Habitat Classification and Inventory Methods for the Management of Oregon Estuaries

ESTUARY INVENTORY REPORT **Vol. 1**

Prepared by

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ESTUARY INVENTORY PROJECT
OREGON

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JOB TITLE: Habitat classification and inventory methods for the management of Oregon estuaries.

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PREFACE

On December 8, 1976, the Oregon Land Conservation and Development Commission (LCDC) adopted the Estuarine Resources Goal, one of four planning goals specifically concerned with Oregon's coastal zone. The goal requires that coastal cities and counties establish policies for the conservation and development of estuarine resources as part of their comprehensive land and water use plans. In order to fulfill the goal, local jurisdictions must first complete inventories of the physical, social, and economic resources of each estuary "in sufficient detail to establish a sound basis for estuarine management and to enable the identification of areas for preservation and areas of exceptional potential for development" (LCDC 1977b).

In February, 1978, the Oregon Department of Fish and Wildlife (ODFW) received a grant from LCDC to assist local jurisdictions in completing the resource inventory requirements of the Estuarine Resources Goal. The project had two primary objectives:

(1) To assemble biological and physical data for selected Oregon estuaries,

(2) To identify data gaps and suggest future research needed for planning and management of each estuary.

In meeting these two objectives, ODFW has provided several types of information, including the material presented in this series of reports. This report is a general introduction to the methods and study design of the technical assistance project, as well as a guide to collecting and organizing resource information for planning. It is also intended to be a reference for the other reports published in this series.

This volume is divided into two parts. Part 1 discusses estuary and estuarine habitat classification as a basis for resource planning. A hierarchical classification system is presented and suggested as an appropriate system for Oregon estuaries. Part 2 of the report suggests guidelines for estuarine resource inventories, including a list of specific categories of data and methods of data collection most needed for planning. The guidelines are also presented as a checklist for identifying research needs for estuaries where these data are not currently available.

Volume 2 in this series consists of several reports summarizing current physical and biological data and describing the habitats for selected Oregon estuaries. Specific management and research recommendations are discussed in each estuary report. Estuaries without a previously completed planning inventory or with special planning needs were given priority for these reports.

Table i summarizes the information compiled during this project. In addition to the separate estuary reports in volume 2, we have collected data and classified habitats in 16 Oregon estuaries as described below:

Data Notebooks

ODFW photocopied and assembled in notebooks available physical and biological data for each of 15 Oregon estuaries. The information was organized by subject according to the data categories in the inventory guidelines described in Part 2 of this report. The notebooks serve as a technical reference to the existing resource data for each estuary. The notebooks are organized so that additional information can be added as new research is completed. A complete set of the notebooks is on file with LDCD, Salem, Oregon.

Estuarine Habitat Maps

For each of the estuaries in Table i, intertidal and subtidal habitats were mapped using a modified version of a U.S. Fish and Wildlife Service (USFWS 1977) estuarine habitat classification system. The system is described in detail in Part 1 of this report. Habitats were delineated by a numerical code on base maps at scales ranging from 1:12,000 to 1:24,000. Full scale copies of the habitat maps may be obtained from ODFW, Research and Development Section, Corvallis, Oregon.

Table i. Products available for each estuary studied during the ODFW technical assistance project.[a]

	Data Notebook	Habitat Map	Resource Inventory Report
Necanicum	X	X	
Nehalem	X	X	
Tillamook	*b*	X	
Netarts	X	X	X
Sand Lake	X	X	X
Nestucca	X	X	X
Salmon River	X	X	
Siletz	X	X	X
Yaquina	X	X	
Alsea	X	X	*c*
Siuslaw	X	X	
Umpqua	X	X	X
Coos	X	X	X
Coquille	X	X	X
Rogue	X	X	X
Chetco	X	X	X

[a] *Estuaries for which the information is available are shown by "X".*
[b] *A notebook was not completed for Tillamook Bay because Tillamook County planners had already compiled a similar reference.*
[c] *Brief summary and planning recommendations are available for the Alsea estuary, but are not included among this series of reports.*

ACKNOWLEDGEMENTS

The reports in this series are the result of the hard work of a large number of individuals whom the authors most gratefully acknowledge. We are especially indebted to Neal Coenen of LCDC for his enthusiastic support and guidance throughout the course of this project.

We wish to thank Dennis Peters and USFWS for granting us permission to use their habitat classification system as a basis for our work. We also appreciate the financial assistance of the Natural Area Preserves Advisory Committee (NAPAC) which allowed us to complete final revisions and habitat definitions for our estuarine classification system. Our thanks to Bob Frenkel and Jeff Goner of NAPAC for their suggestions concerning the classification system.

Many individuals from ODFW spent long hours reviewing numerous drafts in this report series. We are especially grateful to our editor, Phil Howell, whose talents have greatly enhanced the quality of all the final reports. We are indebted to Jim Lauman, Jim Lichatowich, Al McGie, and Dale Snow for their suggestions and comments. We also wish to thank the following ODFW district biologists for their assistance in preparing habitat maps and reviewing reports: Reese Bender, Dave Heckeroth, Jim Hutchison, John Johnson, Warren Knispel, Al Mirati, Bill Mullarkey, Rik Riikula, Gene Stewart, Harold Sturgis, Doug Taylor, and John Thiebes.

Our thanks also to Marita Loch for her assistance with graphics and to Ernie Whited who spent months drafting all the habitat maps. We appreciate the time and talent donated by Harold Smith in designing our report covers. For typing many drafts under a very tight time schedule we also send thanks to Jan Ehmke, Bev Hester, Jane King, Margie Lamb, Terry McCormick, and Vivian Sanders.

We must reserve a very special thank you for two individuals who steadfastly and enthusiastically encouraged our work the past 18 months. We deeply appreciate the support and ideas offered by Harry Wagner and Jim Lichatowich throughout this project.

CONTENTS

Part I - Estuary and Estuarine Habitat Classification

INTRODUCTION

An estuary is defined by Pritchard (1967b) as "a semi-enclosed coastal body of water which has a free connection with the open sea and within which sea water is measurably diluted with fresh water derived from land drainage." There are 21 major estuaries (Fig. 1) along Oregon's coastline. Their dimensions vary considerably, ranging from the 93,782 acre Columbia River estuary (Division of State Lands [DSL] 1973) at the northern border to the 130 acre Winchuck estuary (Percy et al. 1974) in the extreme south. The ecological characteristics of Oregon estuaries also vary significantly in terms of river flow, depth, salinity, mixing, sediment composition, and shape. Corresponding differences in the composition and distribution of the biological communities represented in each system are also evident.

Economic and social activities associated with Oregon estuaries are as varied as their physical and biological features. A variety of user groups compete for limited estuarine space for boat moorage, water-born transportation, shoreland development, waste disposal, recreation, harvest of fish and shellfish, and scientific research. The division of resources among these diverse interests requires difficult choices between preservation and development of specific sites within each estuary. In order to make informed decisions, planners must consider the physical and biological factors that typify each estuarine system and the potential effects of each proposed activity.

Resource planning and management decision-making for most natural systems are complex due to the large number of variables that interact and influence the cycling of materials, flow of energy, and distribution of species. This is particularly true of estuarine systems, where dramatic environmental changes occur throughout tidal, diel, and seasonal cycles. Because ecosystems are complex, resource classifications have often been developed as a convenient

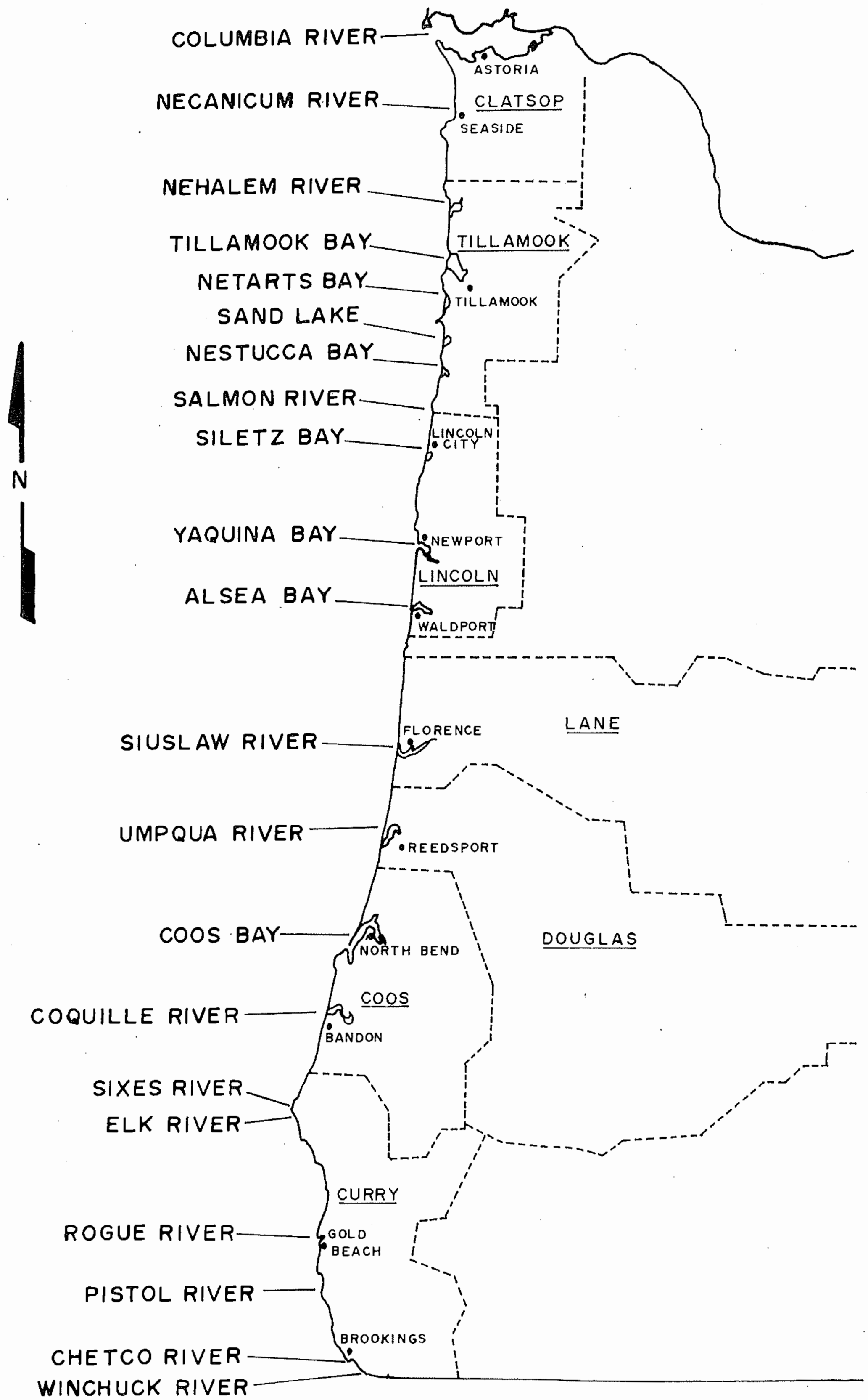


Fig. 1. Oregon estuaries.

method for simplifying, generalizing, and categorizing information. Ecological classifications help to identify controlling factors in natural environments. They also highlight similarities and differences among biological and physical resources and processes that may warrant similar or distinct management strategies. Classification systems that can be applied to specific geographical zones can be particularly useful to resource managers. Regulatory boundaries can be superimposed over those natural features that are most important to the management program.

This report describes a physical and biological classification system developed to facilitate resource management decisions and impact assessments of Oregon estuaries. LCDC's Estuarine Resources Goal (LCDC 1977b) requires that coastal planning agencies establish regulatory boundaries or management units to govern uses and protect the diversity of Oregon estuaries. This resource classification system is based on many of the habitats and communities discussed in the Estuarine Resources Goal, and, therefore, has direct application for designating appropriate management units for particular estuarine locations.

CRITERIA FOR ESTUARINE CLASSIFICATION

Several classifications have been used to describe major physical features typical of entire estuarine systems. Pritchard (1967b) identified four major categories of estuaries according to their geomorphology: drowned river valley, fjord, bar-built, and tectonic. Of the 21 major estuaries in Oregon, all but two fall under the drowned river category. Although drowned river estuaries have been further defined according to their mixing characteristics (Pritchard 1967a), the majority of Oregon estuaries experience large seasonal variations in river flow that can result in a variety of mixing classifications.

Geographical classifications have been used to differentiate estuaries according to biological, geological, and climatic characteristics (Hedgpeth 1957).

Most geographical approaches have not been helpful in identifying types of Oregon estuaries because they have focused on very broad regional differences. West coast biogeographical provinces have not been satisfactory for Oregon estuarine classification either, since local environmental variations in depth, circulation, degree of exposure, and river flow are generally more significant than coastal climatic differences, upon which biogeographical distinctions are based.

In 1974, during the early phases of development of Oregon's coastal zone management program, twelve categories of estuaries were identified in the state (Table 1) according to four criteria: geomorphology, mixing characteristics, relative amounts of tidelands and eelgrass, and "terrestrial and marine biological value" (Wilsey and Ham 1974). The categories were used in a broad evaluation of the "tolerance of use" or a general impact analysis for each class of estuary.

This classification is inadequate for selecting areas within estuaries appropriate for development or preservation for a variety of reasons. There are more than half as many categories as there are major estuaries in Oregon. Thus, it does little to highlight similarities. Geomorphology and mixing type alone provide little basis for differentiating Oregon estuaries. The remaining factors--amount of tidelands and eelgrass and terrestrial and marine biological value-- are ill-defined and were subjectively applied.

Researchers have also developed more detailed classifications, but these have often tended to overemphasize single factors. Carriker (1967), for example, divided estuaries geographically according to salinity ranges and resulting species distributions (Table 2). However, seasonal variability in Oregon estuaries complicates salinity patterns, particularly in estuaries having large drainages. Salinity gradients in estuaries with small drainages are compressed over relatively short distances and are not easily defined.

Table 1. Classification of 20 major Oregon estuaries (Wilsey and Ham 1974).

Physical type	Mixing characteristics	Marine biological/ terrestrial value	Percentage eelgrass/ tideland	Estuaries
Blind	well-mixed	moderate/low	low/low	Elk River Pistol River Sixes River Winchuck River
Bar-built		high/moderate-high	moderate-high/ moderate-high/	Netarts Bay Sand Lake
Drowned river		low/moderate	low/low	[a]
		low-moderate/low	low-moderate/ low-moderate	Isthmus and Davis Sloughs Shinglehouse, Coalbank, Pony and Kentuck Sloughs (Coos Bay)
		low-moderate/moderate-high	moderate/moderate	Coos Bay/Coos River
		moderate/moderate	low/high	Biggs Cove (Tillamook Bay) Catching Slough (Coos Bay) Lint and Eckman Sloughs (Alsea Bay)
		moderate/high	moderate-high/ moderate-high	McCaffery and Poole's Sloughs (Yaquina Bay) North, Haynes, South, and Joe Ney Sloughs (Coos Bay) South Slough (Siuslaw River)
	partially mixed or two-layered	low/low-moderate	low-moderate/ low-moderate	Necanicum River Chetco River
		low/moderate-high	moderate/moderate-high	Little Nestucca Salmon River
		moderate/moderate-high	low-moderate/ low-moderate	Alsea Bay (including Drift Creek) Coquille River Nehalem Bay
		high/moderate	low-moderate/ low-moderate	Nestucca Bay/Nestucca River Rogue River
		high/high	moderate/moderate	Siletz Bay (including Drift and Schooner Creeks) Tillamook Bay, Miami Cove Umpqua River (including Smith River) Yaquina Bay Siuslaw

[a] *The minor estuaries in this category are not among the 20 estuaries considered in this report.*

Table 2. Classification of approximate geographic divisions, salinity ranges, and types and distribution of organisms in estuaries (from Carriker 1967).

Divisions of estuary	Venice system: Salinity ranges (%)	Venice system: Zones	Ecological classification: Types of organisms and approximate range of distribution in estuary relative to divisions and salinities				
River	0.5	limnetic	↑	limnetic			↑
Head	0.5 - 5	oligohaline	│	oligohaline	↑	↑	│
Upper reaches	5 - 18	mesohaline	mixohaline		true	│	│
Middle reaches	18 - 25	polyhaline	│	↑	estuarine	│	│
Lower reaches	25 - 30	polyhaline	│	↓	↓	↓	↓
Mouth	30 - 40	euhaline	↓	stenohaline marine		euryhaline marine	migrants

Perhaps one of the most common approaches to ecological classification of marine and estuarine environments is based on characteristic associations of benthic species (Petersen 1913; Thorson 1957). In many cases ecologists also have attempted to correlate observed benthic distributions with sediment characteristics (Sanders 1958). Although sediment may be the major factor in relatively stable marine communities, salinity, temperature, and degree of exposure may prove to be of equal or greater importance in determining community composition and distribution, particularly in Oregon's relatively small, shallow estuaries.

In order to consider a number of factors that may concurrently influence community distribution, biologists have identified major geographic, biologic, or geomorphic features that appear to represent distinct estuarine environments. For example, Ricketts and Calvin (1968) identified typical species associated with a number of ecological subdivisions within estuaries such as rocky shores, wharf pilings, and sand, mud, and eelgrass flats. Although the method of Odum et al. (1974) also included some habitat categories (e.g. marshes, temperate grass flats), it did not incorporate the full range of estuarine habitat types and generally confused entire ecological systems with subdivisions of those systems.

The following criteria were stressed in developing an estuarine classification system for Oregon in light of planning and management needs and the inadequacies of existing classifications:

1. The categories chosen for a classification system should reflect the particular goals of the management program. For example, it is important to classify those processes or features that are vital to estuarine productivity such as salt marshes, submerged grass beds, etc. The degree of specificity of the classification system is also

dependent upon the management goals. Very broad management objectives may be served by a classification of estuary types, but decisions concerning the siting of facilities within an estuary require much more detailed habitat analyses.

2. The components of the classification system should be readily identifiable and measurable. Factors that are highly variable seasonally or spatially are more difficult to define than those that are more stable.

3. The classification should be immediately useful but flexible so that it can be revised and updated as new information is available.

The USFWS developed a habitat classification system (Cowardin et al. 1977) for estuaries that satisfies many of the above criteria (Fig. 2). Their classification is hierarchical, ranging from the broad categories of subtidal and intertidal to more specific characteristics (e.g. sediment types). As a result, it can be adapted to general estuarine management policies or site-specific proposals. The hierarchy can be readily updated and more detail can be added as new resource data become available.

The habitat categories in the USFWS classification characterize ecological subunits within estuaries that control the density and composition of biological communities. The class level of the hierarchy consists of natural features that can be easily mapped from aerial photos or observations, while more intensive sampling programs may be required to determine subclass and community-type categories. The USFWS classification also lists additional factors or "modifiers" of the classification to describe salinity range, degree of tidal inundation and exposure, and types of man-made alterations.

We have modified and expanded the USFWS classification system to include estuary and subsystem types as well as habitats. The following discussion

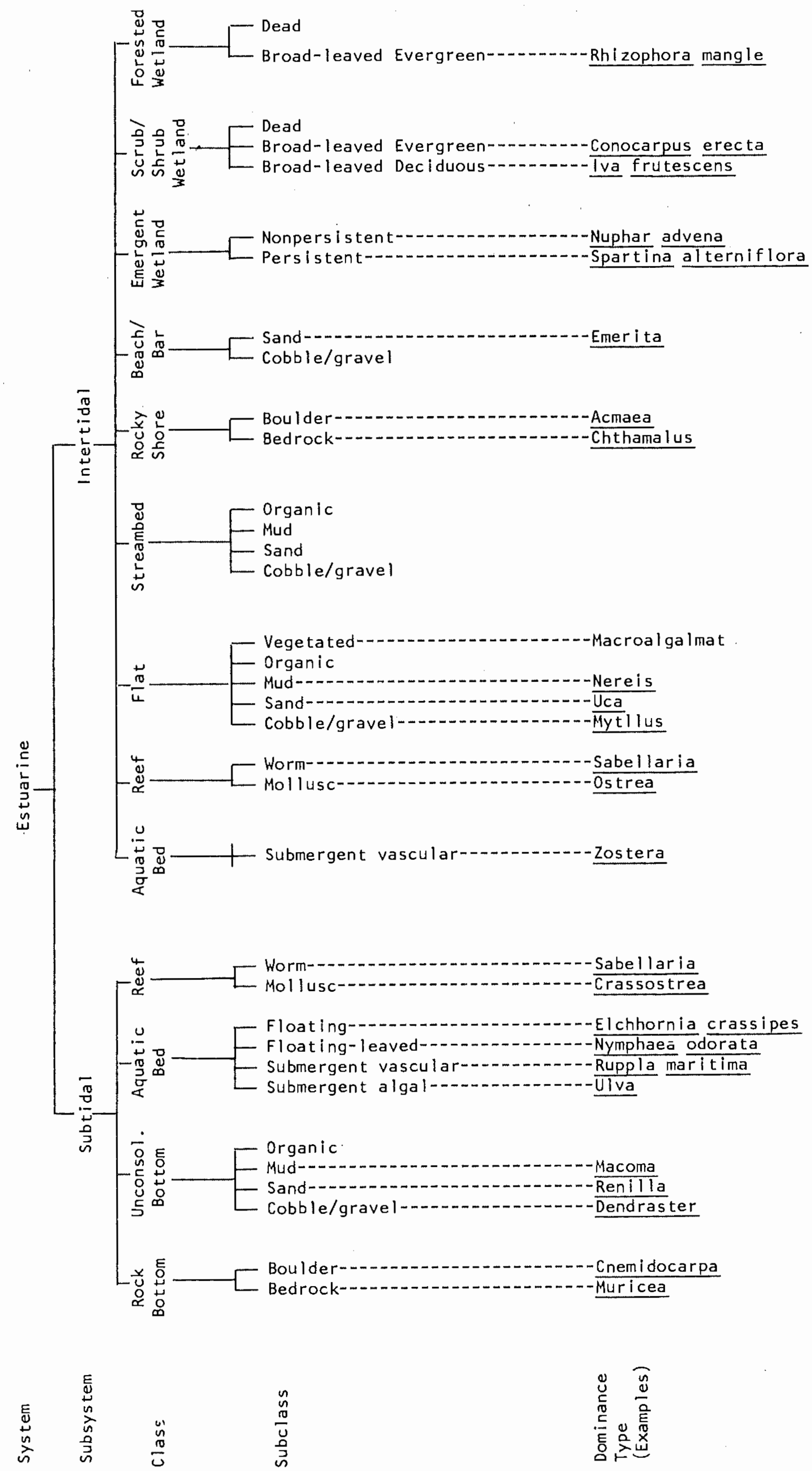


Fig. 2. A hierarchical classification of estuarine habitats (Cowardin et al. 1977).

describes this classification as it applies to the various types of estuaries in Oregon.

PHYSICAL CLASSIFICATION OF OREGON ESTUARIES

In developing an estuary classification system for Oregon, we have examined the 20 larger estuaries shown in Fig. 1, excluding the Columbia River estuary. The LCDC Estuarine Resources Goal (1977b) defines the upstream boundary of these estuaries as the head of tide. Many researchers emphasize the extent of salt water intrusion as the inland limit of estuarine conditions (Pritchard 1967b). In a number of Oregon's larger drowned river estuaries, tidal influence continues far beyond the zone of fresh and saltwater mixing, and there is often a marked ecological transition from deeper tidewater sections to the fast flowing rivers and tributaries that rise in the coastal mountains. For consistency with Oregon's present management program, the following classification incorporates LCDC's tidal definition of estuaries.

Physiographic Provinces

Although similar climatic conditions prevail throughout most of the Oregon coast, two major physiographic provinces divide north and south coast estuaries.

The Coast Range

A primary feature of the central and northern coast of Oregon is the Coast Range (Fig. 3), bounded on the east by the Willamette River, on the north by the Columbia River, and on the south by the Coquille River (Dicken 1965). The irregular coastline in this region consists of beaches interrupted by basaltic headlands, river mouths, and shallow bays. Although a number of rivers descend the western slopes within a short distance of the Willamette Valley, only the Umpqua crosses the entire province.

