 15 ha Elk River estuary (Washington Coast) over an 11-year period following removal of a dike in seventy-two 1 m^2 plots. Tanner and others (2002) documented 61 unique plant taxa in the 23.7 ha restoration project area associated with the Spencer Island dike breaching in the Snohomish River estuary (central Puget Sound). Plant species richness varied by year, beginning with 37 species prior to dike removal in 1994, then dropping to a low of 14 species in 1995, and increasing to 38 by 1998. Most species observed in 1994 were within forested wetland plant communities (35 species), whereas by 1998 most species occurred within emergent marsh plant communities. Plots varied in size and shape, so calculations of sampled area were not possible. Hutchinson (1988) sampled 17 intertidal delta marshes in the Strait of Georgia and the Puget Sound, not including those of the Strait of Juan de Fuca, and documented a total of only 80 plant species, two of them macroalgae. Of the sampled deltas, the Cowichan (32 species), Campbell (30), Fraser (28), and Skokomish (28) deltas had the greatest plant species richness. However, Hutchinson sampled only 1,810 m^2 (905 1 × 2 m plots). The relatively high plant diversity present in the Elwha River estuary is striking, given that it historically and presently represents less than 1 percent of Salish Sea coastal wetlands (Collins and Sheikh, 2005).

The relatively high species richness probably is a function of intense searching in a larger sample area (Stohlgren and others, 1997), as well as the presence of a greater diversity of vegetation types compared with other Pacific Northwest coastal wetland studies. For example, “mixed riparian forest,” “willow-alder forest,” and “riparian shrub” vegetation types may not have been sampled in some of the other studies. Based on cluster analyses, Hutchinson (1988) identified five classes of deltas and seven plant communities. All seven of Hutchinson’s plant communities would be classified as emergent marsh under our sampling scheme; all are graminoid-dominated or graminoid/forb co-dominated. No other types were sampled. Of his seven, two are possibly present within the Elwha estuary: *Scirpus americanus-Scirpus maritimus* and *Juncus balticus-A. egedii*. Burg and others (1980) identified 12 plant associations and 24 plant species characteristic of those associations in the salt marshes of the Nisqually River estuary in southern Puget Sound. In their results, they did not include a full plant species list, so we cannot compare floristic diversity between our study and theirs. However, new vegetation studies of the Nisqually estuary are currently in progress, and the preliminary plant list includes 51 species (U.S. Geological Survey, 2009). Of the 12 associations they identified, 2 of them also could be within our study area: pure stands of *Carex lyngbyei* and *C. lynbyei-Festuca rubra*. These are the most productive plant associations that Burg and others (1980) sampled. The *C. lyngbyei* association was the most productive per unit dry weight (1,390 g dry weight/m^2, contributing 6.7 percent total marsh production), followed by *C. lynbyei-Festuca rubra* (1,086 g dry weight/m^2, contributing 10.5 percent total marsh production). Both species are present within the Elwha estuary and were encountered in vegetation patches classified as emergent marsh or shrub-emergent marsh transition. The other plant associations they identified are much more characteristic of low tidal salt marshes, which are not present within our study area.

A somewhat unusual aspect of the Elwha estuary vegetation is the lack of a well-developed salt marsh community, given the historic extent of salt marshes in the Salish Sea region and their representation in Pacific Northwest coastal wetland literature. Nor does an Elwha River salt marsh community appear to have been present historically, which Collins and Sheik (2005) attributed to the high wave energy environment on the Strait of Juan de Fuca coast. Characteristic salt marsh taxa, including *Salicornia virginica* (pickleweed), *Distichlis spicata* (saltgrass), and *Triglochin maritima* (seaside arrowgrass) are entirely absent from our sample plots in the Elwha estuary (table 8.2).

Introduced Species

Although the literature on estuarine vegetation vulnerability to invasion is not well developed, riparian systems have been shown in a number of studies to harbor a greater number of introduced species than adjacent upland ecosystems (DeFerrari and Naiman, 1994; Stohlgren and others, 1998; Brown and Peet, 2003), largely due to high levels of disturbance, rapid seed dispersal potential, and high resource availability. The number of introduced species and the proportion of the local flora in our study exceed that reported in several other studies of riparian ecosystems from around the world (DeFerrari and Naiman, 1994; Planty-Tabacchi and others, 1996; Hood and Naiman, 2000; Brown and Peet, 2003). For example, DeFerrari and Naiman (1994) reported species richness and cover of introduced (exotic) plants in riparian communities along the Dungeness and Hoh Rivers on the Olympic Peninsula, Washington, and found 40 and 30 species, respectively, comprising 28 percent of the flora in both systems. These lower values were found despite the fact that they sampled approximately three times as many plots (plot size was 50 m^2). Planty-Tabacchi and others (1996) reported that 30 percent of 851 total species found along three drainages in western Oregon (Willamette River, MacKenzie River, Lookout Creek) were introduced. Thus, our finding of 37 percent of the Elwha estuary flora as introduced is higher than commonly reported and is of potential concern to resource managers (Woodward and others, 2008). Physical habitat changes expected following dam removals on the Elwha could increase physical disturbance and perhaps facilitate the spread of some of these taxa, as is projected further upstream in the Elwha watershed (Woodward and others, 2011).

