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 nonexistent, 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.

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