Geologic features of the Coast Range influence the physical and biological

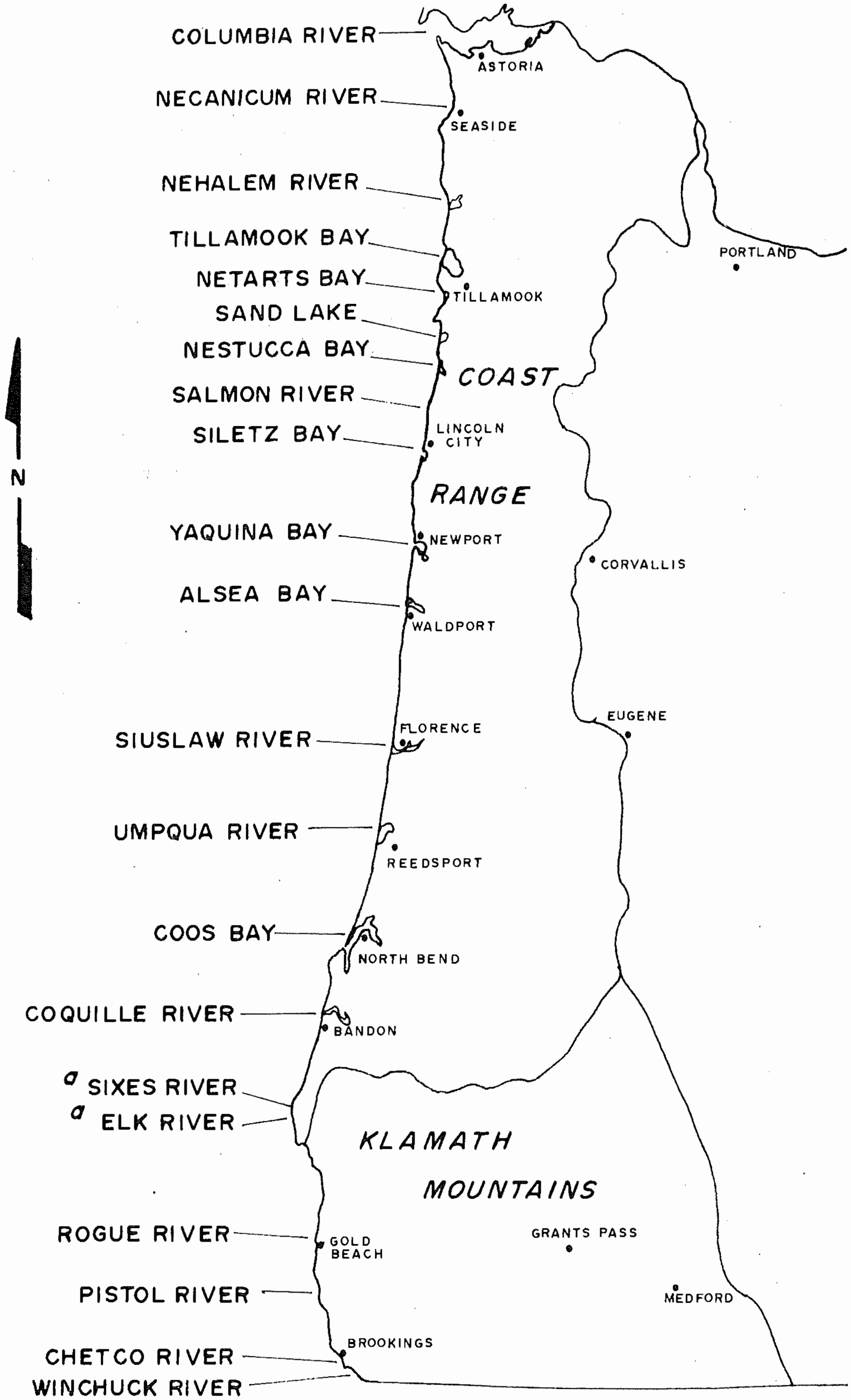


Fig. 3. The Coast Range and Klamath Mountain physiographic provinces of the Oregon Coast.

[a] *The headwaters of the Elk and Sixes drainages are in the Klamath Mountain province although the mouths of these rivers are within the Coast Range province (Dicken 1965).*

characteristics of the northern Oregon estuaries and distinguish them from those to the south. Predominant formations include sandstone, shales, and intrusions of igneous rock (Dicken 1965). North coastal soils in this region are much less stable. As a result, ample material has been available to build dunes, particularly between Coos Bay and the Columbia River. The dunes have had a major impact on the north coast, changing river courses and blocking smaller drainages to form coastal lakes. Extensive deposits of fine Coast Range sediments, which have created productive intertidal habitats, occur in numerous north coast estuaries.

The Klamath Mountains

South of the Coquille River and east of the Cascade lava plateau (Fig. 3), the land is highly dissected, and the rock formations are relatively old and metamorphosed (Smith 1940). Folding and faulting is relatively more complex, topography is generally steeper, and the rock is more resistant to erosion than in the Coast Range (Dicken 1965). Consequently, the sediment load of estuarine tributaries is low, and the broad productive tidal flats and marshes associated with the larger, shallow embayments of the north coast are less characteristic of estuaries in the Klamath Mountain province. The steep slopes restrict the landward extent of the tide and, hence, the size of estuaries located in the region. Tidal influence on the Rogue River, the largest drainage on the south coast (5100 mi^2) and the only river to traverse the entire Klamath region, extends only about 4.5 miles from the estuary mouth.

Geomorphology

Within the two major physiographic provinces of the Oregon coast, several classes of estuaries have already been identified according to their geomorphology (Wilsey and Ham 1974). This classification distinguishes three primary types of estuaries (Table 1).

Drowned river valley estuaries

Most of Oregon's estuaries are drowned river valleys, formed as the lower portions of rivers were inundated by a rise in sea level. Along the East Coast of the United States, such estuaries are often associated with broad coastal plains (Pritchard 1967b). However, the coastal plain in Oregon is narrow, and the estuaries are relatively small. In the drowned river estuaries of the Coast Range with low gradients, tidewater often extends beyond the maximum extent of saltwater intrusion. On the Coquille, for example, tidal influence extends 41 miles to Myrtle Point, although salinity only extends to approximately River Mile 26.

Blind estuaries

Blind estuaries are a special type of drowned river valley where river flows are very low during the summer and often insufficient to maintain the opening at the estuary mouth (Wilsey and Ham 1974). The tide and waves from the ocean build a bar across the mouth that may temporarily close the estuary or form a sill that retards tidal mixing of marine and river waters. In the Pistol River estuary, mass mortalities of marine organisms in the estuary have been documented (Clifton et al. 1973) when salinities dropped following long periods of fresh water ponding behind the bar.

Bar-built Estuaries

Bar-built estuaries are formed by the buildup of spits or barrier beaches between headlands. The barrier beach may be broken by inlets (unlike blind estuaries), which remain open due to tidal action rather than river flow (Wilsey and Ham 1974). Bar-built estuaries are often fed by several small drainages, and the total freshwater input is small. They are frequently elongate and parallel the coastline (Pritchard 1967b), as exemplified by Netarts and Sand Lake, the only two bar-built estuaries in Oregon.

Drainage Area vs. Estuarine Surface Area

By definition estuaries are transitions between marine and freshwater environments and, as such, contain both similar and distinct features. Biological and physical characteristics within estuaries are largely influenced by the relative contribution of each of these environments. Therefore, it is useful to further classify Oregon estuaries according to the size of the drainage area feeding each system and the total area influenced by the tide. Figure 4 illustrates a continuum of Oregon estuaries ranging from relatively small estuaries with small drainages to larger systems with large drainages.

Estuarine mixing characteristics (mixing of salt and fresh water) reflect the balance between tidal and river forces. In systems where the ratio of river flow to tidal flow is very high seasonally or throughout the year, stratification generally occurs. This is typical of many of the drowned river estuaries on larger drainages of the north coast. Marine dominated systems in Oregon characterized by relatively low river flows are generally completely or partially mixed due to tidal and, in some cases, wind energies. The smaller bar-built estuaries are examples of marine dominated systems.

River dominated estuaries may approach fresh conditions very near the mouth, particularly during seasonally high flows. In marine dominated estuaries not only are salinities generally higher further up the estuary, but seasonal variations related to flow conditions are likely to be much less severe. Although local geological characteristics ultimately determine the composition of estuarine deposits, the distribution and particle size of sediments deposited in the estuary will vary with river and tidal currents. For example, fine terrestrial materials transported downstream may not be deposited during high flows in river dominated systems. On the other hand, shallow protected sloughs and embayments may serve as settling basins for river-born silts and clays. The sediment distribution in Yaquina Bay (Fig. 5) illustrates

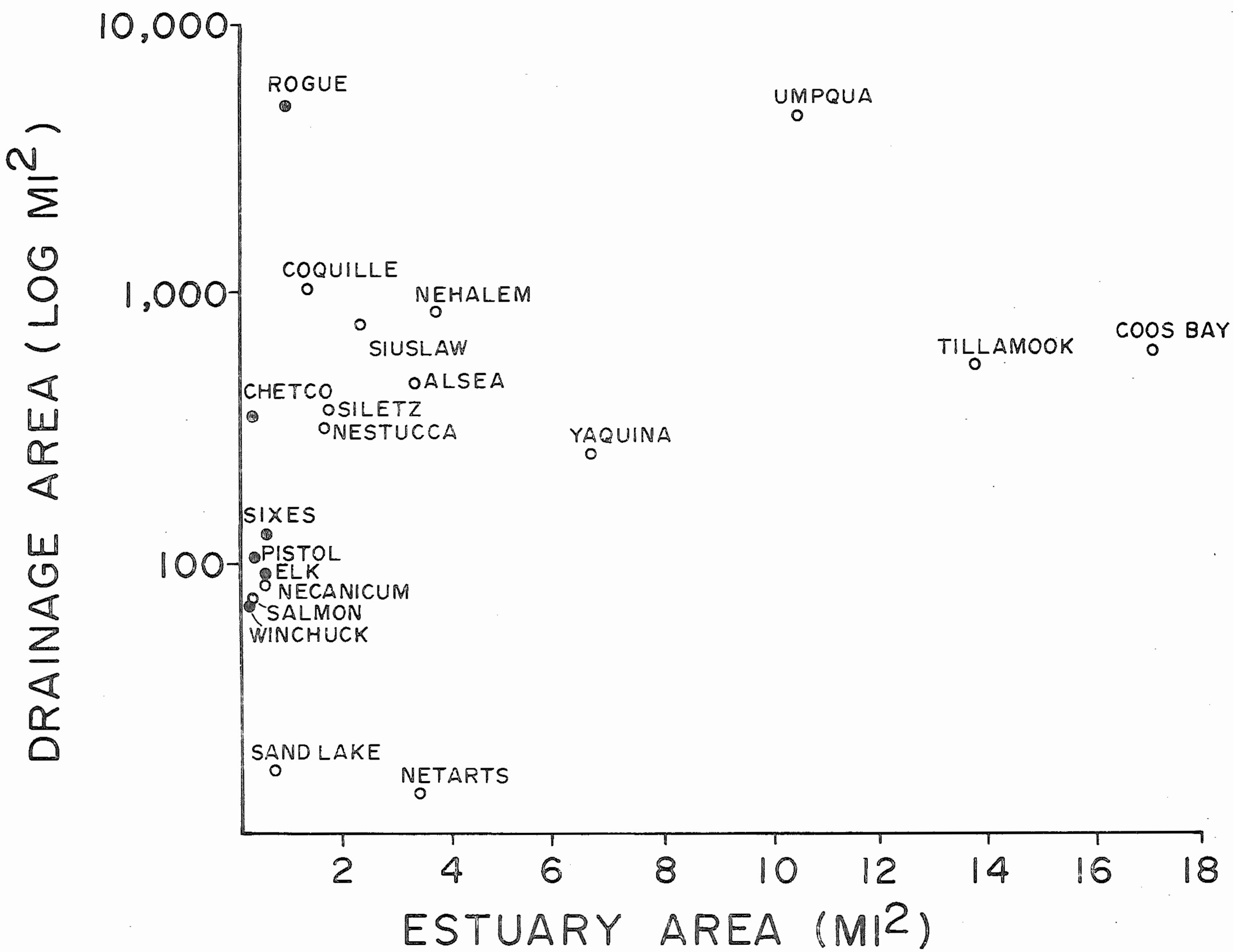


Fig. 4. Drainage area vs. estuarine surface area for 20 Oregon estuaries[a].

[a] *Estuarine surface area estimates are from DSL (1973) values at MHW excluding high marshes. In many cases surface area measurements are not to head of tide. However, the relative values on this graph are not greatly affected.*

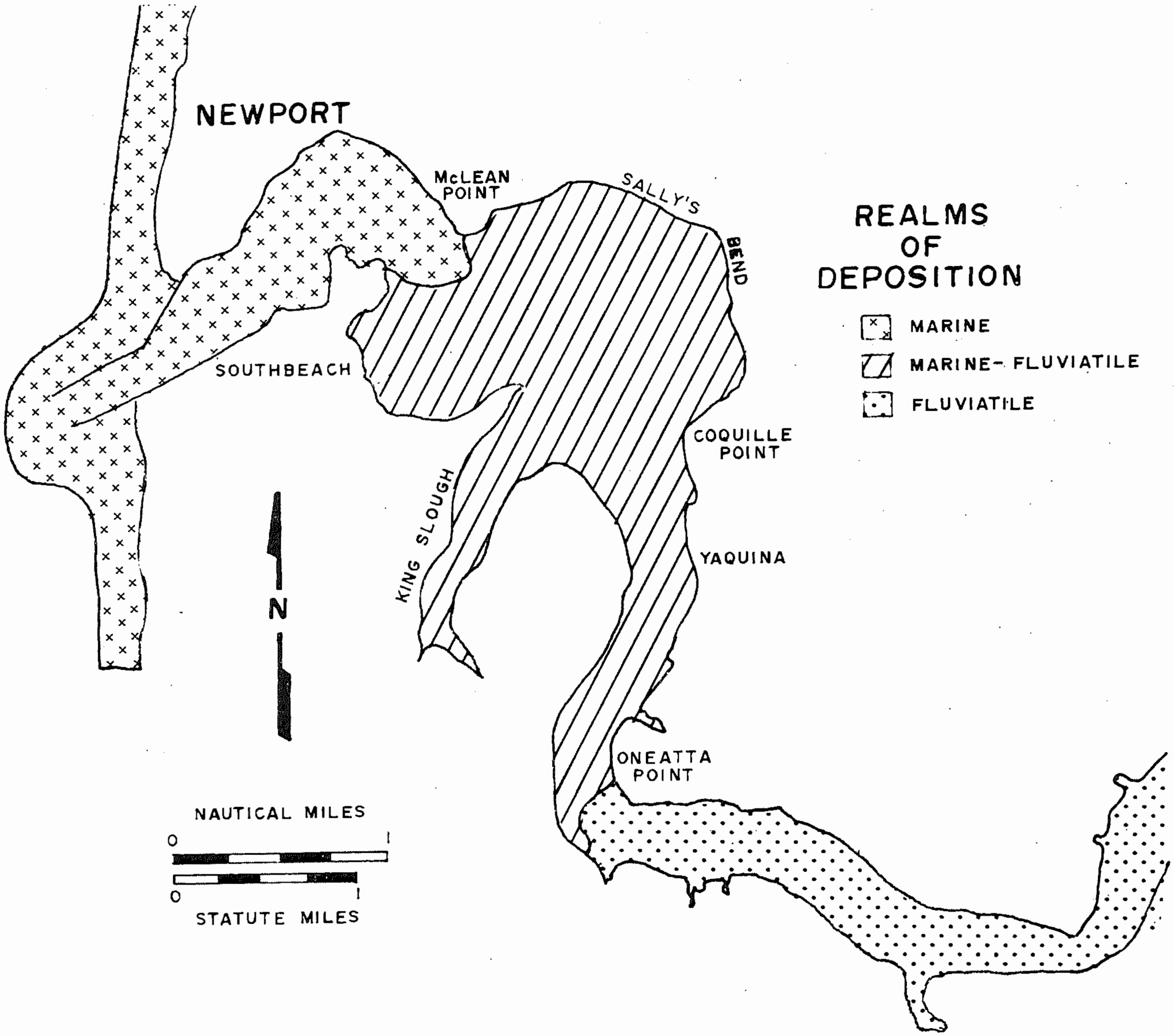


Fig. 5. Realms of deposition in Yaquina Bay (Kulm and Byrne 1967).

the influence of tidal and river flows on the deposition of marine and riverine sediments in an estuary.

Species composition and distribution also directly and indirectly reflect the relationship between tidal and river forces in Oregon estuaries. Variations in sediment distribution are important in determining the composition and distribution of benthic faunal communities. Benthic floral communites are also affected by factors such as current, salinity, sediment type, and morphology of the estuary basin. Major salt marsh or eelgrass assemblages occur in larger bays in broad valleys or flats and in sloughs. These conditions are not common in river-dominated estuaries, where the shoreline is straight and steeply sloped and freshwater flows predominate.

The physical and biological variations resulting from the assorted sizes of Oregon estuaries and their drainages are complex. Figure 6 outlines a classification of these estuaries. In the Klamath Mountain region the slope of drainage is steep, and even estuaries on larger rivers are very small. In the Coast Range where river gradients are generally less severe, the range of estuary sizes is more directly related to the size of each drainage. The classification groups estuaries according to major physical features which influence biological communities.

OREGON ESTUARINE SUBSYSTEMS

The influence of geologic, riverine, and tidal forces on the composition and distribution of materials and species makes it possible to identify characteristic sub-environments or subsystems within Oregon estuaries. The presence and size of a particular subsystem in a given estuary is a reflection of the relative influence of these factors. Although exact boundaries cannot be drawn due to the dynamic nature of estuaries, it is possible to broadly define four principal types of subsystems that occur in Oregon estuaries:

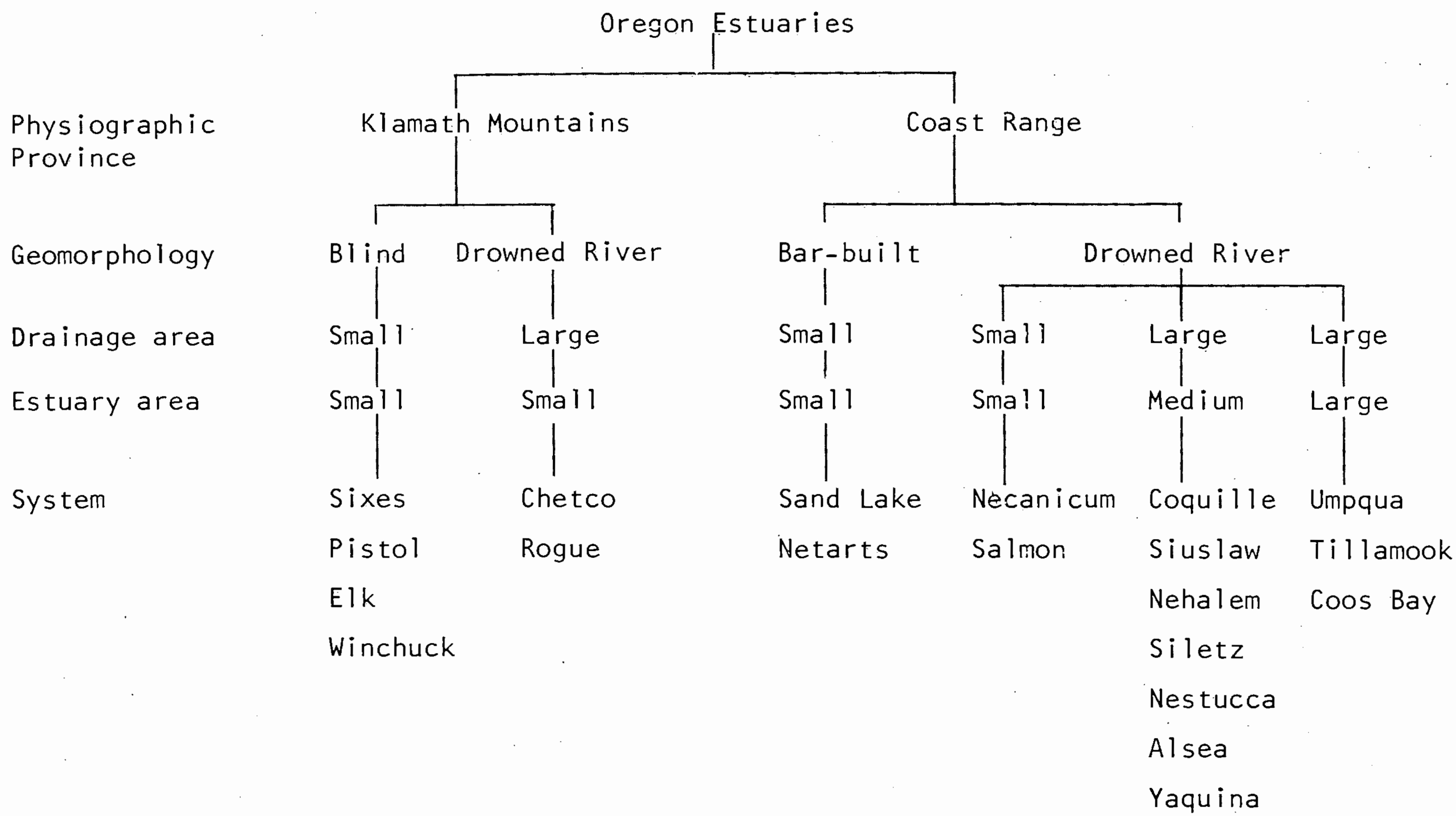


Fig. 6. Classification of estuaries in Oregon according to physiography, geomorphology, and relative drainage and estuary area.

marine, bay, slough, riverine (Fig. 7).

Marine Subsystem

The marine subsystem is a localized area near the estuary mouth. It is a high energy zone subject to frequent or constant wave and tidal surges. Salinities are generally high, although on large river systems values may be lower, particularly at low tide and during heavy winter flows. Sediments are generally coarse, clean sands of marine origin. Rocky substrates are also common, and in larger estuaries, rock jetties have been constructed to stabilize the estuary mouth and ensure a navigable entrance. Usually only a small percentage of the marine subsystem is intertidal.

Benthic invertebrates in this zone may include species found along the outer coast as well as those that require the slightly more protected environment found within the estuary mouth. Turbulent conditions in the marine subsystem often require plants and animals to have specialized adaptations for attaching themselves to hard, wave-battered substrates or for rapid burrowing in shifting sand. Kelp and other large algal species may be found on rocky substrates, but unconsolidated sediments are generally devoid of larger plants. Most fishes utilizing Oregon estuaries are marine species. This subsystem often harbors the most diverse assemblage of fishes in the estuary.

Due to its proximity to the mouth and its relatively deep conditions compared to locations further up the estuary, the marine subsystem is often a preferred site for boat basins and marinas. Commercial and industrial development is also common where coastal towns are located adjacent to the estuary. Although flushing is usually rapid in this subsystem, crowded marinas, where sewage, fish wastes, and petroleum residues may concentrate, and boat basins with constricted entrances that reduce tidal exchange potentially threaten water quality. Dredging of boat basins and ship channels commonly

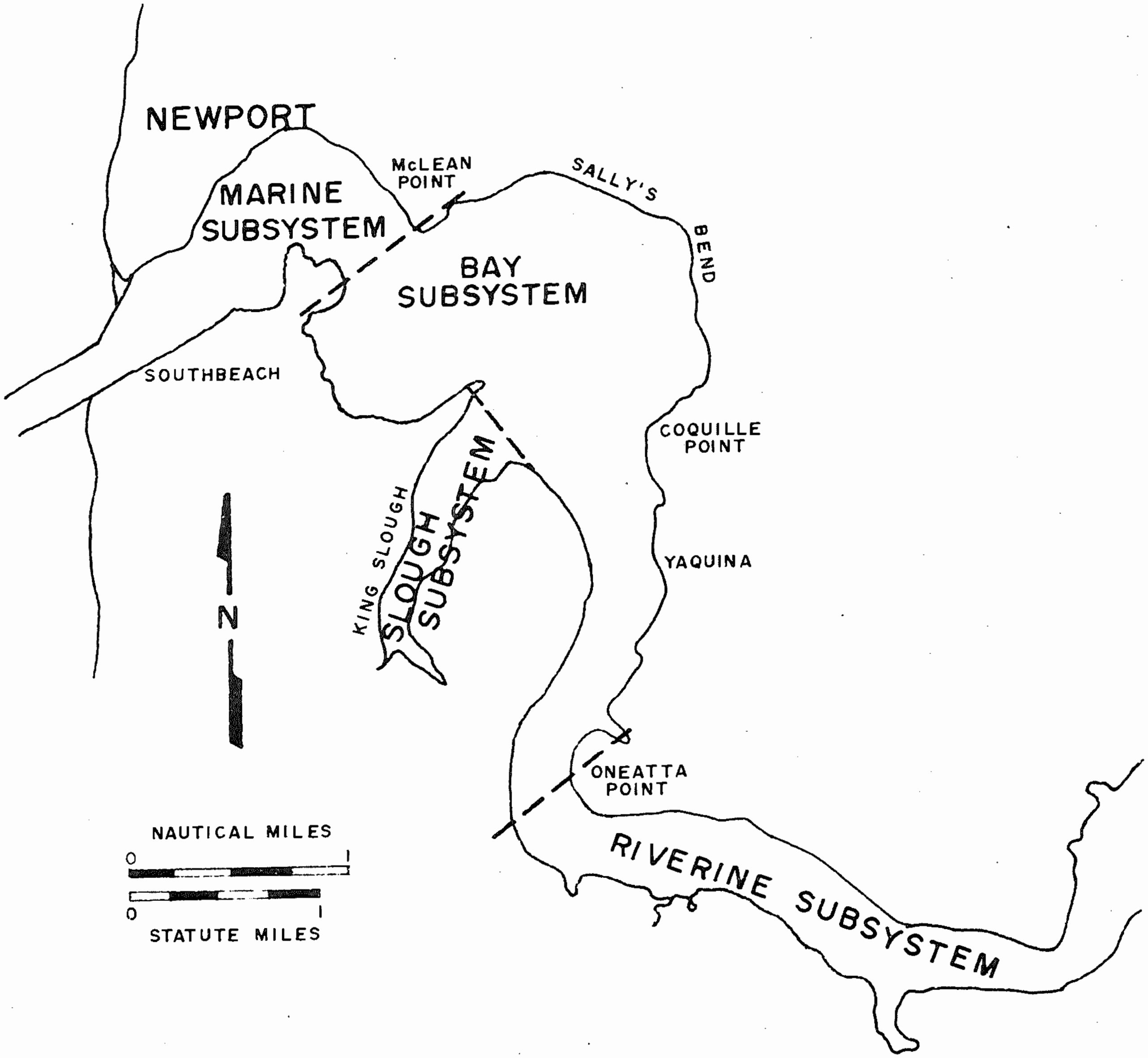


Fig. 7. Yaquina estuary illustrating four major subsystems: marine, bay, slough, and riverine.

alters benthic habitats in the marine subsystems of many Oregon estuaries. The total impacts of these various disturbances are not easily predicted.

