

3.3 Summary and Current Status of Oregon's Estuarine Ecosystems

James W. Good

*Coastal Resources Specialist, Oregon Sea Grant and
Director, Marine Resource Management Program, College of Oceanic and Atmospheric Sciences, OSU*

Report Card

Available evidence on the health of Oregon's estuaries is mixed. Some estuarine indicators demonstrate the significant adverse effects of past and present human activities; conversely, others show the positive impact of recent protective measures. Other indicators suggest continued threats and risks to estuaries, or raise concerns about long-term, cumulative effects of change. Limited data availability for most indicators makes for high scientific uncertainty and underscores the need for more focused research and regular monitoring.

- Historic loss of tidal wetlands is high, but restoration of diked former wetlands is reversing loss trends, increasing habitat availability and the functionality of estuaries for juvenile salmon and other estuary-dependent species.
- Estuarine habitats are well protected from some potential disturbances like dredging, filling, and other major physical alterations.
- Aquatic nuisance species are already well established in most Oregon estuaries; new arrivals and potential introductions pose unknown threats to native species and estuarine ecosystem function generally.
- Freshwater inflow to estuaries is below historic levels, particularly during summer months, based on appropriated withdrawals. The ecological impacts of these changes are not known, but projected growth in coastal population and water use suggest the need for research to determine impacts and the need for minimum estuary inflows.
- Water quality is insufficiently monitored to draw conclusions about the condition and risks associated with increasing point source and runoff pollution introductions that can be expected as population grows.
- Principal threats to estuaries today are continued physical alterations, mostly shoreline modifications for upland development and dredging for navigation projects; invasions of aquatic nuisance species; excessive sediment and runoff pollution from local and watershed sources, and other pressures associated with population and tourism growth.

Indicators

1. Change in area of estuarine habitats (acres and percent).
 - 1a—Change in overall estuary area
 - 1b—Change in area of estuarine tidal marsh and swamp habitat.
 - 1c—Change in area of eelgrass beds.
2. Area of estuarine habitats protected (acres and percent).
3. Aquatic nuisance species (occurrence and extent).
4. Freshwater inflow (flow rate and timing).
5. Estuarine water quality trends.

Introduction

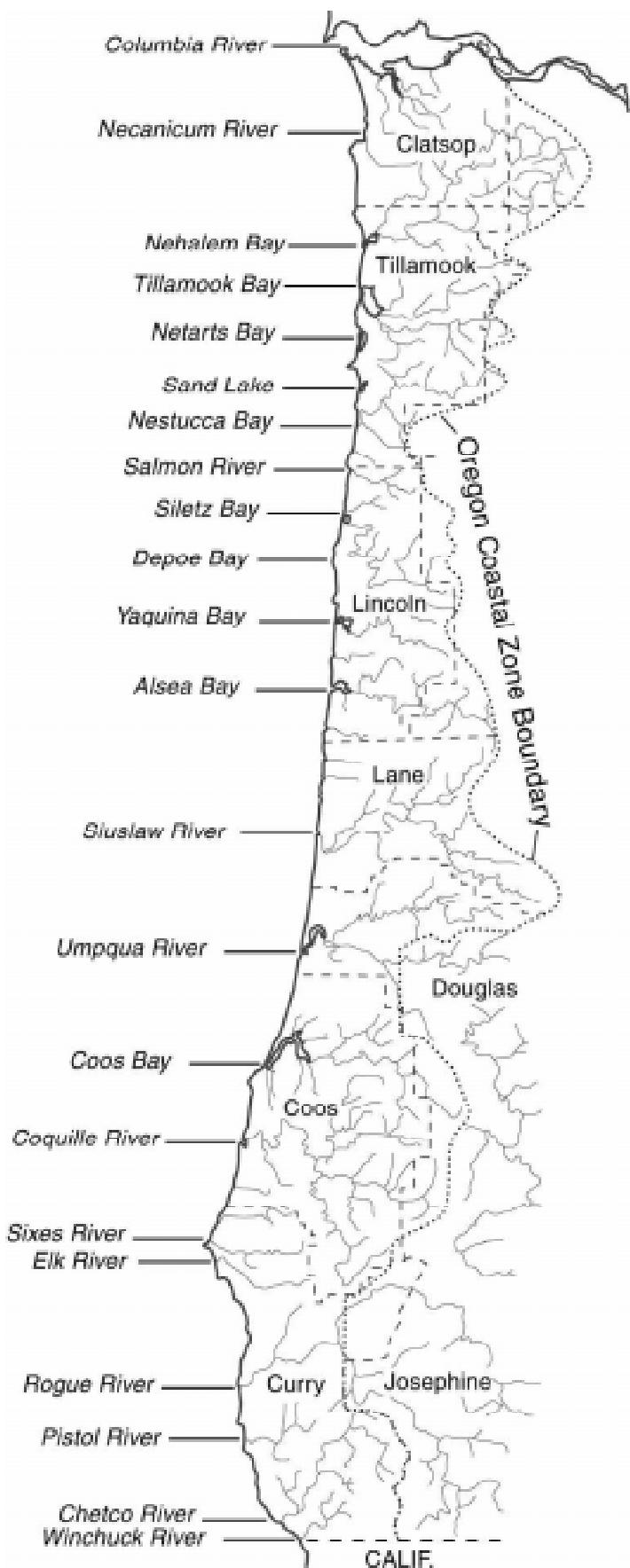
Oregon's twenty-two estuaries (Figure 3.3-1) are ecological transition zones, integrating features of the watersheds they drain with those of the marine environment. Physical characteristics strongly influence the structure, functions, and capacity of estuaries to provide valued ecosystem goods and services. Some of these physical characteristics are similar for most estuaries along the coast—the amount of precipitation, solar heat input, and tide levels at river mouths, for example. Other characteristics, such as the estuary size and shape, watershed area, geology, land use, and river gradient make for variety among Oregon estuaries. Regional ocean conditions also strongly influence Oregon estuaries. For example, ocean upwelling or storm events can change water properties in estuaries throughout the region within just one or two tidal cycles (Hickey, 1999).

Estuaries are biological “hot spots” along the coast. They are permanent or temporary home to a wide variety of organisms—some of marine origin, others from upstream, and some unique to the mixing zone. Biological productivity in this mixing zone is especially high, fueled by an abundance of food and tidal energy. Estuarine habitats—marshes, eelgrass beds, mudflats and tidal channels (see: Figure 13, “Estuary Habitats” in *SOER Statewide Summary*)—serve important roles in the life cycles of marine and anadromous species like crab, salmon, herring, migratory waterfowl, shorebirds, and hundreds of less well-known species.

