Natural Resources of Siletz Estuary

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PREFACE

This report is one of a series prepared by the Oregon Department of Fish and Wildlife (ODFW) which summarizes the physical and biological data for selected Oregon estuaries. The reports are intended to assist coastal planners and resource managers in Oregon in fulfilling the inventory and comprehensive plan requirements of the Land Conservation and Development Commission's Estuarine Resources Goal (LCDC 1977).

A focal point of these reports is a habitat classification system for Oregon estuaries. The organization and terminology of this system are explained in volume 1 of the report series entitled "Habitat Classification and Inventory Methods for the Management of Oregon Estuaries."

Each estuary report includes some general management and research recommendations. In many cases ODFW has emphasized particular estuarine habitats or features that should be protected in local comprehensive plans. Such protection could be achieved by appropriate management unit designations or by specific restrictions placed on activities within a given management unit. In some instances ODFW has identified those tideflats or vegetated habitats in the estuary that should be considered "major tracts", which must be included in a natural management unit as required by the Estuarine Resources Goal (LCDC 1977). However, the reports have not suggested specific boundaries for the management units in the estuary. Instead, they provide planners and resource managers with available physical and biological information which can be combined with social and economic data to make specific planning and management decisions.

CONTENTS

INTRODUCTION

The Siletz estuary, once used for commercial enterprises, is now primarily a recreational area. Its proximity to major inland population centers has encouraged the development of resort areas on and around the estuary. Land adjacent to the bay portion has been used for residential homes, vacation homes, motels, and condominiums. Mobile home parks, travel trailer parks, and marinas extend upriver.

The trend toward increased recreational and residential use of the land surrounding the estuary is expected to continue. A large number of building requests have been filed in the past years for the Siletz Keys, Taft, and Cutter City locations, and the river bank areas up to the head of tidewater. As more people visit or move into the area, additional recreational facilities will be required to meet their needs.

With an increase in population, greater demands will be placed on the natural resources of the Siletz estuary. Many of these resources exist in a delicate equilibrium, and careful planning is necessary to ensure that these resources are properly managed. The Oregon Land Conservation and Development Commission (LCDC) has classified the Siletz estuary as a conservation estuary, which is to be managed for long-term uses that do not require major alterations. This report summarizes some of the physical and biological characteristics of the estuary and proposes recommendations for land and water use management.

THE SILETZ ESTUARINE SYSTEM

The Siletz estuary has been the subject of numerous studies and reports, most of which focus upon physical parameters. Three reports, *Analysis of Siletz Bay Estuary* (Zinn 1970), *Oregon Estuaries* (Percy et al. 1974), and the *Siletz Wetlands Review* (U. S. Army Corps of Engineers [USACE] 1976), summarize most of the available information on the estuary. The purpose of this report is not to duplicate those documents but to provide a more detailed analysis of specific areas of the estuary for planning and management.

Description of the Area

The Siletz estuary is located in Lincoln County on the mid-Oregon coast (Fig. 1). Several estimates of the surface area of the Siletz Bay have been published (Table 1). Discrepancies are due to differences in tidal datums, the upper limits of the riverine portion, and the accuracy of the measurements. According to the Oregon Division of State Lands (DSL 1973), the Siletz estuary encompasses a total of 1,187 acres. Tidelands represent about 71% (775 acres) of that area.

Table 1. Surface area of Siletz Bay (Percy et al. 1974).

Reference	Surface area (acres)	Measured at	Tidelands		Submerged lands	
			Acres	Percent	Acres	Percent
Johnson 1972	1,086	HW				
Marriage 1958	1,203	[a]				
DSL 1973	1,187	MHT	775	65	412	35
	412	MLT				

[a] *Specified by Marriage (1958) as the area affected by tidal action.*

The Siletz River, the primary tributary of the estuary, is 79.1 miles long from the end of the North Fork to its mouth. It has a steep, highly dissected drainage basin of 308 mi^2 with a 4,500 acre-feet average runoff per square mile of watershed (Oregon State Water Resources Board [OSWRB] 1965). The steep terrain of the watershed creates a highly peaked flood hydrograph, which results in rapidly fluctuating water levels and salinities in the estuary after heavy rains. Drift Creek, with a drainage basin of 41 mi^2, and Schooner Creek, which drains 15 mi^2, are two major streams which also discharge directly into the bay (Fig. 1).

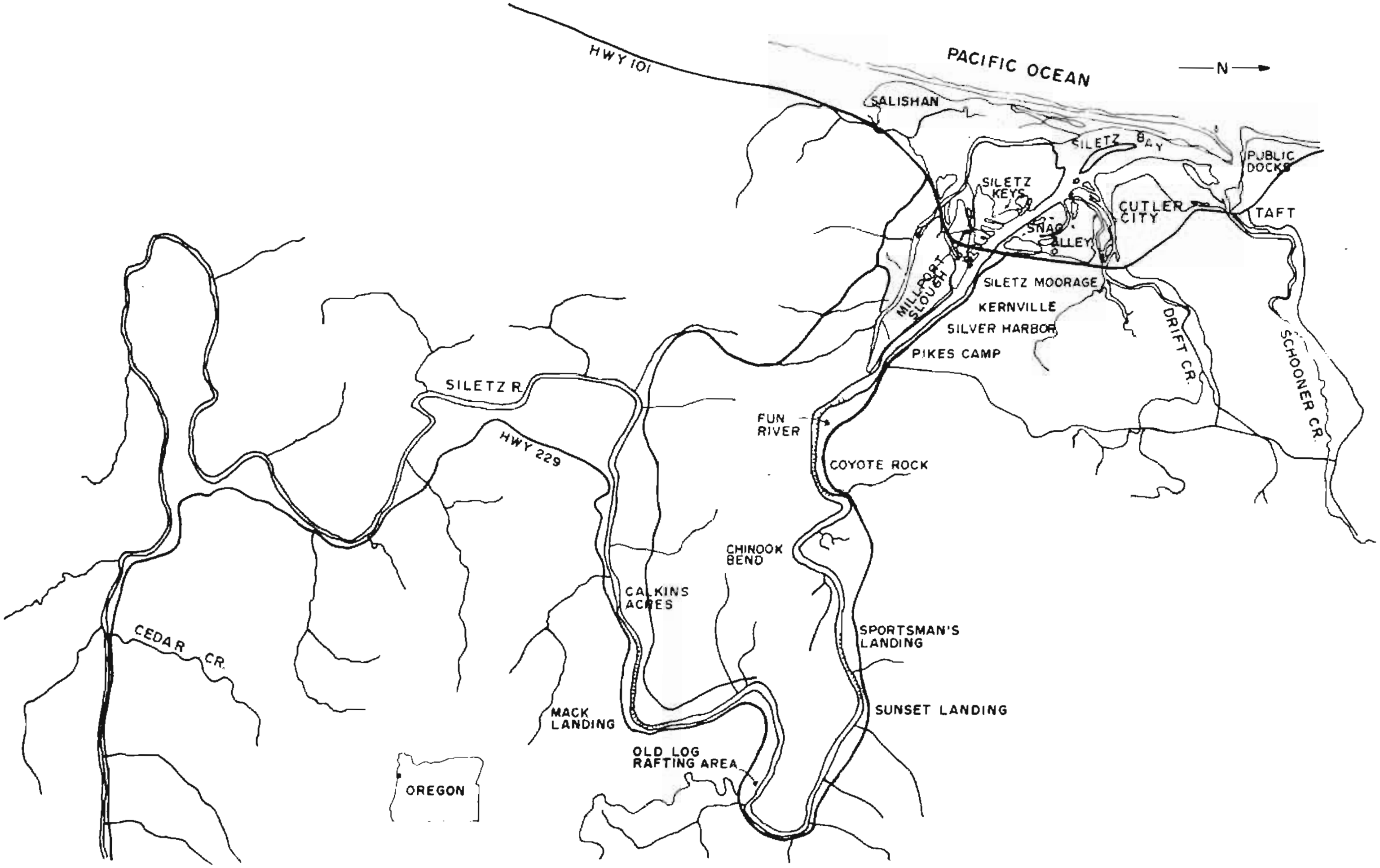

Fig. 1. Map of Siletz estuary (USACE 1976).

Historical Changes

In the early years of this century, the estuary supported a large commercial salmon fishery, a commercial clam fishery, and a log export industry. Close to 800,000 lbs of anadromous fish were landed in 1924 (Cleaver 1951). Commercial clam diggers collected 240-320 lbs/person per tide (Snow 1973). Between 1925 and 1939 log rafts totaling 1.25 billion board feet of lumber crossed the bar (Rea 1975).

The estuary is now devoid of industry and large vessel traffic. The commercial salmon fishery was declining when the estuary was closed to gill net fishing in 1957. Clam populations are too small to support a commercial fishery, and log rafts are no longer towed across the bar. Although reasons for the decline of the salmon populations have not been ascertained, the decline of the clam fishery and log export industry can be attributed to major hydrographic changes caused by a rapid increase in the sedimentation rate in the estuary.

Activities in the early years of this century contributed to the increased sedimentation. Extensive logging in the drainage basin caused an increase in the river's sediment load which covered clam beds and clogged the estuary, so deep draft ships could no longer cross the bar. Extensive diking of marshland prior to 1928 also increased the sedimentation rate in the bay (Zinn 1973). Sediment, once deposited in the marsh, was carried into the bay during winter floods (Dicken et al. 1961).

Diking also altered water courses. The causeway for the U.S. Highway 101 bridge built in 1926 and the diking of Millport Slough (Fig. 1) in 1951 prevented high velocity flood waters from reaching the south bay. Consequently, scouring no longer occurred, and the south bay rapidly filled with sediment. Instead, channelization caused the fast water to erode the inside of Siletz spit (Rea 1975). Rea (1975) measured the erosion rate on the bay side of the spit at 4.6 ft/yr since 1912. The recent (September 1978) removal of the Millport Slough dike may increase scouring of the south bay and reduce the erosion of the spit.

Activities of the past few decades have also influenced estuarine conditions. The estuary has been partially filled for housing developments and used for sewage disposal. Since 1939, 35 to 40 acres of land have been filled (Rea 1975). Three sewage treatment plants discharge into the estuary which may affect water quality. The effects of these recent alterations are not easily discernible, however, because baseline data are absent.

Physical Characteristics

Four data sources contain most of the quantitative information published about physical processes of the Siletz estuary. Goodwin et al. (1970) and Goodwin (1974) provide comprehensive analyses of tidal characteristics in the Alsea, Siletz, and Yaquina estuaries, including excellent comparisons of the three estuaries during low river flows. Johnson (1972) summarized some inlet characteristics of Pacific coast estuaries and estimated tidal prisms for most Oregon estuaries. The most comprehensive study of physical processes was reported in a thesis by Rauw (1975), who collected data in 1973 and described seasonal variations in tidal dynamics, water quality, and sediments. Other reports (Oregon Department of Environmental Quality [DEQ] 1978; OSWRB 1974; U. S. Geological Survey [USGS] 1977; Weise 1974) also presented physical data, but Rauw sampled several variables concurrently. His sampling was designed to account for seasonal (river flow) and tidal effects, so that relationships among parameters could be easily observed.

Tides

The mean tidal range for the entrance to the Siletz estuary is 5.0 ft, and the spring tidal range is 6.6 ft (National Oceanic and Atmospheric Administration [NOAA] 1977). The mean tidal range multiplied by the mean surface area between mean lower low water (MLLW) and mean higher high water (MHHW) produces a tidal prism value of 3.5×10^8 ft^3 (Goodwin 1974). Although this is a crude estimate, it provides a basis for comparison with other estuaries. From values reported by Johnson (1972) and computations from the tide tables, it is apparent that the Siletz estuary has a similar volume of salt water exchange as Nehalem, Netarts, and Siuslaw estuaries (Table 2).