Bay Subsystem

The bay subsystem is a transition zone between marine and fresh water. In many estuaries it is characterized by a broad embayment between the constricted estuary mouth and narrow, upriver tidewater sectors. In some cases the bay subsystem may be less conspicuous but identifiable by a relatively large percentage of intertidal land. Salinities in this region may be quite variable due to seasonal changes in river flow, although moderate to high salinity ranges are usual. As an intermediate environment, sediment types in the bay subsystem range from coarse marine sands to fine riverine materials (Fig. 5). Bay subsystems are best represented by estuaries in the Coast Range province, where soft parent materials have eroded and been deposited to create broad intertidal flats.

The bay subsystem is a relatively protected environment, isolated from turbulence near the mouth and strong currents during peak flows in the riverine portion of the estuary. The mixture of marine and riverine sediments and a variety of vegetation types provide a diversity of habitats for benthic species. In many Oregon estuaries major clam and shrimp beds typically occur in productive intertidal flats of the bay environment. Extensive marsh and eelgrass habitats are also common in the larger Coast Range estuaries.

Development in the bay subsystem is varied. Periodic dredging in larger estuaries has been necessary to maintain ship channels. In some areas dredged materials have been dumped in the bay, smothering benthic organisms. Marshes and flats have been filled to provide more area for development. As in the marine subsystem, commercial and industrial facilities are common along the bay shoreline of many estuaries and in the past have contributed pollutants from runoff or direct discharge. Because the bay subsystem is usually an area of very high biological productivity, it is also a favorite site for bird watching, clamming, and occasional crabbing and fishing.

Slough Subsystem

Isolated arms or sloughs have often formed in minor drainages entering the bay and marine subsystems of many larger estuaries. Salinity and other characteristics of a slough subsystem will vary with its location relative to the estuary mouth and the volume of freshwater entering its upper reaches. Sloughs are usually sheltered environments with fine organic sediments, except where tidal currents sweep through narrow channels. Often sloughs are shallow with a high percentage of intertidal land.

Larger slough subsystems may be a microcosm of the entire estuary and, like the bay subsystem, encompass a variety of intertidal and subtidal habitat types. Productive marshes, eelgrass, and mudflat communities are common. In many areas sloughs and marsh channels provide protected rearing sites for juvenile fishes and crabs as well as prime resting and feeding sites for waterfowl.

In Oregon many marshes bordering sloughs have been diked for agricultural uses, restricting tidal flushing and the flow of nutrient-rich organic material into the estuarine system. Residential and commercial development is also common along some sloughs. Isthmus Slough in Coos Bay provides an example of industrial development in a slough subsystem. Mills along the banks have used the area for log storage, which has reduced dissolved oxygen levels and degraded water quality. Pollutant discharges and septic tank failures may also threaten water quality in slough subsystems where freshwater input is negligible and flushing is often poor.

Expansive intertidal flats in bay subsystems often contain large clam populations such as this productive softshell bed in the Nestucca estuary. (P. Howell)

Riverine Subsystem

The riverine subsystem includes the upper tidewater portions of the larger tributaries entering the estuary. Much of the subsystem is subtidal along narrow, deep river channels. Salinities are low most of the year, and stretches of tidewater are fresh on larger drainages. Large seasonal variations in river flow have a dramatic influence on this portion of the estuary. During low flows, flushing time may be very long in upper riverine locations. During peak flows, erosion of river banks and high turbidity are common and may impact lower sections of the estuary.

Salt marshes may extend along the borders of the riverine subsystem, grading into fresh marshes or shrub wetlands beyond saltwater influence. Riparian vegetation on banks and dikes protects the shoreline and provides shade and cover for organisms in the shallow areas. The river transports organic matter and nutrients from these and other terrestrial sources that may be important to the total productivity of the estuary.

Many riverine subsystems also serve as rearing and holding areas for juvenile anadromous and freshwater fishes. They are also corridors for adult salmonids during spawning migrations and are heavily fished by sportsmen. Adult striped bass and shad congregate and spawn in the upper tidewater of several larger estuaries (e.g. Coos, Umpqua, Coquille).

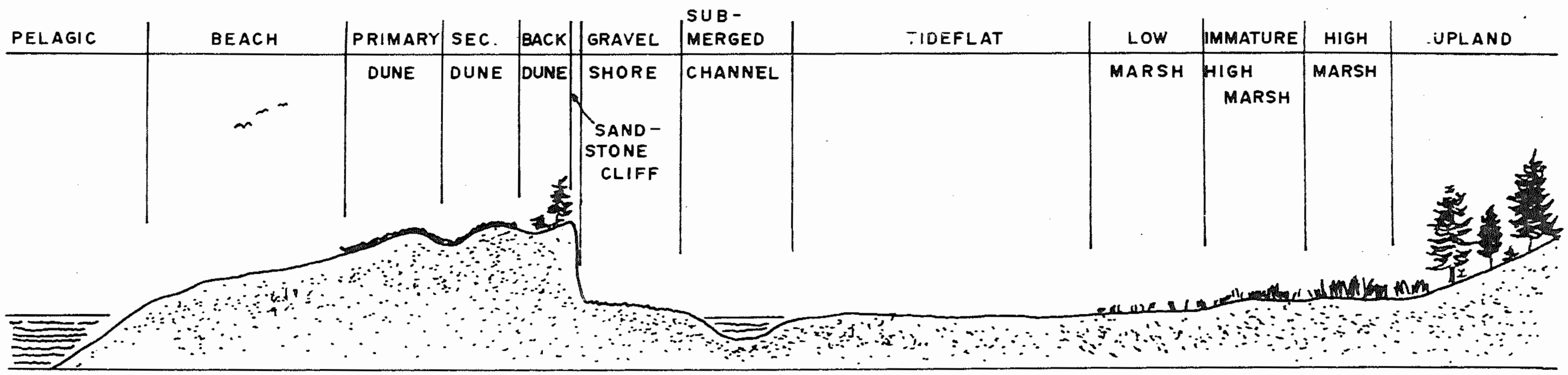
A number of activities frequently associated with the riverine sybsystems have altered Oregon estuaries. The construction of dikes and bulkheads, withdrawal of water for irrigation, and the introduction of non-point pollutants (fertilizer, pesticides, sediment, and livestock wastes) associated with agricultural uses may affect fish and wildlife habitat, estuarine hydrology, and water quality. In a number of estuaries, huge expanses of salt and freshwater marsh have been diked to create pasture. Riprap and bulkheads placed

A narrow fringing marsh dominated by *Carex lyngbyei* follows the shoreline of this riverine subsystem. Fringing marshes bind sediments, prevent streamside erosion, and provide shallow water habitat for fish and waterfowl in the upper estuary. (P. Howell) along the riverine shore to protect residential homes and property frequently cause erosion along other stretches of the river. Pollutants introduced in this section of the estuary during seasonally low flows may remain for long periods due to the slow rate of flushing.

OREGON ESTUARINE HABITAT CLASSIFICATION SYSTEM

Within Oregon estuaries and their component subsystems a number of environmental factors influence the composition, distribution, and production of biological communities. The environment occupied by a species often varies considerably with its life cycle and activities. For example, there are often distinct locations for feeding, resting, rearing, and spawning for a single species, each characterized by a unique set of environmental conditions. Despite changes through time in the ecological requirements of each organism and the biological and physical characteristics of each estuary, it is possible to identify unique environments within a system or subsystem that tend to control the production and composition of the communities that utilize them. For purposes of classification and estuary management we will refer to these environments as habitats. Fig. 8 illustrates a variety of typical habitat types and associated communities in a cross section of the Siletz estuary.

Classification of habitats and their communities is useful in considering site-specific proposals and evaluating potential environmental impacts in estuaries. Fig. 9 outlines an estuarine habitat classification system for Oregon incorporating tidal regime, land form, and sediment or vegetation type as primary factors controlling biological communities. Obviously, a classification of benthic substrates does not address all types of communities in estuaries, but sessile plants and invertebrates are directly influenced by bottom types, and adaptations for burrowing, attachment, and feeding are closely linked to specific types of substrate. The distribution of fishes and



Kelp	Beachgrass	Coastal pine	Fir	Diatoms	Plankton	Diatoms	Eelgrass	Seaside arrow	Tufted hair grass	Alder
Plankton	Annuals	Salal	Spruce	Algae		Algae	Algae	Sand spurry	Salt grass	Fir
	Clover	Myrtle	Pine					Three-square rush	Rush	Blackberry
	Red fescue	Brackenfern	Cedar					Salt grass	Creeping bent	
	Bearberry	Huckleberry						Sedge	Marsh clover	
									Glasswort	

Salmon	Plover	Beetle	Chickaree	Cockle	Seal	Crab	Limpet	Muskrat	Pigeon	Deer
Cutthroat	Gull	Spider	Blue heron	Turnstone	Herring	Seal	Snail	Nutria	Deer	Elk
Tuna	Sand crab	Mice	Pigeon	Softshell	Clams	Flounder	Crab	Mink	Mink	Owl
Herring	Pill bug	Sparrow hawk	Shrew	Shrimp	Ducks	Ghost shrimp	Shrimp	Otter	Muskrat	Bear
Anchovy	Sandpiper	Ants	Coast mole	Shorebirds	Coho	Clams	Clams	Mallard	Raccoon	Grouse
Shad	Smelt	California quail	Chipmunk		Chinook	Mussel	Brant	Pintail	Otter	Pigeon
Sole	Perch	Sparrow			Steelhead	Blue heron	Ducks	Coot	Nutria	Warbler
Shrimp		Goldfinch			Crab	Plover	Geese	Wigeon	Shrew	Coyote
Whale					Sculpin	Killdeer	Swans	Blue heron	Vole	Bobcat
Seal					Surfperch	Sandpiper	Blue heron	Shorebirds	Seal	Mountain quail
Gull					Flounder	Gull	Herring	Young fish	Ducks	Woodpecker
Scoter					Cutthroat	Whimbrel	Smelt	Crabs	Blue heron	Goshawk
Auklet						Dunlin			Sparrow	
Murre						Sole				
						Sculpin				
						Pigeon				

Fig. 8. General habitats and associated species of Siletz Bay, Oregon (Howard, Needles, Tammen, and Bergendoff Co. 1975).

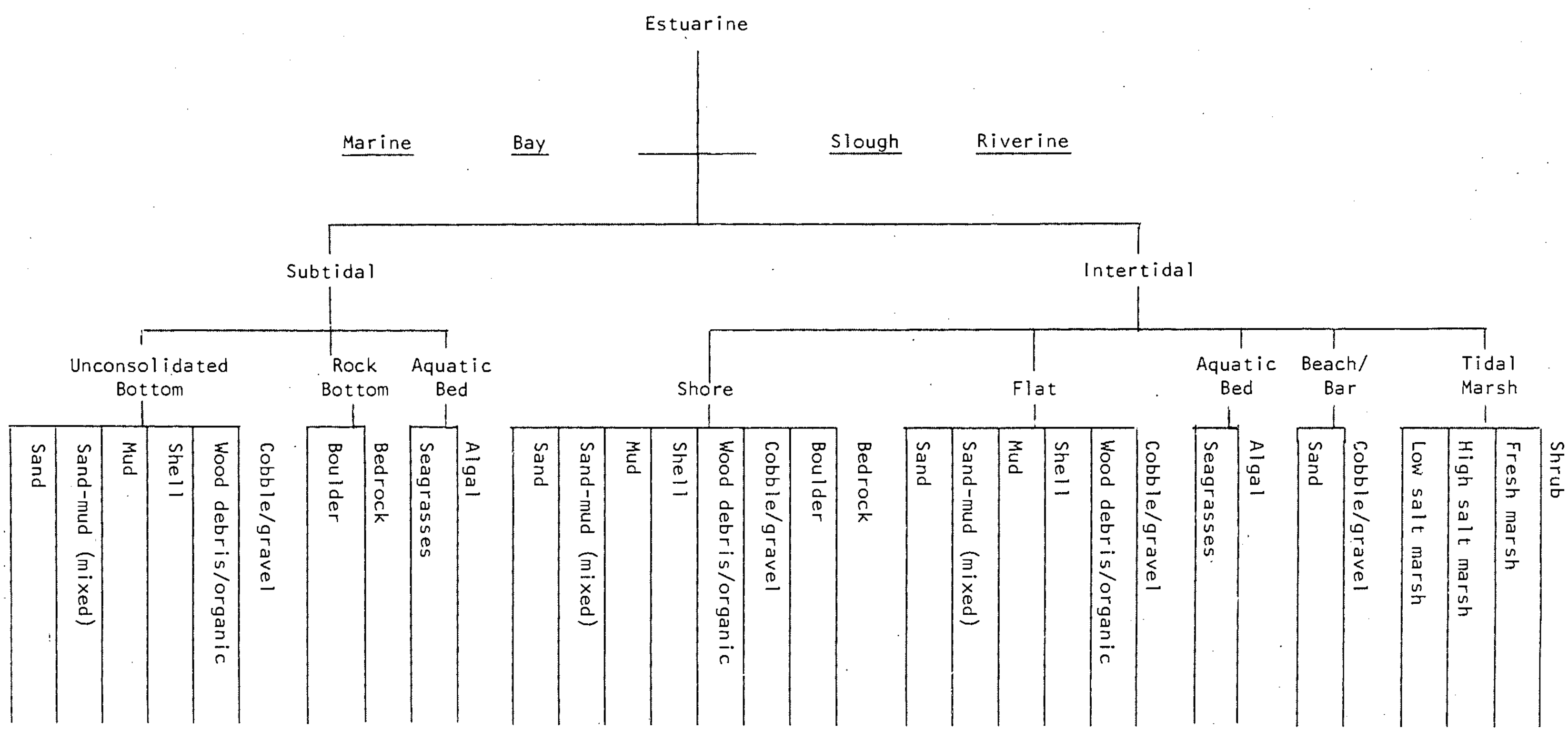


Fig. 9. Oregon estuarine habitat classification system (modified from Cowardin et al. 1977).

other mobile species are also related to feeding and spawning areas and protective cover along the estuary bottom. Benthic filter feeding invertebrates also can influence the distribution and density of phytoplankton and zooplankton in the water column.

Sediment distribution reflects not only the source of parent material but also the velocity and direction of tidal or river forces transporting the sediment. Therefore, habitat distribution is also influenced by the balance of these forces. River dominated systems, for example, have a high percentage of low salinity subtidal habitat containing terrestrial sediments. Marine sediments and high salinities are infrequently found in these systems. Estuaries with large intertidal habitats in bay and slough subsystems and a generous mixture of marine and riverine sediments offer a greater diversity of habitat types and, in turn, probably support a greater diversity of species. Although each subsystem may have a full range of substrate and vegetation types, Table 3 illustrates the habitat types most commonly associated with each of the four major subsystems in Oregon estuaries.

It is important to distinguish between sediment type and habitat type, since similar classes of substrate alone do not represent similar environments. For example, communities that inhabit subtidal sand bottoms in the lower and upper estuary may differ significantly due to variations in salinity or other factors independent of substrate type. The use of salinity and tidal modifiers in the USFWS (Cowardin et al. 1977) habitat classification system is one method to distinguish otherwise similar environments. The designation of habitat types by subsystem should also provide adequate differentiation, since we have defined subsystems according to salinity, currents, and other factors that vary along a gradient from lower to upper estuary.

The classification system presented here is a conceptual model of community - habitat - subsystem relationships in Oregon estuaries.

Table 3. Commonly occurring habitat types in the four major subsystems of Oregon estuaries.

Habitat class	Marine	Bay	Slough	Riverine
A. Subtidal 1. Unconsolidated bottom	Sand Cobble/gravel	Sand Sand/mud Mud	Sand Sand/mud Mud	Sand Sand/mud Mud Cobble/gravel
2. Rock bottom	Boulder Bedrock	Boulder Bedrock		Bedrock
3. Aquatic bed	Algae	Algae Eelgrass	Algae Eelgrass	
B. Intertidal 1. Shore	Sand Boulder Bedrock Cobble/gravel	Sand Sand/mud Mud	Sand Sand/mud Mud	Sand Sand/mud Mud Cobble/gravel
2. Flat	Sand	Sand Sand/mud Mud	Sand Sand/mud Mud	
3. Aquatic bed	Algae	Algae Eelgrass	Algae Eelgrass	
4. Beach/bar	Sand Cobble/gravel			
5. Tidal marsh	Low salt marsh	Low salt marsh High salt marsh Diked marsh	Low salt marsh High salt marsh Diked marsh Fresh marsh	Diked marsh Fresh marsh High salt marsh Shrub marsh

Verification of these relationships will require surveys of benthic communities and substrates and may necessitate revision of the model. The major categories of habitats shown in Fig. 9 are defined in Appendix A and described below:

Tidal Regime

The tide is a major limiting factor for many species in estuaries and nearshore marine environments. The classification in Fig. 9 distinguishes intertidal and subtidal habitats, since biological communities may differ significantly according to the degree of tidal influence. Special adaptations are required by intertidal species to resist dessication and tolerate large variations in temperature and salinity that may be associated with tidal exposure.

Within intertidal areas, a marked zonation of species is often apparent due to variation in the frequency and duration of exposure between lower and upper intertidal elevations. The USFWS classification (Cowardin et al. 1977) includes modifiers for irregularly exposed, regularly flooded, and irregularly flooded intertidal areas. These modifiers are appropriate to further differentiate intertidal habitats represented in Oregon estuaries. However, intertidal elevations are not presently mapped for any Oregon estuaries.

Habitat Classes

Unconsolidated bottom

Physiological and morphological adaptations of benthic organisms allow certain species to flourish in particular types of sediment. The habitat classification system (Fig. 9) identifies a range of sediment sizes that represent unique environments of particular benthic species. For example, feeding adaptations of invertebrates are related to sediment size. Coarse, clean sands are generally inhabitated by organisms that filter food from the water column. In quiet waters where fine, organically rich muds occur, deposit feeding polychaetes or other invertebrates ingest the sediment directly. The unconsolidated bottom class only applies to subtidal substrates and communities.

Most invertebrates in unconsolidated sediments live within the substrate. Some species maintain permanent burrows, while others live on the surface. Sediment type influences the construction and burrowing methods and, therefore, the composition of benthic invertebrate communities. The importance of subtidal benthic habitats to fishes varies with the availability of preferred food items in each type of substrate.

Because sediments largely influence the type of invertebrates colonizing an area, activities which alter sediment characteristics have a significant impact on benthic communities. Although dredge or spoil sites can be recolonized, community structure will vary with new sediment properties. Activities or structures that alter existing current patterns can have a similar impact on benthic communities if established patterns of erosion or deposition are affected. Construction of jetties, dikes, and breakwaters and the dredging of navigation channels can alter flow rates and patterns, eroding or depositing sediment. Where deposition is rapid, benthic communities may be smothered, and where erosion is significant, only orgranisms adapted to unstable substrates may be able to survive. An important consideration in evaluating proposed development in estuaries is the impact on current patterns and sedimentation processes and the resulting effects on benthic habitats and communities.

Rock bottom

Rock habitats in the high salinity zone near estuary mouths are very productive environments for marine fishes and invertebrates. Most subtidal rock habitats in Oregon estuaries are located near the mouth, where strong tidal currents and turbulence require that organisms be firmly attached or seek the protection of sheltered cracks and crevices. Rock outcrops also extend into the upper estuary, particularly in the smaller systems of the Klamath region. Jetties have created the most extensive rock bottom habitats in Oregon estuaries.

Specialized and diverse fauna are adapted for attachment or browsing along rock substrates. Sucking devices, such as the tube feet of star fish, or more permanent methods of attachment, such as the byssus threads of mussels, are examples of adaptations for rocky substrates. Soft silt and sandstone outcrops in a few locations provide a unique habitat for highly specialized piddock clams capable of boring into the rock. A diversity of algal species attach to rocky substrates with a strong basal holdfast.

In the well flushed environment near estuary mouths, few alterations directly threaten subtidal rock habitats. However, in calmer waters excessive shading or turbidity may decrease plant and animal production, and rapid sedimentation can cover attached species.

Aquatic bed (intertidal and subtidal)

The aquatic bed categories (Fig. 9) refer to algal and eelgrass beds that frequently occur subtidally and intertidally in bay and slough subsystems. In Oregon, *Zostera marina* is the most common species of eelgrass. It can be found growing in sand as well as mud substrates. It is a rapid growing plant that provides habitat for a diverse community of estuarine plants and animals (Thayer and Phillips 1977). Its leaves support large numbers of algal and invertebrate epiphytes which are consumed by fish and larger invertebrates. Numerous clam species are often associated with eelgrass beds. Eelgrass leaves are the primary food of black brant during their migration along the Oregon coast. However, most of the energy in eelgrass is utilized

Eelgrass *(Zostera marina)* blankets the water's surface as the rising tide inundates this aquatic bed in Netarts estuary. Productive eelgrass beds stabilize sediments, contribute rich organic matter at the base of estuarine food chains, and provide habitat for fish and a variety of clams and other invertebrates. (P. Howell) via detrital food chains as dead leaves decay and nutrients are released. In some estuaries, eelgrass leaves provide a spawning surface for herring (Miller and McRae 1978). Thick beds of eelgrass reduce currents near the bottom and promote deposition of sediment, while roots and rhizomes bind sediments and prevent erosion (Zieman 1977).

Diverse algal beds occur in Oregon estuaries over unconsolidated or rock substrates, which also provide a habitat for fish and invertebrates. Huge mats of *Enteromorpha, Ulva,* and other algal species turn broad intertidal flats bright green during spring and summer. During late fall and winter biomass declines as the algae decays, contributing rich sources of organic matter and nutrients to the system. In some deeper, high salinity areas where there is suitable substrate for attachment, long blades of kelp (e.g. *Nereocystis luetkeana*) may be seen floating at the water's surface. Kelp holdfasts represent a unique microhabitat for a rich community of invertebrates (Markham 1967).

Plant production in Oregon estuaries is highly seasonal. The timing of fish migrations and spawning and invertebrate reproduction in estuaries corresponds closely with dramatic increases in plant production during the spring and summer. Algal and eelgrass communities probably represent a significant portion of the primary production in many Oregon estuaries.

Estuary plans should protect aquatic beds both as a source of organic matter for the entire system and as a habitat for fish and invertebrates. Reduction of light penetration due to shading or turbidity can limit plant growth. Logging and road construction in the upper watershed and dredging activities in the estuary can increase turbidity. Reduced flushing of eelgrass and some algal communities may decrease nutrient and gas exchange and, as a result, plant production. Significant modification of temperature or salinity

Dense mats of green algae appear along the flats of many Oregon estuaries during the spring and summer, providing estuarine food chains with another important source of organic material. A thick growth of sea lettuce *(Ulva lacctuca)* covers this cobble/gravel flat. (P. Howell) patterns from changes in freshwater flow or estuarine circulation may further threaten aquatic beds.

Shore

Shores are narrow, steeply sloped intertidal habitats that occur where river and tidal currents are relatively strong. Because these are generally high energy environments, rocky substrates or coarse sediments often predominate. Algal and invertebrate species are firmly attached to rocky shores, but waves and currents may limit plant and animal production on unstable, unconsolidated shores. As in other intertidal habitats, there is a pronounced zonation of plant and animal species from lower to upper intertidal elevations with generally fewer species inhabiting the upper intertidal zone. In some estuaries, mud and sandy shores are inhabited by burrowing or tube dwelling invertebrates, which are food sources for bottom feeding fishes at high tide. In some locations, intertidal shores serve as haul out areas for harbor seals.