Because estuaries experience great variability in temperature, salinity, tides, and river flow, estuarine ecosystems and the organisms found there are highly naturally resilient to disturbance. However, the cumulative effects of human alterations such as filling, diking, dredging, and wood removal; the introduction of non-indigenous species; and excessive waste disposal have reduced the functional capacity and natural resiliency of these ecosystems.

Humans have been attracted to estuaries for millennia. Native peoples built their villages along their sheltered shores, harvested the abundant salmon, oysters, and other fish and shellfish, and used them for local transportation and trading. Early white settlement of the coast also centered on estuaries, with early cities at Astoria, Newport, Reedsport, and Coos Bay (then Marshfield). White settlers were attracted to estuaries by transportation convenience, and access to seemingly inexhaustible natural resources. Coastal rivers were used to transport logs down to estuaries for storage, processing at local mills, or shipment to distant markets. The 20th century saw growth of existing and new settlements; improvements in ports and navigation; industrial and commercial development; and commercial and recreational exploitation of salmon, oysters, and other living resources. In recent years, residential and recre-

Figure 3.3-1. Oregon's principal estuaries and coastal watersheds.



ational development have replaced industry along some estuary shorelines, bringing with it demands for more shoreline public access and amenities.

Today, a variety of local, state, and federal laws, regulations, and programs are in place to govern the actions of a diverse group of public and private estuary and shoreline users. Subtidal and intertidal lands and natural resources in estuaries are mostly state owned and managed, although there is some federal ownership of wildlife refuges and recreation areas, and concurrent federal regulatory jurisdiction over some uses and activities. A significant fraction of estuarine lands are in private ownership—mostly tidal marshes and swamps above the mean high tide level, and tidelands that were sold off by the state early in the 20th century. Land along estuary shorelines is almost exclusively in private ownership and con-

trol, although local governments are required by land use laws to give preference to water-dependent shoreline uses.

Definition and indicators of estuarine ecosystem health

From the ecological perspective, estuaries are healthy when they provide for sustained biological productivity and essential ecological processes, and the maintenance of biotic communities, native species, and genetic and demographic diversity. From a more human-centered perspective, healthy estuarine ecosystems provide sustainable yields of fish, shellfish, wildlife, and host of less visible species they depend upon. Estuaries provide sustainable flows of other valued ecosystem goods and services, such as clean water, and flood and erosion mitigation as well. Yet another way of evaluating estuarine health is to ask whether or not the public and private

Table 3.3-1. Estuarine ecosystem health indicators: type, frame of reference, significance, and principal data sources.

Indicator and Type ¹	Reference Condition	Significance	Data Sources
1 – Change in area of estuarine habitats (acres & percent) 1a—estuary-wide 1b—marsh/swamp 1c—eelgrass Type 1 & 2	Pre-Euro-American settlement area	Directly measures structural integrity and habitat diversity; indirectly measures functional integrity	Thomas, 1983 Boule and Bierly, 1987 Cortright et al., 1987 Simenstad and Feist, 1996 Hoffnagel et al., 1976 Steve Rumrill, pers. com. 1999 Kathy Taylor, pers. com. 1999 Good, 1999 ODSL, 1972 USEPA, 1998
2 – Area of estuarine habitats protected (acres & percent) Type 3	Habitat area in 1977 when estuary plans were initiated	Measures outcomes of policies to protect remaining estuarine habitat and species	Cortright et al., 1987 Fishman Environmental Associates, 1987 Good et al., 1998 Good, 1999
3 - Aquatic nuisance species (occurrence & extent) Type 1 & 2	Pre-Euro-American settlement native species (none)	Measures health of estuarine biological communities	Carlton and Geller, 1993 Paul Heimowitz, pers. com. 1999 John Chapman, pers. com. 1999 Steve Rumrill, pers. com. 1999
4 – Freshwater inflow (flow rate and timing) Type 1 & 2	Estimated pre-Euro-American settlement flow	Measures the integrity of estuarine mixing processes	Bastasch, 1998 Quigley et al., 1999
5 – Estuarine water quality trends Type 2 & 3	State water quality standards	Measures physical, biological, and chemical integrity of estuarine waters	NOAA, 1998 Skelton, 1999 (DEQ data) Greg McMurray, pers. com., 1999

¹ Indicator Type 1: Ecosystem structure- and function-based; Type 2: Ecosystem goods- and services-based; Type 3: Environmental policy-based

decisions with potential to affect ecosystem health are consistent with local, state, and national policy and with principles of sustainability.

Each of these perspectives is useful in selecting meaningful indicators. However, choosing indicators is complicated by an incomplete knowledge of how estuaries function and what is most important. High natural variability in climatic and oceanographic conditions influencing estuaries and the lack of good baseline data and regular monitoring of estuarine conditions and changes present additional challenges. Nevertheless, much can be gained by compiling, organizing, and analyzing the data that are available.

Five indicators of estuarine ecosystem health were selected for this report (Table 3.3-1). The choice of indicators was based on their *significance* as measures of ecosystem health or condition, their *sensitivity* to environmental change, and the *availability of sufficient data* to draw conclusions about the direction of change. Three of the indicators are measures of physical or biological structure and function. Each of these can also be directly or indirectly related to significant attributes that the public values—clean water, and high quality habitat for fish, crab, clams, and wildlife, for example. Two indicators measure the on-the-ground outcome of environmental poli-

cies designed to protect these valuable ecosystems and resources.

Current conditions and trends

Indicator 1: Change in area of estuarine habitats (acres and percent).

Most Oregon estuaries have been significantly altered historically, mostly through the diking and draining of estuarine marshes in the early to mid-1900s for pasture and other agricultural use. Filling of intertidal lands for urban and port development up through the late 1960s further reduced the area of estuaries, as ports grew and navigation channels were deepened to support that growth. At the time, these changes stimulated economic growth and there was little concern or appreciation for the ecological damage being done. Not until the 1960s did growing public concern over these practices lead to new laws that dramatically reduced filling and prohibited new diking. In recent years, preliminary evidence suggests that restoration of tidal wetlands has begun to reverse loss trends. Implementation of salmon and watershed recovery plans will likely accelerate this trend.