Table 2. Siletz estuary tidal prism compared with selected Oregon estuaries.[a]

Estuary	Tidal Prism (ft^3)	Ratio of other estuaries to Siletz
Siletz	3.5×10^8	1.0
Tillamook	2.49×10^9	7.1
Coos	1.86×10^9	5.3
Umpqua	1.18×10^9	3.4
Yaquina	8.35×10^8	2.4
Alsea	5×10^8	1.4
Nehalem	4.28×10^8	1.2
Netarts	3.3×10^8*	0.9
Siuslaw	2.76×10^8	0.8
Nestucca	1.8×10^8*	0.5
Coquille	1.32×10^8	0.4
Sand Lake	8.2×10^7*	0.2

[a] *Values indicated by an asterisk (*) are calculated from DSL (1973). All others are from Johnson (1972).*

Typically the tidal wave is amplified as it progresses up an estuary, and the effect of this amplification is an increase in the tidal range. Goodwin et al. (1970) suggested that the Siletz estuary does not conform to the typical tidal model as does the nearby Yaquina estuary. As the incoming tidal wave entered the estuary, they found it was dampened between the mouth and Kernville at river mile (RM) 2.3, measured from the mouth of the estuary. The observed tidal range was less than the range at the entrance to the estuary. After the wave passed Kernville, the anticipated amplification of tidal range occurred. A small tidal range at the mouth was amplified to a larger degree upstream (Goodwin et al. 1970).

Rauw (1975) measured seasonal variations in tidal range and observed a dampening of the tidal wave throughout the estuary with an increase in river flow. At a river flow of approximately 10,000 cfs, the tidal range at Siletz Moorage was 65% of its value at the mouth, and at Sportsman's Landing the tidal range was 45% of its value at the mouth. He suggested that river flow was the dominant force influencing tidal amplification.

Goodwin et al. (1970) and Rauw (1975) also measured flow characteristics of the tidal wave as it moved up the estuary. Although slack water occurred near high and low waters, there was a lag time between slack water in the lower estuary and upstream that varied daily and seasonally. Lag times in fall and winter (high river flows) were shorter than lag times in spring and summer.

River discharge

The combined flow of the three major streams yields an estimated 1.8 x 10^6 acre-feet of water annually; however, this runoff is not evenly distributed (OSWRB 1965). Although there is no stream gauging station near the head of tide, values from the Siletz River gauge at RM 44.6 give an indication of seasonal fluctuations in flow. About 80% of the average annual yield occurs during November through April, and the period from December through February accounts for almost 50% of the average annual yield (OSWRB 1965). Mean monthly river discharge is above 1600 cfs from November through April, and it is below 200 cfs during July, August, and September (Fig. 2).

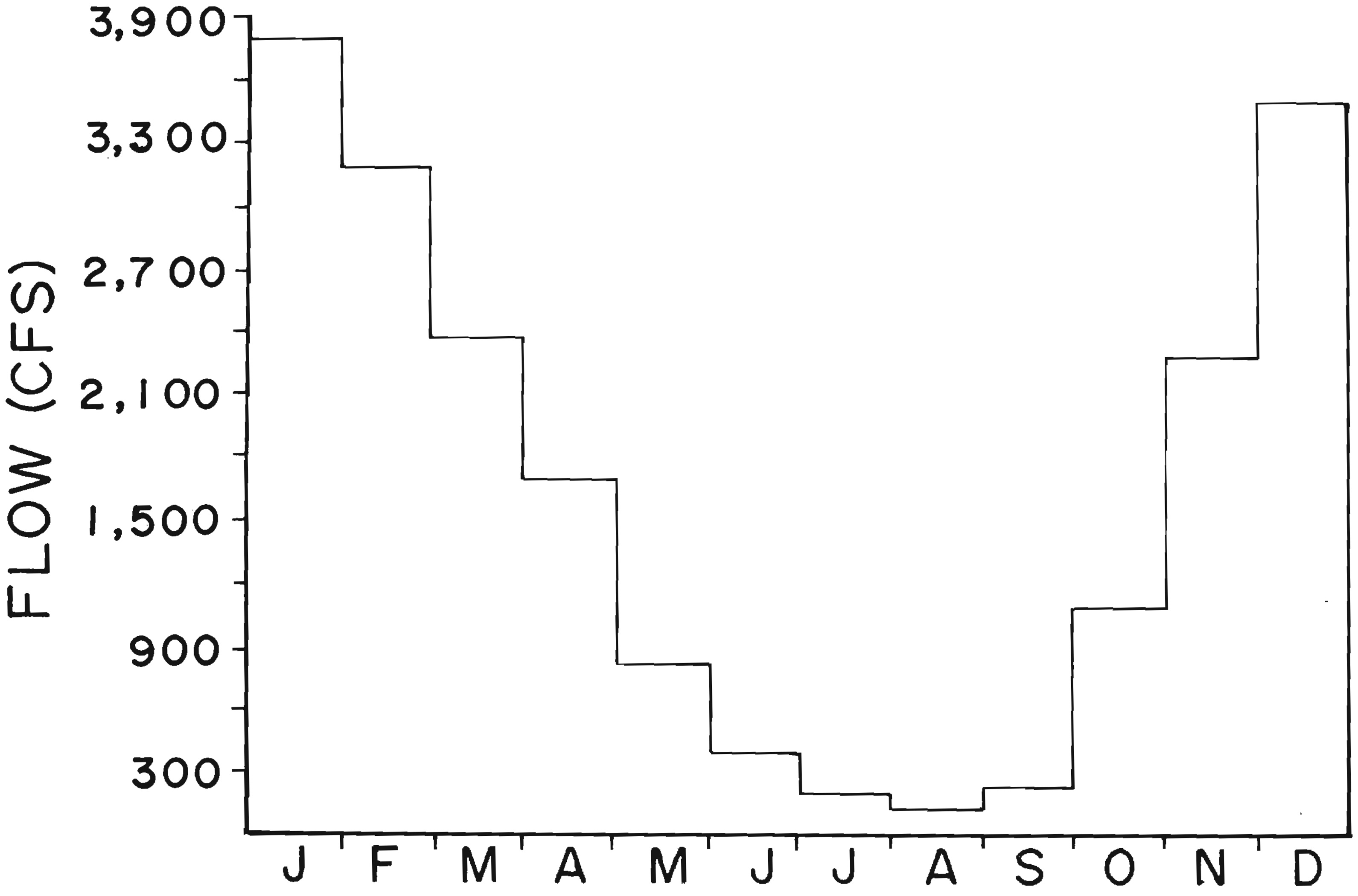

Fig. 2. Mean monthly discharge, Siletz River near Siletz, Oregon, USGS gage #14-305500, 1951-1960 (Smith and Lauman 1972).

The extremes in river flow greatly influence estuarine conditions. High river flows in winter combined with high tides and storm surges have caused extensive flooding in the estuary (Oregon Department of Geology and Mineral Industries [DGMI] 1973). Much of the land adjacent to the estuary is located in the 100 year flood plain (Fig. 3).

Mixing characteristics

The diversity of river flows, fluctuating winds, and tides create a variety of mixing regimes in the estuary, which vary seasonally and spatially. Burt and McAlister (1959) reported the Siletz estuary was partially mixed in October and stratified in January and April. Rauw (1975) arrived at two sets of mixing classifications for the estuary by computing the mixing characteristics with the flow-ratio method and the salinity difference method. Although the two methods produced different mixing classifications, Rauw's (1975) opinion was that the estuary is partially mixed during high tide and well mixed during low tide in the spring. Low river flows during the summer encourage tidal diffusion resulting in a well mixed estuary. The estuary is either well mixed or partially mixed in the fall depending upon tidal stage and river discharge. High flow in winter creates a stratified estuary.

Spatial differences in mixing will also occur due to variations in water depth and circulation pattern. The flats are usually well mixed, while the deeper portions of the estuary may be well mixed, partially mixed, or stratified. The mouth of the bay is usually well mixed due to turbulence induced by tidal action.

Flushing

Flushing times provide a rough estimate of the residence time of pollutants entering the estuary. Although flushing rates vary for different parts of the

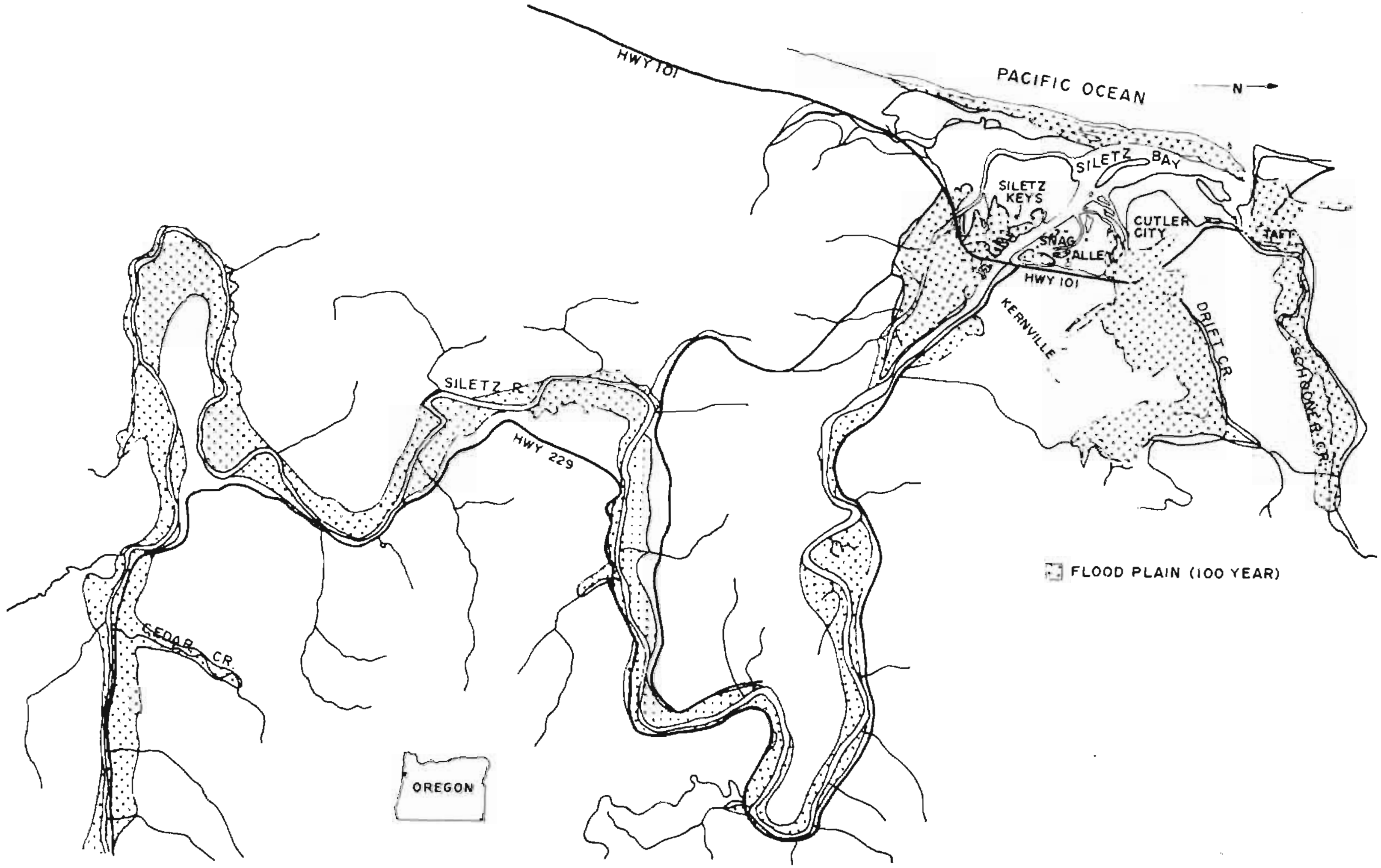

Fig. 3. Flood prone areas of Siletz estuary (USACE 1976).

estuary and for different hydraulic regimes, they are useful for making decisions about the introduction of a pollutant to an estuary. Rauw (1975) calculated the maximum flushing time in the estuary to be 1 tidal cycle with a river flow of 10,000 cfs, 7 tidal cycles at 1000 cfs, and 13 tidal cycles at 100 cfs. In the Siletz estuary the residence time of a pollutant will thus increase as the river flows decrease and as the point of introduction moves upriver.