Shore habitats are most directly impacted by development along adjacent uplands. Shading by docks, log rafts, and other structures can reduce plant and animal production along estuarine shores. Communal dock facilities help prevent the proliferation of shoreline structures than can reduce benthic communities and alter flow patterns in the immediate vicinity. In a few estuaries logs stored along riverine shores ground at low tide crushing benthic organisms and contribute large quantities of decaying bark debris that degrade sediment and water quality. Destruction of riparian vegetation above intertidal shores increases bank erosion and losses of property and shore habitat. Sloped shores dissipate current energies and therefore are more resistant to erosion than vertical banks. Where possible, vegetation is preferred to riprap for controlling erosion along estuarine shores.

Waves of sediment stripe this sand shore, a testimony to the strong currents that frequently scour the borders of marine subsystems. High energy sand shores are often seemingly barren, but in many estuaries they are frequented by large numbers of juvenile salmonids, flatfish, and other species that feed in shallow shoreline areas at high tide. (P. Howell)

Flat

Broad intertidal flats commonly occur in slough and bay subsystems of Oregon estuaries. Large shallow flats store heat and may have an important role in the temperature budget of the entire estuary. They are generally sheltered from strong currents and wave action, and their gradual slopes tend to dissipate wave and tidal energies. As a result, flats form a relatively stable environment for colonizing species as reflected in the high density and diversity of organisms that generally live there.

Sediments of flats vary from fine mud to coarse cobble or gravel. Shallow depths, maximum light, and warm temperatures often result in extensive growths of algae during the spring and summer, when many of these flats may be classified as intertidal aquatic beds. Even where macrovegetation is not evident, the yellow-brown coloration at the surface of some mudflats suggests benthic diatoms may be a very significant source of production.

Cockle (*Clinocardium nutallii*), gaper (*Tresus capax*), butter (*Saxidomas giganteus*), littleneck (*Protothaca staminea*), and softshell (*Mya arenaria*) clams and mud (*Upogebia pugettensis*) and ghost (*Callianassa californiensis*) shrimp are frequently associated with Oregon mud and sand flats. Recreational clamming is popular in these areas during low tides, particularly in the spring and summer. Bottom feeding fishes graze over flats during high tide. Great blue heron (*Ardea heriodias*), great egret (*Casmerodius albus*), and a variety of shorebirds feed in the shallows as the tide recedes.

Benthic organisms of tideflats are specially adapted for particular grain sizes of sediment and the temperatures and exposure of an intertidal environment. Activities which alter sediment characteristics or tidal elevations can therefore be expected to influence benthic communities. Filling and dredging represent the most obvious threats to flat habitats. In the past broad flats

This productive mud/sand flat in Netarts Bay supports tremendous numbers of shrimp as evidenced by millions of tiny burrows that cover the surface as far as the eye can see. (P. Howell) have been filled to extend the area of level upland available for shoreland development in estuaries. In a few locations grounding of logs stored on intertidal flats and shores at low tide has decimated benthic populations (Zegers 1978). Accumulations of bark and wood debris near log storage sites contribute leachates, reduce oxygen levels, which can adversely affect subtidal and intertidal benthic communities. Sewage, fish wastes, or other organic pollutants discharged over flats may also accumulate in the sediments and reduce oxygen levels. Large numbers of opportunistic polychaetes (e.g. *Capitella capitata*) or other invertebrates indicative of degraded habitats colonize these areas, and species diversity decreases.

In some estuaries logging activities in the upper watershed have tremendously increased the rate of sedimentation. Tillamook Bay is a prime example of an estuary that has rapidly filled since the area was first settled. This has greatly increased the acreage of flats and decreased the area of subtidal habitat.

Because of their very high productivity and their role in temperature regulation and nutrient cycling, estuarine tideflats should be protected in local comprehensive plans. Dredge and fill; tideland log storage; pollutants, such as sewage and sulphite waste liquor; and activities that threaten circulation and sediment characteristics are of primary concern. Research is also needed to evaluate the feasibility and impact of habitat restoration in those few instances where filling has been extensive. In all cases strict regulation of activities in upper watersheds is imperative in maintaining the balance and diversity of habitat types within Oregon estuaries.

Beach/bar

Beach/bar habitats are highly dynamic environments subject to strong tidal currents and wave and river energies. Bars occur within estuaries as elongate ridges of coarse sand, cobble, or gravel, which are bordered by water on at least two sides. In Oregon, bars form during summer at the mouths of smaller blind estuaries and, in some cases, prevent marine water from entering the estuaries. Shifting bars also occur near the mouths of larger estuaries or in upper riverine sections. Because bars continually shift with the currents, colonization is limited to rapidly burrowing and opportunistic species, including molluscs, crustaceans, and polychaetes.

Shallow intertidal bars may extend as spits from shores near the mouths of estuaries. In larger systems these may be periodically dredged to provide access and a navigable route for ships passing through the estuary. Gravel removal operations have occurred on bars in the riverine sections of a few south coast estuaries. The impacts on these habitats and the estuary as a whole have not been studied. A sand bar that formed near the entrance of the Charleston boat basin in Coos Bay was colonized by a dense population of razor clams (*Siliqua patula*).

Tidal marsh

Tidal marsh habitats, characterized by rooted herbaceous or woody hydrophytes that grow between lower high tide and the line of non-aquatic vegetation, occur in many Oregon estuaries. These can be divided into four major subclasses: high and low salt marsh in marine and brackish areas and fresh and shrub marshes beyond saltwater influence. Community composition of these marshes varies with tidal elevation and frequency of flooding, sediment type, and salinity regime.

Salt marshes have been ranked among the most productive ecosystems in the world (Niering and Warren 1977). Plant producers in salt marshes include not only marsh grasses but also macroalgae entwined among the grass stems, microalgae on the mud surface, and phytoplankton in the water column. Organic

Well defined channels draining high marshes transport nutrients to and from the open waters of the estuary and provide habitat for fish, brids, and small mammals. Salt marshes retard shoreline erosion and purify water draining into the estuary by filtering out wastes and pollutants. (P. Howell) material and nutrients stored by marsh producers are consumed directly or transferred to other portions of the estuary as detritus.

Marshes are an important habitat for invertebrates, waterfowl, and small terrestrial mammals. A diversity of insects live in and graze on marsh grasses. Detritus-feeding snails, scavenging crabs, and a variety of amphipods and other invertebrates seek the food and/or protection of marshes. The well defined channels of high marshes in Oregon's bays and sloughs are heavily used by juvenile Dungeness crab (*Cancer magister*) and a variety of small fishes (e.g. *Gasterosteus aculteatus*). In some areas they may provide important rearing habitat for juvenile chinook salmon (Dunford 1972). Marshes also provide resting and feeding areas for large numbers of migrating waterfowl.

Estuarine marshes are important sediment traps that reduce the frequency of dredging required for navigation (Niering and Warren 1977). They help to stabilize the shore, dissipate flood waters, and protect shoreland property from storms. Marshes also filter and process nitrates, phosphates, and other wastes, thus providing a pollution buffer between adjacent upland activities and the estuary.

Tremendous areas of Oregon marsh have been diked to create upland for pasture and other uses. This has greatly reduced the habitat and productivity of the estuaries. Extensive diking of fresh marshes along riverine and other subsystems has altered marsh community composition, channelized the estuarine water course, reduced productive intertidal surface area, and restricted the transport of organic materials and nutrients to and from the estuary. Construction of causeways and roadbeds has similarly restricted tidal flow and modified marsh communities. Filling for shoreland development has sacrificed huge expanses of marsh in many Oregon estuaries. Clark (1977) notes "the higher the degree of shorelands development, the greater is the need to preserve coastal wetlands." In view of the extensive losses in many of our estuaries, comprehensive plans should prevent further draining, filling, diking, and polluting of estuarine marshes. The effects of breaching dikes to restore the natural functions of tidal marshes in the estuary should receive a high priority for research in Oregon, both as a means of habitat restoration and as potential mitigation for estuary filling.

ESTUARY CLASSIFICATION AND THE LCDC ESTUARINE RESOURCES GOAL

The LCDC Estuarine Resources Goal (1977b) establishes its own type of classification system to guide planning decisions in Oregon estuaries. The central concept of the goal is diversity--management of estuaries and areas within estuaries so that a wide range of uses and activities can occur without causing severe damage to the estuarine ecosystem. For planning purposes it is important to understand the relationship between the classification of estuaries described in this report and the classification established by LCDC (1977a,b).

To provide for a diversity of uses, the Estuarine Resources Goal (LCDC 1977b) requires that local comprehensive plans classify each estuary into management categories and "establish policies and use priorities for each management unit." The goal describes three types of management units--development, conservation, and natural--and defines the criteria for the areas included and the uses that will be allowed for each of these categories. Tables 4 and 5 describe the purpose, areas of concern, and permissible activities for each LCDC management unit.

LCDC also adopted an administrative rule (1977a) classifying estuaries according to "the most intensive level of development or alteration allowable." The classification designates shallow and deep draft development, conservation, and natural estuaries. Each of these categories includes specific management units. Development estuaries have all three types of management units; conservation estuaries have conservation and natural units; and natural estuaries only

Table 4. Purpose and area of concern for natural, conservation, and development management units in Oregon estuaries.[a]

Natural Management Unit

Purpose

To assure protection of significant fish and wildlife habitats, continued biological productivity, and scientific, research, and educational needs; To preserve natural resources in recognition of dynamic, natural, geological, and evolutionary processes.

Areas of Concern

At a minimum, all major tracts of salt marsh, tideflats, and seagrass and algal beds.

Conservation Management Unit

Purpose

For long-term uses of renewable resources that do not require major alterations of the estuary, except for the purpose of restoration; To conserve natural resources and benefits including areas needed for maintenance and enhancement of biological productivity, recreational and aesthetic uses, and aquaculture.

Areas of Concern

Tracts of significant habitat smaller or of less biological importance than Natural Management areas and oyster and clam beds. Partially altered areas or estuarine areas adjacent to existing development of moderate intensity (unless otherwise needed for preservation or development consistent with the Oregon Estuary Classification).

Development Management Unit

Purpose

To provide for navigation and other identified needs for public, commercial, and industrial water-dependent uses, consistent with the level of development or alteration allowed by the Oregon Estuary Classification.

Areas of Concern

Deep-water areas adjacent or in proximity to the shoreline, navigation channels, subtidal areas for in-water disposal of dredged material and areas of minimal biological significance needed for uses requiring alteration of the estuary.

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[a] *Management Unit designations from LCDC (1977b).*

Table 5. Permissible uses for natural, conservation, and development management units in Oregon estuaries.[a]

Natural Management Unit

1. Undeveloped low-intensity water-dependent recreation
2. Research and educational observation
3. Navigation aides, such as beacons and buoys
4. Protection of habitat, nutrient, fish, wildlife, and aesthetic resources
5. Passive restoration measures

And, where consistent with the resource capabilities of the area and the purposes of this management unit:

6. Aquaculture
7. Communication facilities
8. Active restoration measures

Conservation Management Unit

1. Uses allowed in natural management unit
2. Active restoration measures
3. Aquaculture
4. Communication facilities

And, where consistent with the resource capabilities of the area and the purposes of this management unit:

5. High-intensity water-dependent recreation
6. Maintenance dredging of existing facilities
7. Minor navigational improvements
8. Mining and mineral extraction

Development Management Unit

1. Uses allowed in Natural and Conservation Management Units
2. Navigation
3. Water-dependent commercial and industrial uses

And, where consistent with the resources capabilities and purposes of this management unit:

4. Water-related and non-dependent, non-related uses not requiring fill
5. Mining and mineral extraction.

As appropriate needs for the following uses also shall be included:

a. Dredge or fill as allowed in the LCDC Goal
b. Water transport channels where dredging may be necessary
c. Disposal of dredged material
d. Water storage area where needed for products used in or resulting from industry, commerce, and recreation
e. Marinas
f. Aquaculture
g. Extraction of aggregate resources
h. Restoration

[a] *Permissible uses from LCDC (1977b).*

have natural management units. Table 6 describes LCDC's "Oregon Estuary Classification" and shows how each estuary has been categorized.

The LCDC estuary classification is based on existing development patterns, rather than physical or biological characteristics. Development estuaries have maintained jetties and channels associated with ship or small boat traffic. Conservation estuaries lack maintained jetties but have urban development along adjacent shorelands. Natural estuaries have no jetties and no urban development.

Figure 10 shows the relationship between the LCDC classification of estuaries according to allowable activities and the classification we have prepared based on physical characteristics. Although the LCDC classification includes a diversity of activities among estuaries, these uses are not distributed uniformly among different estuary types. For example, all development estuaries are large drainage/drowned river systems, while natural estuaries are small bar-built, drowned river, or blind estuaries with small drainages. There are only two natural estuaries among the 14 Coast Range systems, while three of the six Klamath estuaries are designated as natural.

Development patterns have been a major factor influencing future management goals for Oregon estuaries. However, the estuaries classified for development are often the most biologically productive. Large drainage/drowned river systems in this category are often characterized by large intertidal vegetated flats and a high diversity of species and habitat types. In order to protect the diversity of Oregon estuaries, comprehensive plans must carefully protect the range of estuary types as well as the habitats and communities within them. This is especially important in the larger conservation and development estuaries, where the potential for environmental degradation is greatest.

Table 6. LCDC Oregon estuary classification (LCDC 1977a)[a].

Category	Definition	Estuary
Natural	Estuaries lacking maintained jetties or channels, and which are usually little developed for residential, commercial, or industrial uses. They may have altered shorelines, provided that these altered shorelines are not adjacent to an urban area. Shorelands around natural estuaries are generally used for agriculture, forest, recreation, and other rural uses. Natural estuaries shall have only natural management units.	Sand Lake Salmon River Elk River (Curry Co.) Sixes River Pistol River
Conservation	Estuaries lacking maintained jetties or channels, but which are within or adjacent to urban areas which have altered shorelines adjacent to the estuary. Conservation estuaries shall have conservation and natural management units.	Necanicum River Netarts Bay Nestucca River Siletz Bay Alsea Bay Winchuck River
Shallow draft development	Estuaries with maintained jetties and a main channel (not entrance channel) maintained by dredging at 22 feet or less. Shallow draft development estuaries shall have development, conservation, and natural management units.	Tillamook Bay Depoe Bay Siuslaw River Umpqua River Coquille River Rogue River Chetco River
Deep draft development	Estuaries with maintained jetties and a main channel maintained by dredging at deeper than 22 feet. Deep draft development estuaries shall have development, conservation, and natural management units.	Columbia River Yaquina Bay Coos Bay

[a] *From Oregon Administrative Rule adopted according to ORS 197.040(1)(b). Nehalem estuary was not classified by LCDC.*

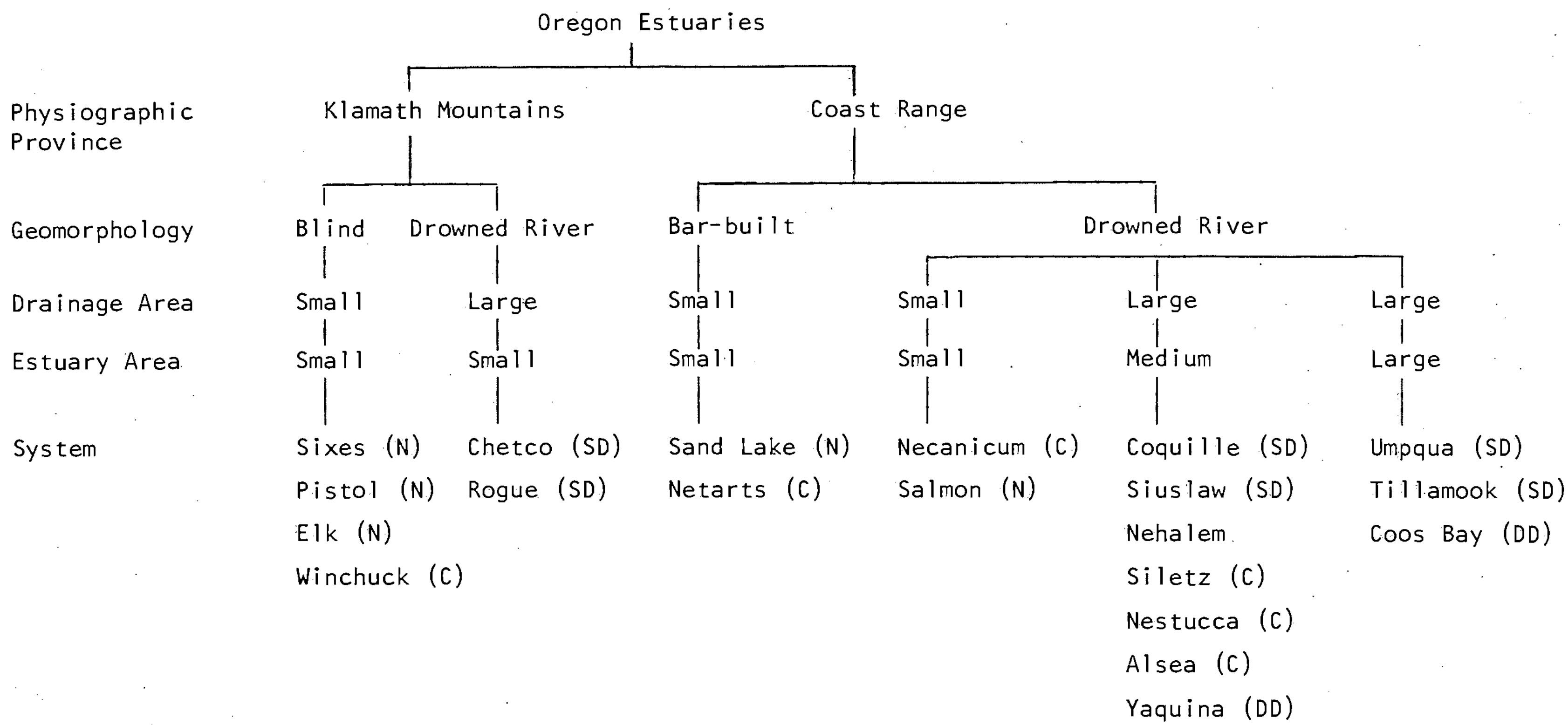

Fig. 10. Comparison of LCDC's Oregon estuary classification based on intensity of development with the proposed physical classification of Oregon estuaries.[a]

[a] *LCDC estuary types shown in parentheses: (N) Natural (C) Conservation (SD) Shallow Draft Development (DD) Deep Draft Development.*

The designation of management units as specified in the Estuarine Resources Goal (LCDC 1977b) will determine the balance between development and resource protection within each Oregon estuary. Although the goal broadly defines the purpose of each management unit, the size of a unit and its location in relation to other management units will be established in each local comprehensive plan. Local comprehensive plans should designate the size and location of management units that will insure protection of major ecological subunits. This may correspond to specific habitats, groups of habitats, or entire subsystems. The classification of estuarine subsystems and habitats (Fig. 9) can be useful in superimposing LCDC management boundaries over functional ecological units.

To a large degree the Estuarine Resources Goal is already directed toward the use and protection of habitats. For example, it specifically requires that "all major tracts of salt marsh, tideflats, and seagrass and algae beds" (LCDC 1977b) be included in natural management units, while deep water habitats near shorelines and navigation channels are suggested as potential development sites. The emphasis on maintaining a diversity of uses and resources within estuaries further suggests that the range of habitats should be identified in planning inventories, so that examples of each type can be protected in the comprehensive plan. The proposed classification system (Fig. 9) categorizes the diversity of habitats represented in Oregon estuaries, including those that are specifically mentioned in the Estuarine Resources Goal.

Although management unit boundaries may be defined by habitat types, it is not sufficient to merely protect a variety of habitats. Habitats, their associated communities, and the processes that characterize them are interrelated. Management based solely on individual habitats may not protect the areas intended or provide for the uses that are most needed. Activities in adjacent natural and development management units, for example, may be incompatible due to the interactions between habitats and communities nearby.

The subsystems illustrated in Fig. 7 represent larger ecological units characterized by distinct habitat and community assemblages. The habitats within these subsystems interact and are influenced by an array of environmental factors such as flow, salinity, energy regime, sediment type, and organic carbon sources. The designation of management units and the policies regulating their use must take into account the interactions between habitats at the subsystem level of organization.

Shoreland and estuarine activities tend to be segregated by subsystem. For example, agricultural uses often occur along riverine subsystems, which require different management strategies than marine subsystems where commercial development is often focused. This also suggests that the subsystem may be the logical level for management unit designations in many cases. Resource inventories should identify and classify estuaries into subsystems as well as habitats to identify the diversity of subsystem types and to allow planners to select the most appropriate form of management.

Existing land and water uses and the distribution of habitats within a large subsystem may warrant more than a single management designation for that particular region. Functional units or habitat assemblages can be identified within large subsystems. A major marsh-mudflat complex, for example, generally justifies a distinct management designation from the dredged channel within the same subsystem. Policies within a given development unit must provide for adequate protection of natural or conservation units within the same subsystem.

The LCDC (1977a,b) classification of estuaries and management units constitutes broad development goals. Management units are established to permit development in suitable locations and to protect other areas from environmental alteration and degradation associated with construction, fill and removal, and commercial and agricultural operations. However, the most complicated resource problems remain after the management units are designated. Policies for each unit, siting decisions for particular development proposals, and performance standards for permissible uses must consider not only direct habitat losses, but also indirect and oftentimes subtle effects on the estuary as a whole. The timing of pollutant discharges or dredging in relation to mixing and flushing characteristics; the size, timing, and numbers of private hatchery salmon released in an estuary; or the cumulative effects of numerous small activities on the entire system extend well beyond the immediate location of the activity or the broad management designation governing it.

Estuary planning in Oregon, like the habitat classification system we have proposed, represents a hierarchy from broad to specific. As planning advances from general guidelines to decisions controlling specific projects, increasingly detailed resource data will be required. Fig. 11 illustrates the relationship between estuary development plans and the resource information needed to evaluate and implement these plans.

As we have shown, broad management designations can be determined on the basis of relatively broad inventories that classify the communities, habitats, and subsystems in each estuary. As general policies are established within each management unit and as specific development proposals are made, more detailed and site-specific inventories and classifications will be necessary to evaluate the potential impact on a given site. However, environmental impact analyses must also consider effects beyond the immediate area, and simple inventories alone are not sufficient. The more detailed questions of estuary-wide impacts demand predictive capabilities requiring systems analysis, modelling techniques, and studies of causal relationships. Data requirements do not stop

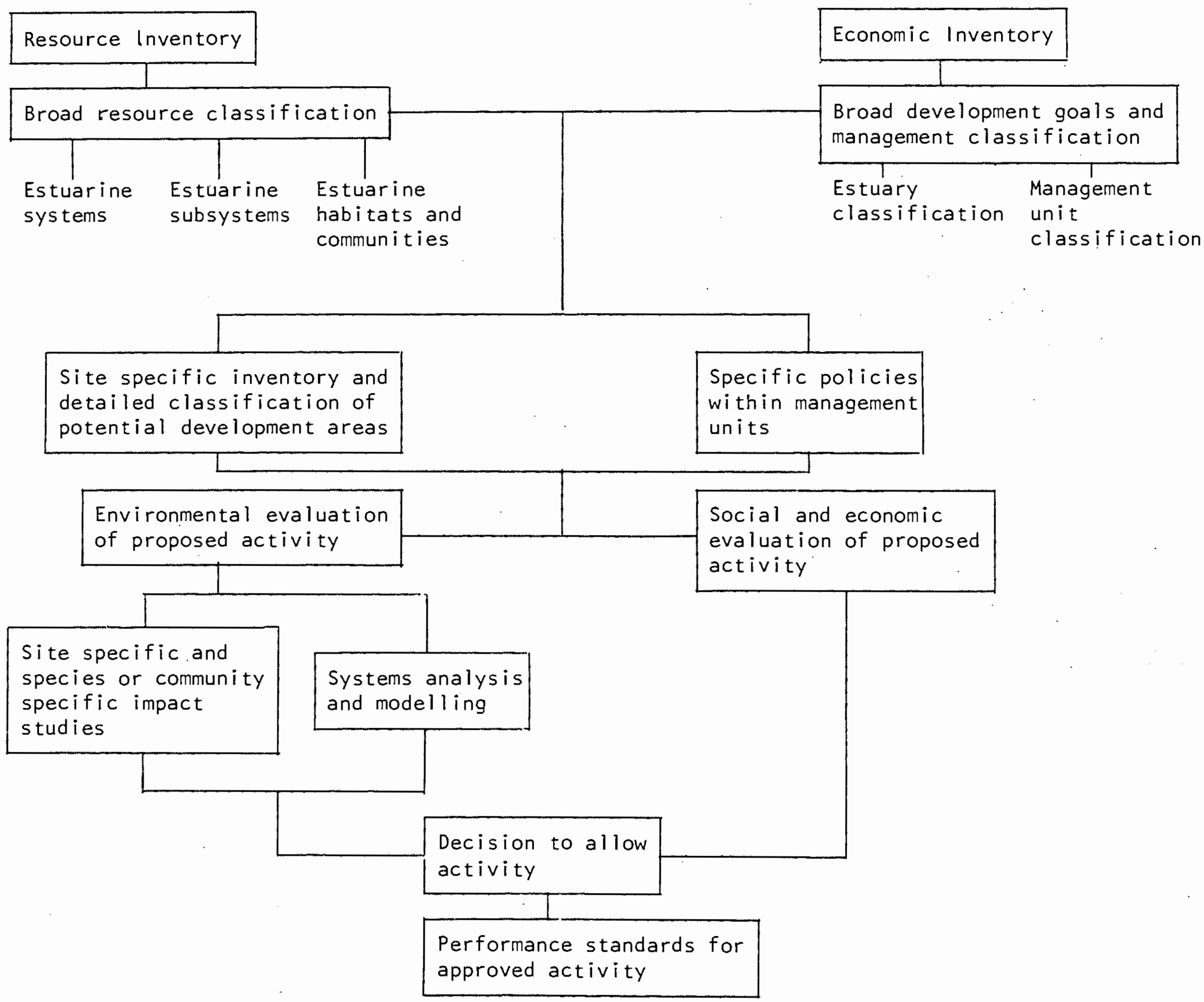

Fig. 11. Relationship between resource data collection and decisions governing estuary uses.

with the resource inventories nor does management cease with the desgination of natural, conservation, and development areas. Research must keep pace with development plans, particularly as development in estuaries proceeds, and the potential for detrimental impact through intense multiple use increases.