Current conditions and trends in habitat examined here include (a) change in overall estuary area, (b) change in tidal marsh-swamp area (the most altered of estuarine habitat types),

Table 3.3-2. Change in total area and area of tidal wetlands (tidal marshes and swamps) for Oregon's 17 largest estuaries, due to filling and diking that occurred from about 1870 to 1970.

Estuary	Actual 1970 Area (acres) ¹		Diked or Filled Tidal Wetland ²	Estimated 1870 Area (acres) ³		Percent Change (1870-1970)	
	Tidal Wetland	Total Estuary		Tidal Wetland	Total Estuary	Tidal Wetland	Total Estuary
Columbia	16,150	119,220	30,050	46,200	149,270	-65%	-20%
Necanicum	132	451	15	147	466	-10%	-3%
Nehalem	524	2,749	1,571	2,095	4,320	-75%	-36%
Tillamook	884	9,216	3,274	4,158	12,490	-79%	-26%
Netarts	228	2,743	16	244	2,759	-7%	-1%
Sand Lake	462	897	9	471	906	-2%	-1%
Nestucca	205	1,176	2,160	2,365	3,336	-91%	-65%
Salmon	238	438	313	551	751	-57%	-42%
Siletz	274	1,461	401	675	1,862	-59%	-22%
Yaquina	621	4,349	1,493	2,114	5,842	-71%	-26%
Alsea	460	2,516	665	1,125	3,181	-59%	-21%
Siuslaw	746	3,060	1,256	2,002	4,316	-63%	-29%
Umpqua	1,201	6,544	1,218	2,419	7,762	-50%	-16%
Coos Bay	1,727	3,348	3,360	5,087	16,708	-66%	-20%
Coquille	276	1,082	4,600	4,876	5,682	-94%	-81%
Rogue	44	880	30	74	910	-41%	-3%
Chetco	4	171	5	9	176	-56%	-3%
TOTAL	24,176	160,301	50,436	74,612	220,737	-68%	-24%

Data Sources:

¹ Cortright et al., 1987; Thomas, 1983

² Filled lands (Oregon Division of State Lands, 1972); Diked lands (Thomas, 1983; Boule and Bierly, 1987; and unpublished data compiled by Czesla, O'Keefe, Gupta, and Good, 1999).

³ 1870 area estimates were derived by adding area of diked and filled land to 1970 area estimates.

and (c) change in eelgrass area. Change in the area of other habitats, such as tide flats, and change in habitat characteristics, such as modified versus natural shoreline, or the length of tidal creeks, are also useful measures, but data for these are not available.

Indicator 1a—Change in overall estuary area. Pre-settlement estuary area compared to present-day area provides a first-order measure of change in the structural and functional integrity of estuarine ecosystems, as well as their capacity to provide valued ecosystem goods and services. The combined area of Oregon's estuaries prior to major alterations (~1870) is estimated to be about 221,000 acres, as compared to about 160,000 acres in 1970—a 24 percent reduction in size (Table 3.3-2). Among individual estuaries, loss of area ranges from 81 percent to less than one percent. Since 1970, very little additional estuarine habitat has been lost, owing to strong protective measures put in place (see Indicator 2). In fact, loss trends have actually reversed in recent years, as diked tidal marshes are restored to tidal action.

Indicator 1b—Change in area of estuarine tidal marsh and swamp habitat. The area of tidal marsh and swamp habitat today as compared to pre-settlement times is a more revealing indicator of estuarine ecosystem change than overall change in estuary area. Because they are along the edges of estuaries at the higher tidal elevations, forested swamps and emergent marshes were the most easily altered estuarine habitat—some were filled, but most were diked for agricultural use. Between 1870 and 1970, combined losses of these estuarine habitats totaled more than 50,000 acres for all estuaries combined, or 68 percent of original acreage. Within individual estuaries, losses ranged from 94 percent to two percent.

The former estuarine marshes that were diked are of special interest because they are relatively easy to restore, as compared to lands that were filled and developed. Restoration of these areas is attractive for several reasons. First, they have very high primary productivity and the grasses and sedges that grow there serve as a primary source of detritus, the foundation of the estuarine food web. They also serve directly as habitat for many fish, shellfish, invertebrates, birds, and other wildlife. The status of these estuarine habitats has received increased attention in recent years with the decline of Pacific salmon and listing of certain stocks under the Endangered Species Act. Coastal watershed councils are identifying opportunities for restoration of former or degraded wetlands and implementing projects, spurred on by a growing appreciation of the important functions that estuaries serve in salmonid life cycles. Most of these sites are former marshes that were diked but no longer serve agricultural uses. Some of this restoration is planned and carefully monitored. Other restoration is inadvertent, as dikes or tide gates fail, allowing the ebb and flood of the tide to passively reclaim estuarine habitat.