Dam Removal Context

Removal of the two dams on the Elwha River is expected to result in the release and transport of sediment and large woody debris trapped behind the reservoirs to sediment-starved river reaches downstream (Konrad, 2009; Czuba and others, 2011, chapter 2, this report). Both of these inputs could lead to higher rates of sediment deposition, increased channel dynamics (Draut and others, 2011; Warrick and others, 2011, chapter 3, this report) and associated vegetation change (Shafroth and others, 2002; Kloehn and others, 2008; Naiman and others, 2010). Maximum depth of sediment deposition in the channel bed in the lower Elwha River near the estuary is expected to be less than 1 m (Konrad, 2009; Czuba and others, 2011, chapter 2, this report). We are not aware of any predictions of flood plain aggradation depth, though it might be expected to be relatively high in reaches with relatively low gradients, and broad flood plain and island complexes, such as those in the first few kilometers upstream of the estuary (Konrad, 2009; Draut and others, 2011). Flood plain aggradation rates and depths will depend largely on the interaction of overbank flooding (including flood magnitude and duration), suspended sediment concentration, and flood plain roughness (including the density and structure of riparian vegetation).

Most research in the Pacific Northwest has focused on characterizing tidal wetlands (Burg and others, 1980; Hutchinson, 1988) or their responses to restored tidal influence from dike removals (Thom and others, 2002; Tanner and others, 2002). A few studies from the Pacific Northwest have examined interactions between sediment, wood, and estuary vegetation. The addition of sediment on subsided intertidal areas accelerated marsh vegetation colonization in Coos Bay's south slough, Oregon (Cornu and Sadro, 2002). Hood (2010) described feedbacks between sediment deposition-induced channel meandering and marsh island vegetation development in the Skagit River delta, Washington. Hutchinson (1988) characterized morphology, physical environment, and vegetation, and concluded that flow volume and discharge regime of contributing rivers, along with the exposure of the delta fronts, accounted for much of the variation in delta vegetation across the region. Large woody debris appears to strongly influence the distribution of some species, such as *Myrica gale* (sweetgale), a nitrogen-fixing shrub, in the Skagit River estuary (Hood, 2007). More generally, the influence of large woody debris on channel and vegetation dynamics in Pacific Northwest river systems is well documented (for example, Abbe and Montgomery, 2003).

Pacific Northwest tidal wetlands appear to respond rapidly to changes to key physical conditions, with elevation above mean sea level and tidal influence strongly driving changes in vegetation patterns. Bucknam and others (1992) documented shifts in wetland types at two sites on Bainbridge Island, Washington (Restoration Point and Winslow). At Restoration Point, a tidal flat was abruptly uplifted about 1,700 years ago, rapidly converting it to freshwater swamps and meadows, with no intermediate, brackish stages. Conversely, a freshwater wetland at Winslow was inferred to have been only slightly elevated above mean sea level before being converted to more saline vegetation types as a result of subsidence. Rapid vegetation change also occurred following dike breaching projects at the Elk River estuary on Washington's southwest coast (Thom and others, 2002) and Spencer Island in the Snohomish River estuary, Puget Sound (Tanner and others, 2002). Within about 5 years of dike breaching and associated reconnection to tidal inundation, most of the Elk River estuary changed from a *Phalaris arundinacea*-dominated wet pasture to a low-elevation salt marsh community dominated by *Distichlis spicata* (salt grass) and *Salicornia virginica* (pickleweed). High coastal marsh, dominated by *Deschampsia caespitosa* (hairgrass) and *D. spicata*, was also present but much less abundant (Thom and others, 2002). In contrast, *P. arundinacea*-dominated communities on Spencer Island either converted to mudflats or to a different freshwater vegetation type (Tanner and others, 2002). Experimental additions of sediment to an Oregon estuary resulted in different marsh vegetation composition and development rates on surfaces that differed in elevation above sea level (Cornu and Sadro, 2002). Thus, rapid changes to the physical environment associated with dam removals could prompt rapid vegetation changes in the Elwha River estuary.

Summary

Six primary vegetation types were identified in the Elwha River estuary: mixed riparian forest, willow-alder forest, riparian shrub, shrub-emergent marsh transition, emergent marsh, and dunegrass. These were identifiable on high resolution aerial imagery and were confirmed by the composition of plants in vegetation plots and grouping of plots determined by a non-metric multi-dimensional scaling ordination.

Overall species richness was quite high in the Elwha River estuary; we identified 121 unique taxa in 22, 100 square meter plots. Between 30 and 52 plant taxa occurred within each vegetation type, typically including several taxa unique to each type. Native species predominated, but approximately 37 percent of taxa were introduced. Introduced species were most common and abundant in the shrub-emergent marsh transition and dunegrass vegetation types. Plants in lower elevation plots were most likely to be categorized as obligately or facultatively occurring in wetlands.

Future analyses will focus on relating the distribution of patch types and patterns of species richness with key physical processes in the Elwha River estuary, such as hydrologic and sediment dynamics, and salinity regimes. Changes to these processes and associated disturbance regimes and environmental gradients following dam removals could change parts of the Elwha estuary vegetation. Quantitative understanding of how physical processes and environmental gradients interact with species dispersal, establishment, and survival would greatly improve our understanding of how Elwha River estuary vegetation may respond to dam removals, and might ultimately be linked to physical process models to predict biological responses over time.

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