PART II - Resource Inventories For Estuary Planning and Management

INTRODUCTION

Since the LCDC Estuarine Resources Goal (1977b) requires broad management unit designations and evaluations of site-specific development proposals, basic physical and biological information about each Oregon estuary must be available. The goal includes some general guidelines for the types of resource data that should be assembled in a planning inventory (Table 1), but it does not detail how this information should be used in the inventory or the comprehensive plan. The goal also calls for the Department of Land Conservation and Development (LCDC) with the assistance of other agencies to develop more comprehensive inventory guidelines and to standardize methods for data collection. As part of this project, we have developed a more specific list of estuary inventory standards and have compiled existing inventory data for many Oregon estuaries.

Table 1. LCDC (1977b) guidelines for estuarine resource inventories.

In detail appropriate to the level of development or alteration proposed, the inventories for estuarine features should include:

1. Physical characteristics

   A. Size, shape, surface area, and contour, including water depths;
   B. Water characteristics including, but not limited to, salinity, temperature, and dissolved oxygen. Data should reflect average and extreme values for the months of March, June, September, and December as a minimum; and
   C. Substrate mapping showing location and extent of rock, gravel, sand, and mud.

2. Biological characteristics
   Location, description, and extent of:

   A. The common species of benthic (living in or on bottom) flora and fauna;
   B. The fish and wildlife species, including part-time residents;
   C. The important resting, feeding, and nesting areas for migrating and resident shorebirds, wading birds and wildfowl;
   D. The areas important for recreational fishing and hunting, including areas used for clam digging and crabbing;
   E. Estuarine wetlands;
   F. Fish and shellfish spawning areas;
   G. Significant natural areas; and
   H. Areas presently in commercial aquaculture.

RESOURCE INVENTORY GUIDELINES

In developing standards for planning inventories, we have concentrated on information needed to classify estuarine habitats and to describe the major environmental factors influencing particular habitats and the estuary as a whole. The inventory standards were designed to include physical and biological characteristics needed to designate management units and establish general planning and management policies within them.

The guidelines we have suggested do not address the more detailed types of research (e.g. ecological models, bioassays) that may be necessary to adequately predict the impact of a specific proposal. These research needs will become increasingly important as the estuary management program is further defined (Part I, Fig. 11).

Guidelines for physical and biological resource inventories are given in Appendix Tables B and C. In addition to listing the estuarine data needed, suggested planning, management, and research applications of that data are included. Suitable methods for data collection based on previous and proposed studies are also briefly outlined. In those cases where the data are already available for many or all Oregon estuaries, the source of information is shown.

Inventory of Physical Characteristics

The guidelines for physical data (Appendix Table B) range from general descriptions of the estuary basin to more specific definitions of the processes of each estuary. Generally there are three major criteria for the physical data listed in the guidelines:

1) Many of the data categories in Appendix Table B directly or indirectly influence the abundance and distribution of biological communities in estuaries. Physical factors such as hydrological characteristics,

water quality, or sediment type are necessary to determine relationships between species and habitat distributions. The potential impact of changes in the physical environment should be a prime consideration in selecting management alternatives and evaluating development proposals.

2) Some of the data--drainage area and river discharge, estuary shape, surface area, and sediment type--are needed to apply the proposed estuary and estuarine habitat classification system (Part I, Figs. 6 and 9).

3) Hydrological characteristics (circulation, mixing, and flushing) are not only important biologically, but are needed to predict the movement of pollutants and the effects of local alterations on the estuary. The flow of water and the distribution of water-born materials in each subsystem determine whether the effects of development will be localized or transported to other areas and whether pollutants will remain for long periods or will be quickly flushed from the estuary.

4) Past and current water and sediment quality data are key indicators of the environmental conditions of an estuary, which should be considered by planners when establishing suitable locations for and the intensity of future development. An ongoing water quality sampling program to continually monitor the effect of the management program is particularly important in estuaries classified for development.

Inventory of Biological Characteristics

The designation of management units requires judgements concerning the most appropriate uses of specific sites within each estuary. The resource inventory should identify and describe the distribution of important species in estuarine food chains. Whenever possible, life histories and distributions should be correlated with habitats and/or subsystems, so that critical areas for feeding, reproduction, rearing, and other life functions can be protected in the comprehensive plan.

The biological data suggested for a resource inventory are shown in Appendix Table C. The list includes all major plant and animal groups that occur in the sediment or water column. Among the data categories are plant groups (e.g. marshes, algal and eelgrass beds) that also provide habitat for other plant and animal species.

In addition to the identification and classification of major plant groups, the guidelines have also singled out plant productivity as an important factor for estuary planning. Because plants function as the source of carbon that fuels estuarine food chains, relative productivity of various plant communities is particularly important in managing development estuaries. There is currently very little information concerning plant production in Oregon estuaries.

The list of inventory data in Appendix Table C is similar for most groups of species and includes broad survey data for each estuary to:

1) identify the diversity of species utilizing the estuary,
2) describe the seasonal and, in some cases, historical distribution of species or communities,
3) determine relative abundance or biomass of each species or community as an indication of their contribution to estuarine productivity,
4) correlate water quality or sediment data (Appendix Table B) with observed distributions and relative abundance.

RESEARCH NEEDS FOR OREGON ESTUARIES

The inventory guidelines in Appendix Tables B and C provide a standard for evaluating the adequacy of existing resource data for planning and management of Oregon estuaries. To complete such an evaluation, we have reviewed published and unpublished data for 16 Oregon estuaries.

Physical Characteristics

Table 2 summarizes the current physical data for Oregon estuaries in relation to the data categories listed in the inventory guidelines. The major inventory needs are briefly highlighted below:

Physical dimensions

Many Oregon estuaries lack published base maps at a scale sufficient for planning or plan implementation. In most cases DSL tideland maps at a scale of 1:12000 provide an adequate planning base. However, these maps do not extend to the head of tide of most estuaries, and, consequently, do not include the entire estuary as defined by the Estuarine Resources Goal (LCDC 1977b). There are no DSL base maps for the smaller south coast estuaries -- the Elk, Sixes, Pistol, and Winchuck. Although a 1:12000 scale is generally adequate for planning purposes, a larger scale is preferable for plan implementation. Planning base maps (1:12000) and implementation base maps (1:3600) which include the entire estuary should be established for all major Oregon estuaries (Part I, Fig. 1).

Surface area measurements for many Oregon estuaries are inaccurate due to the inadequacy of existing base maps. DSL tideland maps are drawn to the line of Mean High Water (MHW), which excludes high marshes above that point. Since many of these maps do not extend to the head of tide, surface area measurements may be further underestimated. Planners require accurate estimates of the total area of each major habitat type in each estuary to monitor changes in the extent and diveristy of habitats and to determine appropriate uses for specific estuarine locations.

Table 2. Physical and chemical data available for major Oregon estuaries.[a]

	Necanicum	Nehalem	Tillamook	Netarts	Sand Lake	Nestucca	Salmon River	Siletz	Yaquina	Alsea	Siuslaw	Umpqua	Coos	Coquille	Rogue	Chetco
PHYSICAL DIMENSIONS																
Estuary Base Map	+	Δ	Δ	+	Δ	Δ	+	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
Drainage Area	+	+	+	+	+	+	+	+	+	+	+	Δ	Δ	Δ	+	+
Estuary Shape		Δ	+	+			Δ	Δ	+	Δ	Δ	Δ	Δ			Δ
Surface Area	Δ	Δ	Δ	+	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
Water Depth		Δ	+	+					+		Δ	Δ	+	Δ	Δ	Δ
CLIMATE																
Wind	Δ	Δ	+	Δ	Δ	Δ	Δ	Δ	+	Δ	Δ	Δ	+	Δ	Δ	Δ
Precipitation	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Fog			+				Δ		+		Δ	Δ	+			
HYDROLOGICAL CHARACTERISTICS																
Tidal Levels		Δ	Δ	Δ					Δ		Δ	Δ	Δ	Δ		
Tidal Wave		Δ	Δ	+			Δ	+	+	+	+	Δ	+			Δ
Wind Waves			Δ	Δ									Δ			
River Discharge	Δ	Δ	Δ	Δ		Δ	Δ	Δ	Δ	Δ	+	Δ	Δ	Δ	Δ	Δ
Flushing			Δ	+			Δ	Δ	+	Δ	Δ	Δ	Δ			Δ
Mixing			Δ	+			Δ	Δ	+	Δ	Δ	Δ	+			Δ
Circulation			Δ	+				Δ	+	Δ	Δ	Δ	Δ			Δ
WATER QUALITY																
Monitoring Program	Δ	Δ	Δ	Δ		Δ	Δ	Δ	+	Δ	Δ	Δ	Δ	Δ	Δ	Δ
Supplemental[b] Monitoring																
SEDIMENTS																
Accretion and[c] Erosion		+	+	+					+				+			
Particle Size	Δ		+	+				Δ	+	Δ	Δ		+			
Sediment Quality			Δ	+					+		Δ					

[a] *A plus (+) is shown where data are available which satisfy the Data Needs column of Appendix Table 3 and have been collected by methods suggested. Incomplete data are indicated by a delta (Δ). All blank spaces indicate that data are unreliable or absent.*

[b] *These data are most appropriately collected on a case by case basis and are therefore not evaluated in this table.*

[c] *Available sediment data are delineated on base maps for all estuaries (e.g. ODFW 1978).*

Information on the depths of many Oregon estuaries is also lacking. Most soundings for Oregon estuaries are available from U.S. Army Corps of Engineers (USACE) dredging reports and National Ocean Survey (NOS) charts. These data are generally confined to the lower subtidal and dredged portions of larger estuaries. Depth information is useful in understanding biological distributions and observed circulation and mixing characteristics, monitoring erosion and desposition rates, and siting proposed facilities. Depth profiles to the head of tide are needed for most Oregon estuaries.

Hydrological characteristics

The LCDC Esutarine Resources Goal (1977b) defines a number of estuarine boundaries in relation to tidal datums. The Oregon Estuarine Habitat Classification System (Part I, Fig. 9) employes some of these same definitions. However, most existing tidal information does not correspond with the LDCD definitions. The DSL tideland maps only show boundaries for MHW and Mean Low Water (MLW). For a few larger estuaries, NOS charts plot soundings relative to a MLLW datum. There are no maps clearly defining the line of non-aquatic vegetation or MHHW, as LCDC defines the upland/estuary boundary. Although habitats have been classified and mapped for most Oregon estuaries (ODFW 1978), intertidal/subtidal boundaries at ELW are gross estimates from aerial photos and field observations. Tide gauges exist in some of Oregon's larger estuaries and additional gauges should be placed so that tidal boundaries defined by LCDC can be drafted on appropriate base maps.

Most hydrological data for Oregon estuaries are very sketchy. Some information on mixing, circulation, and flushing are contained in student theses for several estuaries. But these studies do not include the seasonal range of flow conditions or major tributaries. The only reported mixing data for many estuaries are from Burt and McAlister (1959), who classified the mixing types of Oregon estuaries from a very limited number of sampling periods and stations during 1959.

Circulation and flushing characteristics are basic for an understanding of biological and material distributions in estuaries and are needed to evaluate the siting and operation of proposed developments. A standard physical inventory program should be developed to characterize mixing and circulation patterns and flushing characteristics for all conservation and development estuaries.

<u>Water quality</u>

The Oregon Department of Environmental Quality (DEQ) maintains a water quality monitoring program for Oregon estuaries. Data collected include temperature, salinity, dissolved oxygen, BOD, pH, turbidity, coliform, and streptococci. Tillamook, Coos, and Yaquina estuaries are sampled regularly three times per year, while other estuaries are sampled three times every third year. Sampling stations are not always distributed throughout the estuaries or on all major tributaries, which precludes a fully representative profile of water quality.

Ideally, a water quality monitoring program should sample conservation and development estuaries seasonally. Sampling should include upper riverine sections to estimate non-point sources of pollution from agricultural and other land uses. Conditions in riverine and slough subsystems during periods of low flow and poor flushing may be particularly important. In development estuaries, annual or semi-annual surveys covering 24-hour periods at a few select sites would help to document daily fluctuations in water quality. Because many water quality parameters are also important to biological and physical surveys, monitoring programs should be designed to maximize their value to estuarine researchers. Salinity profiles from surface to bottom, for example, could be valuable in characterizing seasonal mixing processes.

Sediments

Sediment particle size and organic content are major factors influencing benthic community composition and distribution in estuaries. Since many fish feed heavily on benthic organisms, their distribution is indirectly related to sediments as well. The Oregon Estuarine Habitat Classification System (Part I, Fig. 9) relies on sediment type as a primary factor defining estuarine habitats and associated communities, which are essential considerations in estuarine planning. Sediment type and quality are also important data to consider in dredge disposal planning in development estuaries.

Sediment distribution has been studied in some detail in Tillamook (Avolio 1973), Netarts (Stout 1976), and Yaquina (Kulm and Byrne 1967) estuaries. Surveys of clam beds in many estuaries provide qualitative data on substrate distribution. Sediment types shown on ODFW habitat maps (1978) reflect data from the literature on qualitative observations. Complete sediment surveys should be conducted in conjunction with benthic invertebrate studies, particularly in conservation and development estuaries.

Biological Characteristics

Table 3 indicates a large gap of basic inventory information on many plant and animal groups in Oregon estuaries. The most notable deficiencies are briefly described below:

Algae

Studies of phytoplankton and benthic micro- and macroalgal communities are primarily scattered among student reports and theses for a few estuaries. Habitat maps classifying algal "aquatic beds" (ODFW 1978) are based on aerial photos and field observations from only a single summer. The LCDC Estuarine Resources Goal (1977b) emphasizes that all major algal beds should be included in a natural management designation. Despite the assumed importance of algal

Table 3. Biological data available for major Oregon estuaries.[a]

	Necanicum	Nehalem	Tillamook	Netarts	Sand Lake	Nestucca	Salmon River	Siletz	Yaquina	Alsea	Siuslaw	Umpqua	Coos	Coquille	Rogue	Chetco
MICROALGAE																
Communities and distribution				Δ					+	Δ			Δ			
Productivity				Δ					+							
MACROALGAE																
Communities and distribution[b]				+					Δ				Δ			
Associated animal species									Δ							
Productivity									Δ							
SEAGRASS																
Communities and distribution[c]				+				Δ					Δ		*d*	*d*
Associated animal species				Δ									Δ			
Productivity				+				Δ								
TIDAL MARSHES																
Communities and distribution	Δ	+	Δ	+	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	+	Δ	Δ	Δ
Diked marsh							Δ						+			
Historical change		+	+	+				Δ		Δ			Δ			
Associated animal species				*e*		*e*					Δ		+			
Productivity		+		*e*		*e*							Δ			
ZOOPLANKTON																
Communities and distribution				+					+	+			Δ			

Table 3. (Continued)

	Necanicum	Nehalem	Tillamook	Netarts	Sand Lake	Nestucca	Salmon River	Siletz	Yaquina	Alsea	Siuslaw	Umpqua	Coos	Coquille	Rogue	Chetco
INVERTEBRATES																
Shellfish	Δ	Δ	Δ	+	Δ	Δ	Δ	Δ	+	Δ	Δ	Δ	Δ	Δ		
Crabs			Δ	+	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ			
Other benthic invert.				Δ					Δ				Δ			
FISH																
Communities and distribution	Δ	Δ	+	Δ	Δ	Δ	Δ	Δ	+	Δ	+	+	Δ	Δ	Δ	Δ
Fishing areas		Δ	Δ	Δ		Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
BIRDS																
Communities and distribution	Δ	+	+	+		Δ	Δ	Δ	+	Δ	Δ		+			
Hunting areas																
Bird watching areas									Δ							
MAMMALS																
Marine species		Δ	+	+		Δ		Δ	+	Δ	Δ		+			
Terrestrial species		Δ		+		Δ	Δ	Δ	+	Δ	Δ		Δ			

[a] *A plus (+) is shown where data are available which satisfy Data Needs column of Appendix Table C and have been collected by methods suggested. Incomplete data are indicated by a delta (Δ). All blank spaces indicate that data are unreliable or absent.*

[b] *Algal beds are delineated on base maps for all estuaries (ODFW 1978).*

[c] *Eelgrass beds are delineated on base maps for all estuaries (ODFW 1978).*

[d] *No eelgrass is reported for the Rogue and Chetco estuaries.*

[e] *Research in progress on productivity and invertebrate and fish utilization of Netarts and Siletz marshes (Morgan and Holton 1977).*

communities at the base of food chains in Oregon estuaries, there have been no extensive quantitative surveys of the seasonal distribution, composition, biomass, or productivity of micro- or macroalgal communities. Nor has the importance of various macroalgal communities as habitat for invertebrates, fish, and birds been studied.

Seagrasses

Eelgrass species have also received little research attention in Oregon. The U.S. Environmental Protection Agency (EPA) is currently studying the productivity of *Zostera marina* in the Netarts and Siletz estuaries (Morgan and Holton 1977). ODFW habitat maps (1978) indicate approximate summer distribution from aerial photos and field observations. However, seasonal changes in cover and biomass have not been documented, nor have concurrent changes in associated benthic species been studied. There has been no research in Oregon on a second species of eelgrass, *Z. nana*, which has been discovered at higher intertidal elevations in a number of estuaries. Basic seasonal surveys of eelgrass distribution, biomass, and associated animal species are needed for most Oregon estuaries.

Tidal marshes

Jefferson (1975; Akins and Jefferson 1973) has conducted broad surveys of salt marsh communities in Oregon estuaries. ODFW habitat maps (1978) show the approximate distribution of high and low salt, fresh, and shrub marshes. However, neither of these sources map distribution to the head of tide on all estuaries. The results of current EPA studies of marsh productivity (Morgan and Holton 1977) in the Siletz and Netarts estuaries may be applied to other estuaries if biomass or density of cover are determined for similar marsh types in these other systems.

Tremendous expanses of salt marsh have been diked in Oregon, producing a significant impact on many estuaries. There have been no comprehensive surveys of diked marshes to the head of tide on most Oregon estuaries, although some have been identified on ODFW habitat maps (1978). Breaching dikes on salt marshes is a possible method of habitat restoration or mitigation for estuary filling as specified in the LCDC Estuarine Resources Goal (1977b). Surveys should document the location and ownership of diked marshes, the state of repair or disrepair of dikes and tidegates, and the species composition and stage of succession for each diked marsh community. Studies are needed to evaluate the impact of dike removal and to compare the utilization of diked and undiked marshes by birds, mammals, and invertebrates. A study of the Salmon River estuary (Morgan and Holton 1977) will provide data concerning plant succession in a high marsh following dike breaching, but additional research is required to document changes in animal utilization after removing dikes on this and other marsh types.

Zooplankton and invertebrates

Zooplankton surveys are available from reports and theses for the Netarts (Zimmerman 1972), Yaquina (Frolander et al. 1973; Zimmerman 1972), and Alsea (Matson 1972) estuaries only. Studies of the distribution and abundance of larval crab and clam species would be valuable for most estuaries. Crab larvae are abundant in many estuaries during the summer, but the growth and survival of crabs from larvae to adults in Oregon estuaries has not been studied.

Most benthic invertebrate surveys have been restricted to adult clams and crabs. ODFW has been conducting surveys of clam and shrimp populations in many estuaries (Hancock et al. 1979). However, information concerning age classes, harvest rates, and spawning periods is lacking for most systems. ODFW resource use surveys (e.g. Gaumer et al. 1973) provide crab harvest data by summer month for many estuaries, but the distribution, relative abundance, size class, and annual variability in the sport catch of Dungeness (*Cancer magister*) and red rock (*C. productus*) crabs have not been documented.

There have been few general surveys of benthic invertebrate communities in Oregon. Limited information is available from student reports and theses for Netarts (Stout 1976), Yaquina (Markham 1967), and Coos (Jefferts 1977; USACE 1975) estuaries. Because changes in the estuary bottom brought about by dredging, filling, alteration of flow patterns, and other disturbances have a direct effect on the benthic community in the area, information concerning the composition, distribution, and abundance of benthic invertebrates is essential for planners to designate appropriate uses for particular sites in the estuary. The identification of characteristic invertebrate assemblages is also needed to define the major types of habitats that occur in Oregon estuaries.

Fish

There have been a number of studies of fish communities in Oregon estuaries. A 2.5-year survey was completed on Tillamook Bay (Bottom and Forsberg 1978; Forsberg et al. 1977). Less extensive sampling programs were conducted on the Coos (Cummings and Schwartz 1971; Hostick 1975), Umpqua (Mullen 1977), and Netarts (Stout 1976) systems. ODFW annual surveys have been conducted on the Siuslaw, Umpqua, and Coos estuaries; and a 6-month study of Yaquina Bay fishes was completed by EPA; however, the results of these surveys have not yet been published. ODFW also completed sportfishing creel surveys for many Oregon estuaries (e.g. Gaumer et al. 1973), and there are plans to update these in 1981. Most other ODFW fish studies have been related to salmonids and hatchery operations (e.g. Reimers 1974). The only published survey of larval fishes was conducted on the Yaquina estuary (Pearcy and Myers 1974). Other studies on Yaquina Bay have emphasized particular species of interest (Beardsley 1969; Gnose 1968).

Despite these recent efforts to catalog and describe estuarine fishes, general surveys covering annual periods are lacking for many Oregon estuaries. Where broad inventories have been conducted, species of interest need to be defined in order to complete in-depth studies of life history, food habits, and habitat requirements. Concurrent studies of food habits and benthic or epifaunal invertebrate distributions are needed to determine feeding habitats for estuarine-dependent species. As fish surveys are completed for a variety of estuary types, species composition, abundance, and distribution should be compared with the habitat types in each stream to help determine the habitat requirements of fishes found in Oregon estuaries.

Birds and mammals

Inventory information concerning birds and mammals of Oregon estuaries is not extensive. Little quantitative data are available for estuarine use by waterfowl and shorebirds. Most data consist of species lists, sometimes indicating qualitative categories of relative abundance (Batterson 1971; Bayer 1978). The USACE Wetlands Reviews for the Alsea (USACE 1976a), Nehalem (USACE 1976b), and Siletz (USACE 1976c) estuaries list presence or absence of species by habitat type. Information concerning specific habitat requirements is very limited. Waterfowl hunting and bird watching may also be important considerations in comprehensive estuary plans, but published information is lacking.

Data concerning marine mammals in Oregon are also generally qualitative (USACE 1976a,b,c). Ongoing studies of population, growth, and feeding habits of harbor seals in Netarts and Rogue estuaries (Morgan and Holton 1977) will provide the most quantitative information to date concerning the utilization of estuaries by marine mammals.

Although there are qualitative listings of terrestrial mammals for several estuaries (e.g. USACE 1976 a,b,c), community composition and abundance by habitat type are generally unavailable.

Research Priorities

As planning proceeds and development goals identified in local plans are implemented, basic inventory data will become increasingly important to all local, state, and federal agencies involved in estuary management. A standard, coordinated inventory program to provide this information is essential to ensure that the most pressing research needs have priority, that research time and dollars are spent most effectively, and that results achieve a high degree of transferability. The Oregon Estuarine Research Council, composed of state and federal agencies and institutions, could help to coordinate research efforts and prevent duplication in future estuary inventories.