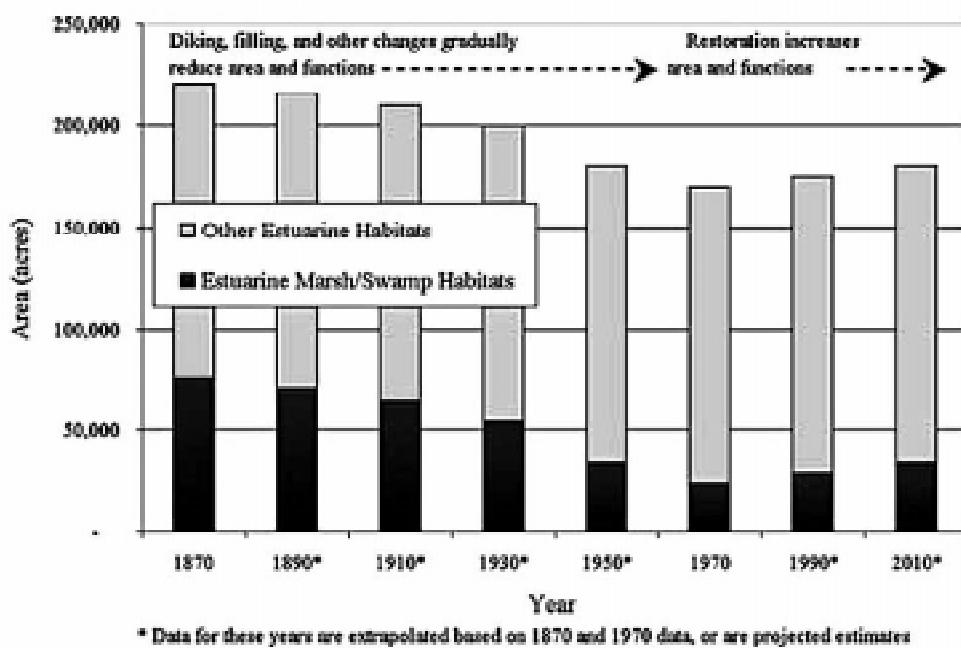
Good data on restored habitat are available for only a few Oregon estuaries. In the Salmon River estuary, the U.S. Forest Service has restored 300 acres of salt marsh as part of a whole-estuary restoration plan and scientists have been monitoring restoration progress for more than 20 years (Robert Frenkel, pers. com., 1999). In the South Slough of Coos Bay, approximately 200 acres of salt and freshwater tidal marshes are being restored as part of an experiment in ecological restoration by National Estuarine Research Reserve scientists (Steve Rumrill, pers. com., 1999). In the Columbia River estuary, somewhat less than 1,000 acres of formerly diked tidal marsh has been restored (Kathy Taylor, pers. com., 1999). In Siletz and Nestucca Bays, and the Coquille estuary, the US Fish and Wildlife Service has restored hundreds of acres of diked salt marsh to tidal flow as part of an effort to improve habitat in the National Wildlife Refuges. Finally, a recent aerial reconnaissance survey of all Oregon estuaries identified 49 probable formerly diked sites that had been breached, but acreage was not included for most sites (Simenstad and Feist, 1996).

Historical habitat loss combined with estimates and projections of habitat restoration conceptually illustrate historic, recent, and projected change in estuarine habitat (Figure 3.3-2). Projections are based on the increasing emphasis being given to estuarine restoration and the very low habitat loss experienced in recent years (see Indicator 2).

Indicator 1c—Change in area of eelgrass beds. Native eelgrass beds (*Zostera marina*) are found along the lower fringes of tidal flats and the shallow subtidal slopes they border. Eelgrass serves a number of important ecosystem functions in estuaries, providing spawning substrate for Pacific herring, a direct food source for migrating black brant geese, an indirect food source for detritus feeders, hiding and feeding areas for young salmon, crab, and many other species, and stabilization for the channels they border (Figure 3.3-3). Because the size and density of eelgrass beds vary naturally by as much as 50 percent from one year to the next, long-term trends are a more important indicator of estuarine health than yearly fluctuations. In an inventory conducted in the mid-1970s, eelgrass beds were found to be about 18 percent of total estuarine area, excluding the Columbia, where the estuarine ecosystem is dominated by freshwater inflow and eelgrass beds are rare (Bottom et al. 1979). More systematic monitoring is just getting underway in several estuaries and should provide a basis for understanding natural variability and the effects of human stressors, such as sedimentation, nutrients, and nuisance species (USEPA, 1998).

Indicator 2: Area of estuarine habitats protected (acres and percent). Although a significant fraction of Oregon's estuarine lands have been converted to other uses and some of the remaining areas degraded by pollutants, nuisance species invasions, and navigation improvement projects,

Figure 3.3-2. Estimated change in the overall area of Oregon estuaries and area of tidal marshes (including tidal swamps), 1870-2010. Data for 1870 and 1970 are from Table 2; values for other dates are estimated to illustrate how losses might have occurred and how recent and projected restoration may be reversing historic trends (adapted from Good, 1999).



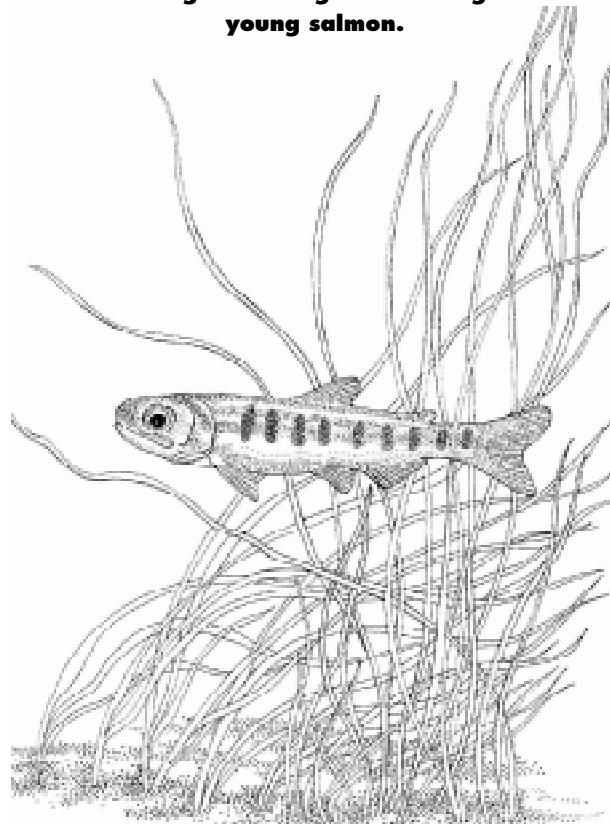
* Data for these years are extrapolated based on 1870 and 1970 data, or are projected estimates

most of the original habitat that existed in the mid-19th century is relatively intact today. Protecting these habitats and the flow of societal goods and services they provide has been a high priority in Oregon for the last three decades. A number of strategies and tools have been used to protect estuaries—land and water use planning and zoning, regulation of physical alterations and waste disposal, and public acquisition and conservation-based land management are among the most important. Most of these approaches do not exclude all uses and activities, but rather are “special management” areas or zones, with some uses and activities excluded or limited to protect important habitat and species. Protected areas can also serve other functions, for example, as relatively undisturbed “controls” for habitat restoration projects and other scientific studies. They also provide hedges against the uncertainty associated with most resource management decisions.

Local coastal plans developed in the 1970s and 1980s following state planning laws resulted in strong zoning protection for estuaries. Ninety-eight percent of estuarine wetlands and 89 percent of subtidal areas were zoned for protection as either *Natural* or *Conservation* management units (Figure 3.3-4). Despite this protective zoning, the portions of estuaries that have been set aside for development have proved more than sufficient to meet demands (Good et al. 1998).