Temperature

River water entering the estuary is colder than the ocean water in the winter months and warmer in the summer months. Thus there are seasonal temperature gradients in the estuary (Fig. 4, 5). In the winter when river water temperatures are cool, surface water temperatures approximate bottom temperatures and weak gradients exist. High temperatures in the river during summer cause significant longitudinal and vertical temperature gradients in the estuary. Water temperatures increase from the bottom to the surface of the estuary and as upstream distance increases.

Chemical parameters

Rauw (1975) measured salt concentrations in the Siletz estuary (Fig. 6, 7). He observed higher salinities near the mouth, on the bottom, and during low river flow and high tide. Salinities decreased upstream from the mouth but decreased more slowly on the bottom. The maximum limit of saline intrusion was at RM 21.0 at a river flow of 93 cfs (Rauw 1975).

Rauw (1975), the USACE (1976), and the DEQ (1978) reported measurements of dissolved oxygen (DO), pH, turbidity, volatile solids, and coliforms. From these limited data, it appears that the only major water quality problems are high turbidities and high coliform concentrations, which occur in the winter when runoff from the land is greatest.

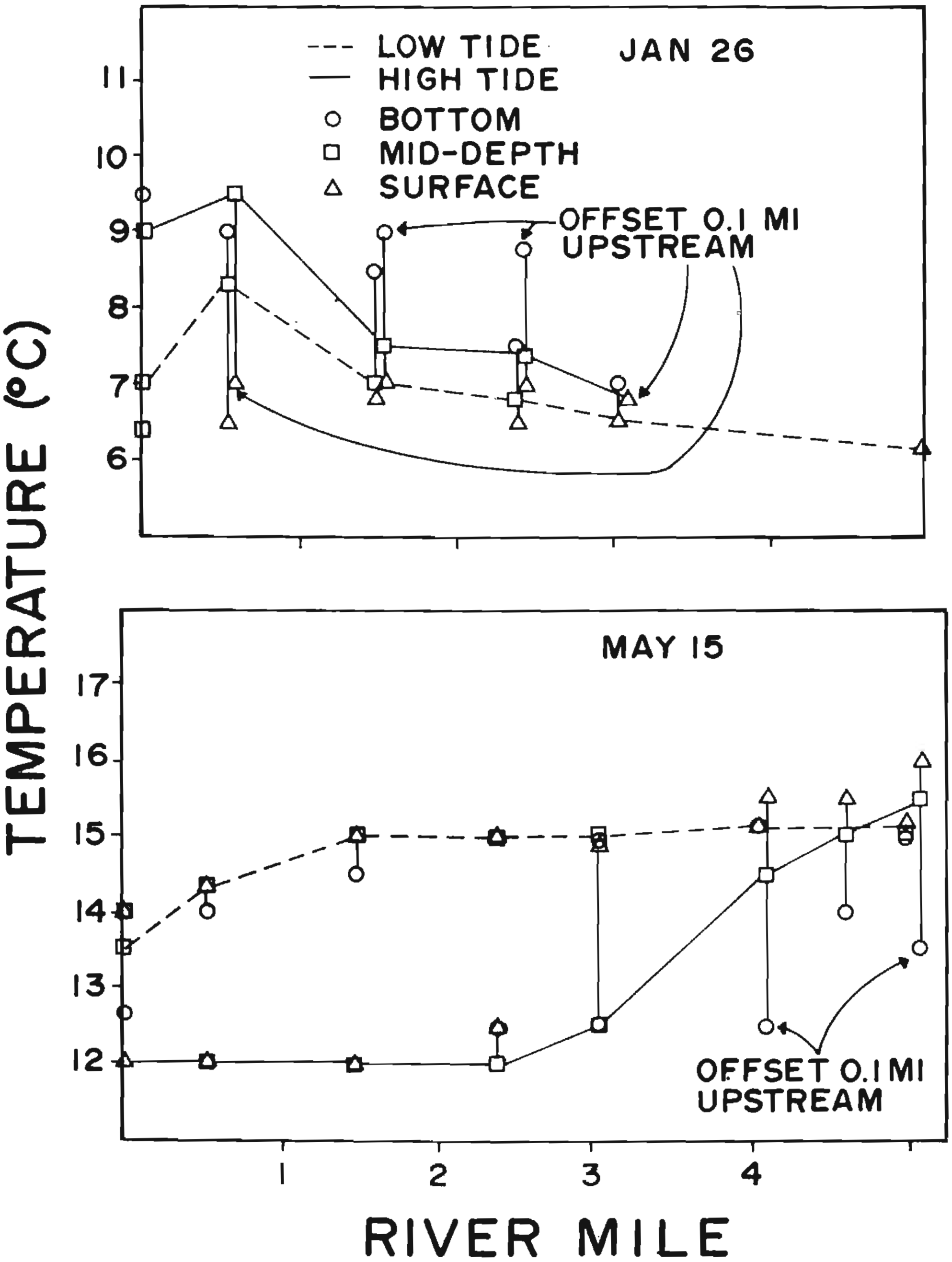

Fig. 4. Temperature vs. river mile, Siletz Bay, January 26 and May 15, 1973 (Rauw 1975).

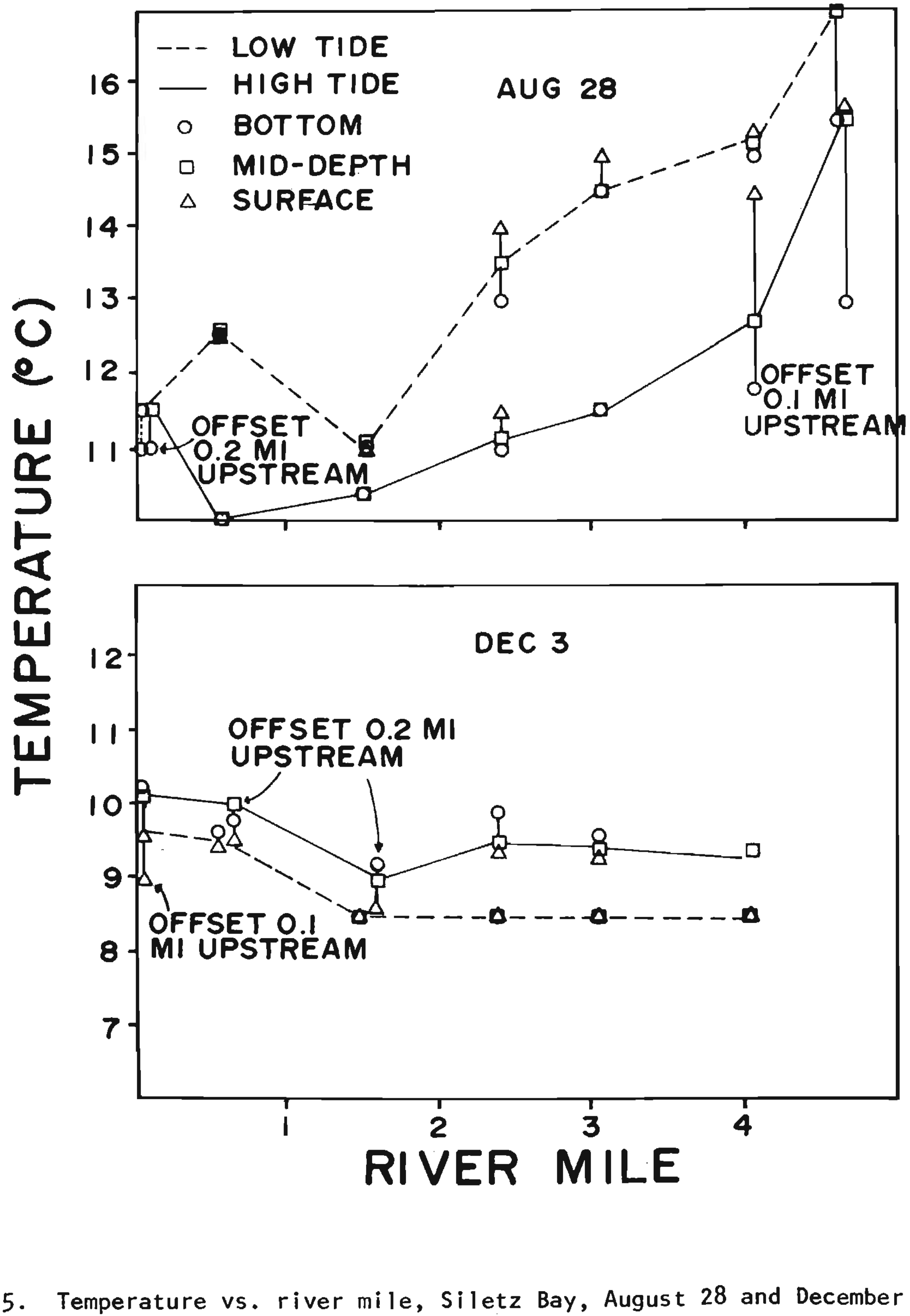

Fig. 5. Temperature vs. river mile, Siletz Bay, August 28 and December 3, 1973 (Rauw 1975).

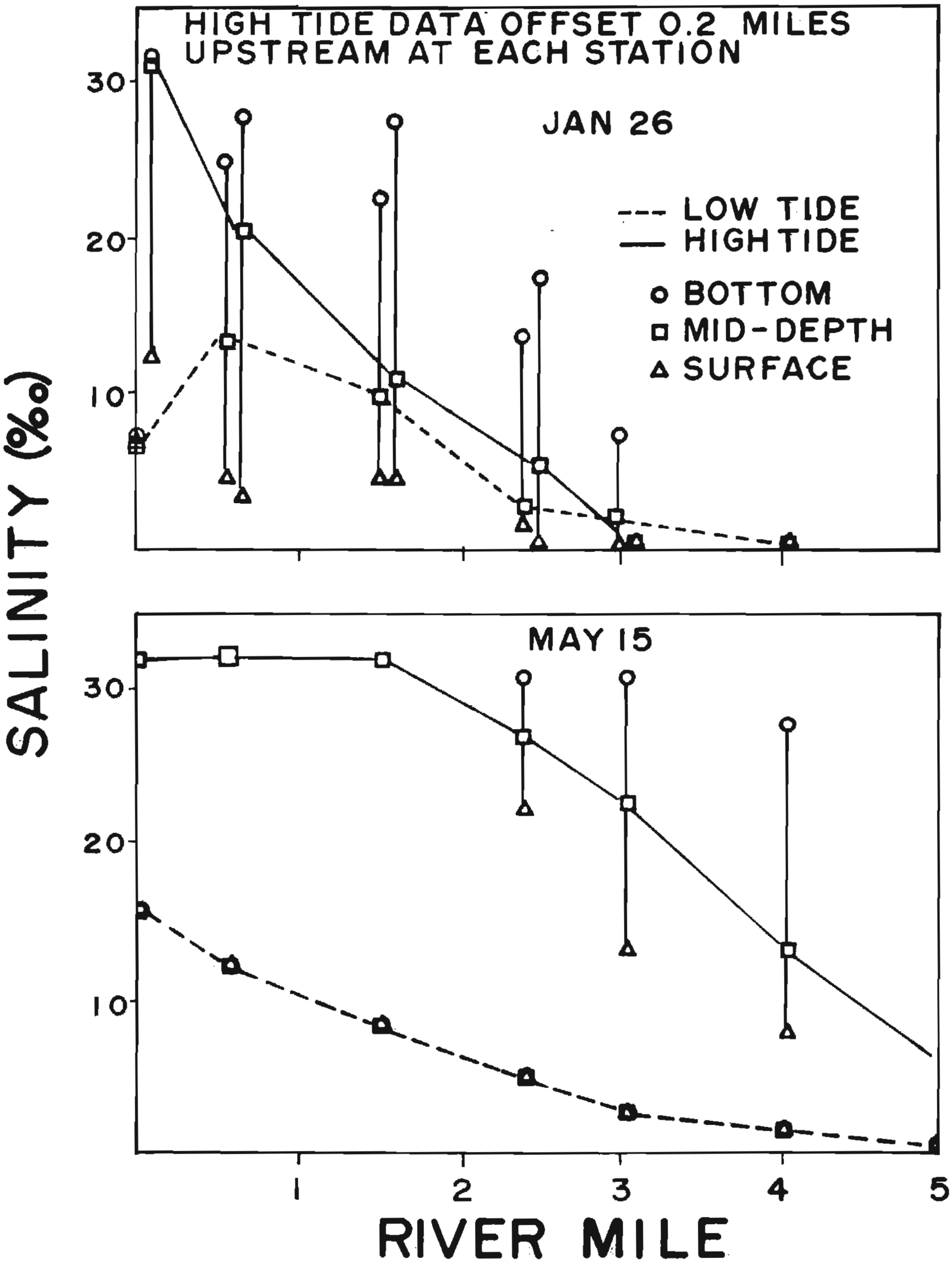

Fig. 6. Salinity vs. river mile, Siletz Bay, January 26 and May 15, 1973 (Rauw 1975).

