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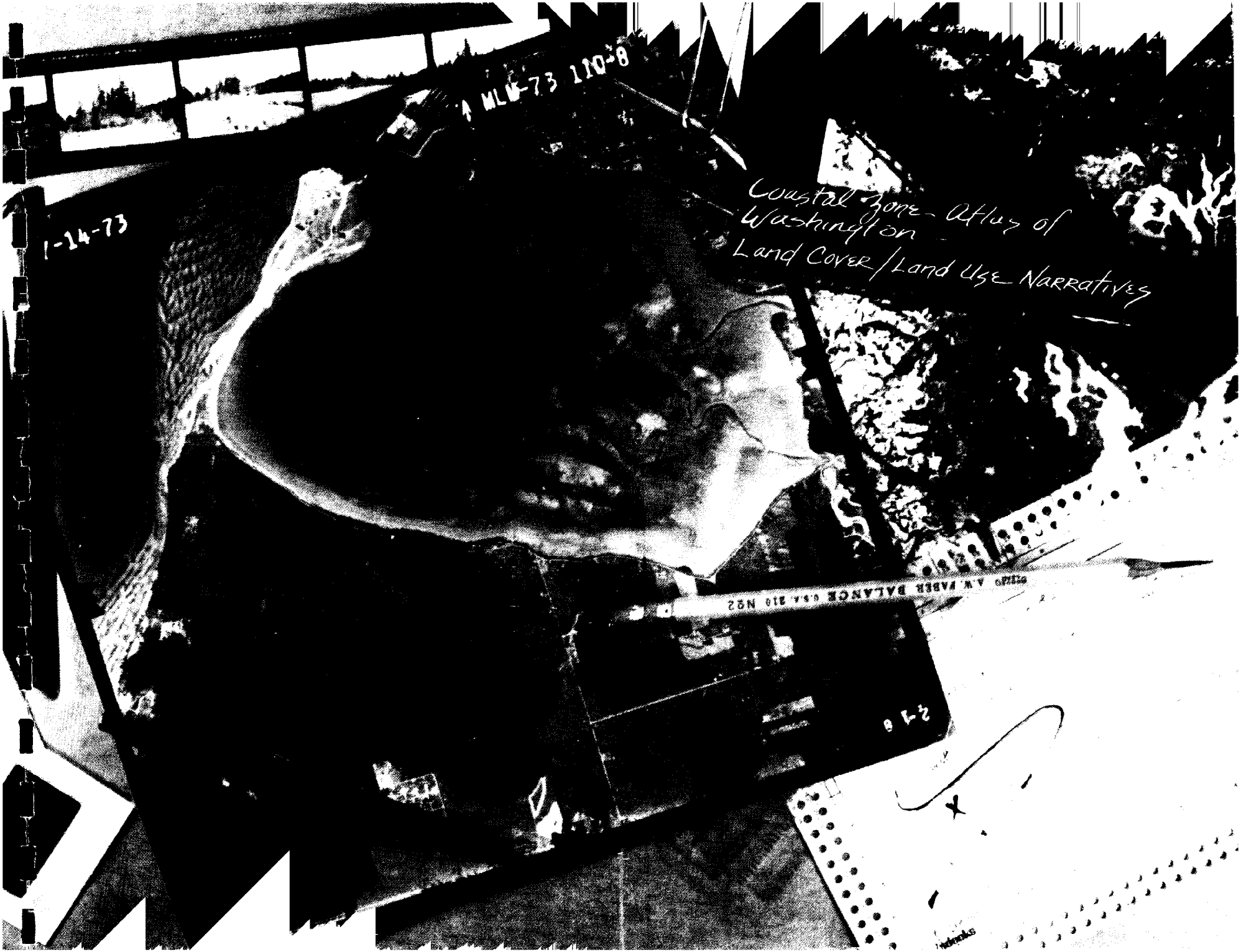
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Coastal Zone Atlas of
Washington
Land Cover/Land Use Narratives

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State of Washington
Department of Ecology

COASTAL ZONE ATLAS OF WASHINGTON

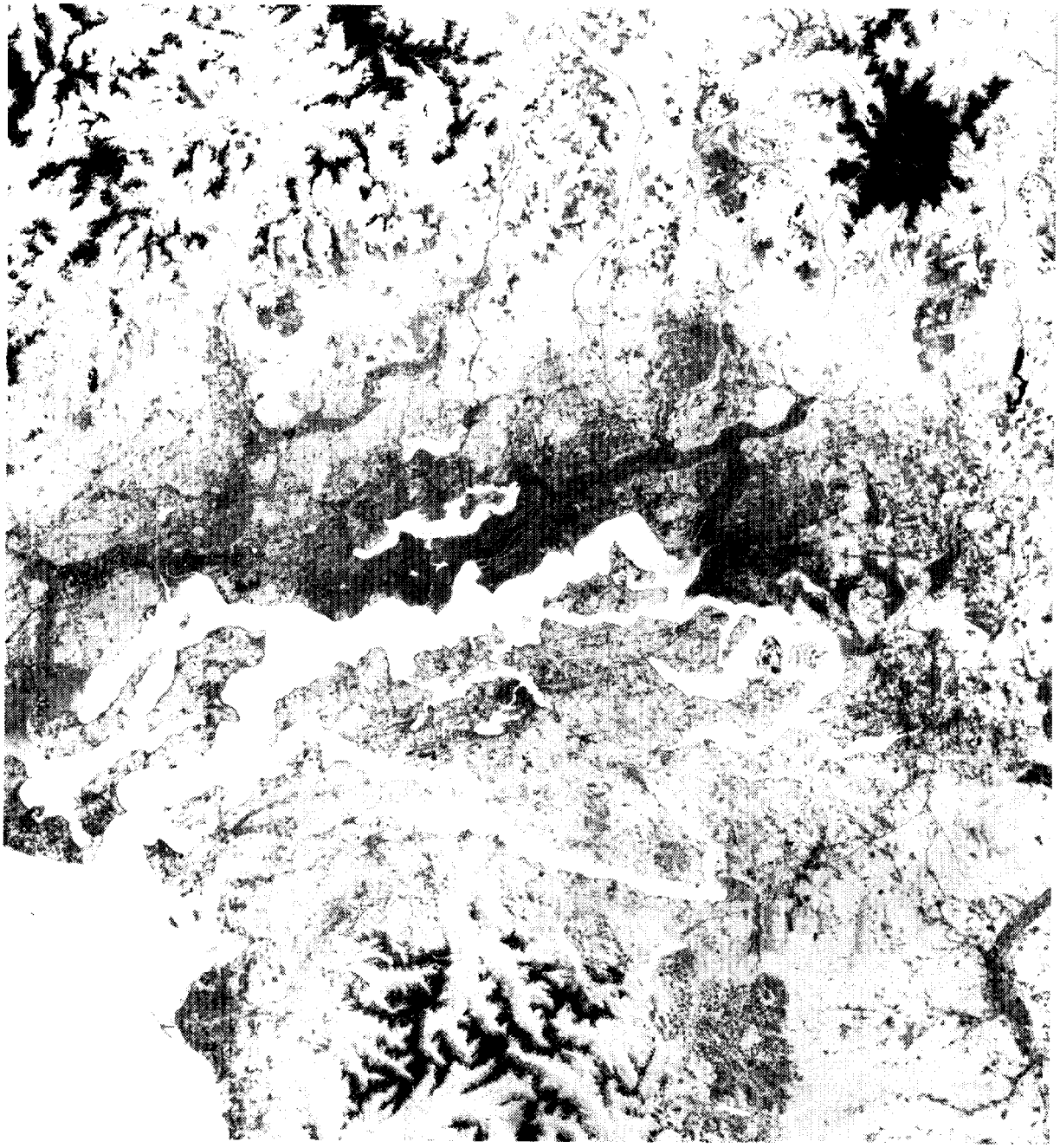
LAND COVER / LAND USE NARRATIVES

Volume I: Urban, Agriculture, Nonforested Uplands, Forest, Water (Pages 1-447)
Volume II: Wetlands, Exposed and Other Lands, Appendices, Glossary, Index (Pages 448-887)

Rick Albright, Ron Hirschi, Ron Vanbianchi, Claire Vita

June 1980

The preparation of this document was aided by the Washington State Department of Ecology through a federal grant from the Office of Coastal Zone Management under the National Oceanic and Atmospheric Administration of the United States Department of Commerce, as authorized by the United States Coastal Zone Management Act of 1972.



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Coastal Zone Atlas of Washington

Land Cover/Land Use Narratives

U.S. DEPARTMENT OF COMMERCE NOAA
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2234 SOUTH HOBSON AVENUE
CHARLESTON, SC 29405-2413

Volume I

Rick Albright, Ron Hirschi, Ron Vanbianchi, Claire Vita

Artists

Karen Helmerson, Jaime Orogo

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"The edge of the sea has a pull which draws poets, artists, and young lovers... those who live in imaginary worlds. It has other qualities which draw naturalists -- those who study the real world in its infinite manifestations. It has two strong messages -- its beauty and its meaning. Certain patterns along the shore provoke pure emotion, while others help us to appreciate the materials and forces of our planet, and the never-ending play between them. Our intuitive feeling for the shore and our knowledge of its structure seem after a while to blend in our thoughts; we develop a life-long conservation ethic toward this meeting place between earth and water."

Victor B. Scheffer

FOREWARD

This book explains the Land Cover/Land Use portions of the Washington Coastal Zone Atlas in detail using narratives, photographs, drawings and tables.

The work was done by Washington State Department of Game employees, and funded by the Office of Coastal Zone Management with a grant through the Washington State Department of Ecology.

Rick Albright, Ron Hirschi and Ron Vanbianchi, having the foresight and ability to conceive of their work as more than a report in final form, have succeeded in writing a very readable book on the coastal zone. Claire Vita's writing contibutions are also gratefully acknowledged. I have gained a considerable amount of respect and admiration for their work and for them during the three years I have worked with them on this Coastal Zone Atlas project.

I think the reader will find the book extremely worthwhile and a perfect reference to go along with the Atlas. The book was designed by Karen Helmerson, and Jaime Orogo's graphics, in particular, make a valuable addition. Assembling the photos, drawings and text was accomplished by Jaime and Karen. Without their artistic talents, the book would be far less enjoyable.

Management personnel in the Game Department essential to the development of this project were Jon Gilstrom and Tom Juelson. Also instrumental, was the interpretation of aerial photos for the Coastal Zone Atlas by Bill Nelson. Their contributions are very much appreciated.

It has been a pleasure being the Department of Ecology representative for this project, and I hope to have the opportunity to work with the Department of Game in the future.

Fred Gardner
Department of Ecology
June 1980

PREFACE

Several studies have preceded this account of coastal habitats, but most have dealt with individual species or have been restricted to certain groups of organisms and few have concentrated specifically along the coastal zone. From these accounts we have drawn much valuable information in our efforts to describe plants and animal communities in various coastal cover types. Rickets, Calvin, and Hedgepeth's Between Pacific Tides; Carefoot's Pacific Seashores; and Kozloff's Seashore Life of Puget Sound, the Strait of Georgia, and the San Juan Archipelago have been invaluable as have several floral and faunal accounts such as Hart's Pacific Fish of Canada; Palmer's Handbook of North American Birds; Hitchcock and Cronquist's Flora of the Pacific Northwest; and Natural Vegetation of Oregon and Washington by Franklin and Dyrness. Various field guides, keys, and checklists were also valuable references and include Wahl and Paulson's A Guide to Bird Finding in Washington; Mattocks, Hunn and Wahl's A Checklist of the Birds of Washington State; Delacy, Miller and Burton's Checklist of Puget Sound Fishes; and Brown's Provisional Checklist of the Inland and Anadromous Fishes of Washington State.

Recent summary reports and baseline sampling research projects have also added considerably to this publication. Notable contributions include Everitt, et al.'s Marine Mammals of Northern Puget Sound; Eaton's Marine Shoreline Fauna of Washington Status Survey; Miller, et al.'s Puget Sound Baseline Program Nearshore Fish Survey; Simenstad, et al.'s Nearshore Fish and Macroinvertebrate Assemblages Along the Strait of Juan de Fuca Including Food Habits of Nearshore Fish; Webber's A Sampling Program of Intertidal and Subtidal Habitats of Northern Puget Sound; and Nyblade's The Intertidal Habitats of Northern Puget Sound.

Innumerous published and unpublished works have also been consulted and, in some cases, quoted at length without ample acknowledgement in the text. To the authors we apologize, but hope that they understand our reasons for omitting footnotes or other means of publication acknowledgement. We have not quoted and have avoided jargon where possible to make the text more readable. (Likewike, scientific names are provided at the end rather than in the body of the text.) We feel justified in that our goal was to relay scientific information in as widely an understandable form as possible without sacrificing meaning. Only especially relevant references are cited in the text at the end of appropriate narratives.

The coastal zone is a complex interface between land, freshwater drainages, and the sea. We have attempted to describe this area using information based on ecological principles and to present our discussion in an understandable fashion while adhering to a format which is easily referred to by planners and other users. An introductory section is provided which explains the organization of the text and its intended use as a narrative volume to accompany the Coastal Zone Atlas. The Atlas provides the map and the text a descriptive voice. Again, the coastal zone is a complex system and no specific site will be quite like another having the same map designator or classification type. Significant variation exists between as well as within each cover type, and many volumes would be required to begin to explain subtle and often significant local variations.

The very nature of the coastal zone further compounds the complexity of variations. The shoreline is an ecotone or edge between overlapping and, in many ways, distinct cover types. In all cases, each upland cover type is different from similar types further inland and each marine type is influenced by an array of adjacent uplands. We suggest that these factors be considered in reading descriptions of each cover type and to use the information as a general guide. In all cases, final judgement on any decision regarding development at a specific locale should be made only after that site is evaluated for its unique place in the coastal ecosystem.

In many cases, little information was available regarding the ecology of a given cover type throughout or in a particular portion of the coastal zone. When possible, we sampled those areas to provide qualitative information upon which to base our discussions. We also consulted local residents, naturalists, agency personnel, scientists, and other knowledgeable persons. Many times we were accompanied by field assistants who contributed a great deal to this endeavor. Discussions with office mates, other researchers, and several persons intimately associated with coastal zone matters often stimulated inclusion of relevant information.

To the following we are indebted. They have contributed in many ways including those mentioned above. C. Detrick, G. Burrell, S. Sweeney, R. Everitt, U. Wilson, N. Hirschi, B. Hirschi, T. Juelson, D. Paulson, G. Munger, T. Mumford, J. Gilstrom, K. Anderson, D. Jamison, P. Vanbianchi , J. Bushnell , S. Cooley , The Washington Natural Heritage Program.

Special recognition goes to Fred Gardner of the Washington State Department of Ecology. His encouragement, editing, and understanding are much appreciated, and added greatly to the quality of the narratives.

We are especially indebted to Katie Rowdybush, Linda Talen, and Lynn Austin who typed various drafts of this text. We are also indebted to the residents of the State of Washington, in particular the coastal inhabitants who tolerated, aided, sometimes questioned, but generally supported our endeavors.

This work was funded by a contract from the Washington Department of Ecology to the Washington Department of Game. Funds were originally supplied to the Department of Ecology by the Office of Coastal Zone Management of the National Oceanic and Atmospheric Administration, U. S. Department of Commerce under Section 306 of the Coastal Zone Management Act.