Plans alone provide little protection unless there are effective regulatory mechanisms to implement them. In Oregon, local governments regulate estuary and shoreland uses—port docks, restaurants, marinas, and so on. Activities like dredging, fill-

Figure 3.3-3. Eelgrass beds, tidal creeks, and marshes are good hiding and feeding areas for young salmon.



(Sharon Torvik drawing, courtesy of South Slough National Estuarine Research Reserve)

ing, and in-water building, on the other hand, are regulated by the Division of State Lands (DSL) and the US Army Corps of Engineers (Corps). Criteria for issuing permits in estuaries are stringent: proposed uses must be water-dependent; a public need must be served; there must be no alternative upland site that could accomplish the same purpose; and unavoidable impacts must be minimized and compensated for by habitat mitigation. Between 1971 and 1987, just 19 acres of estuarine intertidal habitat was filled (0.03 percent of the 1970 base) (Fishman Environmental Services, 1987). About five acres of habitat were restored or created to compensate for part of that loss. Dredging between 1971 and 1987 involved about 111 acres of estuary area, mostly subtidal areas for navigation channel maintenance. Although data have not been compiled by the state since 1987, it is estimated that filling and dredging acreage have continued to decline since then.

Public acquisition and management for conservation is another important protection strategy for Oregon's tidal wetlands. More than 10,000 acres of tidal wetlands in the Columbia River estuary are managed as wildlife refuges by the US Fish and Wildlife Service. Three additional refuges in the Nestucca, Siletz, and Coquille estuaries protect additional wetlands. The South Slough National Estuarine Research Reserve in Coos Bay is protected for research, education and conservation, and includes 1,310 acres of estuarine habitats and 3,460 acres of upland forests—4,770 acres in all. Private conservation groups such as the Trust for Public Lands, The Na-

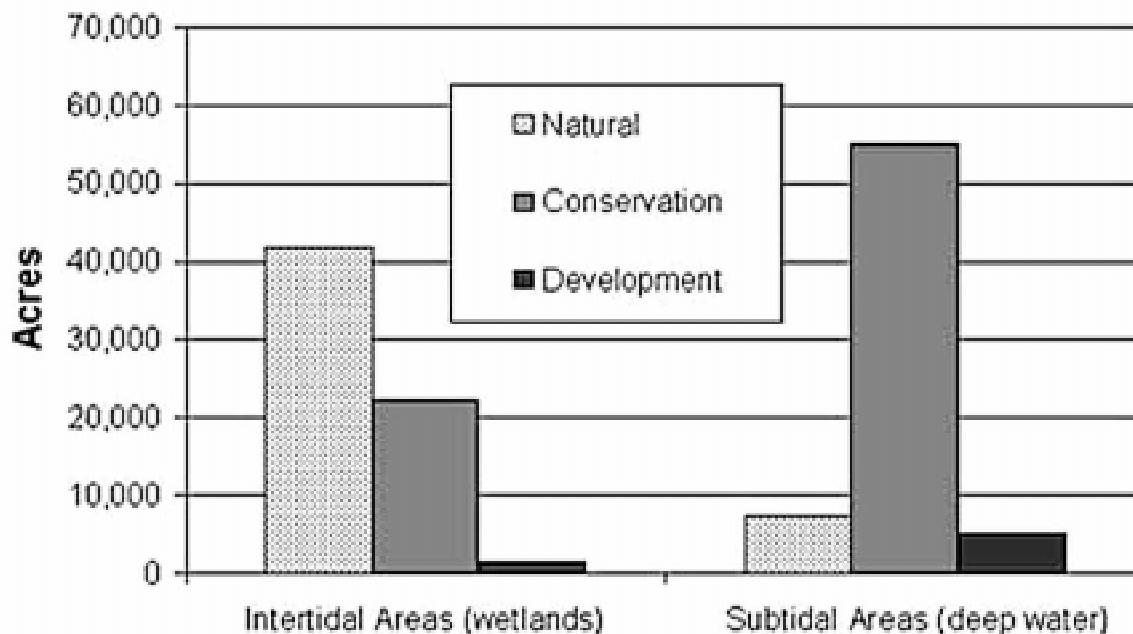
ture Conservancy, and local land trusts also hold some estuarine wetlands for conservation management.

Indicator 3: Aquatic nuisance species (occurrence and extent).

Some non-indigenous species found in estuaries are highly valued commercial or recreational species—the Japanese oyster (*Crassostrea gigas*), striped bass (*Roccus saxatilis*), and eastern softshell clam (*Mya arenaria*) are examples. Other introduced species, however, are recognized as serious threats to the integrity of estuarine ecosystems, such as the European green crab (*Carcinus maenus*). First found on the west coast in 1989 in San Francisco Bay, green crab were discovered in Coos Bay in 1996, and later in Yaquina and Tillamook Bays. Voracious predators, green crab feed on mussels, oysters, other crabs, shrimp, small fish, and a variety of other organisms, creating potential impacts on local fisheries through direct predation and indirect competition for prey resources. Oregon biologists are also on constant lookout for the Chinese mitten crab (*Eriocheir sinensis*), a species that has become well-established in the San Francisco Bay and Delta region, causing significant damage there as they burrow into dikes.

Introduced species are estimated to make up significant components of Oregon's estuarine flora and fauna today. At least 30 percent of benthic organisms in Yaquina Bay are estimated to be introduced species (John Chapman, pers. com., 1999). In the Columbia, an introduced Japanese clam (*Corbicula manilensis*) dominates tidal flats, while introduced zooplank-

Figure 3.3-4. Combined zoning acreage for intertidal and subtidal habitats in 22 Oregon estuaries.



(Data from the *Oregon Estuary Plan Book*, Cortright et. al., 1987)

ton (e.g., the copepod *Pseudodiaptomus inopinus*) make up a significant component of water column species. Scientists sampling ballast water from 159 ships visiting Coos Bay between 1986 and 1991 found 367 species of invading organisms that were ultimately pumped into the bay. All marine trophic levels are represented—carnivores, herbivores, omnivores, deposit and filter feeders, scavengers, parasites, and primary producers. Increasing international trade makes ballast water introduction of non-native species a global problem.