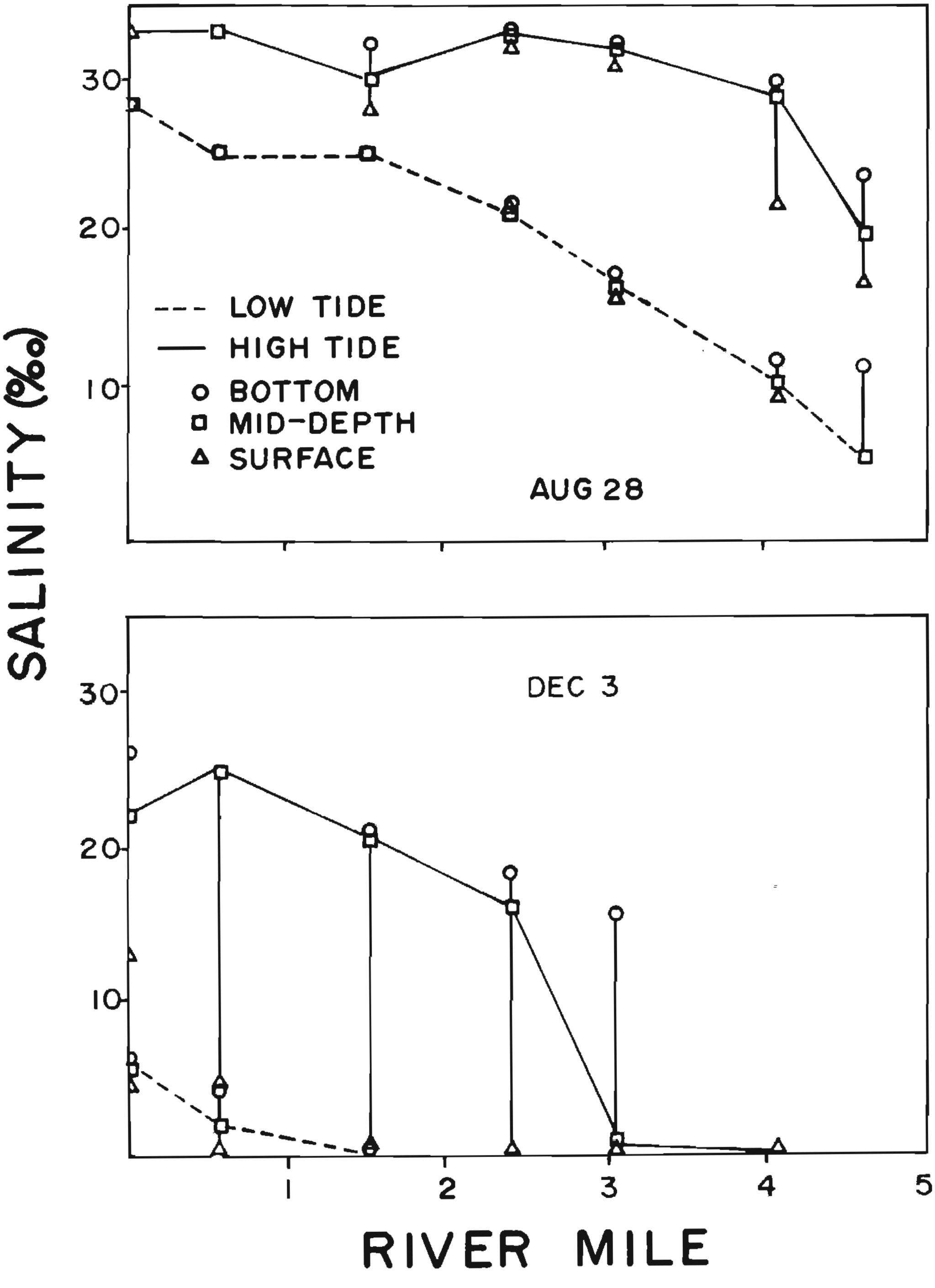

Fig. 7. Salinity vs. river mile, Siletz Bay, August 28 and December 3, 1973 (Rauw 1975).

Sediments

Comprehensive sediment data are not available for the estuary. Rauw (1975) sampled sediments on two occasions and found that grain sizes upstream from RM 2.5 remained unchanged despite seasonal fluctuations in current velocity. Gaumer and Halstead (1976) and the Oregon Department of Fish and Wildlife (ODFW 1978) mapped estuarine substrates based on qualitative sediment observations (Fig. 8).

Biological Characteristics

The biological characteristics of the Siletz estuary have been documented less extensively than the physical characteristics. A shellfish survey and a brief angler catch survey represent the only quantitative data published.

Plants

Plants provide energy for the grazing and detritus food chains in an estuary. Important smaller plants such as phytoplankton and benthic microalgae have not been studied, but Gaumer and Halstead (1976) mapped the distribution of some of the more obvious aquatic plants in portions of the estuary. Akins and Jefferson (1973) classified and mapped the salt marshes.

Invertebrates

Softshell clams (*Mya arenaria*), once quite abundant, are now virtually absent in most parts of the bay (Snow 1973). Despite the recent decrease in sedimentation, clam populations may not return to pre-logging levels because the flats are now higher in elevation and the substrate composition has probably changed. Attempts to introduce Manila littleneck (*Protothaca staminea*) clams in the estuary were unsuccessful (conversation October 10, 1978, with Dale Snow, ODFW, Newport, Oregon). Pacific oysters (*Crassostrea gigas*) were also introduced but did not survive (conversation December 15, 1978,

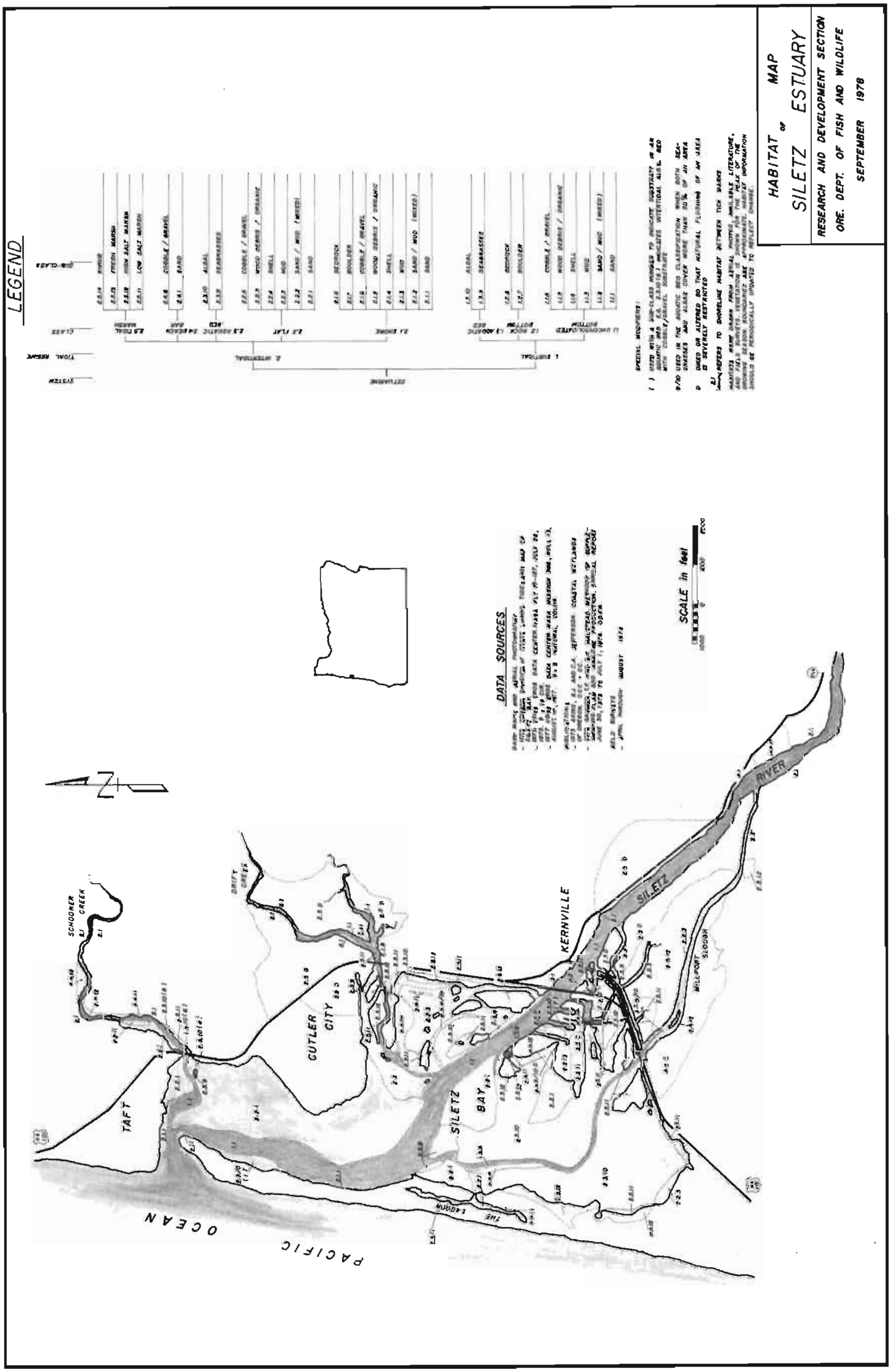

Fig. 8. Habitat map of Siletz estuary (ODFW 1978).

with Laimons Osis, ODFW, Newport, Oregon). Oyster production is inhibited by heavy sedimentation, low salinities in winter caused by high river flows, and high salinities in summer. Parts of the estuary are now closed to the commercial harvesting of shellfish by the State Board of Health; and based on their criteria for closure, much of the estuary could be closed in the future due to the locations of the sewage treatment plant outfalls.

Shellfish studies are the primary source of information on estuarine invertebrates. Other than observations of crabs, kelp worms, and shrimp, there is no discussion of invertebrates in the literature. Data collected from eelgrass communities in Puget Sound suggest that many species of invertebrates may be present in the seagrass beds (Thayer and Phillips 1977).

Fish

There have been no comprehensive surveys of fish in the Siletz estuary, but angler-catch data indicate some of the important sport fish found in the estuary. Starry flounder (*Platichthys stellatus*), Pacific staghorn sculpin (*Leptocottus armatus*), shiner perch (*Cymatogaster aggregata*), and redtail surfperch (*Amphistichus rhodoterus*) are frequently caught in the estuary (Gaumer et al. 1973). Other fish caught in lesser numbers include Northern anchovy (*Engraulis mordax*), Pacific herring (*Clupea harengus pallasi*), tomcod (*Microgadus proximus*), greenling (*Hexagrammos* sp.), and several species of perch (*Embiotocidae*).

Salmonid species, which also use the estuary but are more frequently caught in the river system, include spring and fall chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*O. kisutch*), summer and winter steelhead (*Salmo gairdneri*), and sea-run cutthroat trout (*S. clarki*). The chinook salmon are from a wild stock, whereas the other salmonid populations are hatchery supported. ODFW hatcheries produced about 25% of the cutthroat trout, 40% of the coho salmon, 60% of the winter steelhead, and 94% of the summer steelhead caught in the river system in 1976 (ODFW 1977).