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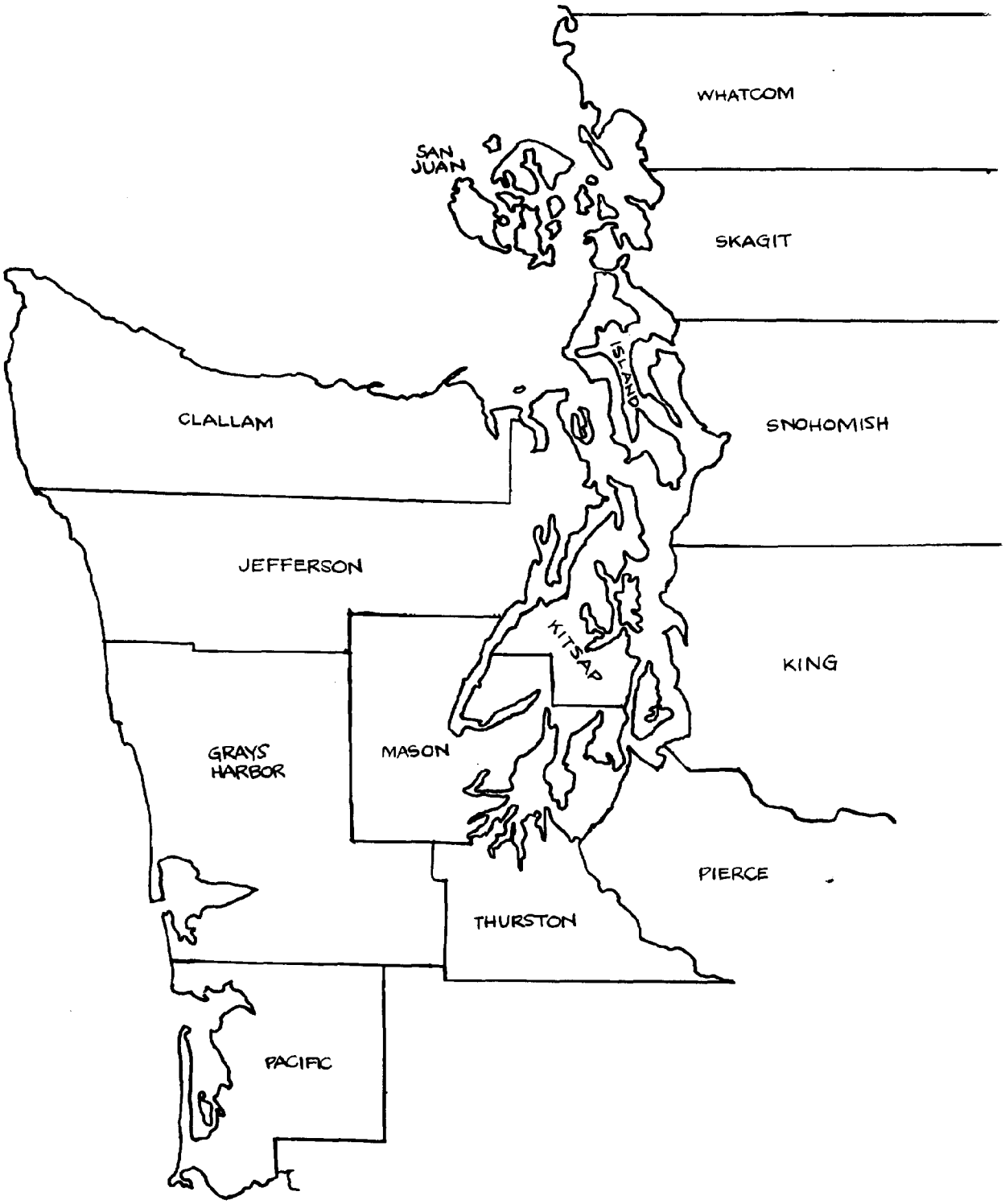
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ISLAND
CLALLAM
SNOHOMISH
JEFFERSON
KITSAP
KING
GRAYS HARBOR
MASON
PIERCE
THURSTON
PACIFIC

INTRODUCTION

This volume was developed to accompany the Washington State Coastal Zone Atlas. Land Cover/Land Use types mapped in the atlas are discussed in terms of their significant biological features and response to impacts. This information is presented to aid coastal zone planners and all those involved or concerned with decisions affecting the shorelines of our state.

Each Land Cover/Land Use category mapped in the Coastal Zone Atlas has a numerical code. These codes correspond both to a map classification scheme and to the chapters in this volume. Thus, one can easily refer to a specific land cover type at a map location by noting the numerical code and then turning to the appropriate chapter for a discussion of that cover type:

For Example:

> Refer to the Salt Marsh Chapter (No. 623) for information on the location noted on the Atlas page illustrated in Figure 1.

Upon referring to the appropriate chapter, bear in mind there is often a need to consult several chapters to more fully understand a given coastal area. This results from the significant interrelationships between habitats [for example, it is necessary to read narratives for Streams (No. 51), Salt Marsh (No. 623, and Mud (No. 638) for an understanding of Bays and Estuaries (No. 54)]. Also, chapters are arranged in order, proceeding from more general to specific land cover/land use types so that it is important to read more general descriptions of certain cover types before proceeding to more specific [for example, to undersand Old Growth Coniferous Forests (No. 414), one must also consult the Forest (No. 4) and the Coniferous Forest (No. 41) discussions].

Each chapter is arranged as follows:

I. Introduction

This section is a brief statement describing the land cover/land use type, general biological features, historical trends, and general distribution throughout the coastal zone.

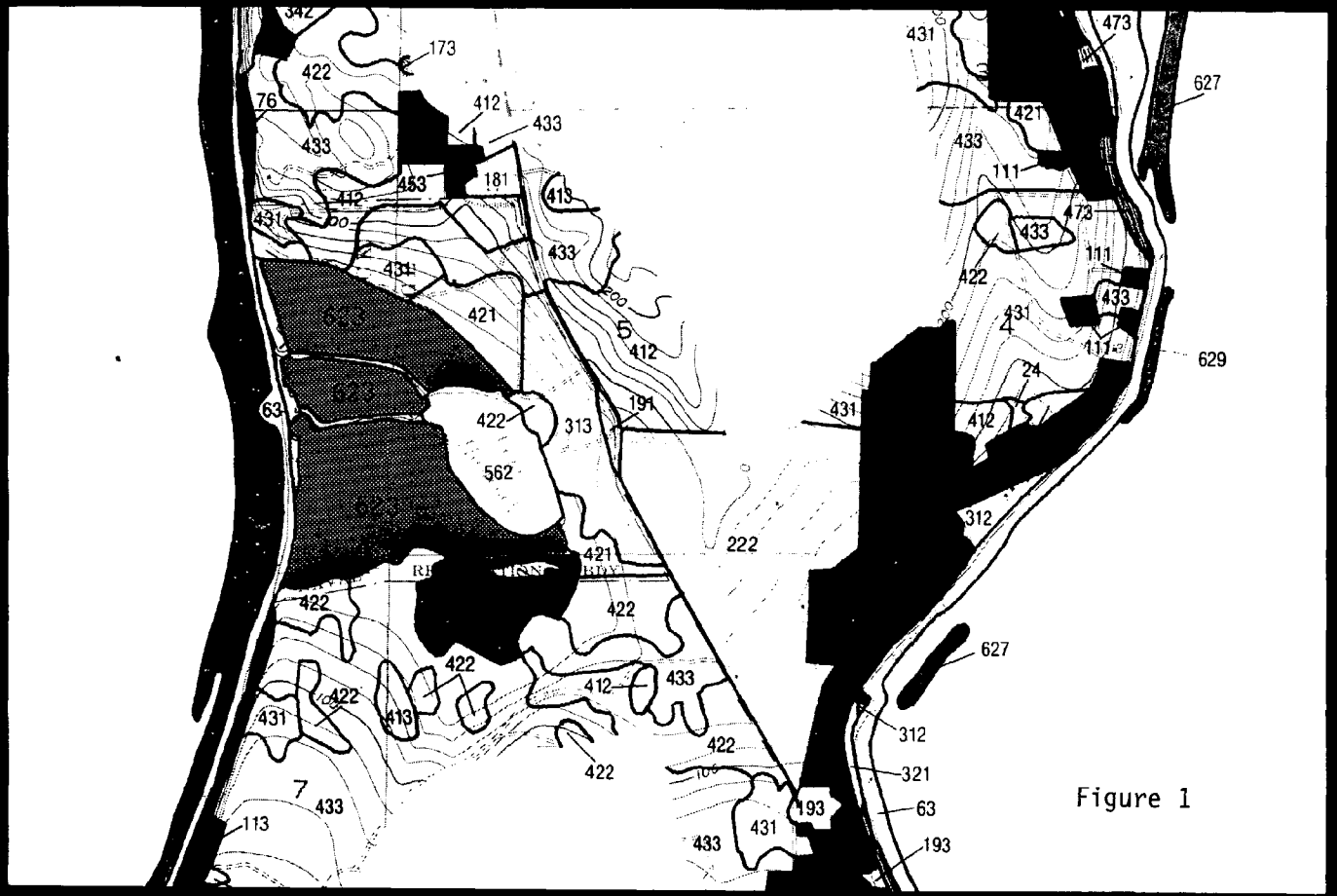
II. Significant Biological Features

More detailed discussions of biological features are presented in this section which focus on the role of each cover type and associated natural communities in maintaining a healthy, productive coastal ecosystem. Topics include the importance of the cover type to wildlife and humans, community structure, interrelationships with other cover types, and characteristic plants and animals. Species lists are presented with notes on rare and endangered species, status, commercial and recreational uses, as well as natural history comments.

III. Impacts

Disturbances which are typically associated with a given cover type are discussed in the Impacts section. Management recommendations and historical trends are presented when sufficient information is available.

Appendices list common and scientific names of species mentioned in the text and rare and endangered species lists. A glossary and index are provided.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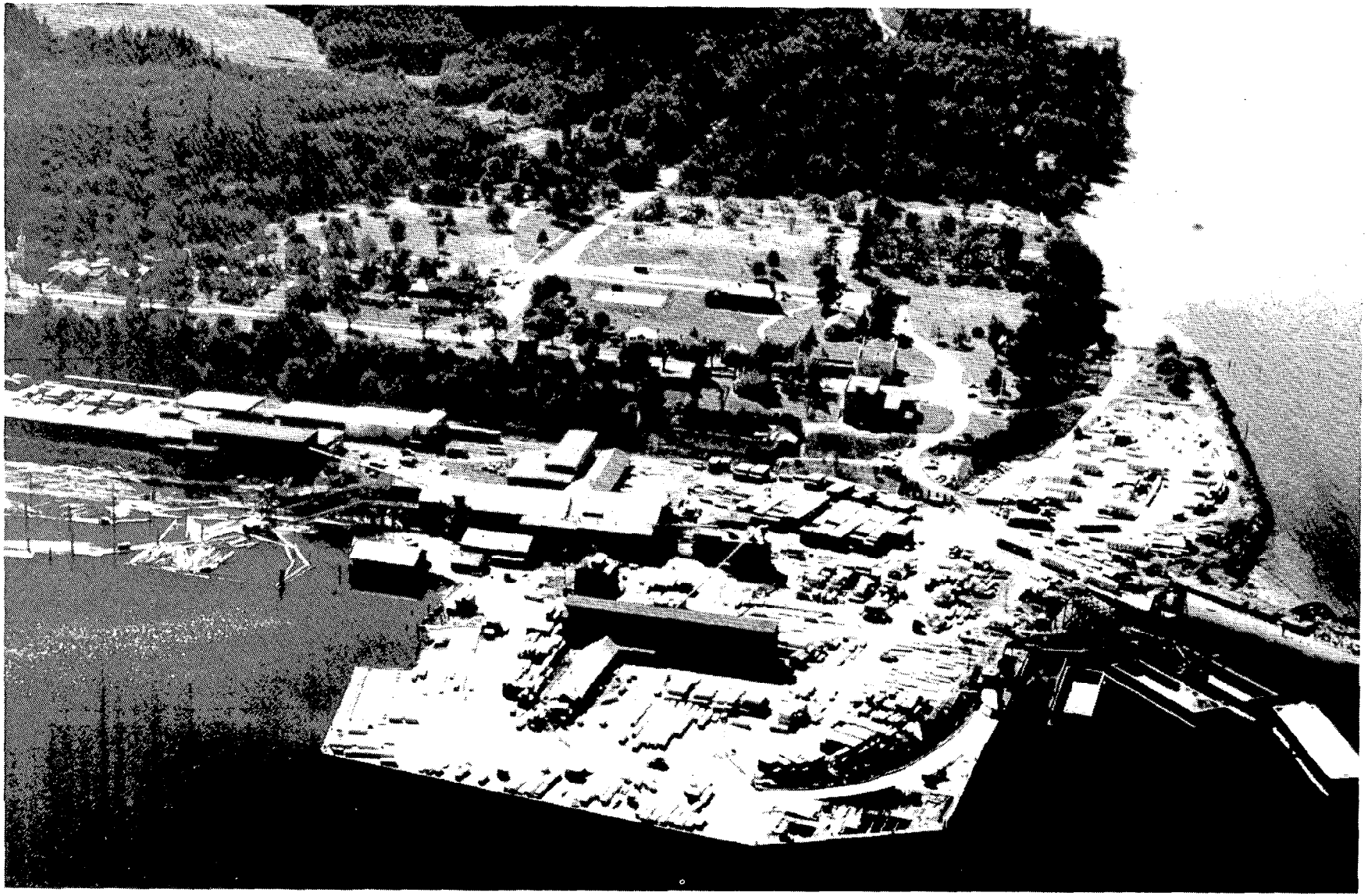


Port Gamble, Kitsap County 1976

INTRODUCTION

"When man first began to build, he watched nature's performance and followed it. His ways rested easily in the environment because the environment was his control and reference; he lacked the power to do otherwise. From the surroundings came his materials: the plants and animals, the rock and dirt. He converted the materials into his tools. He learned the vernacular of his materials, the strength of wood, and the shapes of clay, the cleavage of stone. He learned the pressures and demands of the biosphere, and he bent to them.

Machine technology drove a steel wedge between man and his home. The farmer who was on intimate terms with his land grew to know it more remotely, for a steel plow need not take account of the peculiarities of regional dirt as it slices through the sod. Mechanical woodcutting is not concerned with deviations in a tree's growth; it tries to reduce everything to its simplest form. Technology has given builders materials and methods that have little to do with climate or environment. Man has left nature's domain for his own. The land has become only a platform to hold his houses and cities and to be manipulated into growing his produce."

Christopher Williams, 1974
CRAFTSMEN OF NECESSITY
Vintage Books, New York

1 Urban

Urbanism was historically the direct result of refining agriculture and animal husbandry to the level that production surpluses made possible the feeding of populations no longer directly concerned with primary production. Towns and eventually cities became cultural incubators for the human race. Peoples with different interests and backgrounds were brought together and had a stimulating effect on one another which expanded our cultural patterns.

Mechanization of food production has steadily contributed to populating of urban areas. In 1800, less than 3 percent of the world's population lived in urban settlements; currently, half of the populations of developed countries live in towns having more than 20,000 people. Urbanized settlement is predicted to continue throughout the world and by the year 2000, 38 percent of the earth's population will be urbanized.