Among invasive plants, Atlantic smooth cordgrass (*Spartina alterniflora*) is considered a major ecological threat to Oregon's estuaries. Native to east coast, *Spartina* was inadvertently introduced into Willapa Bay early in the 20th century along with eastern oysters. The east coast oysters never thrived, but *Spartina* got a foothold, is expanding rapidly today, and has spread to other Washington estuaries (Kathleen Sayce, pers. com., 1998). *Spartina* was also introduced into the Siuslaw estuary, but active efforts to eradicate it there have apparently been successful. Once established, *Spartina* can spread rapidly, invading tide flats, displacing algae beds and mudflat dwellers like oysters, clams, worms, shrimp, and other benthos. In the worst case, a *Spartina* invasion could fundamentally alter estuarine habitat structure and diversity, species assemblages, and ecological processes and functions, although these ecosystem-level effects have not been validated. A hybrid relative, *Spartina anglica*, is also a significant threat, having invaded northern Puget Sound wetlands (Simenstad, pers.com., 2000).

Indicator 4: Freshwater inflow (flow rate and timing). Estuarine ecosystem health is in part dependent on maintaining freshwater inflow within the range of natural variability. The mixing of this fresh water with marine waters from offshore creates the characteristic salinity regime for estuarine plants and animals that makes estuaries so productive. Freshwater entering an estuary may also help dilute pol-

lution and promotes the flushing of wastes out of the system.

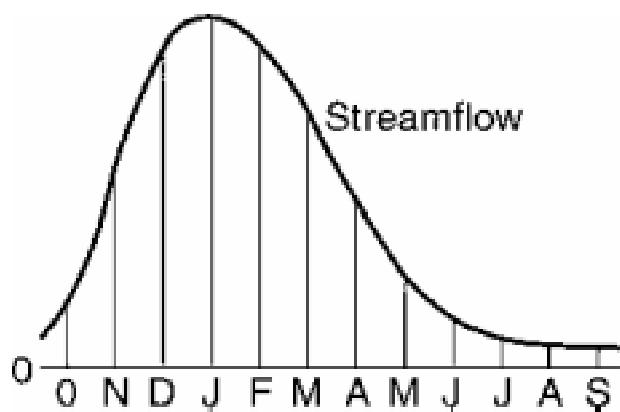
Coastal watersheds deliver relatively large quantities of water to streams and rivers compared to other areas in Oregon. Coastal basins produce 33.7 percent of Oregon's average annual discharge of water on 8.3 percent of the land in Oregon (Bastasch, 1998). However, because there is no snow pack in the Coast Range, streamflow tends to follow seasonal precipitation patterns (Figure 3.3-5). Freshwater inflows may still be within historic ranges during parts of the year, but summer low flows are much less than historic levels, due to consumptive water use by municipal and other users of rivers or streams flowing into an estuary. For example, consumptive water use in the Coquille basin is nearly 80 percent of the total flow available in late summer; in the Necanicum, a smaller north coast watershed, consumptive water use is nearly 60 percent of the total available (Quigley, et al., 1999, based on Oregon Water Resources Department, Water Availability Report System data).

Many coastal communities now experience water shortages during summers—their peak demand period. As coastal population and tourism grow, more and more water will be withdrawn from coastal rivers for municipal and other consumptive uses. The ecological consequences of gradually reducing freshwater inflow to estuaries are not known and little studied. Estuarine salinity zones would be expected to migrate up the estuary over time, in turn stressing and gradually changing the distribution of plants and animals, as well as optimum locations for oyster farming and other uses. Freshwater intakes in the upper estuary may also become brackish as salt water migrates farther upstream.

Indicator 5: Estuarine water quality trends. Water quality in estuaries and nearshore waters is strongly influenced by high natural variability in climate and ocean conditions. At a single estuary sampling site, for example, salinity, temperature, dissolved oxygen (DO), turbidity, pH, nutrients, and other measures may vary greatly from season to season, from week to week, and from high water to low water during a given day. Longer term climatic patterns like interannual El Niños and La Niñas also affect water quality measurements. Finally, the characteristics of an estuary—its size, shape, tidal volume, freshwater inflow, flushing rate, and biogeochemical cycling, as well as drainage basin geology, soils, and vegetative cover—also strongly influen

Water quality measurements in estuaries and nearshore waters reflect the combination of highly variable natural background conditions and human-caused pollution. Most pollution entering Oregon estuaries and nearshore coastal waters comes from upstream sources or direct inputs. Point sources such as municipal sewage, food processing wastes, pulp and paper mill wastes, and other industrial discharges are important sources in urbanized estuaries. However, runoff pollu-

Figure 3.3-5. Coastal watershed stream flows typically follow seasonal rainfall patterns.



tion such as dairy and other animal waste, leaky septic systems in rural areas, urban storm runoff, and sediment from streamside erosion, construction sites, and logging operations are also important, and especially difficult to detect and control. Other pollution comes from offshore marine sources—spilled oil and marine debris are two examples that affect both the open coast and estuaries.

Data for assessing water quality in Oregon's marine and estuarine environment are sparse. For example, NOAA's National Estuarine Eutrophication Survey found that 10 of 12 Oregon estuaries surveyed could not be assessed because data were lacking (NOAA 1998). Despite this, the study suggested that Oregon estuaries—having large tidal prisms that promote good flushing—had only low to moderate susceptibility to eutrophication, although the trend was probably toward worsening conditions.

Skelton (1999) examined water quality data available from the Department of Environmental Quality for nine estuaries. For all nine estuaries, temperature and dissolved oxygen tend to track expected seasonal patterns—warm with low dissolved oxygen (DO) in late summer (approaching anoxic conditions for some, such as Coos Bay), cold and higher DO in winter. Estuaries surrounded by significant agricultural land uses—Tillamook Bay and the Coquille, for example—have relatively high to moderate fecal coliform concentrations, although other estuaries exhibited occasional high levels following periods of high runoff. Generally, nutrient levels seem to be low and decreasing over time in estuaries classified for management as *Natural* or *Conservation* systems, but increasing in those managed as *Development* estuaries. Given the limited data available, these interpretations must be viewed with caution.

Strengths, threats, and information needs

Awareness of the importance of estuaries from the ecological and human use perspectives has grown dramatically in the past three decades in Oregon, providing cause for optimism about the future of estuarine ecosystem health. Important environmental policy initiatives have been implemented, providing long-term, secure protection from alterations for most estuarine marshes, flats, and seagrass and algae beds. Efforts to control point sources of municipal and industrial pollution have been relatively successful, and policies and programs to control runoff pollution have been strengthened. Projects completed recently for the National Estuary Program in Tillamook Bay and the Lower Columbia River are another institutional strength, providing the coordination and clear guidance needed for continued water quality and habitat improvement in those systems.