The sport catch of fall chinook salmon and coho salmon has declined in most coastal rivers over the past 10 years (ODFW 1976). However, the Siletz River still produces more chinook and coho than many other coastal streams (ODFW 1977). The river also maintains some of the largest coastal populations of sea-run cutthroat trout, summer steelhead, and winter steelhead. It is one of the top summer steelhead streams in the state and produces brood stock for other streams.

Birds

The Siletz estuary is located in the Pacific flyway and is an important resting stop and wintering area for many migratory waterfowl and shorebirds. The estuary is also important for other types of birds, including bald eagles (*Haliaeetus leucocephalus*) and band-tailed pigeons (*Columba fasciata*). Bird use of the estuary is well documented (Heinz 1971; USACE 1976; Bayer 1977); however, bird usage by specific location and habitat is unknown.

Mammals

Harbor seals (*Phoca vitulina*) feed in the estuary at high tide and rest there at low tide. Although more seals have been observed in the estuary since the passage of the Marine Mammal Protection Act in 1972, the seal population has been estimated to be 1/10 of the population of 100 years ago (conversation November 7, 1978, with Bruce Mate, Oregon State University [OSU], Newport, Oregon).

Many terrestrial mammals occur on lands adjacent to the estuary. Blacktail deer (*Odocoileus hemionus columbianus*), Roosevelt elk (*Cervus canadensis roosevelti*), black bear (*Urus americanus*), and cougar (*Felis concolor*) use the area for wintering grounds (Percy et al. 1974). Many smaller mammals are permanent residents of adjacent lands and rely upon riparian and marsh vegetation for cover and food.

SILETZ ESTUARINE SUBSYSTEMS

The Siletz estuary can be divided into a marine, a bay, and three riverine subsystems, based on sediment size, habitats, and geographic location (Fig. 9). Physical and biological differences in each subsystem are due to the relative influence of ocean water, river water, and currents. Although the subsystems do not function independently, a separate discussion of each of the five subsystems is useful in considering management options.

Marine Subsystem

The marine subsystem extends from the mouth of the estuary to approximately RM 1.5 (Fig. 9). It is an area where ocean waters and strong tidal currents dominate. Thus it is a high energy environment which experiences dramatic seasonal changes. Ocean storm waves travel through the mouth of the estuary and hit the shoreline at Taft. Marine sands comprise much of the substrate.

The marine subsystem is the least altered of the five subsystems. Sections along the bay side of Siletz spit and parts of the Taft and Cutler City shorelines have been riprapped to retard erosion. A fishing pier is located in the intertidal sand shoreline at Taft.

Physical characteristics

Although the substrate in the marine subsystem is primarily marine sand in origin, two rock formations occur. In the intertidal flat just south of Schooner Creek, exposed rocks are part of a Tertiary basalt dike (DGMI 1973). A subtidal "ledge of soft rock" was encountered at the mouth of the bay by the USACE (1897).

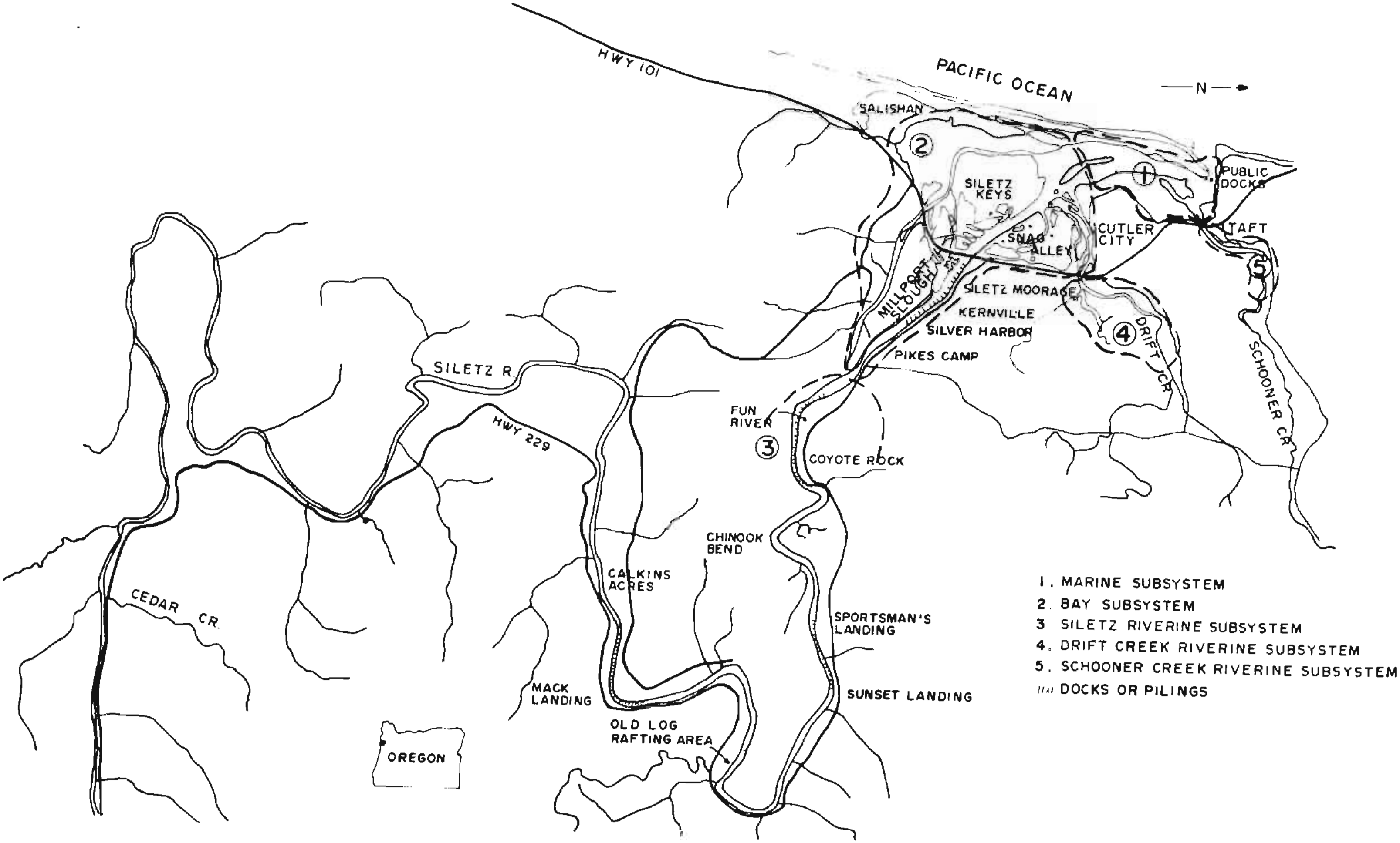

Fig. 9. Siletz estuarine subsystems (base map from USACE 1976).

The USACE (1897, 1934) charted soundings at the mouth of the estuary and from the entrance to Kernville. More recently, Rauw (1975) measured depths at his sampling stations and found that water depths in the marine subsystem changed seasonally. Greater depths occurred in the winter, when high river flows raised the water level and scoured the channel. The channel was shallower in the summer, when small, short period ocean waves overpowered the low river flows and pushed marine sediment through the mouth of the estuary.

Seasonal changes in river discharge also influenced the salinity distribution in the marine subsystem (Fig. 6, 7). Moderately low flows in the spring induced a well mixed condition with identical surface and bottom salinities at high and low tides throughout the marine subsystem (Rauw 1975). Spring high tide salinities were 32 $^{o}/oo$, indicating a dominance of ocean water, while low tide salinities decreased from 15 $^{o}/oo$ at the mouth to 8 $^{o}/oo$ at RM 1.5. Summer low flow conditions formed a well mixed subsystem with high salinities thoughout the marine subsystem. Winter and fall high flows created a stratified condition with low surface salinities and high bottom salinities (Rauw 1975).

The marine subsystem contained the coolest water in the estuary in the summer during low flows, when river temperatures were high (Rauw 1975). In the winter when ocean water was warmer than river water, temperatures in the marine subsystem were higher than in other parts of the estuary. Rauw (1975) also observed that the turbidity maximum for the estuary occurred at low tide in the winter at about RM 0.5.

Habitats and species

Intertidal sand habitats account for about 67% of the surface area in the marine subsystem (Table 3). Gaumer and Halstead (1976) sampled transects in this subsystem and found that shrimp inhabitated the flats and shores, but only a few softshell and baltic (*Macoma balthica*) clams were observed in the same area. The sand flats north of Cutler City are closed to the commercial harvest of shellfish due to the sewage treatment plant outfall located on Schooner Creek.

Table 3. Approximate percentage of habitat surface area within two subsystems of the Siletz estuary.[a]

Habitat	Marine Subsystem		Bay Subsystem	
Subtidal	32		12	
Unconsolidated bottom		32		9
Seagrass bed				2
Seagrass/algal bed				1
Intertidal	68		88	
Sand shore		2		
Rock shore		*		
Sand flat		65		6
Sand/mud flat				4
Mud flat				1
Undifferentiated flat				1
Seagrass bed				4
Algal bed		1		25
Seagrass/algal bed				*
High marsh				20
Low marsh				10
Diked marsh				17

[a] *Values estimated from habitat map of Siletz Estuary (ODFW 1978).*

* *Less than 1%.*

Although there are apparently few species of macroinvertebrates in the intertidal sand habitats,the area is used by many fish species. Work in other Oregon estuaries suggests the largest diversity of fish species in the estuary often occurs near the mouth (Bottom and Forsberg 1978). In the winter when salinities are extremely low in other subsystems, many marine species entering the estuary may be confined to this subsystem. Marine species would also move into the marine subsystem in larger numbers at high tide. Anadromous fish pass through this subsystem, and some species, such as juvenile fall chinook salmon, may rear in the area before entering the ocean. In some estuaries, juvenile chinook rear the entire summer in shallow water over sand substrates prior to seaward migration (Reimers 1970).

Creel surveys indicate some of the sport fish found in the estuary. Dungeness crab (*Cancer magister*), Pacific staghorn sculpin, shiner perch, and starry flounder are most often caught by shore and boat anglers in this subsystem (Gaumer et al. 1973). The sand shore and fishing pier at Taft are the most heavily used shore fishing areas in the estuary.

Gulls and shorebirds feed and rest in the intertidal areas. The largest bird concentrations occur in the fall and spring. The intertidal sand shore on the inside portion of the Siletz spit is a seal resting area. Seals probably utilize the estuary during all seasons. As many as 65 seals have been observed at a single time (conversation November 7, 1978, with Bruce Mate, O.S.U. Newport, Oregon).

Management recommendations

The intertidal surface area of the marine subsystem should be maintained, since it is an important fish rearing area. The sand flats north of Cutler City should be considered as major tracts which require inclusion in a natural designation as described by the LCDC (1977) Estuarine Resources Goal. The shore areas on the inside of Siletz spit should be maintained so they continue to provide rearing habits for fish. Limited development along the riprapped shoreline at Taft may be encouraged if it is built to withstand storm waves, and it does not require intertidal fill or dredging, does not compact the surface sediments, and does not excessively shade the substrate, which could destroy benthic communities.

Bay Subsystem

The bay subsystem is located between the marine and riverine subsystems of the Siletz River (Fig. 9). It starts at approximately RM 1.5 and extends to the head of Millport Slough at RM 4.0. This subsystem is a transition zone between salt and fresh waters and contains all the major marshes and flats in the estuary. Two classes of intertidal habitats, marshes and aquatic beds, account for 76% of the total subsystem surface area (Table 3).

Physical characteristics

Major alterations in terrain, water courses, and biota have occurred in the bay subsystem (Fig. 10). The terrain has been altered by diking and filling. Fills for U.S. Highway 101 and Siletz Keys are the most significant alterations, but fills also occur on the Kernville-Siletz highway, the marshland east of Siletz Keys, and along the southern shoreline of the bay. The northern shoreline from the highway bridge to the edge of this subsystem is lined with docks, piers, and pilings from new marinas and old mills, canneries, and log storage areas.