Modern urban areas still function as centers of cultural exchange and trade. However, with increased populations, our urban areas have extended into the countryside, and in many localities, borders between separate urban areas are no longer discernible. The coastal zone is threatened by formation of such a megalopolis between the densely populated areas of Seattle, Tacoma, and Olympia.

Expansion of development to undeveloped lands or to moderately disturbed areas will further pressure and displace wildlife and native plant populations. Wildlife can be used as indicators to measure the quality of habitat relative to undisturbed conditions. The presence of wildlife tends to indicate decent air quality and low levels of toxic chemicals. Specific species occurrence and diversity also reflect the habitat diversity of developed areas.

Urbanized areas can attract wildlife as well as humans. Although not all loss of vegetation and wildlife through displacement can be prevented, developed areas can be managed to maintain many native plants and animals. The presence of native vegetation and wildlife enhances the esthetics of urban living and may cut the costs of landscaping developments. In turn, properly managed urban areas provide valuable habitat for many wildlife species.

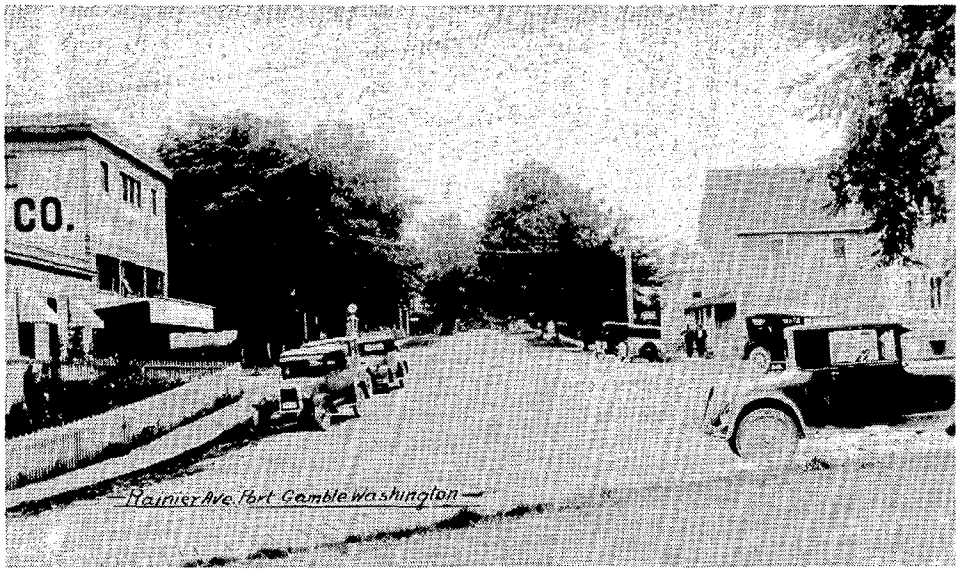
URBAN STRUCTURE

Residential (No. 11)

Residential areas are the most widespread man-made habitats in the coastal zone. Proper planning and management for wildlife in these areas are important because residential yards represent a substantial portion of space available for wildlife in urban areas.

Construction of residential areas has been most destructive of wildlife habitat; vegetation and dependent fauna have been physically displaced by houses. Human activity, domestic animals and structures also displace other organisms through competition and predation and by frightening timid species away.

Residential developments can have tremendous effects on wildlife abundance and diversity. The conversion of farmland into an urban area in Maryland resulted in a general trend of decreasing the varieties of bird species there. However, absolute numbers of birds increased. Both numbers of bird species and individuals increase with time in aging suburban environments relative to populations present after initial construction. Although numbers of birds increase, suburbanization may result in displacement of native bird species in a given area. Garden



Port Gamble,
circa 1927

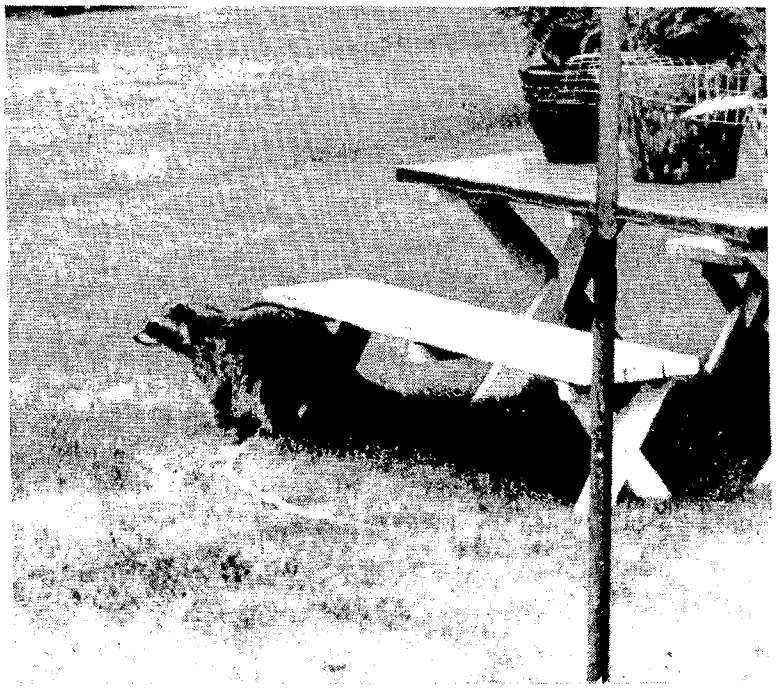
Port Gamble,
circa 1980

plantings are most influential in determining distribution and density of birds; other factors such as bird feeders and the presence of cats and dogs may also be important.

Even robins, commonly thought to be adapted to areas of human disturbance, require areas of restricted human activity and protection from domestic pets for successful nesting. Low production of robins in some areas may be due to intense human activity at ground level and inadequate food supply. Robin food is often limited by careful manicuring of residential lawns and gardens which can eliminate earthworm habitat in drier summer months.

Squirrel populations and nesting sites are limited by the lack of large trees in housing tracts. Crevice denning areas are not readily available due to pruning and removal of trees that would be choice locations for squirrel dens.

Raccoons are also limited to vegetated areas supplying cover. Chain-link fences, roaming dogs, lack of cover, and few suitable den sites discourage raccoons from using an area. Some raccoons and squirrels do make use of parts of the residential environment by nesting in attics, basements or chimneys. Screening of these areas will prevent the animals from taking up residence.



Predation and harassment of wildlife by domestic cats and dogs affects species composition, productivity, and survival of animals within a community. Feral cats (wild housecats) also have an impact on wildlife. They appear to be opportunistic predators and scavengers, eating whatever species are available in a given area. In undeveloped areas feral cats eat native species while in inhabitated areas they primarily eat mice. Birds, lizards, salamanders, snakes, and invertebrates are of secondary importance as feral cat food items.

Non-Wooded Low Density Residential (No. 111)

Non-wooded low density habitats contain scattered housing and are usually outside incorporated communities. The natural cover of these areas is drastically altered, but small wooded areas may remain. Non-wooded low density areas are widespread in the coastal zone. They become more crowded as new homes are built and eventually evolve into high density residential areas.

Many of the birds and mammals which occur in residential areas depend on rather extensive and undisturbed adjacent woodlands. Their presence in residential areas depends on suitable habitat for feeding in gardens and landscaped areas around houses. However, their continued existence depends upon the maintenance of these adjacent woodlands and other natural areas. Adequate breeding habitat acts as a reservoir for the many birds which frequent residential areas. Corridors of natural vegetation such as bluffs and riparian areas offer travel routes to and from breeding habitat and more developed areas.

In general, larger birds and mammals require larger territories and will be the first to disappear when residential expansion reduces adjacent natural vegetation. Predators, such as the birds of prey (eagles, hawks, falcons, and owls), are dependent on large areas to support an adequate supply of prey. They may range over a wide area and can be viewed from coastal residential areas, but usually breed in more isolated areas.

breeding birds

The following breeding birds were observed during a 2½ year period in a sparsely wooded low density residential area of one acre along Hood Canal. Additional wildlife species observed are listed on following pages.

Breeding Birds	Artificial* Nest Site	Natural Nest Site
House Sparrow o	X	
Starling	X	
Violet-green Swallow	X	
Barn Swallow	X	
Cliff Swallow	X	
Chestnut-backed Chickadee o	X	
Steller's Jay o		X
Song Sparrow o		X

o Indicates species killed by pet cats.

* Artificial nest sites include nest boxes, building eaves, and Barn and Cliff Swallow nests attached to side of building or other building support.

other wildlife observed

Most of the birds listed are migrants, but some may nest nearby and include residential areas as a portion of their breeding territory, e.g., Downy Woodpeckers often observed during breeding season foraging in wooded areas.

	Comment
Great Blue Heron	Occasionally roost in trees along water's edge. Feed near shore and susceptable to slight disturbance.
Sharp-shinned Hawk	Uncommon; one killed flying into picture window.
Bald Eagle	Common flying by; has perched in trees near houses, but roosts are all in undeveloped areas nearby.
Merlin	Uncommon; hunts birds at feeder.
California Quail	
Ring-necked Pheasant	
Glaucous-winged Gull	Common.
Band-tailed Pigeon	
Common Nighthawk	
Rufous Hummingbird	
Belted Kingfisher	Occasionally perches in trees along shore.
Common Flicker	Regular visitor.
Pileated Woodpecker	Rare.
Red-breasted Sapsucker	
Hairy Woodpecker	
Downy Woodpecker	
Western Flycatcher	

other wildlife (continued)

	Comment
Western Wood Pewee	
Tree Swallow	
Rough-winged Swallow	
Common Crow	Common.
Black-capped Chickadee	Prefer broadleaf trees, also forage in shrubs.
Bushtit	
Red-breasted Nuthatch	Require large trees.
Brown Creeper o	Also require large trees and, like nuthatch, feed along trunk of tree.
Winter Wren o	
American Robin o	Common.
Swainson's Thrush o	
Varied Thrush o	Also known as Alaska robin.
Golden-crowned Kinglet	
Ruby-crowned Kinglet	
Cedar Waxwing o	Feed on fruits such as berries of cascara.
Warbling Vireo	
Orange-crowned Warbler	Warblers and other insectivorous birds consume a large number of insect pests.
Yellow Warbler	
Wilson's Warbler	
Red-winged Blackbird	
Brewer's Blackbird	
Brown-headed Cowbird	
Western Tanager	
Evening Grosbeak	Easily attracted to feeder with sunflower seeds.

other wildlife (continued)

	Comment
House Finch	
Pine Siskin	
American Goldfinch	Feed on the ground, but require shrubs and trees for nesting.
Rufous-sided Towhee o	Common in shrubs.
Dark-eyed Junco o	
White-crowned Sparrow	
Golden-crowned Sparrow	
Fox Sparrow o	
Reptiles and Amphibians	
Garter snake o	Consume slugs in the garden.
Northern alligator lizard o	
Mammals	
Vagrant shrew o	
Trowbridge's shrew o	
Unidentified bat(s)	
Deer mouse o	
Townsend's vole o	
Raccoon	
Coyote	
Domestic dogs	
Domestic cats	
Douglas squirrel o	Require trees for feeding, nesting, and escape.
Coast mole o	

o Indicates species killed by pet cats.

High Density Residential (No. 112)

High density residential areas occur predominantly in urban areas. As housing has already displaced native habitat, these are appropriate sites for concentrating human populations. Development centered in established residential areas would limit growth and preserve open land in outlying areas which would otherwise be engulfed by encroaching construction. Rejuvenating old urban centers through reconstruction and remodelling is preferrable to new construction, and planting of trees and shrubs would make the areas more esthetically pleasing to humans and encourage wildlife.

Wooded Residential (No. 113)

Wooded residential areas are the least destructive of low density residential areas because the natural cover is only minimally altered. The forest canopy is often left intact and associated birds and mammals remain. However, subcanopy and ground layers are often altered, severely displacing native vegetation and associated fauna from these lower areas.

Species occurring in these areas are characteristic of wildlife occurring in comparable undisturbed vegetative cover types. Refer to specific woodland narratives for information on wooded area wildlife.

Recommendations

The development of residential areas has a profound impact on native flora and fauna. Impacts can be modified by comprehensive plans for directing development and growth. Portions of the coastal zone are especially vulnerable to impacts from development, particularly in riverine, salt marsh/meadow and estuarine areas. Protective management of coastal areas includes leaving a buffer zone of at least 200 feet along the shoreline above extreme high water or beyond the upper extent of the wetlands. As large a buffer as possible should be left in more sensitive areas, such as along salt marsh edges and river mouths. Refer also to discussions of forest size and buffers in the Forest Narrative (No. 4).

Housing developments should be clustered in already established urban areas. Developments in outlying areas should be required to permanently maintain areas of open space as large as possible. Proposed housing developments should have plans for retaining as much native vegetation as possible.

Much can be done to enhance the value of established residential areas for wildlife. Homeowners might not object to developing their yards as wildlife habitat if they knew the U.S. Forest Service has suggested that the presence of trees around a house has a tangible positive effect on its marketability. Trees enhance the value of property by as much as 20 percent and increase the value of architecturally similar houses by an average of 5 to 10 percent. In addition to increasing their home's monetary value, the homeowners will have an esthetically pleasing environment.

The public should be educated by state and federal agencies on the value of developing wildlife habitat. Many people appreciate the presence of birds, but are ignorant on how to attract them; others just don't realize the impact a housing development can have on wildlife. Neighborhood groups working together and planting wildlife-attracting vegetation could add large areas of wildlife habitat to urban areas.

Suggested plantings which attract wildlife in the Northwest are:

Herbaceous Growth:
Sedge spp.
Timothy
Sunflower
Filaree
Lupine
Tarweed
Wild oats
Knotweed
Redmaids
Bromegrass
Deer vetch
Chickweed
Miners lettuce
Fescue-grass
Clover spp.
Bur-clover
Bluegrass
Buttercups

Shrubs:
Blackberry
Blueberry
Snowberry
Oregon grape
Kinnickinnick
Gooseberry
Salal
Russian olive
(introduced)
Red elderberry
Madrona
Cascara
Willow
Rose

Trees:
Serviceberry
Dogwood
Hawthorn
Sitka spruce
Douglas fir
Western white pine
Lodgepole pine
Western red cedar
Grand fir
Oregon white oak
Bigleaf maple
Wild cherry
Red alder
Paper birch
Trembling aspen
Madrona
Hazelnut

Commercial Services (No. 12)

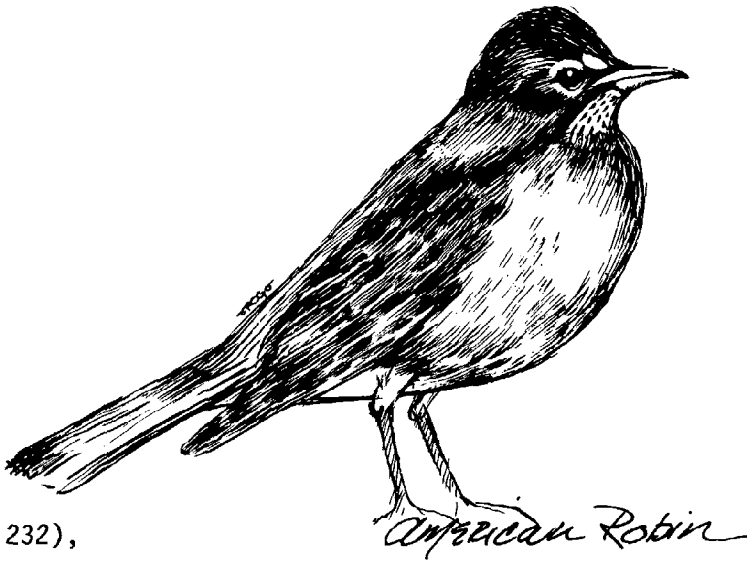
These areas are developed for commercial or public service purposes. The vegetation in these land use types is usually altered as are wildlife species composition of the developed areas. However, the grounds of these services' properties offer wildlife management possibilities and should be developed to enhance wildlife habitat. Commercial services are created to serve the needs of the public and as such should be located in population centers. The commercial services classification includes areas classified as follows:

Business/Government (No. 121)

Many office parks are now being built to create esthetically pleasing environments. Such areas may include ponds for waterfowl, native coniferous trees and native shrubs for cover. These developments can provide open space and a retreat within urban areas for workers and the general public.