Establishing priorities for estuarine resource inventories in Oregon is difficult, since the list of data needed is both long and broad. Life history studies, primary productivity measurements, and hydrologic and faunal surveys are all important research needs at this early stage of estuary planning and management. To date the most extensive research has been on large development systems, including Coos, Tillamook, and Yaquina estuaries. Among conservation estuaries, the most comprehensive inventories are from the USACE Wetlands Reviews for the Alsea (USACE 1976a), Siletz (USACE 1976c), and Nehalem (USACE 1976b) systems and a student research project on the Netarts estuary (Stout 1976). Generally, there has been very little research on the smaller south coast estuaries classified by LCDC (1977a) for development or conservation. The potential and pressure for development of these systems combined with the lack of available resource data suggest that the following estuaries receive the highest priority for research: Siuslaw, Umpqua, Coquille, Rogue, and Chetco. Among conservation estuaries, the Necanicum and Nestucca are in greatest need of inventory work.

Although there is more immediate need for research on particular development and conservation estuaries, natural systems may provide the best opportunity for studies of undisturbed habitats or communities. Smaller unaltered systems may be very useful for modelling and studies of factors influencing species distributions. Results of this research may be applied and tested in larger, more complex systems.

Research design and methods that provide information which is useful beyond the immediate focus of a particular research project may be as important as the specific subject matter of the study. Standard methods for collecting, analyzing, and reporting ecological data are needed so that results are comparable from one study site to another. Habitat classification provides a standard means of organizing resource inventories and survey findings and assembles the information in a highly usable form for planners and resource managers. Representative estuary types should be selected to maximize the application of findings to other similar estuaries and to define subsystem habitat-community associations that will verify or modify the Oregon Estuarine Habitat Classification System (Part I, Fig. 9). The classification of estuary types (Part I, Fig. 6) may be useful in selecting appropriate estuaries for this research.

The timing of research activity is equally critical. Surveys of impact studies frequently are initiated long after development plans are well underway. As a result, findings often lag behind the important phases of decision-making. Impact studies should not be confined to short-term analyses of specific alterations but should also assess long-term effects of development projects and the cumulative results of a large number of activities. Standard indicator species should be selected for bioassays and studies to monitor chronic impacts and the synergistic effects of increasing levels of development in estuaries.

A combined program of broad inventories for general planning applications together with detailed research on estuarine processes and the impact of alterations would best serve immediate and long-term planning needs in Oregon estuaries. However, a monitoring program should continue so the management strategies implemented for each estuary can be evaluated and revised where necessary.

LITERATURE CITED

Akins, G. and C. Jefferson. 1973. Coastal wetlands of Oregon; a natural resource inventory report. Oreg. Coast. Conserv. Dev. Comm. Florence. 159 pp.

Avolio, G. 1973. Granulometric analysis of recent sediments of Tillamook Bay, Oregon. M.S. Thesis, Portland State Univ., Portland. 67 pp.

Batterson, W. 1971. Nestucca Bay, conflicts in estuary uses. Oreg. State Game Comm. Special Rep.

Bayer, R. 1978. Birds of Lincoln County, Oregon. Sea Grant Marine Advisory Program. Oreg. State Univ., Newport. 19 pp.

Beardsley, A. 1969. Movement and angler use of four foodfishes in Yaquina Bay, Oregon. Ph.D. Thesis, Oreg. State Univ., Corvallis. 173 pp.

Bottom, D. and B. Forsberg. 1978. The fishes of Tillamook Bay. Oreg. Dep. Fish Wildl. 56 pp.

Burt, W. and W. McAlister. 1959. Recent studies in the hydrography of Oregon estuaries. Fish Comm. Oreg. Res. Briefs 7(1):14-27.

Carriker, M. 1967. Ecology of estuarine benthic invertebrates: a perspective. Pp. 442-487 *in* G. H. Lauff (ed.), Estuaries. Pub. No. 83, American Association for the Advancement of Science, Wash., D. C.

Clark, J. 1977. Coastal ecosystem management, a technical manual for the conservation of coastal zone resources. The Conservation Foundation. John Wiley and Sons, New York. 928 pp.

Clifton, H., R. Phillips, and R. Hunter. 1973. Depositional structure and processes in the mouths of small coastal streams, southwest Oregon. Pp. 115-140 *In* D. R. Coates (ed.), Coastal Geomorphology, Binghamton, N.Y.

Cowardin, L., V. Carter, F. Golet, E. LaRoe. 1977. Classification of wetlands and deep-water habitats of the United States (an operational draft). J. H. Sather (ed.). U.S. Fish and Wildlife Service. 100 pp.

Cummings, T. and E. Schwartz. 1971. Fish in Coos Bay, Oregon, with comments on distribution, temperature and salinity of the estuary. Fish Comm. Oreg. 85 pp.

Dicken, S. 1965. Oregon geography, the people, the place, the time. 4th edition. Dep. Georgr., Univ. Oreg., Edwards Brothers, Inc., Ann Arbor, Mich. 147 pp.

Dunford, W. 1972. Space and food utilization by salmonids in marsh habitats of the Fraser River estuary. M.S. Thesis, Univ. British Columbia, Vancouver. 81 pp.

Forsberg, B., J. Johnson, and S. Klug. 1975. Identification, distribution, and notes on food habits of fish and shellfish in Tillamook Bay, Oregon. Oreg. Dep. Fish Wildl. 85 pp.

Frolander, H., C. Miller, M. Flynn, S. Myers, and S. Zimmerman. 1973. Seasonal cycles of abundance in zooplankton populations of Yaquina Bay, Oregon. School of Oceanography, Oreg. State Univ., Corvallis. 14 pp.

Gaumer, T., D. Demory, and L. Osis. 1973. Alsea River estuary resource use study, 1971. Fish Comm. Oreg.

Gnose, C. 1968. Ecology of the striped seaperch, *Embiotica lateralis*, in Yaquina Bay, Oregon. M. S. Thesis. Oreg. State Univ., Corvallis. 53 pp.

Hancock, D., T. Gaumer, G. Willeke, G. Robart, and J. Flynn. 1979. Subtidal clam populations: distribution, abundance, and ecology. OSU Sea Grant program, Corvallis. 243 pp.

Hedgpeth, J. 1957. Marine biogeography. Pp. 359-382 *In* Hedgpeth (ed.), Treatise on Marine Ecology and Paleoecology, Vol. 1, GSA Memoir 67.

Hostick, G. 1975. Numbers of fish captured in beach seine hauls in Coos River estuary, Oregon, June through September 1970. Fish Comm. Oreg., Coastal Rivers Invest. Inf. Rep. 74-11. 22 pp.

Howard, Needles, Tammen and Bergendoff Co. 1975. Wetlands review of Siletz Bay, Oregon. Preliminary Draft, U.S. Army Corps of Engineers, Portland, Oregon.

Jefferson, C. 1975. Plant communities and succession in Oregon coastal salt marshes. Ph.D. Thesis. Oreg. State Univ., Corvallis. 192 pp.

Jefferts, K. 1977. The vertical distribution of infauna: a comparison of dredged and undredged areas in Coos Bay, Oregon. M.S. Thesis. Oreg. State Univ., Corvallis. 145 pp.

Kulm, L. and J. Byrne. 1967. Sediments of Yaquina Bay, Oregon. Pp. 226-238. *In* G. H. Lauff (ed.), Estuaries. Pub. no. 83, American Association for the Advancement of Science, Wash., D. C.

Markham, J. 1967. A study of the naimals inhabiting laminarian holdfasts in Yaquina Bay, Oregon. M. A. Thesis, Oreg. State Univ., Corvallis. 62 pp.

Matson, A. 1972. Zooplankton and hydrography of Alsea Bay, Oregon, September 1966 to September 1968. Ph.D. Thesis, Oreg. State Univ., Corvallis.

Miller, B. and E. McRae. 1978. Herring spawning survey Coos Bay, Oregon, winter 1977-78. Oreg. Dep. Fish Wildl. 10 pp.

Morgan, J. and R. Holton. 1977. A compendium of current research and management programs concerning Oregon's estuaries. Oregon Estuarine Research Council Pub. no. 2, Oreg. State Univ., Corvallis.

Mullen, R. 1977. The occurrence and distribution of fish in the Umpqua River estuary, June through October 1972. Oreg. Dep. Fish Wildl., Inf. Rep. Fish. no. 77-3. 39 pp.

Niering, W. and R. Warren. 1977. Salt marshes. Pp. 697-702 *in* Clark, Coastal ecosystem management, a technical manual for the conservation of coastal zone resources. The Conservation Foundation, John Wiley and Sons, New York. 928 pp.

Odum, H., B. Copeland, E. McMahan. 1974. Coastal Ecological Systems of the United States. The Conservation Foundation. Washington D.C. Four volumes.

Oregon Department of Fish and Wildlife. 1978. Habitat maps of Oregon estuaries. Portland.

Oregon Division of State Lands. 1973. Oregon estuaries. Salem.

Oregon Land Conservation and Development Commission. 1977 a. Administrative Rule Classifying Estuaries. Salem. 6 pp.

Oregon Land Conservation and Development Commission. 1977 b. Statewide planning goals and guidelines. Salem.

Pearcy, W. and S. Myers. 1974. Larval fishes of Yaquina Bay, Oregon: a nursery ground for marine fishes? Fish Bull. 72(1):201-213.

Percy, K., C. Sutterlin, D. Bella, and P. Klingeman. 1974. Descriptions and information sources for Oregon estuaries. Sea Grant College Program, Oreg. State Univ., Corvallis. 294 pp.

Peterson, C. 1913. Valuation of the sea, II. The aniaml communities of the sea-bottom and their importance for marine zoogeography. Report of the Danish Biological Station to the Board of Agriculture. 21:43 pp.

Pritchard, D. 1967 a. Observations of circulation in coastal plain estuaries. Pp. 37-44 *In* G. H. Lauff (ed.), Estuaries. Pub. No. 83, American Association for the Advancement of Science, Wash. D.C.

Pritchard, D. 1967 b. What is an estuary: physical viewpoint. Pp. 3-5 *in* G. H. Lauff (ed.), Estuaries. Pub. no. 83, American Association for the Advancement of Science, Wash., D.C.

Reimers, P. 1974. The length of residence of juvenile fall chinook salmon in Sixes River, Oregon. Fish Comm. Oreg. Res. Rep. 4(2):1-43.

Ricketts, E. and J. Calvin. 1968. Between Pacific tides. Fourth edition, revised by J. W. Hedgpeth. Stanford Univ. Press, Stanford, Calif. 614 pp.

Sanders, H. 1958. Benthic studies in Buzzards Bay. 1. Animal-sediment relationships. Limnol. Oceanogr. 3(3):245-258.

Smith, W. Klamath Mountains province. 1940. Pp. 49-54 *in* Oregon State Board of Higher Education. Physical and economic geography of Oregon. 319 pp.

Stout, H. (ed.). 1976. The natural resources and human utilization of Netarts Bay, Oregon. Oreg. State Univ., Corvallis. 247 pp.

Thayer, G. and R. Phillips. 1977. Importance of eelgrass beds in Puget Sound. Marine Fisheries Review 39(11):18-22.

Thorson, G. 1957. Bottom communities. Pp. 461-534 *in* Hedgpeth (ed.), Treatise on marine ecology and paleoecology, Vol. 1 , GSA Memoir 67.

U.S. Army Corps of Engineers. 1975. Final supplement Coos Bay, Oregon. Deep draft navigation project environmental impact statement. Portland.

U.S. Army Corps of Engineers. 1976 a. Alsea wetlands review. Portland.

U. S. Army Corps of Engineers. 1976 b. Nehalem wetlands review. Draft summary report. Portland.

U. S. Army Corps of Engineers. 1976 c. Siletz wetlands review. Portland.

Wilsey and Ham. 1974. Estuarine resources of the Oregon Coast. A natural resource inventory report to the Oregon Coastal Conservation and Development Commission. 233 pp.

Zegers, P. 1978. The effects of log raft grounding on the benthic invertebrates of the Coos estuary. Oreg. Dep. Environ. Quality, Roseburg. Unpub.

Zieman, J. 1977. Sea grass beds. Pp. 702-704 *in* Clark, Coastal ecosystem management, a technical manual for the conservation of coastal zone resources. The Conservation Foundation. John Wiley and Sons, New York. 928 pp.

Zimmerman, S. 1972. Seasonal succession of zooplankton populations in two dissimilar marine embayments on the Oregon coast. Ph.D. Thesis, Oreg. State Univ., Corvallis.

Appendix A

OREGON ESTUARINE HABITAT CLASSIFICATION SYSTEM*

* Modified from Cowardin et al. (1977). Entire sections of the USFWS classification system were used in the definition of terms.

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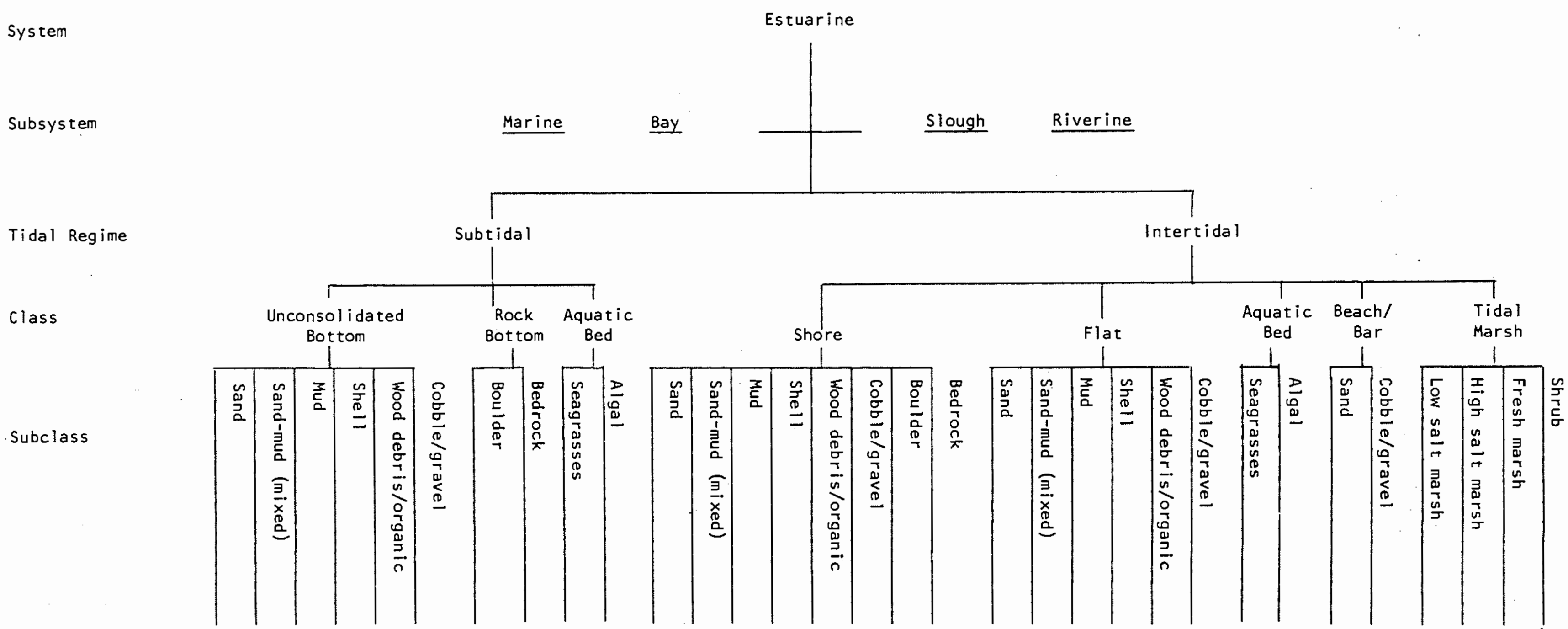
OREGON ESTUARINE HABITAT CLASSIFICATION SYSTEM



ESTUARINE SYSTEM

An estuarine system has been defined as "a semi-enclosed coastal body of water (including submerged land, tideland, and tidal marsh) which has a free connection with the open sea and within which sea water is measurably diluted with freshwater derived from land drainage" (Pritchard 1967). Estuaries extend upstream to the head of tidewater and landward to the line of non-aquatic vegetation where marshes border the estuary, or to mean higher high water (MHHW) where the line of non-aquatic vegetation cannot be determined. The seaward limit of an estuary is defined by a line across the mouth of the estuary, although estuarine conditions may extend seaward of this line during periods of high freshwater runoff. The distribution of plants and animals in the estuarine system primarily reflects differences in salinity, substrate composition, and elevation.

SUBSYSTEMS

Marine

The marine subsystem is a high energy zone located near the estuary mouth. The bottom is influenced by strong currents, and the substrate is primarily coarse marine sand, cobble, and rock. Salinities are generally high due to the dominance of ocean water, but may be greatly reduced during high river flows in winter. Kelp and other algal species often cover the rock substrates and form microhabitats for many species (Markham 1967). Benthic invertebrates in this zone may include marine and estuarine species. Most fish utilizing this subsystem are marine species.

Bay

The bay subsystem is a relatively protected environment, often characterized by a broad embayment between the estuary mouth and narrow, upriver reaches of tidewater. Normally the bay subsystem has a large percentage of intertidal land. Because it is a transition zone between marine and freshwater environments, sediments of the marine subsystem are primarily a mixture of coarse marine sands and fine river-borne silts and clays. Salinities during summer are moderate to high depending on the size of the drainage, but may vary considerably with tidal stage and freshwater flow. Most bays have a wide diversity of habitats with extensive intertidal flats, eelgrass beds, algal beds, and marshes.

Slough

The slough subsystem is a sheltered environment, which is usually a narrow, isolated arm of the estuary. Freshwater drainage into the slough subsystem is either low or dispersed by a number of small creeks, so that the current flowing through the slough channel is slow. The salinity is influenced by the proximity of the slough to the estuary mouth. Sloughs usually have fine organic sediments and high percentages of intertidal land, consisting of extensive flats, eelgrass beds and marshes.

Riverine

The riverine subsystem includes the upper tidewater portions of the larger tributaries which enter the estuary. A large percentage of the subsystem is narrow, subtidal river channel. Current velocities exhibit dramatic seasonal changes which influence benthic communities. Salinities are low most of the year, and portions of the subsystem may be entirely fresh water. Sediments range from fine silts and clays to cobble and gravel. Small fringing marshes occur on the narrow, intertidal portions of the river bank.

TIDAL REGIME

Subtidal

Subtidal habitats are below the extreme low water (ELW) tide level and have continuously submerged substrates.

Intertidal

Intertidal portions of the estuarine system are exposed and flooded by tides as frequently as twice daily or as infrequently as a few times a year. Intertidal habitats are above ELW and include tidal marsh areas. The upper limit of the intertidal zone is defined as the line of non-aquatic vegetation, or as MHHW in areas where the line of non-aquatic vegetation cannot be determined.

SUBTIDAL CLASSES AND SUBCLASSES

Unconsolidated Bottom Class

This class includes subtidal habitats with bottoms composed of unconsolidated sediments that are less than 30% covered by vegetation. Coarse substrates are usually found in the marine and riverine subsystems, while fine material is deposited in sloughs and low energy portions of the bay subsystems (Kulm and Byrne 1966). Unconsolidated bottoms do not have large, stable surfaces for plant and animal attachment. They are found in high and low energy regimes and may be very unstable. Exposure to wave and current action, sediment size, temperature, salinity, and light penetration influence the composition and distribution of organisms. Consequently, plant and animal communities occupying consolidated bottom habitats will vary from the open ocean to the upper end of the estuary. The majority of animals in unconsolidated sediments live within the substrate. Some animals, such as certain polychaetes, maintain permanent burrows, and other animals may live on the surface, especially in coarse sediments.

Subclasses of unconsolidated bottom

(1) Sand. The substrate is primarily sand (75% or more of the sediment is 0.0625-1 mm in diameter) in the Wentworth sediment classification system), although finer or coarser sediments may be intermixed. The sand bottom has a less diverse fauna and flora than either mud, mixed sand-mud, or cobble/gravel bottoms.

(2) Sand-mud mixed. The substrate is a mixture of sand and mud. These habitats are typically higher in organic content than sand and are firmer and more aerated than mud.

(3) Mud. The substrate is primarily silt and clay (75% or more of the sediment is less than 0.625 mm in diameter), although coarser sediments and organic material may be intermixed. Organisms living in mud must often tolerate low oxygen concentrations.

(4) Shell. The surface of the substrate is at least 75% shell. Subtidal shell bottoms may be covered with a layer of shell several centimeters thick.

(5) Wood debris/organic. Substrates composed of primarily wood debris and other organic material usually occur where current velocities are low, and/or there is a steady supply of additional organic material.

(6) Cobble/gravel. The substrate is primarily cobble and gravel (fragments less than 256 mm, but greater than 1 mm in diameter), although finer sediments may be intermixed.

Rock Bottom Class

This class includes subtidal habitats with rock substrates that are less than 30% covered with vegetation. It is usually a high energy habitat with well aerated waters. The firm substrate is a primary factor determining abundance, composition, and distribution of organisms. Temperature, salinity, current, and light penetration are other important factors affecting the composition of the benthic community. Animals are generally firmly attached to the rocky surface by hooking or sucking devices. Some species move about over the substrate in search of food, while others are permanently attached to the rock surface. A few animals hide in rocky crevices and under rocks, and others burrow into finer substrates between boulders. Plants are firmly attached. Most rock bottoms occur in the marine subsystem.

Subclasses of rock bottom

(1) Boulder. The substrate consists of rock fragments larger than 256 mm in diameter. Often finer material is mixed with the larger fragments.

(2) Bedrock. The substrate consists primarily of bedrock surfaces. Unconsolidated sediments may seasonally cover portions of the rock surfaces. Piddock clams may burrow into soft sedimentary rock (Ricketts and Calvin 1968).

Aquatic Bed Class

This class includes subtidal habitats with substrates that are at least 30% covered by submergent plants for the majority of the growing season. The plants greatly influence the composition of the resident animal species.

Subclasses of aquatic beds

(1) Seagrass. Subtidal seagrass beds are composed primarily of vascular aquatic seed plants, principally eelgrass (*Zostera marina*). Eelgrass leaves support many epiphytes which are consumed by fish and larger invertebrates (Thayer and Phillips 1977). Eelgrass beds reduce currents and promote sediment deposition.

(2) Algal. Subtidal algal beds consist of macroalgae attached to rock substrates and unconsolidated substrates. Genera common in Oregon estuaries

include *Enteromorpha, Ulva,* and *Fucus* spp. Beds of kelp with holdfasts (order Laminariales) occur in the marine subsystem near the mouths of some estuaries and contain many invertebrates (Markham 1967). Many macroalgae attach to unconsolidated substrates by means of a basal holdfast or disc. However, in sand and mud, algae penetrate the substrate, and higher plants can successfully root if wave action and currents are not too strong.

INTERTIDAL CLASSES AND SUBCLASSES

Shore Class

This class includes intertidal habitats with rock or unconsolidated substrates occurring as a narrow band between uplands (or tidal marshes) and a subtidal water course. Shores are generally high energy habitats which are exposed to strong waves and tidal and river currents. Shores are usually unvegetated because of the scouring effect of the currents but may have fringing marshes and seasonal algal cover. In shore habitats with unconsolidated substrates, scattered perennial emergents and shrubs may occur but not in sufficient density (less than 30% cover) to classify the area as tidal marsh. On rocky shores the substrate is stable enough to permit the attachment and growth of sessile or sedentary invertebrates, algae, and lichens. Shores usually display vertical zonation, which is a function of tidal range, river flow, wave action, and degree of exposure.

Subclasses of shores

(1) Sand. The substrate is primarily sand (75% or more of the sediment is 0.0625-1 mm in diameter), which occasionally may be scoured by storm waves or flood currents to expose boulders or bedrock.

(2) Sand-mud mixed. The substrate consists of mixed sand and mud. The mud may be removed from shores subject to seasonally varying water velocities during high flows, or the entire substrate may be periodically swept away.

(3) Mud. The substrate is primarily silt and clay (75% or more of the sediment is less than 0.0625 mm in diameter). The substrate of shores subject to seasonally varying velocities may change from mud to sand-mud mixed.

(4) Shell. The surface of the substrate is at least 75% shell fragments. Very few unaltered areas would be classified as shell shore, since shell is usually a small fraction of the substrate composition in intertidal areas.

(5) Wood debris/organic. The substrate is predominantly wood debris and other organic material. Scouring may also periodically change the substrate of these shores.

(6) Cobble/gravel. The substrate is primarily cobble or gravel (fragments less than 256 mm but greater than 1 mm in diameter) often carried downstream with high winter flows, deposited on the estuary shore at the mouths of small steep creeks, or fragmented from estuarine headlands and islands.