Major changes in circulation have resulted from the alteration of water courses. Millport Slough was diked causing accelerated erosion of Siletz spit and accelerated deposition of sediments in the south bay. Sijota Creek was also diked and channelized as it passes through the Salishan development. The Siletz Keys and Salishan sewage treatment plant discharges also may have affected water quality, but those effects have not been determined. The State Board of Health may ultimately close the south bay to the commercial harvest of shellfish due to discharges from the sewage treatment plants.

The species composition of the marshes changed where dikes were constructed to create pasture land. Most of the land south of Millport Slough, much of the island east of highway 101, and areas north of the Kernville road have

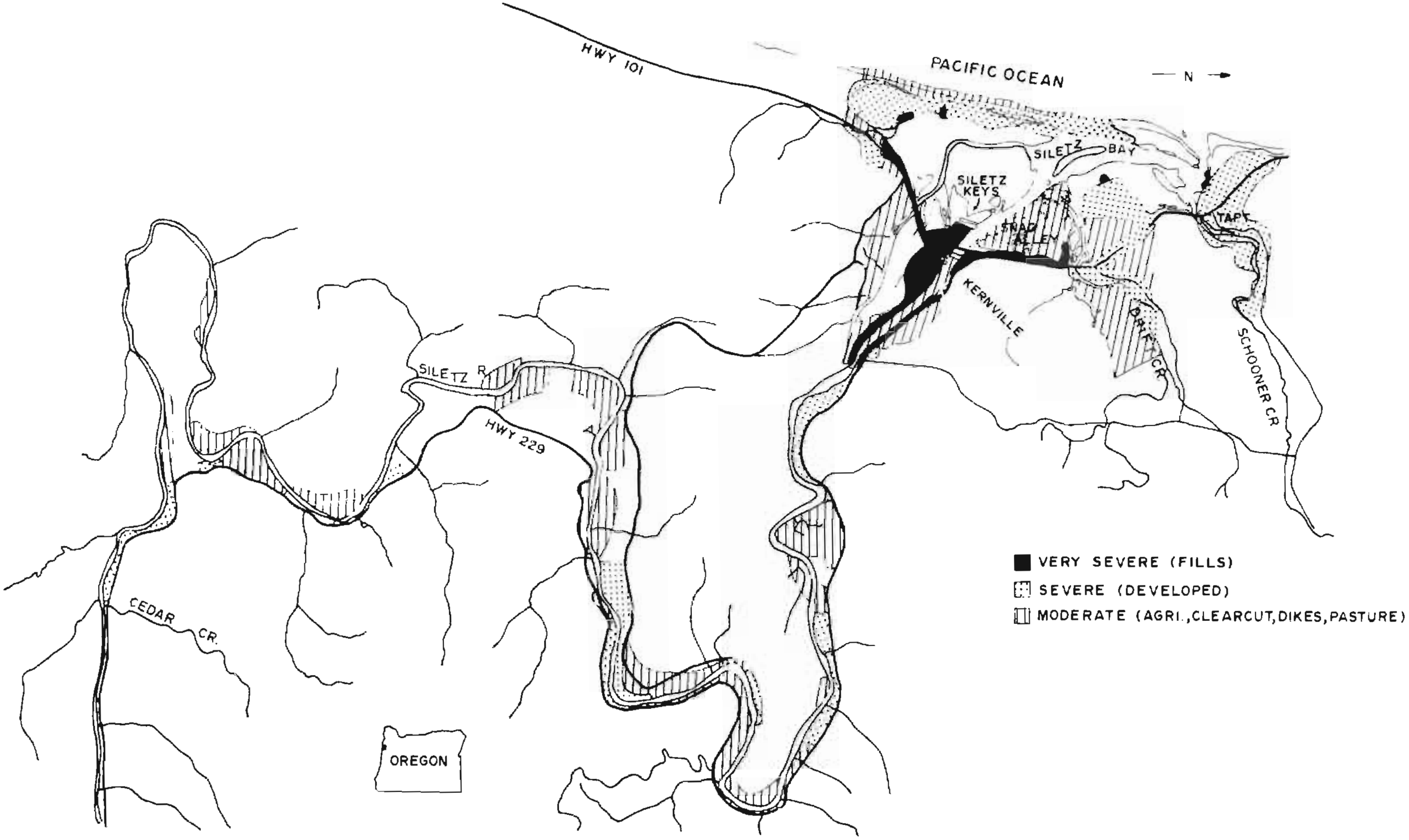

Fig. 10. Extent of physical alterations to the Siletz estuary (USACE 1976).

been diked for pasture (Fig. 10). Increased sedimentation in this subsystem from logging in the drainage basin has encouraged marsh expansion, particularly in the south bay and south of Cutler City. Log storage in the Kernville area has probably changed the benthic fauna. Since no studies are available for this area, it is difficult to assess the effects of logs pounding on the intertidal shore. Studies in Coos Bay by the DEQ, however, have shown that grounded logs can have a dramatic impact on the diversity and abundance of benthic species (Zegers 1978).

The sediments of this subsystem have been characterized as marine-fluviatile. Rauw (1975) observed that mean grain sizes decreased from RM 1.5 to RM 3.0, then increased rapidly to RM 4.0. Sediments on the South Bay and Drift Creek flats were fine grained and much smaller than channel sediments.

Water depths in the main channel of the bay subsystem were also measured by Rauw (1975). The channel was relatively shallow from RM 1.5 to RM 2.5, and depths gradually increased to the edge of the subsystems. His data indicated a slightly deeper area at RM 3.0 at the site of the old U.S. Highway 101 bridge. Water depths and current velocities increased during winter high river flows.

Rauw (1975) observed large vertical salinity gradients in the bay subsystem in the fall and winter. The limit of saline intrusion was located in this subsystem between RM 2.5 and RM 4.0 for both high and low tides. In the spring the channel portions of the bay subsystem were partially mixed at high tide and well mixed at low tide. During the summer this subsystem was well mixed at all tidal stages.

During winter, horizontal and vertical temperature gradients were absent (Rauw 1975). In late spring, summer, and fall during low stream flow, this subsystem exhibited the strongest longitudinal temperature gradient in the estuary. Vertical temperature gradients were not as large due to the well mixed conditions at low flows.

Habitats and species

The bay subsystem contains the greatest variety of habitats in the estuary. The habitats exhibit typical vertical zonation from lower intertidal to extreme high water as seagrass beds graduate into algal beds, flats, low marshes, and high marshes (ODFW 1978). To facilitate discussion of this wide array of habitats, the bay subsystem has been further divided by geographic location. Habitats and species are discussed as they occur in Snag Alley, the main channel, south bay, and in the Siletz Keys and Millport Slough marshes (Fig. 11).

Snag Alley, at the mouth of Drift Creek, is an area with large tracts of flats and low marshes. A low sedge (*Carex* sp.) marsh is expanding near the highway, and the rapid rate of sediment accretion is encouraging the colonization of flats by many circular clumps of seaside arrow grass (*Triglochin maritima*). High marsh, located on the perimeter of Snag Alley, provides habitat for small mammals. The extensive flats which occur at Snag Alley are covered in the summer with green algae (primarily *Ulva* and *Enteromorpha* spp.). In winter smaller microalgae dominate. Eelgrass (*Zostera* sp.) exists in the moist depressions of these flats. Large populations of ghost shrimp (*Callianassa californiensis*) and mud shrimp (*Upogebia pugettensis*) may be found here, and small populations of softshell clams, baltic clams, and bentnose clams (*Macoma nasuta*) also occur on the flats.

The flats and marshes of Snag Alley are heavily used by migratory birds. Large numbers of waterfowl, shorebirds, and wading birds feed and rest here during the winter (Heinz 1971; Bayer 1977). In late summer, bandtailed pigeons use the mouth of Drift Creek as a watering and resting area. Seals also rest on the low islands along the channel.

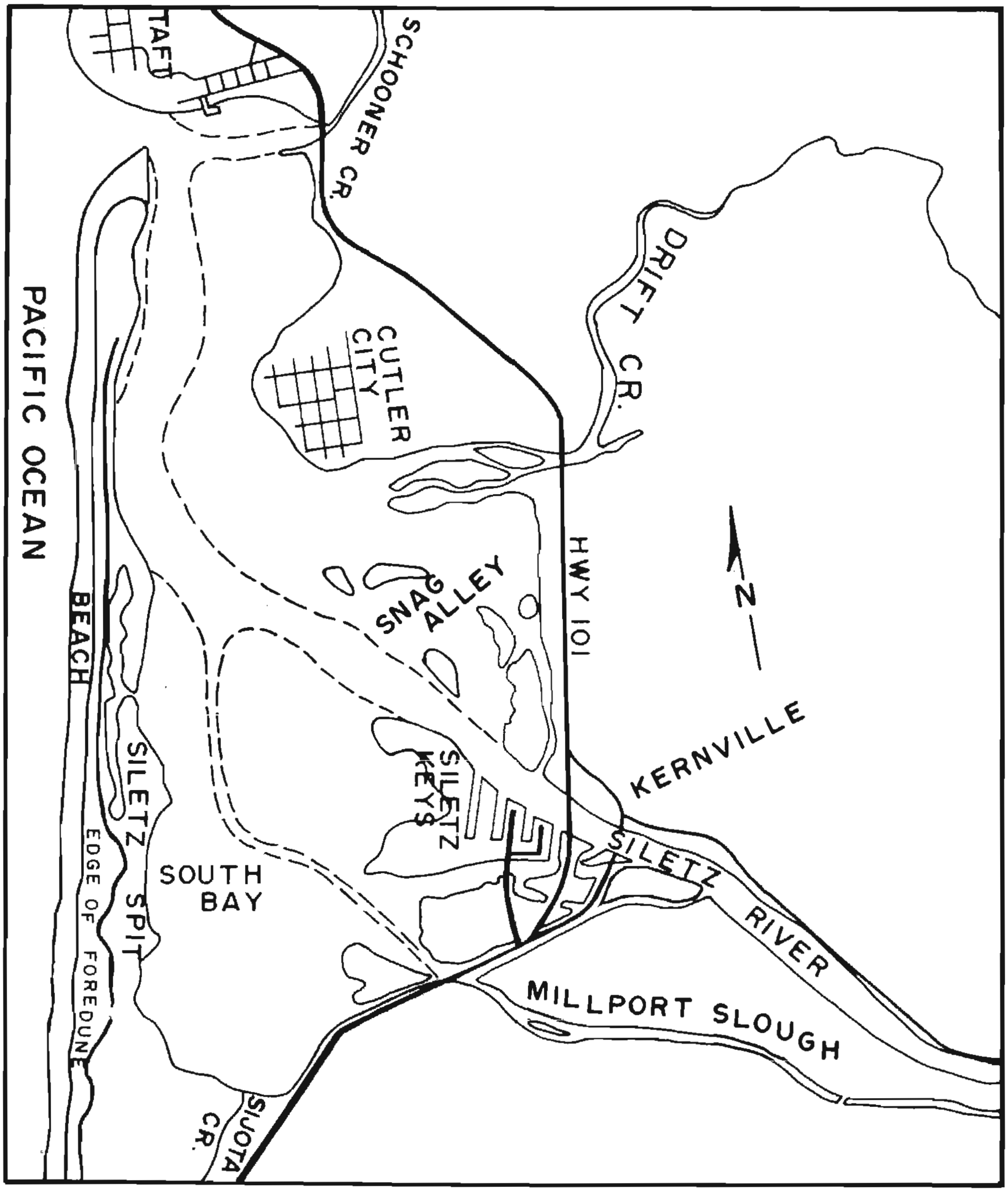

Fig. 11. Bay subsystem (Rauw, 1975).

The main channel of the Siletz River (Fig. 11) is primarily comprised of subtidal habitats with unconsolidated sediments (Fig. 8). Gaumer and Halstead (1976) stated that clams were absent from the substrate. They noted that the unconsolidated substrate appeared to be suitable clam habitat, but postulated that strong currents precluded larvae from settling on or surviving in the substrate. Current velocities in the channel may decrease now that the Millport Slough dike has been removed.