Commercial/Light Industrial (No. 122)

This type of commercial service is most likely to have disturbed/altered vegetation and wildlife. Often the vegetation, when present, is composed of weedy species.



Institutional (No. 123), School (No. 231), Hospital (No. 232), Cemetary (No. 233)

Institutional grounds compose a large percentage of open land in urban areas. Cemetaries alone often constitute as much as one-third of a major city's open space. These areas are usually covered with grass which is mowed, and varied amounts of native and ornamental trees and shrubs. Landscape designs which stress tall trees in expanses of grass or low ground cover are not the best use of these areas as wildlife habitat. Songbirds and other animals require medium-height shrubs which provide dense cover for nesting and escape. The absence of an intermediate shrub layer reduces the size and diversity of the songbird population.

These areas should be opened to multi-purpose recreational useage. As such, they would add large areas to urban park systems. Institutional areas can provide excellent, easily accessible areas to the public in which they can enjoy urban wildlife. Many cemetaries throughout the country already distribute pamphlets to the visiting public describing their plants and wildlife.

Resort/Hotel (No. 124)

Other Commercial Services (No. 125)

Industrial (No. 13)

Industrial areas are very often extremely disturbed land covered with structures and/or machinery which aid in the production or storage of such industrial products as petroleum, wood products, textiles or processed food. Principal impacts of these land uses are potential oil spills, and pesticides and other toxic chemicals and waste products discharged into water, air and soil by industrial plants. Industrial pollutants pose great threats to intertidal communities because their impacts may extend over large areas.

In addition to toxicity to wildlife, effluents may also increase the turbidity of water, reducing plant productivity.

Light Industry (No. 131), Heavy Industry (No. 132)

The pulp and paper industry has had a long history of impacting the Northwest's waterways. Pulp mill discharges of waste liquor and solid materials have driven away or directly killed invertebrates and fish populations in water adjacent to discharge areas. Humans have been affected by esthetically damaged environments (discoloration and bad odors) and by a decrease in harvestable shellfish and fish due to pulp mill effluents. Legislation and improving technology are currently working together to maintain higher water quality standards than in the past.

Petroleum/Chemical Processing and Storage (No. 133)

The petroleum refining industry has built safeguards into their plants to prevent damaging discharges into waterways. The main threat the petroleum industry poses is that of potential oil spills. Increased occurrence of supertankers in Washington's waters leads to potential water quality degradation from leakage, spills, and collision. Construction of new deepwater facilities required to handle oil-carrying ships can also deteriorate water quality. Commercial and sport fishermen, waterfront homeowners and environmentally concerned citizens often object to the development of supertanker ports and the shipment of oil over Washington's inland marine waters.

Spilled oil may damage eelgrass and kelp, which are important foods for marine life. Birds and mammals contacting oil products are severely affected. Loss of the insulating abilities of feathers or fur can result in death of the animal from exposure. Fish and invertebrates also have shown low tolerance to oil products. Further discussion on the impacts of oil on various habitats are discussed in Salt Marsh (No. 623), Seagrass (No. 627), Kelp

Community (No. 628), Other Algal Community (No. 629), and Beach Substrates (No. 63) Narratives.

Industrial processing and storage of chemicals can also have effects on water quality and marine wildlife. Harbor seals in Puget Sound have higher PCB and DDT residues in their bodies than seals occurring along the outer coast of Washington.

Food Processing (No. 134)

In the past, the food processing industry, particularly fruit and vegetable processors seasonally discharged large amounts of organic waste into Puget Sound and the lower reaches of its tributaries. Many milk processing and meat packing firms also disposed of wastes into Puget Sound's waters. Much of this has stopped because waste treatment facilities have been built.

Addition of large amounts of organic wastes lowers water quality by causing eutrophication of waters. Resultant decreased dissolved oxygen concentrations can result in fish and invertebrate mortality.

Other Industrial (No. 135)

Transportation/Utilities (No. 14)

This land use class includes facilities associated with transportation or utilities which are of significant size in terms of area covered or have an important impact on wildlife or wildlife habitat. The diverse subclasses of land use within this group have varying effects on wildlife. All classes disrupt the native fauna and flora to some extent, but some wildlife species do use these areas.

Airports (No. 141)

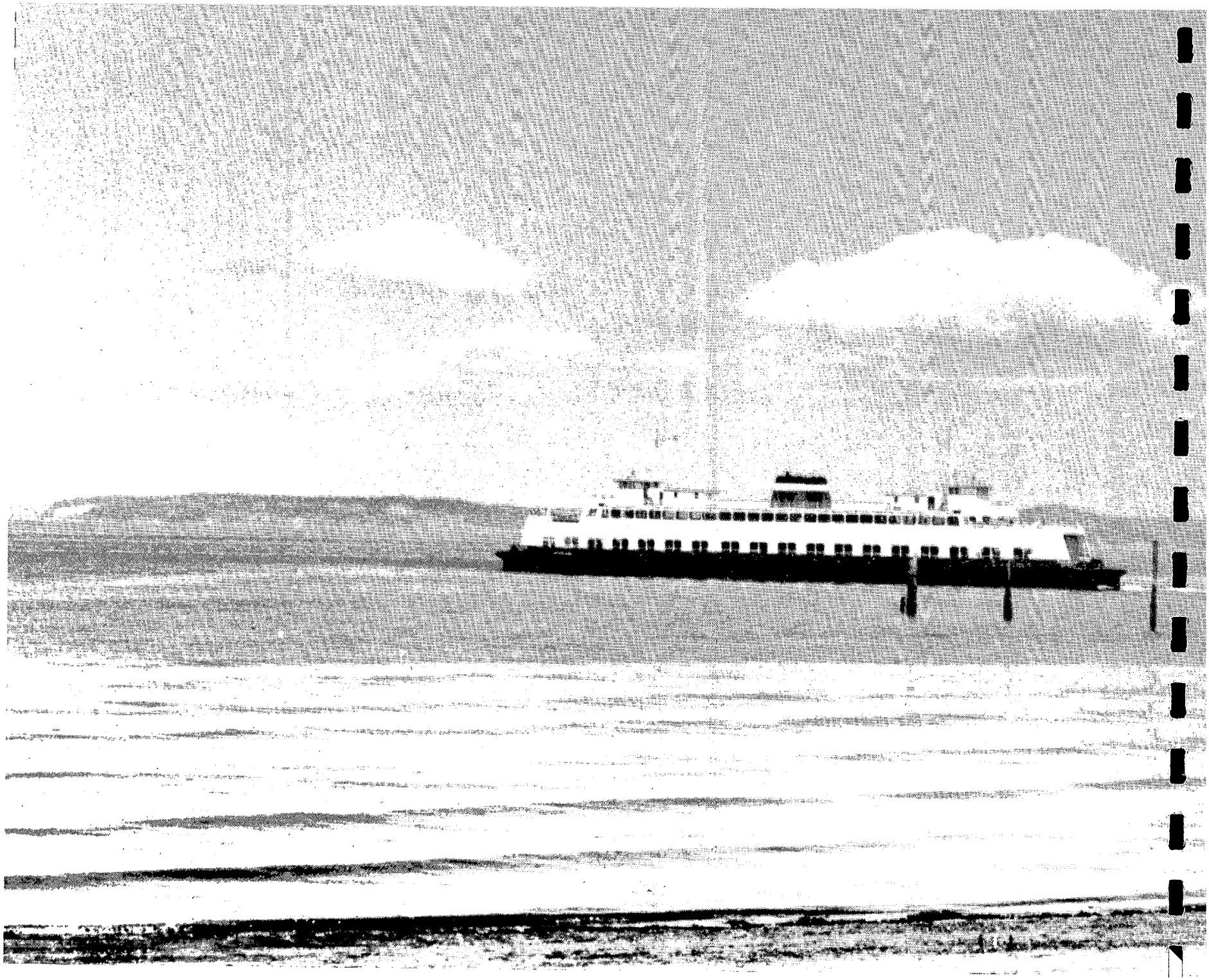
Wildlife, especially birds, occurring at airports can be hazardous to human life and property. Between 1960 and 1972, bird-caused air disasters in North America resulted in more than 100 deaths and property damage of more than $100 million. Three-quarters of civil aircraft collisions with birds occur at or near airports, usually near cities.

Planning and management of airports should be aimed at discouraging wildlife. Established large airports should eliminate or minimize areas providing water, food, and shelter to birds. New airports should only be established in areas having low value to wildlife and agriculture. Attention should be paid to the negative impacts airport noise pollution can have on surrounding communities.

There has been a vast increase in private planes and flying in general. Flying has made many areas more accessible both in distance and travel time. These impacts of Washington residents are more widespread, with the use of seaplanes which permit individuals to land on isolated bays and lakes which may not otherwise have been disturbed. Marine mammals, nesting birds and flocks of feeding waterfowl may all be harassed by seaplanes. There is also a conflict of interest between backpackers and seaplanes or helicopters. The arrival of an aircraft on a lake to which a backpacker has hiked several miles for a wilderness experience is more than irritating to some. The noise and physical presence of a seaplane in a remote lake easily disturbs the wilderness qualities of the lake.

Ferry Service (No. 142)

Ferry runs have predictable routes and are not quite as disruptive to marine birds and mammals as are other boats and ships. In addition to necessary transportation, ferries provide the public and researcher with opportunities to view wildlife along the coast. Information for the Coastal Habitat Inventory Study was gathered on ferry runs.



An interested observer can view differences between nearshore and open water species, reflecting habitat differences. There are also species differences between ferry routes; birds occurring along the San Juan ferry route differ from birds found along a Seattle route. Commuters and other persons who take the ferries in different seasons will observe seasonal changes in bird species occurring along their route.

"Once you cursed the bold crudeness
that stripped the earth of its ore
Now you've changed and you've
gone over to them and learned to love
what you hated before.
Once I thanked God for my treasures
now like rust they corrode
and I can't help but blame your going
on the coming of the road."

Billy Ed Wheeler
in "Coming of the Road"

Highway (No. 143)

Highways have extreme influences on habitat and wildlife. Habitat destruction occurs at road sites and along rights-of-way. Even more significant is the alteration of areas caused by the building and existence of roads; new businesses and houses that locate along roads all contribute to urban sprawl.

Plants and animals are also affected directly by roads. Large numbers of animals are killed by cars annually. Roads function as corridors for dispersal of exotic animals and plants (e.g., Starlings and Scot's broom) which compete with native species.

Highway rights-of-way can be managed as valuable wildlife edge habitat provided animals are protected from crossing roads. Roads crossing migration routes of reptiles and amphibians result in heavy losses of these animals during the breeding season. Tunnels and culverts underneath roads enable these animals to migrate safely. Deer can also be protected from cars by tunnels or deer-proof fences along roadways.

Roadside vegetation is often used by birds and other animals. Seasonal management of these areas can enhance wildlife populations. An example of correct management is the delay of roadside mowing or spraying until July or later. This delay will save many bird nests and young birds from destruction.

Some of Washington's highways were built along the shoreline, severely altering the important edge between upland and marine environments. Examples of such construction include:

- Highway 101 which lines Hood Canal and Highway 16 which parallels the remaining shoreline of Hood Canal in Mason County. These highways and almost continuous housing development has eliminated most of the natural shoreline edge in the area.

- Roads along Birch Bay and Drayton Harbor, Whatcom County.

- Much of King and Pierce County roadways are adjacent to and parallel the Puget Sound shoreline.

Because of the severe effects roads have on disrupting the transition between upland and marine environments, any opportunities for relocation of these routes should be considered as an alternative. In most cases, new construction along the shore should be discouraged. Areas designated as critical habitat for threatened and endangered species must be avoided in selecting highway routes.

Routing should also avoid crossing wetlands and creating the necessity for channelizing streams. Roads built where there will be a minimum of direct runoff of stormwaters into lakes, streams, sloughs, etc. will reduce highway pollutants in these waters. Oil and chemical spills from trucks travelling roads which parallel water can be a serious local threat to water bodies.

Many existing roads along shorelines are scenic routes which the public enjoys. These areas could be enhanced for public enjoyment by planting trees along the route and providing safe bicycle paths along the roadside.

Railroad (No. 144)

Railroad impacts on habitat are similar to those of highways. They often parallel the shoreline at the interface of uplands and beaches. Because rail routes are less frequently used than roads, the threat of killing animals is less. Railroads occurring at Steilacoom in Pierce County may be responsible for destroying chain-fern habitat. Chain-fern is currently being considered for proposal as a rare, endangered, or threatened plant species.

Pipeline (No. 145)

There are very few pipelines in Washington. However, proposed lines are one of the most pressing issues in the coastal zone. The direct and indirect threats of oil pipelines, such as spills, construction of refineries and many of the problems associated with pipeline routes, are serious.

Pipelines occurring in the coastal zone as of this writing include those at Fort Lewis, military installations in Kitsap County, and small lines in Anacortes and Cherry Point.

Bridge (No. 146)

The most prominent environmental impacts resulting from bridge construction are alterations in current velocity and water circulation patterns. Salinity may be affected in estuarine environments and other

areas subject to tidal flow. Water circulation in a marsh may also be affected.