(7) Boulder. The substrate consists primarily of rock fragments larger than 256 mm in diameter. Often finer material is mixed with the larger fragments.

(8) Bedrock. The substrate consists primarily of bedrock surfaces. Unconsolidated sediments may seasonally cover portions of the rock surfaces.

Flat Class

This class includes intertidal landforms with a gradual slope, which normally occur in areas sheltered from strong currents and wave action. Shapes and locations of flats vary, but most flats occur in the bay and slough subsystems. Flats are broader, more gradual in slope, and subject to slower current than adjacent shores. This class includes vegetated flats less than 30% covered by plants during the summer. More densely vegetated flats are classified as aquatic beds or tidal marshes.

Community structure is influenced by sediment characteristics, currents, wave action, temperature, and salinity. Regularly flooded flats support diverse populations of tube-dwelling and burrowing invertebrates including worms, clams, and crustaceans. These invertebrates are primarily detritus feeders. Flats also are commonly colonized by macroalgae, diatoms, and seagrasses. Animals and plants have adapted to the wide ranges of temperature and salinity characteristic of flats. A flat may be relatively stable, or may increase in total area, elevation, or percentage of vegetative cover. Flats seldom decrease in elevation or size under natural conditions.

Subclasses of flat

(1) Sand. The substrate is composed primarily of sand (75% or more of the sediment is 0.0625-1 mm in diameter), often with particles of other sizes intermixed. Although population densities may be very high, species diversity is often low.

(2) Sand-mud mixed. The substrate is a mixture of sand and mud. Sand-mud flats are typically higher in organic content than sand flats and are firmer and more aerated than mud flats.

(3) Mud. The substrate is primarily silt and clay (75% or more of the sediment is less than 0.0625 mm in diameter) and is often anaerobic below the surface. Organic content is generally higher than in the other subclasses of flats (except wood debris/organic).

(4) Shell. The substrate is at least 75% shell. This type of flat is not common under natural conditions.

(5) Wood debris/organic. The substrate is primarily waterlogged wood debris, peat, and other organic material.

(6) Cobble/gravel. This substrate consists primarily of cobbles or gravel (fragments less than 256 mm but greater than 1 mm in diameter), often with shell fragments or finer sediments intermixed.

Aquatic Bed Class

This class includes mainly lower intertidal habitats with at least a 30% vegetative cover during the majority of the growing season. As in the subtidal aquatic bed class, two subclasses of plants are dominant in the composition of the resident community.

Subclasses of aquatic beds

(1) Seagrass. Intertidal seagrass beds are composed primarily of vascular aquatic seed plants, such as eelgrass (*Zostera marina, Z. nana*).

(2) Algal. Intertidal algal beds consist of macroalgae attached to rock and unconsolidated substrates. Genera common in Oregon estuaries include *Enteromorpha, Ulva,* and *Fucus* spp.

Beach/Bar Class

This class includes sloping intertidal landforms created by waves and currents, which are composed primarily of unconsolidated sand, gravel, or cobbles. These high energy habitats have less than 30% vegetative cover. Beaches are limited to areas in the marine subsystem influenced by ocean waves and currents, and extend landward to a distinct break in landform or substrate type (e.g., a foredune, cliff, or bank) or to the point where vegetation covers 30% or more of the substrate. Bars are elongate ridges, banks, or mounds with water on at least two sides. Bars most often occur in the marine and riverine subsystems. Bars may only be irregularly or seasonally flooded.

Beaches and bars are characterized by a shifting, unstable substrate with high permeability, variable surface moisture, and low percentage of organic matter. The surface layer has a high oxygen content, but there is often a deeper anaerobic layer. Beaches and bars may be sparsely vegetated and are populated by specialized burrowing invertebrates, such as molluscs, crustaceans, and polychaetes. Faunal distribution is influenced by waves, currents, interstitial moisture, salinity, and sediment grain size.

Subclasses of beach/bar

(1) Sand. The substrate is primarily sand (75% or more of the substrate is 0.0625-1 mm in diameter). Cobble or gravel may be intermixed.

(2) Cobble/gravel. Cobble and gravel (fragments less than 256 mm but greater than 1 mm in diameter) dominate the substrate, although sand is usually mixed with these larger particles. Some of the larger cobbles and occasional boulders found in these areas may support sessile organisms. Cobble/gravel beaches and bars typically form where wave action or currents are particularly strong. As a result, sand and silt particles may be eroded and transported from the beach or bar and deposited in deeper waters.

Tidal Marsh Class

This class includes higher intertidal landforms that are more than 30% covered by erect, rooted herbaceous, or woody hydrophytes. The tidal marsh generally occurs from slightly below mean high water (MHW) inland to the line of nonaquatic vegetation. Community composition varies primarily with tidal elevation but is also influenced by sediment type and salinity. Plant producers in salt marshes include not only marsh grasses but also macroalgae entwined among the grass stems, microalgae on the mud surface, and phytoplankton in the water column. Organic material and nutrients stored by marsh producers are consumed directly or transported to other portions of the estuary as detritus. Marshes provide habitat for fish, invertebrates, waterfowl, and small terrestrial mammals. A diversity of insects live among and graze on marsh grasses.

Subclasses of tidal marsh

(1) Low salt marsh. Low salt marshes are entirely flooded by most high tides, and, therefore, contribute to the estuarine food supply on a daily basis. Tidal runoff is generally diffuse rather than contained by deep ditches. The marsh surface is generally flat but slopes slightly upward toward land. Depending on the substrate a colonizing marsh community near mean high water is comprised of seaside arrow grass (*Triglochin maritima*), seacoast bullrush (*Scirpus maritimus*), or Lyngbye's sedge (*Carex lyngbyei*) (Frenkel and Eilers 1976). This lower intertidal marsh frequently shows high species dominance and low diversity (Eilers 1975).

(2) High salt marsh. High salt marshes usually rise abruptly 0.3 to 1 m above the adjacent flat, shore, or low marsh (Jefferson 1975). The marsh surface is irregular with generally continuous plant cover interspersed with pot holes, salt pans, and channels. The marsh surface is covered by most higher high tides and tidal runoff follows well defined channels with natural levees. Diversity is usually greater in high marsh communities than in low marshes. Typical high marsh and transition zone species are described by Frenkel et al. (1978).

(3) Fresh marsh. Fresh marshes occur inland of salt marshes where soil salinity is low or in the upstream portion of the estuary where fresh water under tidal influence periodically inundates the marsh. Vegetation is herbaceous with sedge (*Carex* sp.), bullrush (*Scirpus* sp.), and cattails (*Typha* sp.) usually dominant (Akins and Jefferson 1973).

(4) Shrub. Shrub wetlands may occur at the inland boundary of the estuary. In Oregon, willow (*Salix* sp.) is the primary semi-aquatic woody plant that is likely to occur. Willow, however, has a low salinity tolerance and, therefore, is most often found in the riverine subsystem.

MODIFIERS

Several modifiers of this habitat classification system help to more accurately characterize estuarine habitats. These modifiers may be applied to any level of the classification system.

Tide Level and Salinity

Tidal elevation and salinity regime are the primary physical factors influencing community composition in an estuary. A marked vertical and longitudinal zonation of species occurs in estuaries due to changes in tidal level and salinity. Intertidal species exhibit special adaptations to resist dessication, to tolerate large variations in temperature due to tidal exposure, and to regulate internal salinity. For a broad level habitat description, suitable modifiers include the general categories used by Cowardin et al. (1977) (irregularly exposed, regularly flooded, irregularly flooded) and the subsystem categories described previously (marine, bay, slough, riverine). For more specific habitat characterizations, tidal levels and salinity should be quantified.

Special Modifiers

Some estuarine habitats have been modified by human activity. Since these modifications may greatly influence the community composition, the following modifiers may be used to describe such habitats.

Excavated

The excavated modifier is used to describe estuarine basins or channels which receive periodic dredging. Benthic invertebrate and plant communities are kept at a low level of succession by the periodic removal of the substrate surface.

Diked

The diked modifier is used to describe habitats (usually marsh) in which the natural flushing is severely restricted by dikes or barriers. Some areas that are partially diked or have open culverts or tidegates may permit reduced exchange of water between the diked area and main body of the estuary. Often these areas have large algal blooms, low oxygen concentrations, and exhibit different floristic characteristics than similar undiked areas.

Artificial

The artificial modifier refers to estuarine substrates resulting from man-made alterations. Jetties, breakwaters, riprap, artificial reefs, docks, piers, and pilings are examples of artificial habitats. Dredge spoil and log storage areas are also included in the artificial category.

LITERATURE CITED

Akins, G. J. and C. A. Jefferson. 1973. Coastal wetlands of Oregon. Oreg. Coastal Conser. Dev. Comm. Florence. 190 pp.

Cowardin, L. M., V. Carter, F. C. Golet, E. T. LaRoe. 1977. Classification of wetlands and deep-water habitats of the United States. (An operational draft) (Sather, J. H., ed). U.S. Fish Wildl. Service, Wash., D.C.

Eilers, H. P. 1975. Plants, plant communities, net production and tide levels: the ecological biogeography of the Nehalem salt marshes, Tillamook County, Oregon. Ph.D. Thesis, Oreg. State Univ., Corvallis.

Frenkel, R. E. and H. P. Eilers. 1976. Tidal datums and characteristics of the upper limits of coastal marshes in selected Oregon estuaries. A pilot study conducted for the Environmental Protection Agency. Dept. of Geogr., Oreg. State Univ., Corvallis. 320 pp.

Frenkel, R. E., T. Boss, S. R. Schuller. 1978. Transition zone vegetation between intertidal marsh and upland in Oregon and Washington. Dept. of Geogr., Oreg. State Univ., Corvallis. 320 pp.

Jefferson, C. A. 1975. Plant communities and succession in Oregon salt marshes. Ph.D. Thesis, Oreg. State Univ., Corvallis. 192 pp.

Kulm, L. D. and J. V. Byrne. 1966. Sedimentary response to hydrography in an Oregon estuary. Marine Geology 4:85-118.

Markham, J. C. 1967. A study of the animals inhabiting laminarian holdfasts in Yaquina Bay, Oregon. M.S. Thesis, Oreg. State Univ., Corvallis, Or. 62 pp.

Pritchard, D. W. 1967. What is an estuary:Physical viewpoint. Pp. 3-5 In H. Lauff (ed.), Estuaries. Pub. No. 83, American Association for the Advancement of Science, Wash., D.C.

Appendix Table B. Data needed to describe the physical and chemical characteristics of Oregon Estuaries.

Data Needs	Use of the Data	Suggested Methods/Data Sources
A. PHYSICAL DIMENSIONS		
1. Estuary base map		
Map of estuary and all tributaries from mouth to head of tide	To provide a suitable and uniform base map produced at three different scales appropriate for (1) implementing estuary plans, (2) recording distributional information for physical and biological inventory data used for planning; mapping management units for the estuary as required by the Land Conservation and Development Commission (LCDC), (3) publishing resource data in the inventory document.	Maps prepared from aerial photos, preferably taken during mid-summer or fall minus tides. Photo base at 1:48,000 scale for permit review and implementation of plan policies. Maps at 1:12,000 scale as inventory/planning base for delineating resource data, shoreland uses, and management units. Update base photos and maps as needed to monitor change in estuarine habitats and shoreland uses. Division of State Lands (DSL) tideland maps available at 1:12,000 scale for many Oregon estuaries, but often do not extend to head of tide.
2. Drainage Area		
Map and measurements for total estuary drainage area including the drainage area for each major tributary	To determine the total area of watershed directly influencing the volume of freshwater inflow and the water quality of the estuary. To determine most significant drainages according to their respective areas. To show the relation of drainage area to size, shape, and habitat of the estuary.	Data available for most drainages from U.S. Geological Survey (1977) and Oregon State Water Resources Board [OSWRB (1974)]. Data summarized by estuary in Percy et al. (1974). Pacific Northwest River Basins Commission River Mile Indices (1968) also provide all drainage areas computed as of 1968. Available maps of drainages include U.S. Geological Survey (USGS) quadrangle maps and OSWRB subbasin maps (e.g. 1961).
3. Estuary Shape		
Map of estuary and tributaries and representative cross sectional profiles (see #5 below)	To evaluate the influence of shape and cross sectional area of the estuary on hydrological characteristics. To determine the influence of these factors on the habitat types and communities represented in the estuary. To calculate cross sectional areas and estuary volumes for various tidal stages.	Map estuary (see #1 above) at scale of 1:12,000. Complete cross sectional depth profiles along representative transects across the estuary basin from the mouth to the head of tide including major tributaries to the level of mean higher high water (MHHW). Compare with historical records to evaluate change in shape and profile due to hydrologic and human influences. Update base photos and profile surveys as needed to monitor change. Historic Coast and Geodetic Survey charts available for some estuaries. Bathymetric records available for some estuaries from U.S. Army Corps of Engineers (USACE), Portland. Methods discussed in Glanzman et al. (1971).
4. Surface Area		
Intertidal, subtidal, and total surface areas (see "HYDROLOGICAL CHARACTERISTICS-Tidal Levels")	To determine relative percentages of intertidal and subtidal habitats. To help evaluate the relationship between area of intertidal and subtidal habitats and the composition and distribution of species occurring in the estuary. Surface areas at various tidal stages and cross sectional profiles (see #2 above) used to calculate estuary tidal prism.	Estimate total area from estuary mouth to head of tide with planimeter from 1:12,000 base map or larger photo base (see #1 above). Estimate subtidal area [the area below the Extreme Low Water (ELW) contour drawn on the base map (see "HYDROLOGICAL CHARACTERISTICS-Tidal Levels")]. Estimate intertidal area (the area between the ELW contour and the MHHW contour). For many estuaries, only available tidal datums are from DSL tideland maps using Mean Low Water (MLW) and Mean High Water (MHW). Often these maps do not extend to head of tide and exclude marshes. National Ocean Survey charts provide soundings at MLLW for portions of some major estuaries. Methods for surface area calculations given in Glanzman et al. (1971).

Appendix Table B. (continued)

Data Needs	Use of the Data	Suggested Methods/Data Sources
*5. Bottom topography/ water depth		
Relative depths above and below MLLW (see #2 above)	To determine relative depths of all habitats and degree of slope and exposure of intertidal habitats. To correlate depths with circulation and mixing. To detect changes in depth due to sedimentation and scouring. To identify deep water areas near shore appropriate for potential development.	Soundings to nearest 0.5 m on 1:12,000 base map from mouth to head of tide including major tributaries. Surveys should be updated as necessary to document significant changes in depth. National Ocean Survey charts show depths relative to MLLW for portions of some estuaries. Historical bathymetric records available for some estuaries from USACE, Portland. Intertidal topography and depths generally unavailable.
B. CLIMATE		
1. Wind		
Prevailing wind direction and mean and extreme velocities by month (present and historical trends)	To relate seasonal wind patterns with physical processes of the estuary such as circulation, mixing, wave directions and amplitudes, or nearshore upwelling. May be an important factor influencing siting of proposed facilities.	Report monthly values for most recent annual cycle(s) as well as long term monthly averages where data are available. Data available for some coastal locations from local weather stations, Coast Guard facilities, and airfields.
2. Precipitation		
Average precipitation by month in vicinity of estuary, average annual precipitation patterns (isopleths) for locations throughout the watershed.	To relate seasonal variations in precipitation with observed river discharges, salinity patterns, and mixing characteristics of the estuary or to estimate freshwater inflow where river discharge data are unavailable.	Report monthly rain gauge measurements for most recent annual cycle(s) and long term monthly averages where data allow. Data available for many coastal locations from National Oceanic and Atmospheric Administration.
*3. Fog		
Periods and areas most frequently influenced by fog	An important factor to consider for navigation, dock access, and location of facilities.	Seasonal observations.
C. HYDROLOGICAL CHARACTERISTICS		
1. Tidal levels		
A map of tidal elevations including the following data:		
a. Head of tide for all major tributaries	To identify upriver extent of the estuary as defined by the LCDC Estuarine Resources Goal. To define area of tidal influence.	Tidal observations on main rivers and tributaries during late summer or fall low flow conditions during higher high tides. Approximate head of tide for most estuaries available from USACE, Portland and Oregon Department of Fish and Wildlife (ODFW) stream surveys for smaller tributaries.

Appendix Table B. (continued)

Data Needs	Use of the Data	Suggested Methods/Data Sources
b. Line of MLLW	To determine intertidal/subtidal boundary as defined by LCDC Estuarine Resources Goal.	Draw MLLW datum on 1:12,000 base map. Estimate MLLW from field survey at selected stations throughout the estuary during predicted MLLW tidal levels. Verify actual tide levels during the survey from nearest available recording tide gauge and make necessary corrections. Appropriate methods available from DSL, Salem. National Ocean Survey charts record soundings for some larger estuaries in relation to the MLLW level.
c. Line of ELW	To differentiate intertidal and subtidal habitats as defined by the Oregon Estuarine Habitat Classification System. To identify "wetlands" as defined by LCDC Estuarine Resources Goal.	Approximations for 1:12,000 planning base can be made from aerial photos and/or field surveys during appropriate spring low tides. Extrapolation of ELW datum also can be made from survey to determine MLLW (see #1b above). Appropriate methods available from DSL, Salem.
d. Line of non-aquatic vegetation	To determine intertidal/upland boundary as defined by LCDC Estuarine Resources Goal and the Oregon Estuarine Habitat Classification System.	Crude estimates from aerial photos and field verification for approximation at 1:12,000 scale planning base. More accurate methods required for implementation of plans and legal purposes. Frenkel, et al. (1978) outline appropriate methods for more accurately determining transition zone from intertidal to upland.
e. Line of MHHW (see "PHYSICAL DIMENSIONS-Surface Area")	To determine intertidal/upland boundary where line of nonaquatic vegetation is not applicable as defined by LCDC Estuarine Resources Goal and the Oregon Estuarine Habitat Classification System.	See methods #1b above for estimating line of MLLW. Appropriate methods available from DSL, Salem.
2. Tidal wave		
Characteristics of tidal wave as it moves through the estuary including lag times, amplification and choking, and velocities (see #6 below)	To determine the effects of the tide on estuarine circulation. To determine local tidal variations due to topographic features of the estuary. To determine predominant type of tidal wave (progressive, standing wave, or both).	Select locations from mouth to upper tidewater for tidal gauge and current measurements. Sampling should cover complete tidal cycles (lower low to higher high tides). As a minimum, studies should be conducted for low flow conditions for both spring and neap tides. Description of standing and progressive wave characteristics given in Dyer (1973).
3. Wind Waves		
Location of high energy environments in the estuary.	To identify potentially unstable and erosive areas. To determine the influence of orientation to wind and waves on the distribution of organisms in the estuary.	Seasonal observations of wave height and direction including average and extreme wind conditions.

Appendix Table B. (continued)

Data Needs	Use of the Data	Suggested Methods/Data Source
4. River Discharge		
Average monthly and extreme flows (above head of tide) for major tributaries of the estuary (current and historical trends)	To determine volumes of fresh water entering the estuary by source. To determine the influence of these sources on flushing times, salinity distribution, mixing characteristics, and species distribution.	Requires stream gauges on the major tribtuaries of each estuary. Data available in many areas from USGS (e.g. 1977). Data summarized for many estuaries in Percy et al. (1977), OSWRB (1974), and the OSWRB basin reports (e.g. 1961). Random values for some smaller tributaries in Oregon Game Commission Environmental Investigations reports (e.g. Smith and Lauman 1972) and Oregon Fish Commission stream surveys (unpublished).
*5. Flushing		
Estimated flushing times for selected estuary locations including major tributaries (see #6 below)	To predict the movement and flushing of introduced pollutants for selected locations for varying flows and tidal regimes. To identify areas of high pollution potential.	Evaluate flushing time for locations from lower to upper estuary for high and low flow conditions. Tidal prism method for calculating flushing times (Dyer 1973) can be used. Slotta and Noble (1977) discuss methods for determining flushing times for marinas in Oregon estuaries. Tidal prism calculations described in Goodwin et al. (1970) and Glanzman et al. (1971). Dye and current study methods for describing flushing characteristics discussed in Glanzman et al. (1971).
6. Mixing		
Mixing classification under seasonal flow conditions (see "WATER QUALITY-salinity)	To evaluate the influence of mixing on the distribution, transport, and concentration of pollutants or other materials in the estuary. To evaluate the influence of seasonal mixing characteristics on the composition and distribution of species in the estuary.	Monitor salinity (see "WATER QUALITY-Salinity") every few meters from surface to bottom over 12½ hour tidal cycle (lower low to higher high tide) from representative stations from the mouth to upper tidewater. (Tide gauge measurements should be made concurrently.) Measure at least quarterly, including extreme high and low flow conditions. Salinity difference method described in Burt and McAllister (1959) may be used to classify by mixing type.
7. Circulation		
Current patterns and velocities for selected locations at varying flow regimes	To determine local and seasonal variations in current velocity and direction. To identify high energy environments and potentially unstable and erosive areas. To determine the relationship between current patterns and transport and distribution of sediments (see "Sediment"), transport and distribution of pollutants or other materials (see #2 above), salinity and mixing patterns (see #3 above), and the distribution of planktonic and larval forms as well as other species in the estuary. (see Table 2 "BIOLOGICAL CHARACTERISTICS").	Velocity and current direction monitored by current meters at fixed stations from lower to upper estuary. Current measurements made at surface and bottom for complete tidal cycles (lower low to higher high tide) for high and low flow conditions. Qualitative information concerning current patterns can be obtained by release and recapture of drogues from selected locations from lower to upper estuary. Methods relating to estuarine current measurements discussed in Glanzman et al. (1971).

Appendix Table B. (continued)

Data Needs	Use of the Data	Suggested Methods/Data Source
D. WATER QUALITY		
1. A routine monitoring program to measure the following concurrently:	To identify naturally stressed environments or polluted areas as evidenced by poor water quality. To identify sources of pollution where water quality is poor.	Establish routine monitoring stations from mouth of the estuary to head of tide. Include areas where pollution potential may be high due to existing onshore development and land use practices or poor estuarine flushing capacity (see "HYDROLOGICAL CHARACTERISTICS-Flushing"). For routine monitoring, surface and bottom samples at high and low tides are sufficient. Sample at least quarterly. More frequent sampling may be required in areas of and during periods of poor water quality (see #2 below). Some data available for parameters below from Department of Environmental Quality (1978).
a. Salinity values	To determine saturation values for dissolved oxygen. To aid in interpretation of other parameters monitored by providing measure of tidal stage, freshwater discharge, and mixing.	Salinity probe, refractometer, or hydrometer sufficient for monitoring purposes.
b. Temperature values	To determine saturation values for dissolved oxygen. To identify potential limitations to estuarine organisms due to temperature extremes.	Centigrade thermometer or salinity-temperature meter sufficient for monitoring purposes.
c. Dissolved oxygen concentrations	To identify areas of environmental stress due to high organic loading and/or poor flushing as evidenced by low dissolved oxygen concentrations. To determine (in conjunction with temperature and salinity data) oxygen saturation values.	Due to diel variations in dissolved oxygen concentrations, monitoring program should establish standard sampling times during the day or night and standard tidal stages to assure that data are comparable from one sampling period to the next. Samples analyzed in the lab with calibrated oxygen meter or modified Winkler technique. Analytical methods in Strickland and Parsons (1968). Determine oxygen saturation values from temperature and salinity data as given in Green and Carritt (1967).
d. Bacterial concentrations, including total and fecal coliform and streptococcus	To determine areas and potential sources of human and animal waste contamination. To restrict harvest of shellfish where levels exceed state and federal standards.	More frequent and intensive sampling may be required where contamination is found, particularly in estuaries where clams are harvested commercially or recreationally. Analytical methods given in American Public Health Association (APHA 1975).
2. A supplemental monitoring program for specific pollutants of interest	To identify contaminants and sources of contamination that may pose a public health hazard or a hazard to the biological productivity of the estuary.	Additional sampling locations, schedule, and parameters (compared with #1 above) determined on a case by case basis where contamintation from domestic or industrial wastes is suspected or discovered. Additional parameters of interest may include turbidity, nutrients, heavy metals, or pesticides. These should be measured occasionally at regular monitoring sites to determine whether supplemental sampling may be necessary. Analytical methods for many water quality parameters included in Strickland and Parsons (1968) and APHA (1975).