Habitat change trends have also reversed, with the large losses experienced up through the 1960s being replaced by modest gains in habitat in recent years as dikes have been breached

to restore salt marshes. However, to adequately quantify these trends, more complete data are needed on recent regulatory losses and gains, and on nonregulatory restoration of salt marshes and other estuarine habitats.

Salmon recovery efforts have further raised awareness about the importance of estuaries, through more focused assessment, planning, on-the-ground habitat restoration projects, and monitoring. Recent monitoring has demonstrated that juvenile salmon and many other species are using restored areas in Coos Bay, the Salmon River estuary, and other locations. However, additional monitoring is needed to better understand the full range of ecosystem functions, goods, and services that restored estuarine habitat (and undisturbed control areas) provide. Such data are important in setting priorities for the use of limited watershed restoration funds.

Increasing coastal population, new development, and the growth of tourism could, if not controlled, overwhelm the positive steps that have been taken in recent decades to protect and restore Oregon estuaries. Point source and runoff pollution from watersheds, shoreline land uses, and oil spills continue to threaten the quality of estuarine waters. New introductions of non-indigenous species also pose serious threats to the biological integrity of estuaries. Uncertainty about the estuarine impacts of increasing water withdrawals in coastal and Columbia basins also pose risks, as does the ecological uncertainty surrounding Columbia River channel deepening. There are numerous specific examples of these threats.

Eelgrass beds, for example, are at risk from three major large-scale ecological stressors on Oregon estuaries: sedimentation, nutrients, and introduced nuisance species. Sedimentation and nutrient load to Oregon estuaries are increasing due to land-use practices and human population growth, reducing water quality and placing eelgrass beds at risk. Increased nutrients may also stimulate algae blooms which can smother and uproot eelgrass. Non-indigenous nuisance species also pose a threat to eelgrass habitat in Oregon estuaries, particularly *Spartina*, which can invade and displace eelgrass in at least part of its tidal range (NOAA, 1998). Separately or in combination, these threats could shift the competitive advantage from eelgrass to other species that provide less functional value (USEPA, 1998).

There are many pathways for introductions of aquatic nuisance species, but the most significant source and threat today is from ballast water discharged by ships calling at Oregon ports from locations throughout the world. Frequent disturbance of existing habitat by natural events like seasonal flooding, storm waves, and erosion, and human activities like dredging, create new substrate that can be colonized rapidly by these and other opportunistic species. Construction of floating docks, piling systems, bulkheads, revetments, and jetties provide additional substrates that are vulnerable to invasion

by introduced species. Some invasions may be gradual, displacing native species from their natural habitats over years or decades. Human-induced stress and disturbance may further increase the vulnerability of natural habitats to the establishment and spread of invasive species. Although the effects of invasions by non-native species are not well understood, it is generally acknowledged that such invasions may be widespread and of sufficient magnitude to precipitate profound ecological changes in estuarine and nearshore marine communities (Carlton and Geller, 1993).

Despite limited data availability on changes in freshwater inflow to estuaries, it was selected as an indicator of estuarine ecosystem health because of its vital importance in the maintenance of characteristic estuarine plant and animal communities. To determine if minimum stream flows are needed for estuaries, more information is needed about how flows have changed over the past 150 years and what impacts those changes have caused. Estimates of historic flow levels and timing prior to major watershed alterations and withdrawals are needed. Such data are available for the Columbia (David Jay, pers. com., 2000), but not for coastal basins. Once estimated, these flows need to be compared to recent data, present withdrawals, projections of future water needs for municipal and other uses, and instream water needs for maintaining healthy salmon and other aquatic resources. Studies are also needed to analyze the effects and degree of effects that upstream water withdrawal has on Oregon estuaries. With these data, the risk of decreased freshwater inflow can be estimated and strategies developed to maintain freshwater inflow at the minimum levels for ecological health.

There is a significant lack of information about the current condition of estuarine ecosystems in Oregon, especially in contrast to original historical conditions. Individual and cumulative effects of land uses on Oregon's estuarine ecosystems have not been quantified or critically evaluated. Water quality in most Oregon estuaries is poorly understood because of limited monitoring. This poses uncertain risks to consumers of fish and shellfish harvested in bays, as well as to oyster and other shellfish farmers. The new Environmental Monitoring and Assessment Program (EMAP) for estuaries provides an opportunity to more fully understand estuarine water quality and related indicators (Greg McMurray, pers. com., 1999). The EMAP assessment includes sampling of physical, chemical and biological indicators in three habitats—water column, sediments, and sediment surface—but will not sample all estuaries.

Projections and conclusions

The outlook for estuarine ecosystem health in Oregon depends on many factors. Among the more important are population growth, demand for fresh water, growth of tourism, efforts to control pollution and prevent the introduction of aquatic nuisance species, the integrity of estuary zoning plans, and initiatives to restore and enhance estuarine habitats and coastal watersheds. Without a robust, systematic approach to data collection, monitoring, and research, Oregon will be unable to develop meaningful, effective strategies and practices to maintain or restore estuarine ecosystem health in the face of any one or a combination of these factors.

Oregon's permanent coastal population was about 350,000 in 1999, with numbers doubling or tripling during peak tourist season. Statewide, Oregon's population is expected to swell from 3.2 million in 2000 to 4.6 million in 2020, with 80 percent of the growth in the Willamette Valley. Many Oregonians living in the Willamette Valley will be part-time coastal residents or at least regular visitors. The permanent coastal population is also likely to grow as more retirees move to the coast. Given this projected growth and other trends, the next 20 to 50 years are likely to result in significant changes in Oregon estuaries. Recent trends suggest the following:

- Estuaries will continue to support a diversity of uses and activities valued by society, including deep-water shipping (Coos Bay, Yaquina Bay, and the Columbia River estuary), home ports for fishing fleets, recreational fishing and marinas, charter fishing, sailing, aquaculture (oysters, clams, and mussels), waterfowl hunting, birding, and other nature activities.
- The strong habitat protection provided by estuary zoning plans likely will prevent significant new dredging or filling for development, except for the Columbia, where planned navigation improvements pose uncertain threats to ecosystem health.
- Population and tourism growth, and resulting increased water withdrawal from streams will reduce freshwater inflow to estuaries, reducing flushing capacity for wastes, changing habitat types and distribution, and posing other unknown risks to these ecosystems.
- Fish and shellfish resources may decline due to increased harvest pressure, particularly from recreational users, or because of declining water quality.
- Understanding of the impacts of runoff pollution will increase, as will the ability to pinpoint sources and provide control technologies. Political considerations and costs will determine whether problems persist, increase, or are reduced.