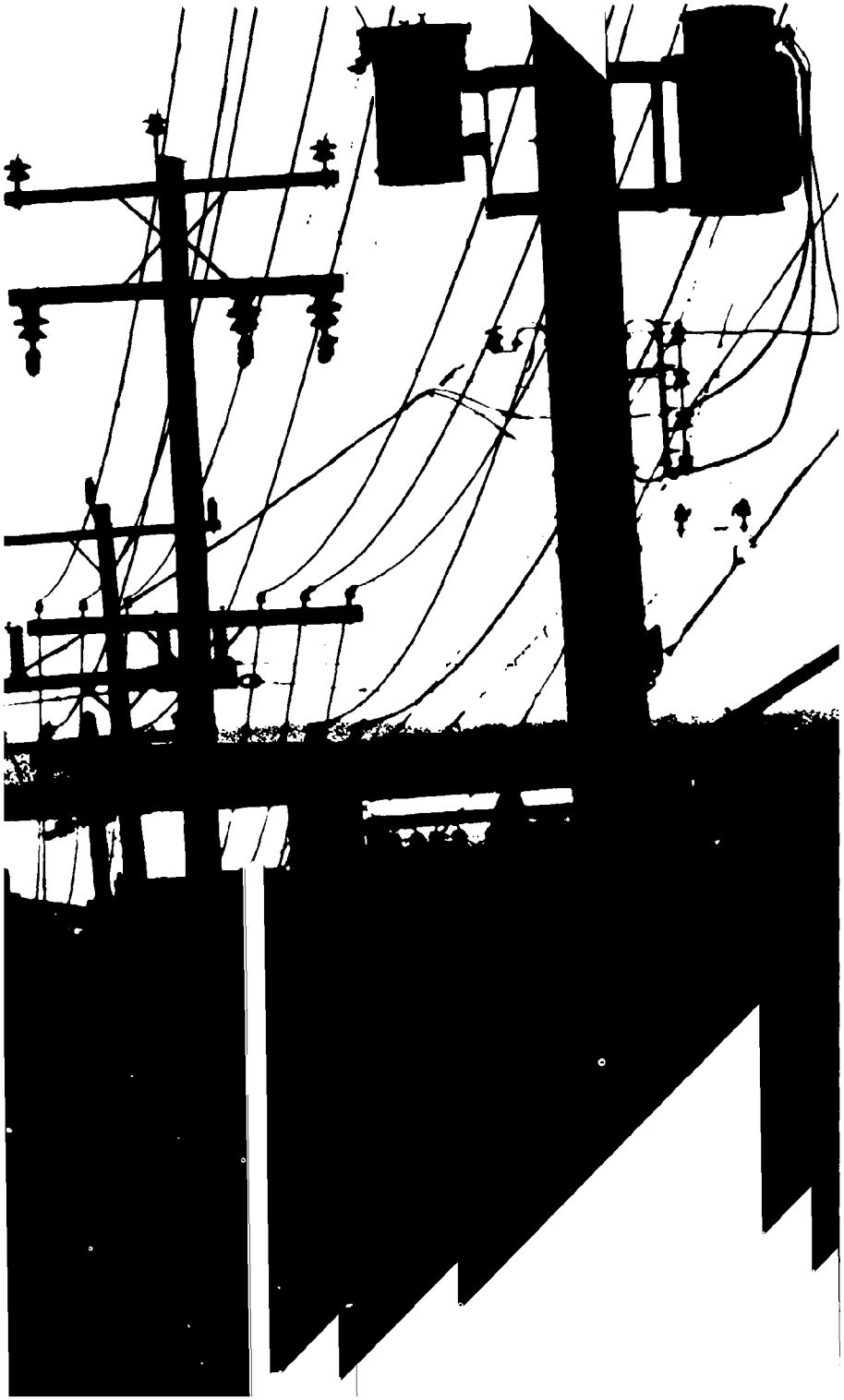
Major bridges can have serious impacts on relatively undeveloped areas by improving and increasing traffic flow, which encourages human use of the areas. An example of this is the Hood Canal Bridge which facilitated development of the Olympic Peninsula. Major bridges may also be potential blocks for large marine mammals. It is ironic that the day after the Hood Canal Bridge was blown down a pod of killer whales swam through the newly created passage.

Small highway bridges may be more beneficial to wildlife than culverts. Bridges over streams do not usually block stream flow or alter sediments as much as culverts.

Power Lines and Rights-of-Way (No. 147)

These areas may act as corridors for the dispersal of exotic species. However, they can be managed to become habitat of higher wildlife value by planting native vegetation. Shrubs planted along the right-of-way improve cover, nesting sites, and wildlife forage. Clearing of these areas is preferrably done by periodic burning which stimulates new growth. Spraying with herbicides does not stimulate growth of native vegetation and thus does not encourage wildlife use.

Rights-of-way are used by animals preferring edge habitat (e.g., brush and trees next to an open area). Wildlife occurring along these routes include Red-tailed Hawk, Merlin, deer, assorted rodents. Rights-of-way can be used as nature trails offering humans an opportunity to view wildlife when managed properly.



Water Treatment and Storage (No. 148)

Water treatment and storage facilities clean municipal waste water before it enters fresh and saltwater bodies. During the period between 1958 and 1965, the per capita sewage flow in the United States was 135 gallons per day. Higher water quality standards established during the last 15 years have improved the quality of fresh and saltwater bodies.

Water polluted by untreated wastes can be cleaned and the eutrophication process reversed. Lake Washington was used as a receptacle for massive amounts of untreated sewage during the early 1900's. Through the development of treatment plants and the eventual diversion of sewage from the lake, it has reversed its polluted state. However, Puget Sound, the present receptacle for these wastes, may suffer from effects of the effluents.

Sewage treatment processes are termed primary, secondary, and tertiary. Primary treatment (also called pretreatment) removes floating materials and suspended solids. It conditions the waste water for discharge or preparation for secondary treatment.

Secondary treatment is performed by many types of microorganisms which actively break down organic matter and stabilize organic wastes. Tertiary treatment is used to remove pollutants not removed by conventional biological treatment processes. These pollutants may include suspended solids, nutrients such as nitrogen and phosphorous, and inorganic salts.

It is possible to spray treated waste water on fields as irrigation water instead of discharging it into lakes, streams, and other waters. From the standpoint of nutrient concentration, wildlife forage improves with this treatment. Crude protein, potassium

and phosphorous levels are significantly higher in an area which has been sprayed with waste water. White-tailed deer in Pennsylvania browse in such treated fields. Release of sewage into marine waters in controlled quantities has also been shown to stimulate the growth of seaweeds.

Seattle is currently involved in the experimental use of sewage sludge as a fertilizer for coniferous forests.

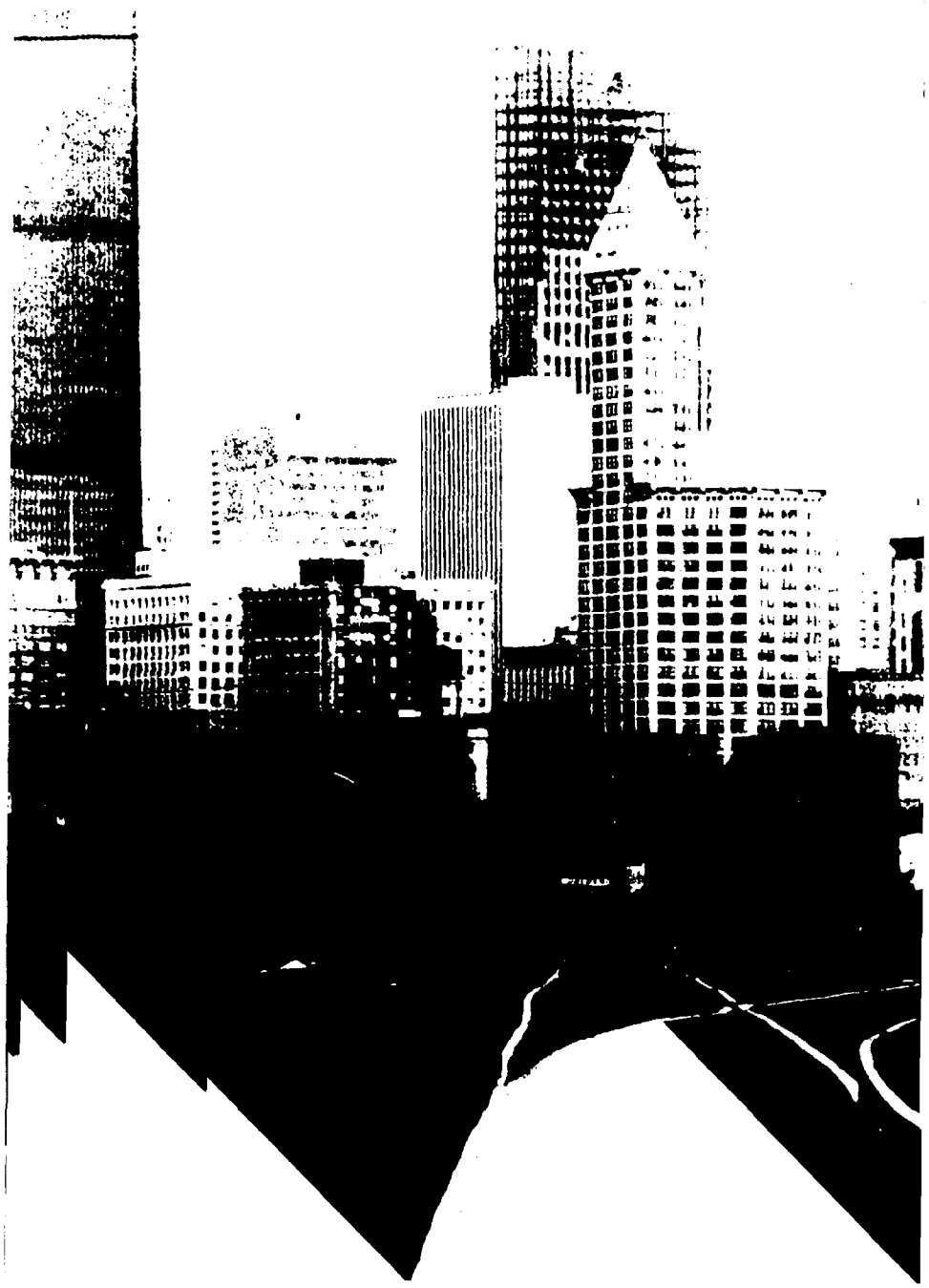
Other Transportation/Utilities (No. 149)

Port (No. 15)

This class includes those facilities located along the shoreline and/or extending beyond the shoreline, which service commercial and recreational water-oriented commerce. It also includes those construction features necessary for protected moorage. Port associated activities can have profound effects on marine wildlife and plants as seen in the discussions of subclassifications of port land use.

Commercial Cargo and Shipping (No. 151)

Commercial cargo and shipping activities often devastate the shoreline involved. Intertidal zones in commercial cargo areas are usually filled and built upon or dredged out to create boat moorages. Both processes destory the intertidal zone and adjacent uplands. Marine primary production zones which often supply offshore areas with nutrients are also destroyed by filling or dredging activities. Many wildlife species which use unaltered intertidal areas, including all commercially important nearshore species, are affected by creation of cargo shipping sites. These species include juvenile salmon and trout, English sole, starry flounder, crabs and clams. Species occurring in a given area vary according to the type of substrate originally present.



Marina (No. 152)

Marinas are areas of moorage for public or private use having multiple docks. Marinas have many negative impacts on marine areas; these are offset only partially by some benefits provided by them.

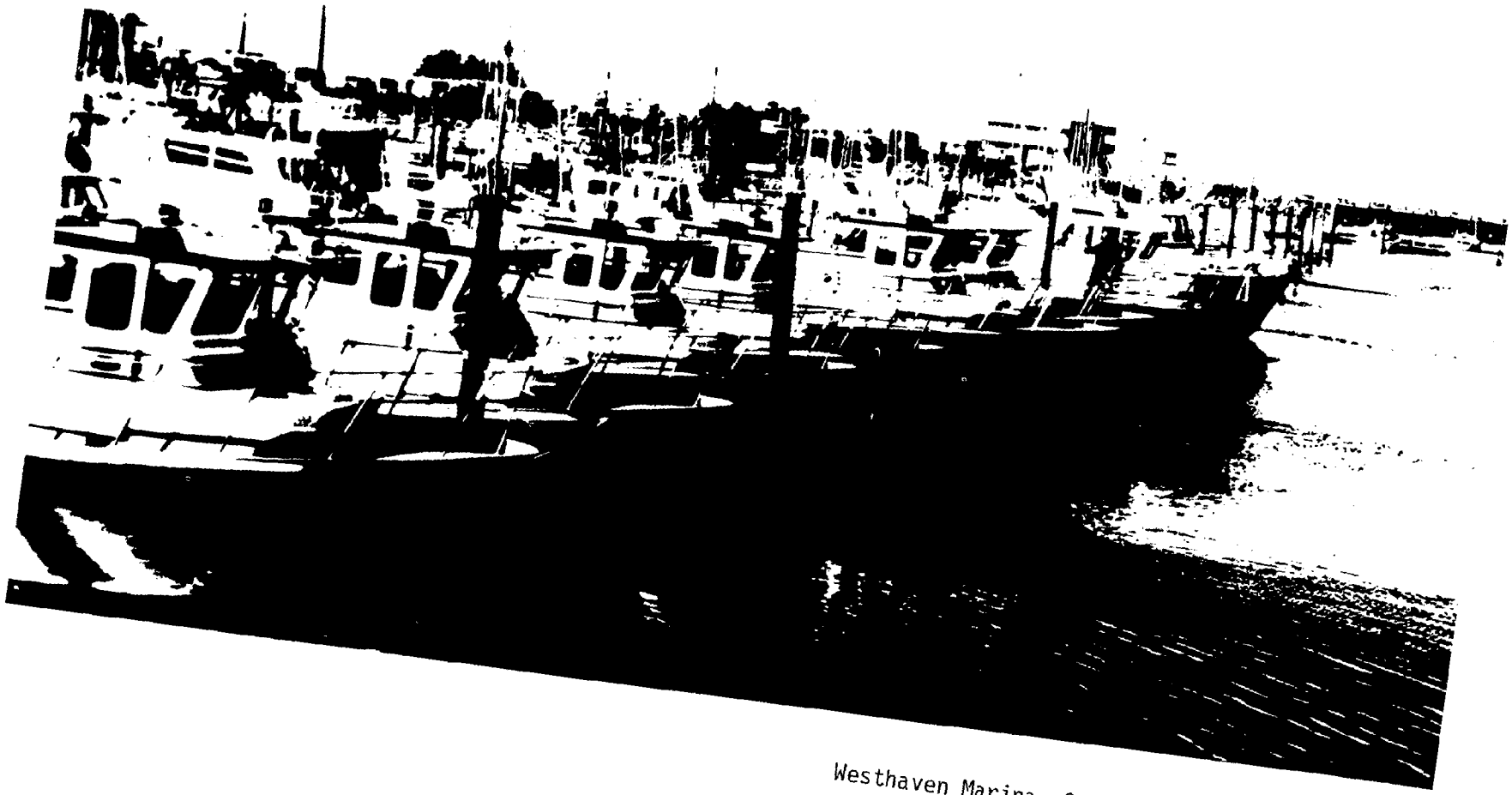
Negative impacts include the development of adjacent uplands near marinas. Increased boating and human activities in marina areas frighten birds and mammals, and thus indirectly displace them. The creation of marinas often destroys the intertidal zone and its dependent species. Intertidal vegetation, including eelgrass in some areas, may be destroyed by marina construction. Marina areas usually have increased sedimentation rates, and eventually the marina must be dredged. The disposal of dredged materials creates even more problems for the marine areas [refer to Dredge and Fill (Narrative No. 182)].

Water quality of marinas is often impacted by oil and gas products used by boaters. Sewage discharge from boats not having self-contained sewage units can create conditions of low oxygen concentrations. These water quality impacts are intensified by poor circulation of water within the marina.

Fish which feed along the shoreline enter the marina and, unable to find their way out, get trapped. Large numbers of fish may build in the marina and soon become very susceptible to poor water quality and predation. Certain marinas, such as the Edmonds Marina, have trapped many juvenile salmon.

Preferred feeding areas of juvenile salmon are shallow water beach areas that have not been impacted by marinas. Marinas, jetties, bulkheads, piers, etc., have been cited as destroying feeding areas for juvenile pink and chum salmon and have thus affected Puget Sound stocks of these fish.

Marinas benefit some wildlife. However, fewer bird species appear in and around marinas than on unaltered intertidal areas. In general, invertebrate species diversity probably increases in marina areas although total abundance and production of organisms may not. Floating docks allow organisms which normally grow in lower intertidal or subtidal zones to grow near the water's surface.