Appendix Table B. (continued)

Data Needs	Use of the Data	Suggested Methods/Data Sources
E. SEDIMENTS		
1. Accretion and erosion		
Historical changes in shoreline configuration and depth as well as areas of accretion and erosion.	To determine areas, degree, and potential causes of erosion and sedimentation. To identify potential restoration sites or measures.	See "PHYSICAL DIMENSIONS-Estuary base map, estuary shape, and Bottom topography/water depth". See "HYDROLOGICAL CHARACTERISTICS-Tidal wave and circulation". Some historical data available from USACE navigation charts and U.S. Coast and Geodetic Survey Maps.
2. Particle size distribution		
Sediment particle size and distribution of predominant grain sizes throughout the estuary, general map of substrate distribution.	To determine primary sources of sediment and chart the transport of sediments in the estuary (see "HYDROLDGICAL CHARACTERISTICS-Circulation"). For review of estuary development permits and for dredged material disposal planning. To correlate distribution of benthic species with substrate. To define habitat types to the subclass level of the Oregon Estuarine Habitat Classification System.	Select core sampling sites to characterize sediments in the major habitat types throughout the estuary. Larger grain sizes (>.062 mm) can be determined by seive analysis using standard set of Tyler seives (Twenhofel and Tyler 1971), while smaller fractions require pipette analysis or hydrometer. Determine median grain sizes and percentages of sand, silt, and clay for each sample. Map sediment distribution on 1:12,000 scale base map. Some qualitative data for sediment distribution available from a series of ODFW habitat maps (e.g. ODFW 1978). Some data available from USACE dredging records. Analytical methods and statistical treatments described in Twenhofel and Tyler (1941) and Holme and McIntyre (1971).
*3. Sediment Quality		
Sediment chemical analyses where dredge and fill operations are considered	To assess potential toxicity of sediments in areas selected for dredge or in-water disposal of dredged material. For dredged material disposal planning.	Parameters of interest include but not limited to volatile solids, chemical oxygen demand, total Kjeldahl nitrogen, oil and grease, mercury, lead, zinc. U. S. Environmental Protection Agency (EPA) standards and analytical methods for sediment analyses described in O'Neil and Sceva (1971). Methods also discussed in Oregon State University (1977a) and USACE (1976).

These data are a higher priority in Oregon estuaries classified by LCDC for Shallow or Deep Draft Development than those classified as Natural or Conservation. However, all data needs are relevant to the resource inventory and should be included if the information is available.

Appendix Table C. Data needed to describe the biological components of Oregon estuaries.

Data Needs	Use of the Data	Suggested Methods/Data Sources
A. MICROALGAE		
1. Phytoplankton		
*a. Community composition, distribution, relative abundance (and influential environmental factors) (See "ZOOPLANKTON")	To determine the diversity of phytoplankton species in the estuary, the relative contribution of marine and riverine species, and significant periodic differences in species composition and abundance from lower to upper estuary. To document timing of algal blooms. To identify major food species for plankton feeding organisms. To correlate abundance and distribution of phytoplankton community with environmental conditions.	Sample at surface and bottom at selected stations beyond the estuary mouth to the head of tide collecting whole water samples or towing plankton net with Clarke-Bumpus Sampler. Survey at least monthly and more frequently during seasonal peaks, preferably more than one annual cycle. Quarterly 24-hour sampling to measure variations due to tide and light levels. Sample zooplankton concurrently. Sampling and counting techniques described in Vollenweider (1974) and Schlieper (1972). Measure nutrient concentrations (nitrate, nitrite, ammonia, silicate, phosphate), temperature, and salinity of water samples concurrently. Methods for nutrient analyses in Strickland and Parsons (1968).
**b. Phytoplankton productivity and chlorophyll a standing crop (and influential environmental factors)	To estimate relative contribution of water column production to the total productivity of Oregon estuaries. To determine ratio of productivity to standing crop (assimilation ratio). To correlate productivity with environmental conditions. To determine variations in productivity with season and location in the estuary.	Select estuaries representative of the range of estuarine conditions in Oregon for studies of phytoplankton productivity. Use C^{14} or oxygen methods of phytoplankton production rates. Generally *in situ* measurements preferred over lab or on deck incubation techniques. Take monthly measurements, preferably for more than one annual cycle, at stations beyond the estuary mouth to the head of tide. Include several depths from surface to bottom. Collect water samples concurrently for analyses described in methods #1a above. Monitor light intensity (surface and subsurface). Production methods described in Vollenweider (1974) and Strickland (1960). Methods for chlorophyll analyses in Strickland and Parsons (1968) and Vollenweider (1974).
2. Benthic Microalgae (Periphyton)		
*a. Community composition, distribution, relative abundance (and influential environmental factors)	To determine the diversity of benthic microalgal species in Oregon estuaries. To evaluate relationship between substrate type and the composition, distribution, and density of microalgal communities.	Select intertidal and subtidal stations for core samples characteristic of the range of salinities, sediment types (see Table 1 "SEDIMENTS"), and tidal elevations from the mouth of the estuary to the head of tide. (Alternative approach for comparison among locations involves counting and identification of species colonizing artificial substrates placed at selected sites.) Sampling methods discussed in Wetzel (1964) and Vollenweider (1974). Collect water samples concurrently for analyses as described in methods in #1a above.

Appendix Table C. (continued)

Data Needs	Use of the Data	Suggested Methods/Data Sources
**b. Benthic microalgal productivity and chlorophyll *a* standing crop (and influential environmental factors)	To estimate relative contribution of benthic microalgal production to the total productivity of Oregon estuaries. To determine ratio of productivity to standing crop (assimilation ratio). To correlate benthic productivity with environmental conditions. To determine variations in productivity with season and location in the estuary.	Select estuaries representative of the range of estuarine conditions in Oregon for studies of benthic microalgal productivity. *In situ* C^{14} or oxygen techniques to measure productivity of communities on natural substrates preferred. Make monthly determinations, preferably for more than one annual cycle, which include intertidal and subtidal stations for selected sediment types throughout the estuary. [Alternative approach involves rate of colonization (biomass estimates) using artificial substrates.] Collect water samples concurrently for analyses as described in methods #1a above. Monitor light intensity (surface and subsurface). Chlorophyll and productivity methods discussed in Vollenweider (1974), Unesco (1973), and Wetzel (1964, 1965). Chlorphyll analyses also described in Unesco (1966).
B. MACROALGAE		
1. Community composition, distribution, biomass, area of cover (and influential environmental factors), map of algal beds	To identify areas with at least 30% cover, which are defined as "aquatic beds" in the subclass level of the Oregon Estuarine Habitat Classification System. To identify "major tracts" of algae as required in the LCDC Estuarine Resources Goal. To determine the diversity of macroalgal species in the estuary. To correlate distribution, biomass, and composition of algal beds with environmental conditions. To determine the relative importance of each type of algal community according to their total standing crop and productivity (see #4 below).	Select intertidal and subtidal sampling stations characteristic of the range of salinities, sediment types (see Table 1 "SEDIMENTS"), and tidal elevations from the mouth of the estuary to the head of tide. Estimate maximum coverage of intertidal and shallow subtidal beds from aerial photos at peak of the growing season and map at scale of 1:12,000. Sample monthly, preferably for more than one annual cycle, to identify species and estimate biomass. Collect water samples concurrently with macroalgal surveys for nutrient analyses (nitrate, nitrite, ammonia, phosphate), temperature, and salinity. Analyses in Strickland and Parsons (1968). Macroalgal distribution available for many estuaries from ODFW habitat maps (e.g. ODFW 1978). Estimate total coverage by algal "aquatic beds" from planimetry using aerial photos or base maps.
2. Animal species associated with macroalgal communities	To determine the relative importance of algal communities as a habitat for benthic invertebrates and fish.	Identify benthic invertebrates attached to algal samples and include benthic core or grab sampling stations within major algal beds as part of benthic invertebrate (see "INVERTEBRATES") and sediment (see Table 1 "SEDIMENTS") surveys. Include seining and/or trawling stations in areas of major algal beds as part of fish survey (see "FISH").

Appendix Table C. (continued)

Data Needs	Use of the Data	Suggested Methods/Data Sources
**3. Macroalgal productivity (and influential environmental factors)	To correlate with algal biomass estimates in each estuary (see #1 above) to determine the relative contribution of macroalgal production to the total productivity of Oregon estuaries. To correlate productivity with environmental conditions. To determine variations in productivity with season and location in the estuary.	Select estuaries representative of the range of estuarine conditions in Oregon, and select predominant species or characteristic aggregations of species. In most cases *in situ* oxygen or C^{14} methods preferable to harvest techniques for estimating production rates. Make monthly determinations, preferably for more than one annual cycle, which include representative intertidal and subtidal macroalgae throughout the estuary. Collect water samples concurrently for analyses described in methods in #1 above. Monitor light intensity (surface and subsurface). Methods discussed in Wetzel (1964; 1965) and Vollenweider (1974). For very large species (e.g. kelp) harvest (Unesco 1973) or growth (Mann 1973) methods may be preferred for productivity estimates.
C. SEAGRASS		
1. Species, distribution, biomass, area of cover (and influential environmental factors), map of seagrass beds	To identify areas with at least 30% cover, which are defined as "aquatic beds" in the subclass level of the Oregon Estuarine Habitat Classification System. To identify "major tracts" of seagrasses as required in the LCDC Estuarine Resources Goal. To determine the diversity of seagrass species in the estuary. To correlate biomass and distribution of seagrasses with environmental conditions.	Distribution of intertidal and shallow subtidal seagrass beds may be based on summer aerial photos. Field surveys and divers required to identify subtidal beds and verify data from photos. Survey at least quarterly, preferably for more than one annual cycle to follow seasonal variations in distribution and area. Collect water samples concurrently with seagrass survey for nutrient analyses (nitrate, nitrite, nitrite, ammonia, phosphate), temperature, and salinity measurements. Nutrient analyses in Strickland and Parsons (1968). Surveys and photos should be repeated periodically to follow changes in distribution. Distribution should be mapped on 1:12,000 base map. Estimate total area of seagrasses in the estuary by planimetry and/or field survey methods. Seagrass distribution available for many estuaries from ODFW habitat maps (e.g. ODFW 1978).
2. Identify animal species associated with seagrass communities	To determine the relative importance of seagrass communities as a habitat for benthic invertebrates and fish.	Include benthic core or grab sampling stations within major seagrass beds as part of benthic invertebrate (see "INVERTEBRATES") and sediment (see Table 1 "SEDIMENTS") surveys. Sampling should also include invertebrates attached to blades of seagrass. Include seining and/or trawling stations in areas of major seagrass beds as part of fish survey (see "FISH").
**3. Seagrass productivity (and influential environmental factors)	To correlate with biomass estimates (see #1 above) to determine the relative contribution of seagrass production to the total productivity of the estuary. To correlate productivity with environmental factors. To determine variations in productivity with season and location in the estuary.	Select estuaries representative of the range of estuarine conditions in Oregon, and select predominant species of seagrass for studies of seagrass productivity. Use harvest or C^{14} methods to estimate productivity. Make monthly determinations, preferably for more than one annual cycle, which include representative intertidal and subtidal species throughout the estuary. Collect water samples concurrently for analyses as described in #1 above. Monitor light intensity (surface and subsurface). Methods discussed in Wetzel (1964, 1965) and Vollenweider (1974). Productivity and nutrient values for eelgrass (*Zostera* sp.) currently being investigated in several Oregon estuaries by EPA (Morgan and Holton 1977).

Appendix Table C. (continued)

Data Needs	Use of the Data	Suggested Methods/Data Sources
D. TIDAL MARSHES		
1. Marsh community composition, distribution, biomass, area of cover (and influential environmental factors) for the major marsh types (high and low salt, fresh, and shrub marsh) including diked marshes; Map of marsh habitats.	To identify "tidal marshes" to the subclass level of the Oregon Estuarine Habitat Classification System. To identify "major tracts" of tidal marsh as required in the LCDC Estuarine Resources Goal. To determine the diversity of marsh species in the estuary.	Aerial photography and field surveys should be conducted throughout the estuary during the summer or early fall, preferably for two or more consecutive years for comparison. Map distribution of marsh types on 1:12,000 base map. Estimate total coverage for each marsh type by planimetry and/or field survey methods. Collect water samples concurrently with biomass and species samples to determine nutrient concentrations (nitrate, nitrite, ammonia, phosphate) in tide channels and flooded marshes, temperature, and salinity. Nutrient analyses in Strickland and Parsons (1968). Aerial surveys updated as needed to record changes in distribution and cover. Data for some marsh types available from Jefferson (1975), Akins and Jefferson (1973), ODFW (1978), and Frenkel et al. (1978). Some methods discussed in Milner and Hughes (1968).
2. Status of dikes (functional or nonfunctional), stage of marsh succession, and elevations of diked marshes	To identify potential restoration sites among diked marshes. To predict the type of estuarine plant and animal community that would likely develop if dike were removed from marsh.	Survey diked marsh communities as discussed in #1 above noting whether or not tide gates and dikes are functional. Evaluate stage of succession of diked marshes based on relative proportions of marsh and terrestrial species. Survey tidal elevations to nearest 0.5 m to predict degree of inundation of the marsh if dike is removed.
3. Historical changes in distribution and area of marshes	To determine changes in distribution and cover. To assess causes of habitat losses or increases.	Historical data available for some larger estuaries from old Coast and Geodetic Survey Charts (currently National Ocean Survey), aerial photos, and Dicken et al. (1961). Establish a baseline for subsequent comparisons (see #1 above). Example of historical assessment of Coos Bay in Hoffnagle and Olson (1974).
4. Animal species associated with each marsh type	To determine importance of tidal marshes as habitat for invertebrates, fish, birds, and mammals.	Identify invertebrates occurring on marsh grasses and include benthic core, grab, or quadrat sampling stations in marsh and marsh channels as part of invertebrate survey (see "INVERTEBRATES"). Include field bird counts in marshes as part of bird survey (see "BIRDS"). Use counting or trapping methods to identify mammals (see "MAMMALS"). Include seining or fish trap stations in selected marsh channels to survey fish (see "FISH") and larger mobile invertebrates (e.g. crabs). A survey of fishes and invertebrates of the Siletz and Netarts estuaries (Morgan and Holton 1977) is in progress.

Appendix Table C. (continued)

Data Needs	Use of the Data	Suggested Methods/Data Sources
**5. Marsh productivity (and influential environmental factors)	To correlate with estimates of marsh density and area in each estuary (see #1 above) to determine the relative contribution of each marsh type to the total productivity of Oregon estuaries. To correlate productivity with environmental factors. To determine variations in productivity with season and location in the estuary.	Select estuaries representative of the range of estuarine conditions in Oregon and the species characteristic of each marsh type. Use harvest methods to estimate productivity. Sample at least monthly, preferably for more than one annual cycle. Collect water samples concurrently for analyses as described in #1 above. Survey tidal elevations to nearest 0.5 m. Sample along transects from lower to higher tidal levels. Harvest underground as well as above ground portions of plants. Marsh productivity studies often accompanied by studies of nutrient and detrital transport to and from the marsh, including estimates of decomposition (weight loss) from "litter" bags placed in the marsh. Current research by EPA for nine species of wetland plants in three Oregon estuaries will provide some of this type of information and should serve as a guide to methods in subsequent productivity studies (Morgan and Holton 1977). General methods discussed in Milner and Hughes (1968).
E. ZOOPLANKTON		
1. Community composition, distribution, relative abundance (and influential environmental factors) (See "MICROALGAE-Phytoplankton")	To identify the diversity of zooplankton species (including larval forms) in the estuary. To determine significant periodic differences in species composition and abundance from lower to upper estuary. To determine the importance of the estuary to larval forms and to document periods and areas of peak larval abundance. To correlate composition, distribution, and abundance with environmental conditions.	Sample at surface and bottom at selected stations beyond the mouth of the estuary to the head of tide, collecting whole water samples or towing plankton net with Clarke-Bumpus sampler. Survey at least monthly and more frequently during periods of peak zooplankton and larval abundance, preferably for more than one annual cycle. Quarterly 24-hour sampling also useful to measure variations due to tide and light levels. Sample phytoplankton concurrently (see "MICROALGAE"). Sampling methods described in Unesco (1968). Monitor temperature and salinity concurrently.

Appendix Table C. (continued)

Data Needs	Use of the Data	Suggested Methods/Data Sources
F. INVERTEBRATES		
1. Shellfish (clams, oysters, shrimp)		
a. Species composition, distribution, relative abundance of clams and shrimp, and age classes of clams (and influential environmental factors), map of intertidal and subtidal clam, shrimp, and commercial oyster beds	To identify the diversity of shellfish species in the estuary and the relative importance of commercial and recreational species. To locate major clam and shrimp beds. To correlate composition, distribution, and relative abundance of clams and shrimp with environmental conditions. To determine differences in age class structure of intertidal and subtidal clam populations.	Select intertidal and subtidal sampling stations characterizing the range of salinities, sediment and habitat types, and tidal elevations from the mouth of the estuary to the head of tide. Monitor temperature and salinity and determine sediment type concurrently with shellfish surveys (see Table 1 "SEDIMENTS"). Determine age classes in subsample of clams in the areas sampled. Update surveys periodically to follow changes in distribution and abundance due to harvest pressures or natural environmental factors. Map distribution by species on 1:12,000 base map including location of commercial oyster leases. Recent intertidal (e.g. Gaumer and Halstead 1976) and subtidal (Hancock et al. 1978) ODFW surveys are completed or in progress for many estuaries. Macro-faunal sampling methods discussed in Holme and McIntyre (1971).
b. Estimated harvest of clams and shrimp by species	To identify clam and shrimp beds most heavily utilized for sport or commercial purposes. To determine harvest pressures and assess impact on age structure of intertidal and subtidal clams (see #1a above). To manage clam and shrimp fishery at levels that will allow maximum sustainable yield.	Survey clammers during peak periods of harvest to determine number and age class of clams taken. Repeat surveys annually or update periodically to monitor trends in harvest rate. Some survey data from 1971 available from ODFW estuary resource use studies (e.g. Gaumer et al. 1973).
*c. Spawning period for commercial and recreational clam species (and environmental factors influencing spawning)	To document critical periods in the life history of clams to determine appropriate timing for proposed in-water activities. To correlate spawning period with environmental conditions.	Count and identify larval clam species from zooplankton surveys (see "ZOOPLANKTON"). Collect adults of the major clam species of sport and commercial interest monthly (more frequently as spawning periods approach) in a few representative estuaries for histological studies. Complete egg counts and determine gonadal development and approximate period of spawning from thin sections of clam samples. Monitor salinity and temperature concurrently with larval surveys and adult samples collected for histological studies.

Appendix Table C. (continued)

Data Needs	Use of the Data	Suggested Methods/Data Sources
2. Crabs		
a. Distribution, movements, relative abundance, size classes, and shell condition (and influential environmental factors) for Dungeness (*Cancer magister*) and red rock (*C. productus*) crabs	To determine areas and periods of heavy use by juvenile and adult crabs. To determine their movements and peak molting periods. To correlate distribution and abundance of juveniles and adults with environmental conditions.	Sample stations beyond the mouth of the estuary to the up-bay extent of distribution. Include sloughs, tributaries, and marsh channels. Sample at least monthly, preferably for more than one annual cycle. Monitor temperature and salinity concurrently with crab surveys. Repeat surveys periodically to detect changes in population distribution, abundance, and shell condition. Several types of sampling gear may be necessary for different habitats. Trawling stations for fish and crab surveys could be sampled concurrently (see "FISH"). Tag and recapture studies (including juveniles and adults) should also be conducted to determine the movement of crabs within and without the estuaries.
b. Crabbing areas, estimated catch, and catch/effort by sport and commercial fishermen	To determine the crab contribution to the fishery and areas of greatest crabbing pressure and success.	Survey crabbers to determine areas, catch, and catch per effort by sport and commercial fisheries. (Record capture sites and movement of tagged individuals. See #1 above.) Repeat surveys annually or update periodically to follow trends in harvest rates. Some data available from 1971 ODFW surveys of Oregon estuaries (e.g. Gaumer et al. 1973).
*c. Peak periods of spawning and larval crab abundance for Dungeness and red rock crabs	To document critical periods in life history of crabs to determine appropriate timing of in-water activities.	Count, identify, and determine stage of larval development for larval crabs collected during zooplankton surveys (see "ZOOPLANKTON"). Determine stages of gonadal development from samples of crabs collected during field and creel surveys. (See 2a and 2b above).
3. Other benthic invertebrates		
a. Community composition, distribution, relative abundance, (and influential environmental factors)	To identify the diversity of invertebrate species occurring in the estuary and in each major habitat type represented in the estuary. To identify important recreational, commercial, and food chain species. To identify important areas and periods of use by major species in the estuary. To correlate composition, distribution, and abundance with environmental conditions.	Select intertidal and subtidal stations for core and/or grab samples representative of the range of salinities, sediment types (see Table 1 "SEDIMENTS"), vegetation types, (see "MACROALGAE," "SEAGRASSES," and "TIDAL MARSH") and tidal elevations in the estuary. Sample at least monthly, preferably for more than one annual cycle. Complete distribution maps (1:12,000) for major species or species assemblages where possible. Sampling gear for various substrate types noted in Oregon State University (1977a). Monitor temperature and salinity concurrently with faunal surveys. Collect subsamples of cores for determination of total volatile solids and particle size of sediments (see Table 1 "SEDIMENTS"). Other sediment parameters may be important to monitor as factors influencing composition and distribution of benthic communities (e.g. reduced sulphide capacity, porosity, redox potential, and chemistry of interstitial waters). Some sediment parameters and analytical methods discussed in Holme and McIntyre (1971) and Oregon State University (1977a; 1977b).

Appendix Table C. (continued)

Data Needs	Use of the Data	Suggested Methods/Data Sources
G. Fish		
1. Community composition distribution, size class, relative abundance (and influential environmental factors)	To identify the diversity of species occurring in the estuary, including commercially and recreationally important species. To identify important habitats and periods of estuarine residence for major adult and juvenile species. To document critical periods in the life history of major species to determine the timing of in-water activities. To differentiate juveniles from adults. To understand their life histories and the timing of their movements through the estuary. To correlate composition, distribution, and abundance with environmental conditions.	Sample at least monthly, preferable for more than one annual cycle. Select sampling stations from the mouth of the estuary to the head of tide, including stations representative of each major sediment (see Table 1 "SEDIMENTS") and vegetation type (see "MACROALGAE," "SEAGRASSES," and "TIDAL MARSHES") in the estuary. Monitor temperature, salinity, and river flow, and collect water samples to measure dissolved oxygen concentrations concurrently with fish surveys (see Table 1 "WATER QUALITY" and "HYDROLOGICAL CHARACTERISTICS-River Discharge"). Appropriate sampling gear for fishes must be chosen according to the depth and characteristics of the habitat studied. Measure appropriate subsample of lengths for the major species collected each month at each sampling station. Plot length frequencies for each major species by month. Appropriate methods and results described in Forsberg et al. (1977) and Bottom and Forsberg (1978).
2. Important sport and commercial fishing areas, catch, and catch/effort by species	To determine the size of the fishery and areas of greatest fishing pressure.	Survey sport and commercial fishermen to determine areas fished, effort, and catch by species. Repeat surveys annually or update periodically to follow trend in harvest. Creel surveys conducted for most estuaries by ODFW in 1971 (e.g. Gaumer et al. 1973).
H. BIRDS		
1. Composition, distribution, and relative abundance; estuarine nesting, feeding, and rearing areas of abundant species.	To identify the diversity of species utilizing the estuary, including recreationally important species. To identify important areas and periods of estuarine use by major species. To identify abundance and critical habitat of threatened and endangered species present in the study area.	Whole area counts at least monthly for areas representative of all major habitat types in the estuary. Repeat surveys periodically to detect change in population abundance and distribution. May also contact local chapters of Audobon Society and ODFW wildlife biologists.
2. Waterfowl hunting areas and estimated intensity of use	To consider areas most heavily used by hunters in management plans.	Survey hunters to determine number of birds killed and areas hunted. Update surveys periodically to note changes in harvest rates and pressure.
3. Important bird watching areas	To consider areas preferred by bird watchers in management plans.	Contact local chapters of Audobon Society and ODFW district biologists.
I. MAMMALS		
1. Composition, distribution, and abundance of marine species	To identify important resting areas, periods, and intensity of use by major species.	Survey haul-out areas and complete counts quarterly (more frequently during periods of heaviest use). Unpublished data available from Bruce Mate, OSU Marine Science Center, Center, Newport.

Appendix Table C. (continued)

Data Needs	Use of the Data	Suggested Methods/Data Sources
2. Identify terrestrial mammals utilizing marsh and shoreland habitats within and surrounding the estuary and describe seasonal changes in species composition and relative abundance (see "TIDAL MARSH")	To identify the diversity of terrestrial mammals directly associated with and dependent upon the estuary. To identify important habitats and periods of use by major species.	Direct methods including counts and trapping and removal techniques. Indirect methods also can be used including identification of tracks, droppings, etc. Methods may vary with large, medium, and small mammals. Methods discussed in Seber (1973) and Caughley (1977).

* *These data needs are a higher priority in estuaries classified by LCDC for Shallow or Deep Draft Development than those classified as Natural or Conservation. However, all data needs are relevant to the resource inventory and should be included if the information is available.*

** *Due to expense, manpower, and broad application of results beyond the immediate area of investigation, these data should be collected in one or a few estuaries representative of the range of conditions throughout Oregon estuaries. These studies should be designed specifically to maximize the transferability of results.*