The south bay, located south of the main channel (Fig. 11), largely consists of flats, algal beds, and eelgrass beds (Fig. 8). The south bay flats contain high concentrations of ghost and mud shrimp. A few baltic clams and a few adult softshells were observed by Gaumer and Halstead (1976), but they did see many softshell sets. The population may be returning, but probably environmental conditions are such that juvenile clams may set but do not survive. The flats may be elevated enough so that increased sediment surface temperatures and time of exposure may limit clam survival.

Fish use of the south bay is not well documented, but perch and flounder have been observed on the edge of the flats (Gaumer et al. 1973). Zinn (1973) reported that flounder spawn on the south bay flats. Data from other estuaries suggest that eelgrass beds harbor more fish species than other habitats in the estuary (Bottom and Forsberg 1978). The extensive eelgrass and flat habitats are used in the winter by waterfowl and shorebirds. Black brant (*Branta bernicla*) feed on eelgrass in the south bay, but apparently do not overwinter (Bayer 1977). Great blue heron (*Ardea herodias*) feed on the flats the entire year.

The Siletz Keys and Millport Slough marshes lie east of the south bay (Fig. 11). This portion of the bay subsystem contains most of the marsh in the estuary. The Millport Slough marshes primarily consist of large expanses high marsh, while the Siletz Keys marshes are primarily rapidly expanding low marshes (Fig. 12). "Marshes on the delta of Siletz River ... provide exceptional examples of extensive sedge marshes" (Jefferson 1975).

The marshes of Siletz Keys are the site of two ecological studies. The U.S. Environmental Protection Agency (EPA) is studying nutrient exchange between marsh and bay and the productivity of several species of wetland plants. Two Oregon State University researchers are studying the seasonal use of marshes by invertebrates and fish (Morgan and Holton 1977).

The channels in both the Siletz Keys and Millport Slough marshes are used by waterfowl, shorebirds, and wading birds. Band-tailed pigeons water at a mineral spring located at the site of the old Millport Slough dike, and the high marshes and diked marshes are used as nesting and resting areas for many bird species. Mammals also utilize the area.

Management recommendations

The bay subsystem contains the greatest diversity of habitats in the estuary. Most of the marshes, flats, and aquatic beds are located in this subsystem, and subtidal habitats comprise a small percentage of the total acreage of this subsystem. The marshes, flats, and aquatic beds are important areas of primary production and provide important feeding and resting areas for many species. The algal beds, eelgrass beds, tideflats, and salt marshes of the Snag Alley and south bay portions of the bay subsystem should be considered as major tracts and protected accordingly.

The intertidal shore of the main river channel near Kernville, on the north bank from the bridge to the end of the bay subsystem, is highly altered. It has been used historically for mills, canneries, and log storage and is presently used for marina operations. The Kernville area, with a deep, self-scouring channel, could accommodate additional marinas and docks.

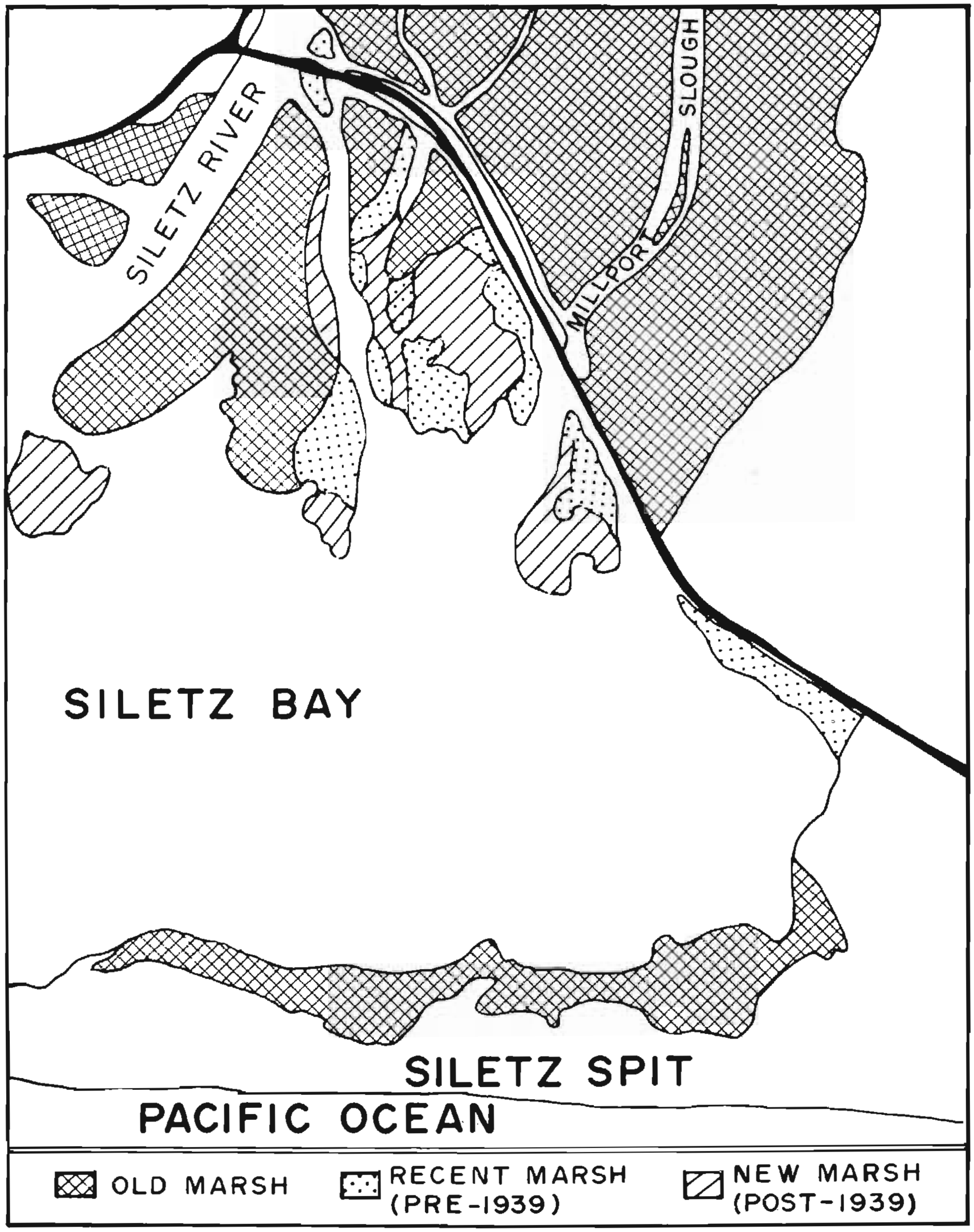

Fig. 12. Marsh expansion in the southern portion of Siletz Bay (Rea 1975).

The Siletz Keys and Millport Slough areas contain the largest tracts of marsh in the estuary. The Siletz Keys development poses a conflict with habitat protection. Additional fill, diking, dock extensions, and bank stabilization should not be allowed to encroach upon the marshes. Culverts should be installed in each of the causeways to increase flushing. This will become more important as the load on the Siletz Keys sewage treatment plant increases. Diked marshes in the Millport Slough area sould be restored or retained for low intensity uses, since they are important bird and mammal resting and feeding areas. Limiting adjacent upland areas to low intensity activities would also help preserve the natural values of the marshes.

Siletz Riverine Subsystem

The Siletz River subsystem extends from the head of Millport Slough at RM 4.0 to Cedar Creek, the head of tide at RM 26.6 (Fig. 9). The estuary in this subsystem has primarily riverine characteristics with fluctuations in water level due to tidal influences.

The shoreline has been altered by commercial and private development. Marinas, trailer parks, and residential subdivisions, interspersed by agricultural and undeveloped land, are clumped along the north bank. A few boat landings are also maintained. This section of the river is heavily used by bank and boat anglers. Riprap, bulkheads, docks, and pilings have altered intertidal areas, and riparian vegetation has been destroyed in many localities.

Physical characteristics

The substrate in this subsystem changes from sand to gravel (Rauw 1975). Water depth, influenced by the tidal range and river flow, is generally greater than in the bay subsystem. The tidal range decreases with high river flows. High flows in winter raise the water level and often flood the surrounding area (Fig. 3). Flood water velocities are high due to the narrow channel.

High winter flows minimize the intrusion of saline water. During a summer low flow, saline water has intruded to RM 21.0 (Rauw 1975). In the summer water temperatures dramatically increase.

Habitats and species

Habitats in this subsystem were not mapped, but the intertidal shore and subtidal categories probably apply to most of the area (Fig. 8). Freshwater mussels live in the river's upper reaches. Mammals such as beaver (*Castor canadensis*), river otter (*Lutra canadensis*), mink (*Mustela vison*), and muskrat (*Ondatra zibethica*) are also residents of the river habitats. Other mammals associated with the riverine subsystem include raccoon (*Procyon lotor*), bobcat (*Lynx rufus*), nutria (*Myocastor coypus*), coyote (*Canis latrans*), red fox (*Vulpes fulva*), deer, elk, bear, and cougar (USACE 1976).

Management recommendations

Recreational angling for anadromous fish is popular in the Siletz River subsystem and has stimulated recreational and residential development on the stream banks. The desire for a river front location has encouraged building as close to the river as possible, although seasonally high ground water causes septic tank failures. Private docks are abundant along the river. Other alterations include the destruction of riparian vegetation and the placement of bulkheads or riprap for bank stabilization.

Much of the land adjacent to the riverine portion of the estuary is in the floodway or floodway fringe. High velocity flood waters which cause erosion are to be expected. Riprap and other bank stabilization measures merely shift the erosional forces from one area to another.

Riprap, bulkheads, and docks also destroy vegetation on the river banks. This riparian vegetation provides cover for fish and terrestrial animals and habitat for terrestrial insects consumed by fish. Docks also reduce production of aquatic plants by shading and may be stranded on the bottom at low tide, decimating the benthic populations.

Increased development in this subsystem poses a potential threat to the habitats in this portion of the estuary. Fish habitats, in particular, could be critically degraded or destroyed. The entire Siletz River corridor should be managed as a unit so that piecemeal destruction of streamside habitats does not occur. Management decisions should be based on a stream corridor plan that incorporates the following recommendations.

To prevent the destruction of organisms which live in or use the estuary, riparian vegetation should be maintained, as suggested by the implementation requirements of the Coastal Shorelands Goal (LCDC 1977). New buildings should be constructed at a sufficient distance from the river so that bank stabilization measures are not required. This would also reduce flooding and flood-induced erosion caused by encroachment into the floodway fringe. This type of a non-structural solution to problems of erosion and flooding is also encouraged by the implementation requirements of the Coastal Shorelands Goal (LCDC 1977).

Restricting docks and other structures to stretches of river where they are already established would help protect riparian and benthic habitats. Thus, additional docks should be limited to the Fun River-Coyote Rock area, Sportsman's Landing-Sunset Landing area, and the Mack landing area (Fig. 9). This would help to maintain a diversity of uses in the estuary with some developed areas and some natural areas. Diversity in the estuary would also be enhanced by retaining the south side of the river for low intensity land uses, such as agriculture.

Public marinas or boat ramps could be estabished as an alternative to additional private docks. These developments should also be built only where structures and bank alterations currently exist. Storage of boats on land should be encouraged as an alternative to storage on the water.

Finally, steps should be taken to prevent the discharge of sewage into the estuary. A pollutant entering the water in this subsystem would remain in the estuary for long periods of time. Adequate waste treatment facilities are needed to prevent introduction of pollutants into the estuary.

Drift Creek Riverine Subsystem

The Drift Creek riverine subsystem covers the area from the U.S. 101 bridge to the head of tide (Fig. 9). Habitats in this subsystem consist of two low sedge marshes, one bedrock shore, other intertidal shores, and some subtidal acreage. This subsystem contributes freshwater and sediments to the estuarine system. Most of the land surrounding this portion of the estuary is within the 100 year flood plain (Fig. 3).