Westhaven Marina, Grays Harbor County

There is a unique fauna and flora associated with floating docks and pilings. These organisms use many substrates present in marinas, including wood and styrofoam. Wood treated with creasote to discourage wood-boring isopods and shipworms also kills harmless organisms. Wildlife found among pilings includes: coon-striped shrimp (which is commercially important), mussels, scallops, ochre stars, and pile perch. Algae are also present. Their abundance is dependent on whether the marina water is covered or exposed to sunlight. Edible algal species include sea lettuce, Monostroma and Enteromorpha (both green algae), and the kelp called sugar wrack. Sugar wrack usually has the greatest biomass of algae in a marina situation. Many microorganisms are also present in the marina community.

Marinas should be developed according to a number of criteria including:

- Proximity of a proposed marina to productive seagrass or algal beds.
- The value of the undisturbed area to recreational and commercial shellfish. (Future permits for commercial mussel culture in Penn Cove are partially dependent on the possible future location of a marina in the bay and associated water qualities.)
- Proximity to critical biological areas. The San Juan Islands may already be saturated with marinas. More moorages would encourage an additional increment of boaters which could destroy eagle, marine bird, and fish habitat.
- General water quality; despite restrictions, oil, gas and sewage continue to degrade water quality in protected bays with marinas.
- Carrying capacity of boats in the immediate vicinity and areas accessible to boats moored at a particular marina. Some shallow protected bays such as Liberty Bay, which have value to waterfowl, commercial oysters and mussels, may already be at their carrying capacity for boats.

Efforts should be made to assess wildlife and esthetic values of potential marina sites before costly development investments are made. This assessment would eliminate the need for extensive environmental impact reports and other costs to developers. Most important, the process would include wildlife and other environmental considerations in the decisions of locating potential marina sites.

Log Storage (No. 153)

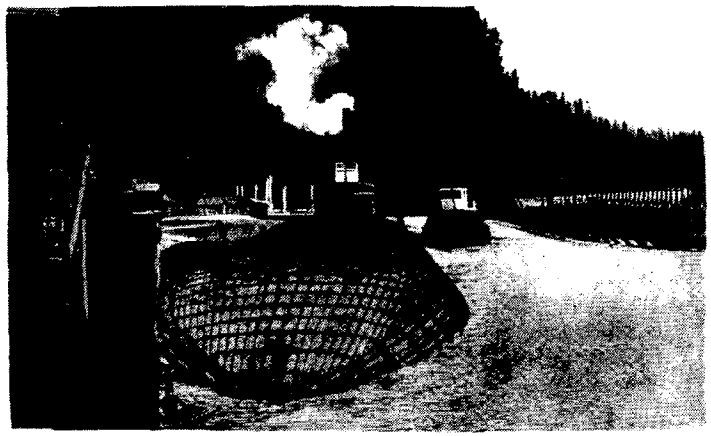
Log storage in the form of floating rafts has played a part in the historical settlement of the Pacific Northwest. Logs are hauled to a log dump or floated down river, then bundled in rafts to be towed by tugboats to a sawmill. Towing the logs by water provides an energy efficient means of bringing the logs to a mill and an expedient method of moving logs into the mill for cutting. The trade-offs between water and land storage sites are not always clear. Water storage does eliminate the need for large land areas for dry storage. It also eliminates the need to sprinkle logs stored on land with water to prevent excessive drying before they are cut.

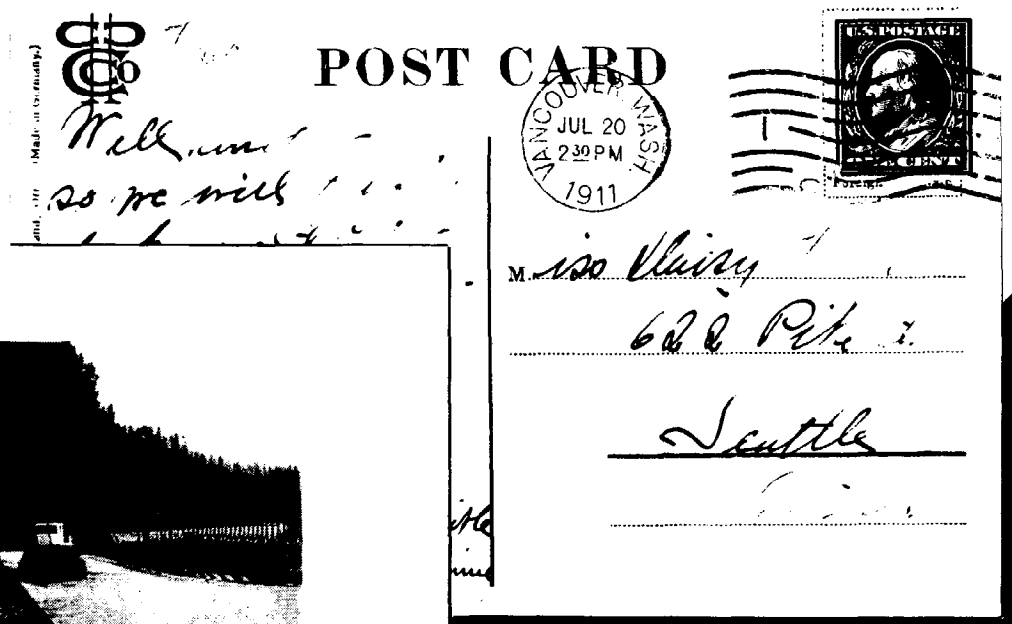
Water storage of logs does impact the local waters. Bark and small pieces of logs which break off become waterlogged and sink. Accumulated pieces of wood create an environment unfit for benthic invertebrates. Bacterial decomposition of the wood causes serious water quality problems in the surrounding waters including decreased concentrations of dissolved oxygen. The tannins and lignins which leach out of the wood are toxic to most fish and invertebrates.

Log rafts are beneficial in some respects to wildlife in that they serve as artificial islands. As islands, they serve as resting sites for marine birds, harbor seals, and river otters. They are also used by other birds, such as Great Blue Herons, as feeding platforms. Canada Geese have regularly nested on purposely undisturbed rafts at the Barbee Mill Company sawmill on Lake Washington since 1944.

The following have been observed on log rafts or feeding among the logs at Port Gamble Bay:

Harbor Seals
Raccoons
Bufflehead
Greater Scaup
Brandt's Cormorant
Pelagic Cormorant
Western Grebes
Great Blue Heron
Bonaparte's Gull
California Gull
Black Turnstone
Bald Eagle
River Otters
Belted Kingfishers
Common Goldeneye
Red-breasted Merganser
Double-crested Cormorant
Crows
Red-necked Grebes
Mew Gull
Glaucous-winged Gull
Western Gull
Common Tern

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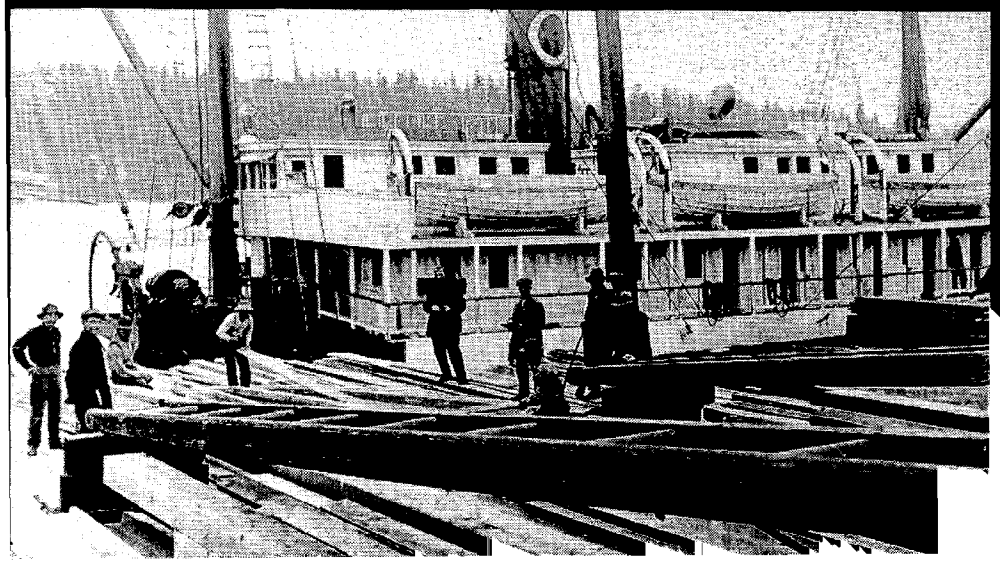

Logs stored in the intertidal zone can lead to crushing of invertebrates. Studies in Everett Bay at the mouth of the Snohomish River indicate heavy mortalities to benthic species occurring on muddy substrate. Because estuarine mud organisms are small and short lived, they can recolonize disturbed areas rather quickly, but only if the logs are removed. Longer living animals occur on different sediment types, such as the littleneck clam found in mixed fine habitats. Impacts on longer living animals may last several years. Logs have the most severe impact on juvenile clams beginning to settle on a substrate.

Both intertidal and open water log storage destroy invertebrates in the immediate area and impact juvenile salmon and small flatfish which feed in these areas of water. Shorebirds which feed on invertebrates are also affected. Both log storage methods alter the vegetation including microalgae and thus affect production.

Revetment (Riprapping) (No. 154)

Riprap is commonly used in jetty construction or to protect eroding areas from wave action. It is also used in association with fill or dredging to serve as a bulkhead in intertidal areas. Such construction eliminates large expanses of intertidal habitat and established intertidal flora and fauna are often buried. Construction activities cause local erosion and new sediment deposits in the vicinity of the revetment. New sediments are often silty and can destroy spawning areas, smother benthic organisms, and reduce bottom habitat diversity and food supply. Riprapping in intertidal areas usually interferes with sediment drift along the shoreline.

The diversity and abundance of revetment organisms depends upon the type of facing, tidal conditions, and structure's location on the beach, and the type of substrate on which the revetment was built. In general, revetment facings that are highly irregular and have a shallow slope are favored biologically over structures with smooth and/or steep sloped surface. Irregular and gently sloped revetments can dissipate wave energy better and have a greater ability to support various organisms. The rocks provide a substrate similar to a protected rock habitat (see the Rock Narrative, No. 631).

Dike (No. 155)

Dikes are considered to be any structure designed to control water flow to prevent flooding or erosion. They may also provide navigable waterways. This land use was commonly mapped around major agricultural areas which were once salt marshes. Major areas having dikes were Skagit Flats, Padilla Bay, Willapa Bay, and the Nisqually Delta.

Dikes often function as part of reclamation projects which ironically convert highly productive aquatic wetlands to upland agricultural systems having much lower total productivity. Diking and filling of wetlands for agricultural purposes often results from a lack of awareness of the

tremendous value of tidal marshes. These marshes contribute to the productivity of nearshore waters and therefore to commercially important oysters, crab, fish and other animals.

Game managers also use dikes to create freshwater marsh or upland crop areas on former salt marshes. While such areas benefit some game birds such as Canada Geese and Mallards, species benefitting from salt marsh productivity such as Wigeon, salmon, flounders, oysters, crabs and many others, are negatively affected by the changes of habitat. Areas managed for game birds by use of dikes include the Skagit Flats and the Nisqually Delta.

The use of dikes does increase the upland wildlife species diversity of marsh areas. They also provide cover and rest areas for raptors which hunt on the adjacent marsh.

Breakwater (Jetty) (No. 156)

Breakwaters are classified as any structure used to protect leeward areas from adverse marine conditions. These structures have negative and positive impacts on marine areas. Solid breakwaters can reduce water circulation, interfere with tides and currents, and obstruct littoral drift; all may decrease the productivity and/or quality of habitat behind the jetty. Breakwaters may also interfere with fish movement (especially that of salmonids) along the shore.

Rock jetties create a rock surf habitat on the seaward side and a rocky calm habitat on the landward side which may increase species diversity of an area and possibly its productivity. Rocks provide substrate for attachment of kelp. They also provide many nooks and crannies used for cover and feeding by small fishes. However, these new habitats are gained at the cost of previously existing benthic organisms.

Species occurring in rock jetty areas include:

Blennies
Pacific Staghorn sculpin
Striped seaperch
Shiner perch
Rockfish spp.
Red rock crabs
Pandalid shrimp
Walleye pollock

The Department of Fisheries has expressed interest in using old concrete slabs to create underwater reefs to increase habitat diversity and the variety of fishes. However, an evaluation of such procedures must take into consideration the areas protected by the breakwater which may be impacted by changes in exposure, water circulation, water quality, and sediment drift. Because these reefs are far below the water surface, changes in these parameters should be minimal.

Deep water associated with shore connected breakwaters can affect longshore fish migration routes. The reduction in shallow water areas reduces the available salmonid fry migration routes and exposes the fry to increased predation because they will not migrate around the structure. The effects of floating breakwaters are generally less severe and the Washington State Department of Fisheries has strongly recommended their use to protect fish.

Construction of breakwaters is accompanied by noise, air and water pollution, and should be timed to avoid periods of fish spawning, fish migration, and bird nesting. Any construction activity disturbing bottom sediment increases water turbidity which can also disturb the wildlife and productivity of an area; toxic substances present in the sediments may also be released. Turbidity should be controlled during construction and maintenance of breakwaters and associated dredging which also physically disturbs benthic organisms should be minimized.

Pilings (No. 157)

Pilings are most often associated with some other land use type such as marinas, piers, or log storage. They are often found scattered as remnants of past uses of an area; remnants of old docks, lumber mills, or canneries. Pilings are used by cormorants, gulls, crows, Great Blue Herons and Bald Eagles. Occasionally they are used as nest sites. For example, a pair of Glaucous-winged Gulls raised two young on pilings at Edmonds Ferry dock in 1978. Many fish, including pile perch, which use piles for cover and feeding sites also occur around breakwaters (see the Breakwater Narrative, No. 156, for a list of species using these areas). Invertebrates which use pilings and piers (No. 158) include mussels, barnacles, and white sea anemones.

Pier (No. 158)

Docks and similar structures were classified as piers. Some piers in Seattle, Tacoma, and other major shipping areas were classified as "Commercial Cargo and Shipping" land use. Piers can provide habitat for some algae, invertebrates and fishes; perch feed on invertebrates attached to pilings. River otters which normally feed in these areas, crawl up on floating piers and use them for sprainting (scent marking) areas. Unfortunately, some humans find this distasteful and treat the otters as pests rather than viewing such visitations as opportunities to appreciate wildlife.

Piers negatively impact species normally occurring along the undisturbed shoreline; they disrupt feeding routes of fish, birds, and marine mammals. The degree of impact on piers depends on their size and structure. Some wharfs cover one to several acres of beach, impacting a much greater area then benefitted by pilings.

The cumulative impact of small and large piers on the shoreline is truly great. Habitat is impacted by piers by shading, pile driving, and dredging. Even construction of small piers requires some dredging when located in protected, flat beach areas. Attendant boating activities and oil and gas pollution can be so disruptive that sensitive wildlife, such as eagles and marine mammals, may leave the area.

Piers and breakwaters have similar fish species (refer to the Breakwater Narrative, No. 156).