- The adverse impacts of introduced species will become better known as scientists continue to study their distribution, spread, and ecological interactions, but the ability to prevent or limit introductions will remain limited.
- Estuarine habitat area will continue to expand as former marsh areas are restored or revert to salt marsh on their own. This trend may lead to improved ecosystem health and increase the supply of fish and wildlife habitat, offsetting other losses.
- Competition for limited shoreline and estuarine surface area likely will increase, with residential developers, marinas, tourist businesses, and recreational users challenging traditional users such as ports, fish processors, oyster farmers, and commercial clammers.
- Natural resource industries that use the estuary, despite decline in recent decades, still will be important economically and culturally.
- Urban shoreline changes will affect ecosystem health by increasing the awareness of and need for ecosystem protection and restoration; it will also create pressure for expanding urban growth boundaries along natural shorelines.

What data are available and how complete are they?

Data sources used in preparing this report are listed in the reference section, with citations for specific indicators listed in Table 3.3-1 and throughout the text. Specific caveats about data quality and interpretation are also included in the text. Generally, quantitative data for indicators were sparse or non-existent, and data interpretation vis-à-vis estuarine ecosystem health is based on the local knowledge and professional judgment of the scientists who contributed to or reviewed the report. As such, overall confidence in the findings is at best moderate. Nevertheless, this assessment is a good first approximation of estuarine ecosystem health. The significant progress that has been made in protecting and restoring Oregon's small but important estuaries is cause for hope. However, the lack of good data for key indicators suggests the need to develop a better understanding of historic and ongoing change, as well as ways to measure that change.

Finally, there may be better indicators than those used here for tracking estuarine ecosystem health and sorting out natural versus human-caused change. Thus, this report should be viewed as a beginning effort to characterize ecosystem health and suggest causal factors for observed trends. It also presents a challenge to the estuarine research and management community: good indicators of ecological health need to be identified, monitoring programs to track changes need to be improved, and mechanisms need to be established for using the findings to improve decision-making processes and land management.

Acknowledgments

This summary report would not have been possible without the significant contributions of Chris Cziesla, Steve Rumrill, Bob Bailey, Steve Ferraro, Anu Gupta, Sheila O'Keefe, and Kate Quigley, who provided draft text, data and graphs, and reviews of the manuscript. Other assistance was provided by Bill Pearcy and Dave Fox.

References

Bastasch, R., 1998. *Waters of Oregon*. Corvallis: Oregon State University Press.

Bottom, D., B. Kreag, F. Ratti, C. Roye, and R. Starr. 1979. *Habitat classification and inventory methods for the management of Oregon estuaries*. Portland: Oregon Department of Fish and Wildlife.

Boule, M.E. and K.F. Bierly. 1987. History of estuarine wetland development and alteration: What have we wrought? *Northwest Environmental Journal* (3(1):43-62).

Carlton, J.T. and J.B. Geller. 1993. Ecological roulette: the global transport of nonindigenous marine organisms. *Science* 261: 78-82.

Cortright, R., J. Weber, and R. Bailey. 1987. *Oregon estuary plan book*. Salem: Oregon Department of Land Conservation and Development. (also at: <http://www.interrain.org/>).

Fishman Environmental Services. 1987. *Estuarine Mitigation Evaluation Project: Final Report*. Prepared for Oregon Division of State Lands.

Good, J. W., J. W. Weber, J. W. Charland, J. V. Olson, and K. A. Chapin. 1998. *National coastal zone management effectiveness study: protecting estuaries and coastal wetlands*. Final Report to the Office of Ocean and Coastal Resources Management, National Oceanic and Atmospheric Administration. Oregon Sea Grant Special Report PI-98-001. Corvallis, OR.

Good, J.W. 1999. Estuarine Science, Management, and Restoration. Chapter II-10, IN: *Watershed Stewardship: A Learning Guide*. EM 8714. Oregon State University Extension Service: Corvallis.

Hickey, B. M. 1999. *Coastal Ocean Coupling: A Physical Baseline for PNCERS*. IN 1998 Annual Report of the Pacific Northwest Coastal Ecosystems Regional Study. University of Washington, Seattle.

Hofnagle, J., R. Ashley, B. Cherrick, M. Gant, R. Hall, C. Magwire, M. Martin, J. Schrag, L. Stuntz, K. Vanderzanden, and B. Van Ness. 1976. *A comparative study of salt marshes in the Coos Bay estuary*. National Science Foundation Student Originated Study. Eugene: University of Oregon.

National Oceanic and Atmospheric Administration (NOAA). 1998. *NOAA's Estuarine Eutrophication Survey. Volume 5: Pacific Coast Region*. Silver Spring, MD: Office of Ocean Resources Conservation and Assessment.

Oregon Division of State Lands. 1972. *Inventory of Filled Lands in Oregon Estuaries*. Salem, Oregon.

Quigley, K., G. Sylvia, and J. Rasmussen, 1999. *Municipal Water Management in Oregon Coastal Communities: Conservation Opportunities and Surmounting the 'Conservation Paradox'*. Oregon Sea Grant. Coastal Oregon Marine Experiment Station.

Simenstad, C. A. and B. Feist. 1996. *Restoration Potential of Diked Estuarine Wetlands: Inferring Fate and Recovery Rate of Historically-Breached Sites*, U.S. Environmental Protection Agency, Seattle, WA.

Skelton, K. 1999. *State of the Oregon coast: water quality trends*. Coastal Resources Management Poster, College of Oceanic and Atmospheric Sciences, Oregon State University.

Thomas, D. W. 1983. *Changes in Columbia River estuary habitat types over the past century*. Astoria: Columbia River Estuary Study Taskforce.

U.S. Environmental Protection Agency, Coastal Ecology Branch (USEPA). 1998. *The effects of habitat alteration by estuarine stressors on ecological resources of Pacific Northwest estuaries*. Research Plan. Coastal Ecology Branch, Western Ecology Division, National Health and Environmental Effects Research Laboratory, U.S. Environmental Protection Agency.