Diked salt marshes are the major alterations to this subsystem. Salt marshes were diked prior to 1928 to provide pasture land and are still grazed (Zinn 1973). The watershed of Drift Creek has been extensively logged, and the resulting deposition of sediment constitutes the only other major alteration to this subsystem.

Physical characteristics

Physical characteristics of the Drift Creek subsystem have not been studied in detail. Random observations of temperature and river flow constitute the only published data (Skeesick and Gaumer 1970; Smith and Lauman 1972). Low river flows with high water temperatures occur in the summer, and high water in the winter brings cold, turbid water into this subsystem. Winter runoff from the adjacent pasture land may raise coliform concentrations there.

Habitats and species

Two low fringing sedge marshes occur near a bedrock shore at the mouth of Drift Creek (Fig. 8). Extensive areas of diked marsh are located on both sides of Drift Creek. Since sediment data are lacking for this subsystem, the other habitats are classified as intertidal shore and subtidal unconsolidated bottom.

Little is known about the physical and biological characteristics of this subsystem. The only information regarding fish specific to Drift Creek comes from spawning ground counts and sport angling catch data. This subsystem is important as a transportation corridor for anadromous fish, especially winter steelhead and fall chinook.

Management recommendations

This subsystem is just upstream from major tracts of tideflats and salt marshes. Alterations to Drift Creek could affect important habitats downstream. Since most of the land in the subsystem is in the flood plain, and sensitive habitats are downstream, alterations which could further reduce low summer flows, increase sedimentation, or impair water quality should be kept to a minimum. With the existing low intensity land uses, bank stabilization measures should be unnecessary. Docks, marinas, and boat ramps are not suited to the area, since large, shallow flats lie between the mouth of Drift Creek and the main channel of the Siletz River.

Preservation of the riparian vegetation is essential to the survival of fish in this subsystem. Bank stabilization measures should be allowed only as part of an overall stream corridor management program.

Schooner Creek Riverine Subsystem

The Schooner Creek subsystem lies between the U.S. 101 bridge and the head of tide, 0.8 miles upstream (Fig. 9). Subtidal and intertidal aquatic beds and low marshes flourish in the lower portions of this subsystem, while the upstream portions are primarily intertidal shores (Fig. 8). Alterations include some riprap, a few pilings, and a sewage treatment plant.

Physical characteristics

Physical characteristics of the Schooner Creek subsystem have not been studied in detail. Random observations of temperature and river flow represent the only data published (Skeesick and Gaumer 1970; Smith and Lauman 1972). Schooner Creek probably has high water temperatures during summer low flow periods. Since Schooner Creek flows through agricultural lands, it may have high coliform concentrations in the winter, when peak runoff occurs. Data documenting the affect of the sewage treatment plant on water quality are absent; however, the State Board of Health has prohibited the commercial harvest of shellfish downstream from the outfall (Osis and Demory 1976).

Habitats and species

A gradient of habitats is evident in this subsystem. Habitats at the mouth of Schooner Creek experience high salinities and are relatively well flushed. Several species of algae attached to gravel form subtidal and intertidal aquatic beds. Sand shores and low sedge marshes typify the region just upstream from the mouth, and some high marshes occur further upstream (Fig. 8). Beyond the sewage treatment plant, the habitats are more typically riverine. Steep banks covered with riparian vegetation predominate. Species specific information is unavailable for this subsystem; however, coho salmon, steelhead trout, and cutthroat trout do spawn above tidewater on Schooner Creek.

Management recommendations

Data needed to evaluate the importance of this subsystem to the estuary are lacking. However, the aquatic beds and the low marshes are probably highly productive and should be preserved. The sand shore is also an important habitat. Maintenance of riparian vegetation is essential for fish survival.

Since Schooner Creek is relatively shallow, marinas and docks for large boats are inappropriate; however, a boat ramp or a few public docks for smaller boats would not severely degrade this subsystem. Such facilities should be located where riprap or bulkheads already exist. Suitable locations for recreational water-oriented developments are west and north of the sewage treatment plant.

SUMMARY AND RESEARCH RECOMMENDATIONS

The Siletz estuary is now primarily used for recreational purposes. Fishing, hunting, bird watching, crabbing, boating, and sightseeing are becoming increasingly popular. Land around the estuary is receiving intense developmental pressure, and future development must be carefully planned to prevent degradation of valuable resources.

Little biological information exists to assess the impact of development on the estuary. Most of the published data come from a few observations and present a static view. Environments in the Siletz estuary are highly dynamic, however, and experience dramatic diurnal, seasonal, and annual changes. Both average and extreme conditions influence the distribution of organisms in the estuary.

Basic biological surveys represent the greatest research need. A list of species currently using the estuary is necessary to predict or evaluate changes due to estuarine alterations. Baseline surveys of plants, invertebrates, fish, birds, and mammals are needed to more accurately characterize the relationships between organisms and their environment. Ecological studies are also desirable to assess impacts of development. A comprehensive study should be conducted to determine the effects a large, private salmon hatchery would have on ODFW hatchery fish, wild salmonids, and non-game fish, which are important components of the estuarine food web.

Physical characteristics of the Siletz estuary have been studied, but additional work is needed to obtain an estimate of average and extreme environmental conditions. Physical process and water quality parameters should be collected concurrently and correlated to season, river flow, and tidal stage. Future studies should collect and present information similarly to maximize the usefulness of the data. Other research needs include analyzing sediments (including grain size, sources, and rates), charting water depths, and monitoring water quality parameters. The DEQ maintains six water surveillance stations in the Siletz estuary. These should be used in a consistent, long-term monitoring program. Also, the effects of septic tank leakage and sewage treatment plant discharges on water quality should be investigated.

Since comprehensive data are lacking, a diversity of habitats should be maintained to minimize the risk of irreversible changes (Bella 1978, LCDC 1977). To ensure that the resources of the Siletz estuary are conserved for future generations, habitats such as the sand flats of the marine subsystem, the shore habitats of the riverine and slough subsystems, and the high marsh habitats of the bay subsystem should be protected, since they provide a place to rest, nest, and feed for many organisms. The flats, aquatic beds, and low marshes of the bay subsystem are highly productive and require protection to ensure the stability of the estuarine food web. The channels in the estuary should remain free of structures which would hinder the passage of anadromous fish. Since the Siletz estuary is classified as a conservation estuary, the channel should only be dredged where it is required to accommodate existing facilities.

Some development of the estuary is desirable to enhance recreational opportunities. Suitable sites for docks, marinas, and boat ramps are located between Kernville and Pikes Camp and at existing sites on the north bank of the Siletz River which are already altered. Parts of Schooner Creek could accommodate some recreational development, and the riprapped shoreline of Taft could accommodate recreational or light commercial development if the sand habitats were not disrupted. Care should be taken in the Taft area not to alter the intertidal habitats by fill, removal, compaction, or the exclusion of sunlight.

REFERENCES CITED

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

Bayer, R. (ed.). 1977. Birds of Lincoln County, Oregon. Sea Grant Marine Advisory Program, Oreg. State Univ. Newport. 19 pp.

Bella, D. A. 1978. Environment, technology, and future generations. Water Resources Research Institute, Oreg. State Univ., Corvallis. 36 pp.

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

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

Cleaver, F. C. 1951. Fishery statistics of Oregon. Fish Comm. Oreg. Contrib. No. 16.

Dicken, S. N., C. L. Johannessen, and B. Hanneson. 1961. Some recent physical changes of the Oregon coast. Dep. Geogr., Univ. Oreg. Eugene. 140 pp.

Gaumer, T, D. Demory, and L. Osis. 1973. 1971 Siletz River estuary resource use study. Fish Comm. Oreg. 25 pp.

Gaumer, T. F. and B. G. Halstead. 1976. Methods of supplementing clam and abalone production. Annual Report July 1, 1975 to June 30, 1976. Oreg. Dep. Fish Wildl.

Goodwin, C. R., E. W. Emmett, and B. Glenne. 1970. Tidal study of three Oregon estuaries. Bulletin No. 45, Engineering Experiment Station, Oreg. State Univ. Corvallis. 32 pp.

Goodwin, C. R. 1974. Estuarine tidal hydraulics -- one dimensional model and predictive algorithm. Ph.D. Thesis, Oreg. State Univ. Corvallis. 220 pp.

Heinz, J. 1971. Salmon and Siletz bays -- conflicts in estuarine uses. Oreg. Game Comm.

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

Johnson, J. W. 1972. Tidal inlets on the California, Oregon, and Washington coasts. Hydraulic Engineering Laboratory HEL 24-12, Univ. Calif. Berkeley. 156 pp.

Marriage, L. D. 1958. The bay clams of Oregon. Condensed from Fish Comm. Oreg. Contrib. No. 20, The Bay Clams of Oregon, their economic importance, relative abundance, and general distribution, May 1954.

Morgan, J. B. and R. L. Holton. 1977. A compendium of current research and management programs concerning Oregon's estuaries. Sea Grant Publication #ORESU-L-77-004. 197 pp.

National Oceanic and Atmospheric Administration. 1977. Tide tables, high and low water predictions, 1978, west coast of North and South America including the Hawaiian Islands. U. S. Department of Commerce.

Oregon Department of Environmental Quality. 1978. STORET retrieval data. Unpub. Water Quality Data (computer printout).

Oregon Department of Fish and Wildlife. 1976. 1976 annual report, fisheries. Portland. 137 pp.

Oregon Department of Fish and Wildlife. 1977. Unpub. catch and release data.

Oregon Department of Fish and Wildlife. 1978. Habitat map of Siletz estuary. Res. and Dev. Sect. Unpub.

Oregon Department of Geology and Mineral Industries. 1973. Environmental geology of Lincoln County, Oregon. Salem.

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

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

Oregon State Water Resources Board. 1965. Mid coast basin. Salem.

Oregon State Water Resources Board. 1974. Freshwater resources of Oregon coastal zone. Oreg. Coastal Conser. Dev. Comm. Florence. 76 pp.

Osis, L. and D. Demory. 1976. Classification and utilization of oyster lands in Oregon. Oreg. Dep. Fish Wildl. Inf. Rep. No. 76-7. 38 pp.

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

Rauw, C. I. 1975. Seasonal variations of tidal dynamics, water quality, and sediments in the Siletz estuary. M.S. Thesis, Oreg. State Univ. Corvallis. 174 pp.

Rea, C. C. 1975. The causes of erosion to Siletz spit, Oregon. M.S. Thesis, Oreg. State Univ., Corvallis. 105 pp.

Reimers, P. E. 1970. Growth and abundance of juvenile fall chinook salmon in Sixes River Estuary, 1969. Fish Comm. Oreg., Coastal Rivers Invest. Inf. Rep. 70-4. 29 pp.

Skeesick, D. G. and T. F. Gaumer. 1970. Potential hatchery sites on Oregon coastal streams. Fish Comm. Oreg. 68 pp.

Smith, A. K. and J. E. Lauman. 1972. Fish and wildlife resources of the middle coast basin, Oregon, and their water requirements (Revised). A report with recommendations to the Oregon State Water Resources Board. Oreg. Game Comm. 98 pp.

Snow, C.D. 1973. Clams eye history of Siletz bay. Fish Comm. Oreg. Unpub.

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

U.S. Army Corps of Engineers. 1897. Preliminary examination of Siletz River, bar, and entrance, Oregon. House of Representatives Document No. 107, 55th Congress, 2nd Session. 3 pp.

U.S. Army Corps of Engineers. 1934. Survey of Siletz River, Oregon, entrance to old Kernville, July. 1934. Portland.

U.S. Army Corps of Engineers. 1976. Siletz wetlands review. Portland. 273 pp.

U.S. Geological Survey. 1977. Water resources data for Oregon, water year 1977.

Weise, H. G. 1974. Airphoto analysis of estuarine circulation. M.S. Thesis, Oreg. State Univ., Corvallis. 98 pp.

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

Zinn, J. A. 1970. Analysis of Siletz Bay estuary. Oreg. Div. State Lands, Salem. 61 pp.

Zinn, J. A. 1973. Analysis of resident property owner perception of resources and the management system of Siletz Bay estuary, Oregon. Ph.D. Thesis, Oreg. State Univ., Corvallis. 230 pp.