Other Port Facility (No. 159)

Construction (No. 16)

Areas classified as construction include sites undergoing obvious developmental change at the time of mapping. The degree of construction activity in these sites varies greatly. Some areas are actively being built upon while others, such as on Anderson Island in Pierce County, only have roads and electricity. A great deal of new construction was noted during this study which points to the necessity of future updating of the Coastal Zone Atlas.

Poor construction practices can cause major damage through destruction of habitat, thus eliminating nesting sites, breeding grounds, and microclimate protection. Builders should be encouraged to conserve topsoil, prevent erosion and disturb the existing vegetation as little as possible.

The construction classification includes the following land uses:

Residential Construction (No. 161)

Commercial Construction (No. 162)

Industrial Construction (No. 163)

Other Construction (No. 164)

Extractive (No. 17)

Extractive activities are potentially detrimental to the marine environment and should be prohibited along the immediate shoreline. Such activities can result in excessive upland erosion, increased sedimentation of nearby waters, and interference with shoreline drift. They can also eliminate seabird nesting areas and reduce recreational opportunities.

Extractive land uses include:

Mineral Extraction	(No. 171)
Stone Quarry	(No. 172)
Sand, Gravel, or Clay Extraction	(No. 173)
Oil and Gas Wells	(No. 174)
Abandoned Mining Operations	(No. 175)

Open Land (No. 18)

The open land classification includes areas extremely altered and relatively devoid of vegetation due to scraping, dredging and filling, or use as refuse stations. The term "open land" in this sense does not mean undeveloped native or park areas as is often used in planning terms.

Scraped Area (No. 181)

Scraped areas refer to areas in the early stage of development and construction.

Dredge and Fill (No. 182)

Dredging activities totally disrupt the benthic community of the local area and can affect water quality of nearby areas by changing turbidity levels and circulation patterns. Many animals and plants are killed or relocated by the dredging process. The disposal of dredged material, called fill or spoils, can have even more devastating effects to shoreline communities.

Disposing of fill in intertidal areas destroys habitat required by all species of the intertidal food chain. Filling has been responsible for destroying many thousands of acres of tidelands in Washington and has affected adjacent upland areas. Filling areas changes population densities, distributions and species compositions. Fill can reduce primary productivity of nearshore waters especially if done in marshes, eelgrass beds, or sea lettuce (Ulva) beds. Currents, tidal action and salinity regimes may also be altered. Changes in water circulation patterns affect primary productivity and fish and bird use of nearby areas. Changed circulation patterns can also induce increased sedimentation in other areas in addition to the fill site.

Even slight increases in substrate elevation as small as three feet caused by filling areas can significantly degrade the environment. Raised substrate elevations can make areas unsuitable for eelgrass growth and decrease invertebrate populations. Primary productivity of such an altered area will decrease and fewer fish, birds, and mammals will be able to feed in the area.

Disposal of fill material on salt marshes destroys these highly productive areas. Salt marsh flora is composed of hydrophytic (water loving) plants. Elevated marsh substrates created by deposited fill, eventually lose moist marsh conditions. Hydrophytic marsh plants diminish and upland plants invade. Recovery of former salt marsh habitats is limited and in some areas salt marsh is permanently destroyed.

Accompanying dredge and fill processes are increased human activities which alter the environment of an area even further. Increased urbanization, shipping, and industrial developments all impact habitat and wildlife. Proposed dredge and fill sites must be examined very carefully and the degree of potential impacts assessed before such activities are allowed to alter nearshore and marsh areas.

Research is underway to examine the possibility of creating habitat with dredge spoils (materials removed by dredging). Disposing of dredge spoils can create marsh or an island for nesting birds when done with environmental planning. However, the building of habitat for some wildlife will destroy habitat for others. Such filling of areas can drastically alter the invertebrate population which supports local fish, shorebirds, and shrimp.

Refuse Station (No. 183)

Refuse stations, or garbage dumps, usually are large cleared areas with small amounts of weedy vegetation if any is present. Dumps subsidize populations of gulls, especially Glaucous-winged Gulls, along the coast.

Sanitary land fills have been successfully converted into parks. Although the initial creation of a dump site is disruptive, the conversion of filled dumps into parks is a good use for these altered sites. Garbage dump sites should not occur within 100 feet of the shoreline and should not be created near marsh areas because of the impact associated fill activities have on these areas (see the Dredge and Fill Narrative, No. 182).

Recreation (No. 19)

Recreation areas, which include parks, camps, and golf courses, and small wood lots within well-developed residential areas, vary in degree of habitat alteration.

Park (No. 191)

Areas mapped as parks include only land actively used as campgrounds and/or picnic areas. Remaining large areas within official park boundaries are mapped as the appropriate vegetation classes. Thus, Point Defiance Park is mapped in the Coastal Zone Atlas to include both recreational and vegetated areas.

The "Park" classification often includes areas of concrete boat ramps and parking in addition to more natural areas such as in Discovery Park in Seattle. The latter has many miles of nature trails through areas of native vegetation. These trails, marked with interpretive signs, provide recreation and serve to educate the public about ecology. Natural park areas which are used heavily, such as Fay Bainbridge State Park in Kitsap County, often have vegetation which is severely impacted.

Seward Park in Seattle, is an urban park having a large forested area. Seward Park has a characteristicly diverse avifauna similar to that of nonurban lowland coniferous forests; it has no marked increase in numbers of species usually occurring in the urban landscape. Smaller parks in Seattle having modified vegetation have fewer native forest species and more urban associated birds. Modified small parks also have a decreased bird species diversity.

Some of the birds occurring in large parks with native vegetation are:

- Bushtit
- Brown Creeper
- Chestnut-backed Chickadee
- Red-breasted Nuthatch
- Winter Wren
- Bewick's Wren
- Swainson's Thrush
- Black-throated Gray Warbler
- Purple Finch
- Rufous-sided Towhee
- Song Sparrow

Birds more commonly occurring in smaller parks with modified vegetation including cleared shrub layers are:

- Starling
- House Sparrow
- House Finch
- Barn Swallow
- Violet-green Swallow
- American Robin
- Common Crow
- Rock Doves

Golf Courses (No. 192)

Golf courses are large areas of open space which are used by several wildlife species. An example of such use is the grazing activity of wigeons on the golf greens. Golf courses are often vegetated only with large expanses of grass and tall trees. These areas can be made more beneficial to wildlife by diversifying the landscape with native shrubs and not removing all dead trees and dead tree limbs.

Urban Wooded (No. 193)

Undeveloped woodlots are usually areas of undisturbed vegetation with the exception of occasional trails. Woods often occur along bluffs and as such are valuable coastal edge habitat which should be maintained. Woodlots provide controls for noise and air pollution and refuges for plants, animals and humans. They create visual diversity within residential areas. They are also important to urban wildlife which use woodlots for feeding, rest, roost and nest sites and for cover. Deer, raccoon and coyote use rural woods for cover during daylight hours and forage in adjacent open areas at dusk and at night.

Larger woodlots with diverse vegetation support more species than smaller homogeneous areas. Woodlots which are connected to a forest by at least small areas of vegetation also have more species than isolated lots totally surrounded by large distances of development. Eastern United States studies of forest fragments have revealed that the number of bird species within an area increases significantly as fragments increase to 59 acres (24 ha) in size. Species diversity probably continues to increase with areas larger than 59 acres (24 ha). An example of increased species diversity with acreage is shown in the observation that small woods of 0.5 acre (0.2 ha) contain only forest edge species while areas of 2 acres (0.8 ha) also had some forest interior species (forest interior species are those requiring large expanses of woodland).

Larger forest patches are essential to maintain a complete regional bird community because human activities threaten some species more than others. Species of high dispersal ability and high reproductive potential, able to live in successional habitat types can survive human environmental changes better than sedentary species of low reproductive potential that require more mature habitats. Urban woods and sometimes single trees are critical sites for maintaining such unusual birds in developed areas as hawks which perch on the trees.

Small woodlots are also valuable because they support a high density of bird species and act as rest stops for species dispersing between forests. Vegetation corridors which permit free movement of forest birds serve to decrease extinctions of species within a locality and facilitate rapid recolonization following local extinctions.

Forest patches in coastal counties are steadily decreasing in size. Pierce, King and Snohomish Counties especially have had not only total woodlot acreage diminish, but also sizes of individual forest patches. Increased rates of development have made these woodlots more valuable to humans desiring retreats from

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urbanization. With foresight, careful planning and restricted development, Washington's coastal forest areas will continue to provide diverse habitats for many wildlife species.

CONCLUSION

Throughout these narratives it has been shown we can enhance wildlife use of urban areas by maintaining natural vegetation in developed areas and by being highly selective in what areas we choose to develop. As development encroaches on undeveloped lands, it is even more important that we recognize wildlife and human needs for open land as habitat and refuge, and that local, county and state development plans address these needs.

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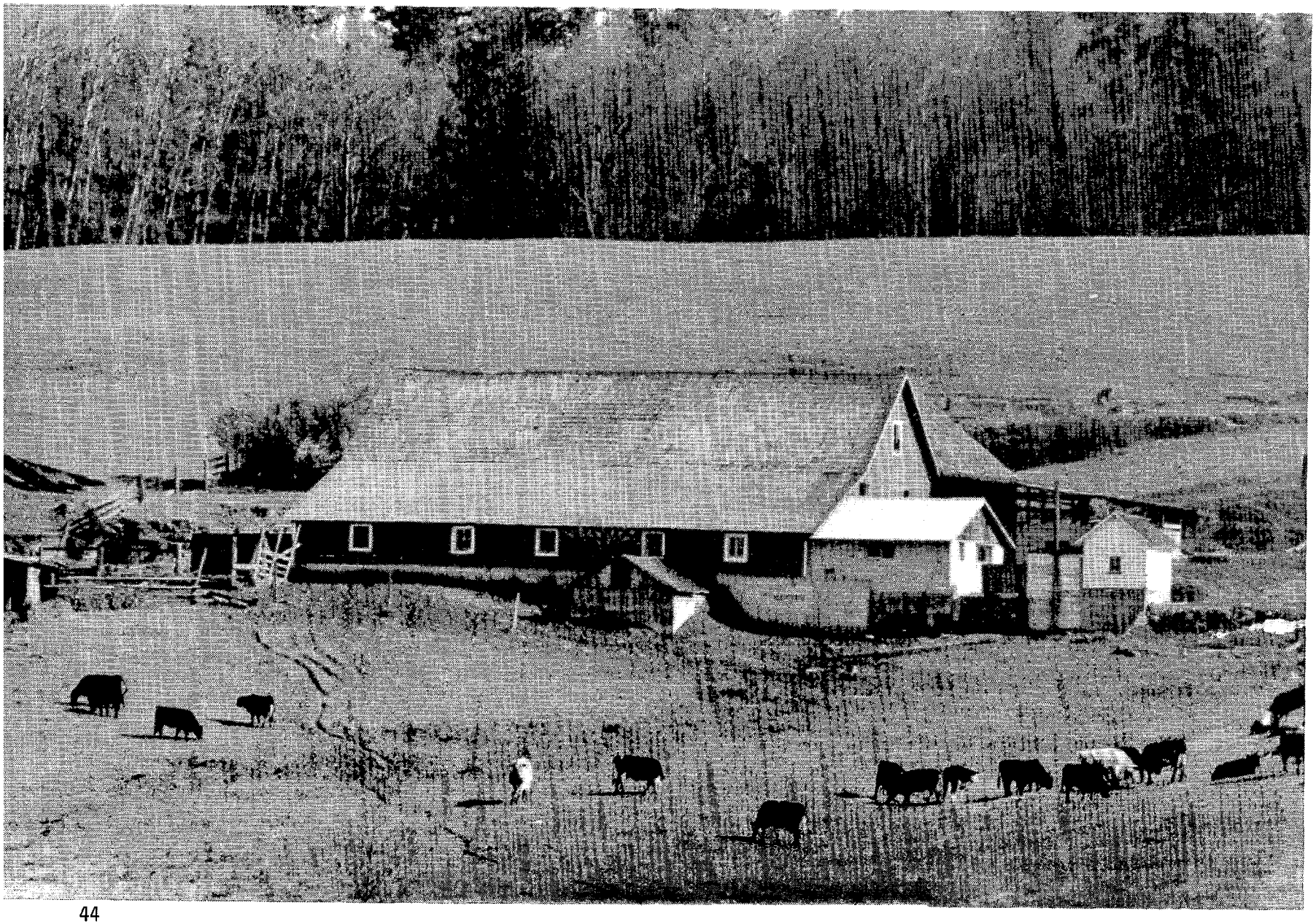


Agriculture 2

AGRICULTURE (No. 2)

I. INTRODUCTION

Coastal lands designated as agricultural include areas being used, or having been recently used, for the production of terrestrial crops and food from the sea (mariculture).

Terrestrial agriculture occurs throughout most of the coastal zone and is especially important in Skagit, Whatcom, and Snohomish counties. Mariculture occurs in several counties. Agriculture benefits the State's economy and often benefits wildlife, depending largely on how crops are grown and fields are maintained. Culture of fish has been a major emphasis of mariculture activities in Washington and has greatly affected salmon populations. Natural stock lost through dam construction and other impacts have been subsidized by hatchery fish. Mariculture of other aquatic organisms is still in early stages of development in our area, but promises a bright future.

II. AGRICULTURE

Crop/Pasture (No. 21)

Crops and pastures are cultivated, mowed or grazed lands and usually occur on flat to gently rolling slopes with good moisture regimes. The crop/pasture classification includes row and field crops. Agricultural usage of these lands may change on an annual basis due to crop rotation. These areas may be the most extensively used agricultural lands by wildlife with the possible exception of inactive agricultural areas (No. 24).

Row Crops (No. 211)

These crops are cultivated annual or perennial crops, such as strawberries and corn, which are raised in rows. Intensive cultivation of these areas and use of biocides lessens their value to wildlife.

Corn fields are used by migrating waterfowl which comb harvested areas in the fall for leftover grain. Mallards frequently use these areas and are attracted to many hunting sites by plantings of corn and other grains. Cultivating expansive areas along migratory routes is a common water fowl management technique to boost bird food supplies. Both public and private lands are managed in this way to attract waterfowl to fill hunter bag limits. Private landowners benefit if they are hunters, but many also lease lands to other hunters, thus providing the farmer with income after crops have been harvested.

Field Crops/Pasture (No. 212)

This classification includes land that supports crops of grains, alfalfa, grass, hay, etc., or land grazed by livestock. Field crops and pasture provide cover, feeding and resting areas, and sometimes nesting sites for small mammals, song birds, waterfowl, and birds of prey. Deer and elk also forage in pastures. Swallows fly over fields catching flying insects. Coyotes, Marsh Hawks, and Red-tailed Hawks hunt rodents occurring in these fields and thus benefit the farmer with inexpensive, ecologically sound rodent control.

Fields and pastures are used for resting and feeding by geese, ducks, gulls, and shorebirds. They often contain extensive wet depressions which are used heavily by these wetland wildlife. In many coastal locations, these areas represent former marshes and swamps which were converted to agricultural use. Farm fields have only partially reclaimed these lowlands and at several locations show signs of reverting to productive natural wetlands. Extensive clumps of soft rush are indicators of these wet areas which often have standing water during fall and winter.

In some areas, particularly on river deltas such as the Skagit and Nisqually , farm fields have been created by diking, draining, and filling salt marshes. Agriculture in these instances has also only partially reclaimed the wetlands. In these areas, wet depressions with standing water are common in fields and pastures as well as in more intensively farmed cropland (e.g., row crops). Typical wetland vegetation has been largely replaced by cultivated plants, however, wetland wildlife still occur. Ducks and geese are abundant and gulls and shorebirds also are present. Waterfowl have used these areas throughout the period of changing land uses. Thus, in many cases agricultural fields can be regarded as partial replacements for the extensive wetlands which once were much more extensive. Unfortunately, many acres of farm land are now being converted to urban developments and are being removed from production for food and wildlife as illustrated in Figure 2-1a and b.

Canada Geese

KAREN

Fields and pastures that support waterfowl and other concentrations of birds also attract birds of prey which may include Peregrine Falcons and Bald Eagles (the Bald Eagle is a threatened species; two Peregrine subspecies are endangered). For example, falcons are noted for using small farm woodlots in Skagit and Clallam counties for roost sites; from these perches they fly out and hunt over surrounding farm land and adjacent coastal areas. The large numbers of species observed in recent surveys such a the 1978 Skagit Flats Raptor Census (see Table 2-1) point out the value of these agricultural areas to birds of prey.

Table 2-1

BIRDS OF PREY IDENTIFIED
DURING THE 1978 SKAGIT FLATS RAPTOR CENSUS

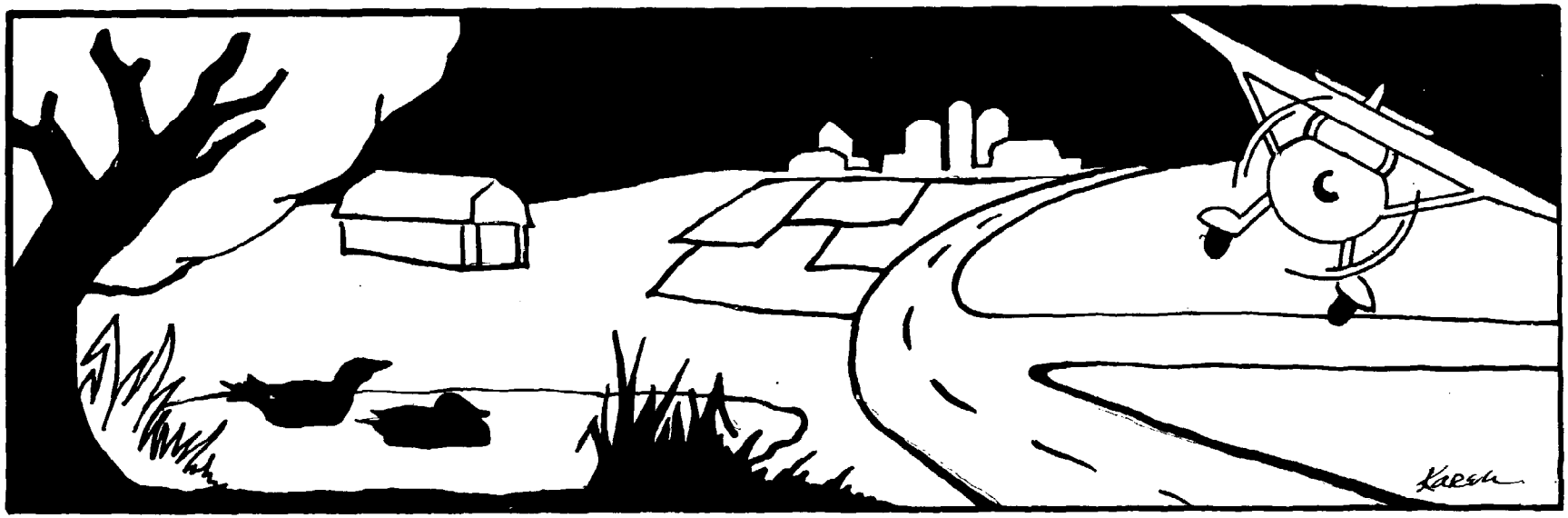
Cooper's Hawk
Sharp-shinned Hawk
Marsh Hawk
Rough-legged Hawk
Red-tailed Hawk
Bald Eagle (Threatened species)
Prairie Falcon
Peregrine Falcon (Endangered species)
Merlin
American Kestrel
Short-eared Owl
Barn Owl
Snowy Owl

Coastal farmlands were often created by diking, filling, and/or draining wetlands. Wet areas still persist on these agricultural areas and wildlife use is often high, particularly by waterfowl.

FIGURE 2-1A

Urbanization of farmlands is now a common feature in the coastal zone, and as farmland is put out of production for humans, it is also lost as a valuable habitat for wildlife.

FIGURE 2-1B



Farm woodlots and small patches of shrubs or fencerow vegetation are also used as cover and nest sites for other wildlife. Owls and Red-tailed Hawks may nest or roost here and forage for rodents in adjacent fields. Coyotes, many song birds, raccoons, skunks, and deer also benefit from farm woodlots and other clumps of vegetation left standing in fields and pastures.

Recommendations

The wildlife value of field crop and pasture lands can be enhanced by diversifying the areas. Leaving stands of trees or planting trees and shrubs along fences encourages wildlife. Farm ponds and drainage ditches can be waterfowl and fish habitat if managed properly. Native riparian vegetation established along these aquatic areas supports many types of birds, mammals and amphibians.

The misuse of fertilizers and pesticides on these lands not only disturbs the fields' ecosystems, but drains into rivers and lakes and can harm those systems. It is ironic that the use of some pesticides reduces the suitability of an area to those species which could aid the farmer in insect and rodent control.

III. ORCHARDS, VINEYARDS, NURSERIES (No. 22)

These areas are intensely cultivated and have almost no understory. Grasses and shrubs may occur along these well defined fields but generally the flora and fauna are greatly reduced compared to native woodlands or shrub areas.

Coastal orchards, vineyards, and nurseries are generally small and often comprise a small percentage of the area of a larger farm. In these instances, the presence of orchard trees or shrubs diversify the immediate landscape and provide habitat for perching birds.

IV. MARICULTURE (No. 23)

Mariculture consists of two subclasses:

231-Oyster and Clam Culture -- Intertidal areas used for the culture of Pacific and Olympia oysters, or clams (particularly littleneck and butter clams).

232-Salmonid Culture -- Subtidal areas or enclosed systems used for pen rearing of salmonid fishes, or hatcheries used for cultivating salmonid fry.

While aquaculture can be defined as the growth of aquatic organisms (both freshwater and marine) under controlled conditions, mariculture refers specifically to "sea farming," or the husbandry of marine plants or animals. Such culture may occur totally on land, in human-constructed impoundments, or in the sea itself. Strictly defined, mariculture refers only to the culture of marine organisms as opposed to the harvest of natural populations. Our classification includes rearing areas of native and cultured marine organisms.

Interest in mariculture in this country has increased greatly over the last two decades. People have come to realize the limits of terrestrial food supplies, and the vast resources of the seas are viewed by many as a logical means of sustaining expected increases in world population. Marine plantations throughout the world produce on the average 5,000 times more food per unit area than ordinary ocean fisheries. Thus, the yield of marine products (primarily food) obtained from the sea has already been increased greatly by mariculture. The bulk of global mariculture involves seaweed production, followed in order by shellfish, crustaceans, and marine fish. In Washington, shellfish and fish culture are by far the dominant types of sea farming. The high cost of most types of mariculture is presently the limiting factor to expansion and diversification. However, the economics seem to be swinging in favor of mariculture, largely as a result of improved culture technology and an increased demand for food.

Few intertidal species in Washington are currently commercially harvested. Hand digging of clams (mostly native littleneck, Japanese littleneck, and butter clams) in Port Discovery and Sequim Bay intertidal areas represents the only substantial harvest in operation. Razor clams, once harvested commercially along the Pacific Beaches, are now only harvested commercially from sand islands at the mouth of Willapa Bay. Extremely limited industries harvest natural stocks of mussels in Hood Canal for food and ghost shrimp for fishing bait. While not a "true" mariculture operation, the harvest of hardshell clams in Clallam County was mapped as mariculture to avoid creating a separate mapping class.

The harvest of natural populations of marine organisms occurs more frequently in subtidal or open water areas (although many of the harvested species use intertidal areas for a portion of their life). These subtidal species include hardshell clams (including Japanese littleneck, butter and horse clams, and geoducks), sea urchins, crabs, shrimp, octopi, and a large variety of fishes.

"True" mariculture in Washington is limited to only a few species at present, and is less extensive relative to many other areas of the world, especially much of the Orient. However, mariculture is showing signs of diversifying into new areas with a substantial amount of research being performed by state agencies on developing economically feasible culture techniques.

The future of mariculture in the State of Washington will largely be determined in the next decade by land use planners. Many human activities which cause pollution are totally incompatible with the culture of food organisms. Many areas of our state are already unfit for culture of food species. To ensure that mariculture will be a viable industry in the future, planners need to designate specific areas for that use, and control or prevent activities in adjacent areas which are incompatible. Marina construction, deposition of many industrial effluents, stream runoff, and sewage effluents are types of activities that are incompatible with mariculture.

Oysters

Oysters are economically one of the most important species farmed in Washington and have a long history of harvest. Harvest of the native Olympia oyster, once extremely abundant in Washington, began in 1851 and represented the beginning of the oyster industry in the state. Within 30 years, the Olympia oyster was severely over-exploited. In the late 1800's, the Eastern oyster was introduced to Washington, reviving the oyster industry until 1917-19 when disease and red tides (blooms of toxic microscopic plants in the phytoplankton oysters eat) apparently killed most of the oysters. Before this time, experiments with transplanting the Pacific oyster to Samish Bay had begun. In 1919, it was accidentally discovered that young seed oysters (or spat) could be imported from Japan on oyster shells rather than importing larger oysters. This was the practical beginning of the oyster industry in Washington as it exists today. In 1947, a smaller relative of the Pacific oyster, the Kumamoto oyster was imported to increase the supply of cocktail oysters which the Olympia oyster has been unable to meet.

Major oyster production areas in the State of Washington are Willapa Bay, Grays Harbor, southern Puget Sound, Dabob Bay in Hood Canal and Samish Bay. Southern Puget Sound also supports a small commercial

industry raising Olympia oysters. Willapa Bay is the most important culture area, usually producing 50 to 55 percent of Washington's total oyster crop of three and one-half to five million pounds (1.6-2.3 million kg) annually. The State of Washington supplies more than 96 percent of the west coast's annual oyster crop.

Pacific oysters spawn regularly only in Willapa Bay and Dabob Bay; other areas are dependent upon obtaining seed oysters. Once obtained, oysters are primarily cultured on mud or muddy sand substrates, although sand and mixed fine substrates are also used.

Raft culture of Pacific oysters has proven highly successful in the Orient, and is used by some oyster farmers in Washington. Several advantages are available by culturing oysters on rafts: 1) oysters are constantly submerged in sea water, allowing more feeding time resulting in a faster growth rate; 2) fewer predators of oysters can reach them on rafts (especially starfish and oyster drills); 3) the amount of area in which oysters can be cultured is increased greatly; 4) the production per unit area can be increased up to ten times; and 5) impacts to plants and animals are reduced compared to culture and harvest operations in intertidal areas.

A major constraint on the oyster industry in Washington is the amount of suitable area for culture. Pollution, particularly sewage, has made many areas unsuitable for farming. The problem with sewage is that it carries human viruses, especially enteric (intestinal) viruses such as hepatitis. When bacterial levels in a body of water become too high, the State Department of Social and Health Services close that area to oyster harvest. In some cases, oysters can be moved to an unpolluted area for a minimum amount of time to cleanse themselves of bacteria before going to market; this procedure adds to the expense of farming oysters.

The introduction of oysters to Washington, first from the East Coast and subsequently from Japan, led to a consequence which nature has had to endure time and time again; the accidental introduction of a variety of organisms along with the oysters. Many of these imported species have become well established. While some have existing or potential value economically, others have had a profoundly negative impact upon the oyster industry (refer to Table 2-2). The two species in the latter category which have caused the greatest problems are the Japanese oyster drill and a flatworm, both of which feed on the oyster.

Table 2-2

SOME ORGANISMS IMPORTED ALONG WITH EAST COAST OR PACIFIC OYSTERS TO THE STATE OF WASHINGTON

COMMON NAME (SCIENTIFIC NAME)	ECONOMIC VALUE	OYSTER PREDATOR OR PARASITE	COMMENT
Soft-shell or Eastern soft-shell clam (*Mya arenaria*)	R, PC		Supports commercial industry on East Coast
False angel wing clam (*Petricola pholadiformis*)			
Eastern mud nassa [*Ilyanassa* (*Nassarius*) *obsoletus*]			
Atlantic oyster drill (*Urosalpinx cinerea*)		x	
Atlantic slipper shell (*Crepidula fornicata*)			
Eastern white slipper shell (*Crepidula plana*)			
Japanese littleneck or Manilla clam [*Tapes* (*Venerupis*) *japonica*]	R, C		
Nestling clam (*Trapezium liratum*)			
Japanese oyster drill (*Ocenebra japonica*)		xx	Causes significant mortalities in oysters
Conch (*Rapana thomassiana*)		x	
Oriental parasitic copepod (*Mytilicola orientalis*)		x	
Cuming's false cenith [*Batillaria attramentaria* (*zonalis*)]			
Chinese jingle shell [*Anomia* (*lischkei*) *chinensis*]			
Flatworm (*Pseudostylochus ostreophagus*)		x	
Brown alga (*Sargassum muticum*)	PC		Considered a pest to British Columbia oyster industry

Harvesting of intertidal oyster beds is accomplished by either hand-picking or using a dredge which essentially rakes the oysters off the bottom. In areas where intertidal vegetation is abundant, particularly eelgrass or sea lettuce, dredging oysters can remove large amounts of this vegetation. This will result in a lower primary productivity in the harvested area. While plants such as eelgrass and sea lettuce may not be used to a great extent as food for the plankton-feeding oysters (oysters do apparently consume some detritus of these and other plants), they are important food sources for many other marine organisms. Oyster growers, on the other hand, see the presence of marine plants in their oyster beds as a nuisance, making harvest of oysters much more cumbersome and expensive. Some also feel that marine plants hinder the growth of oysters by slowing water currents and increasing siltation within the oyster bed, which interferes with oyster feeding.

The farming of oysters in intertidal areas can have other impacts as well, depending largely on the nature of the beach being farmed. Mud and muddy sand beaches have in the past been greatly altered to better facilitate farming. Changes have including dumping gravel on the beach to create a firmer substrate into which oysters will not sink, and construction of cement retaining walls to keep oysters inundated by water at low tides. The latter effort was partially foiled by burrowing animals, especially mud and ghost shrimp, through whose burrows water drained.

A major impact of both intertidal and raft oyster harvest involves heavy consumption of their phytoplankton food source. Oysters compete for phytoplankton with other marine organisms, most notably clams, mussels, and zooplankton. Many larval and adult fishes which prey upon zooplankton are also affected by this competition. Oysters also affect themselves in their competition for food, mostly by slow growth rates. When Pacific oysters were first introduced into Willapa Bay, they attained a large market size in appoximately 18 months. Several years later, after the number of oysters present greatly increased, growth slowed appreciably, and it now takes oysters two to four years to reach a comparable size. This effect of competition applies to many cultured species (especially those species, such as oysters and mussels, which are not artificially fed), and must be taken into consideration by planners zoning future mariculture sites.

Mussels

Farming another type of shellfish, the edible or bay mussel, is currently just beginning in Washington. The culture appears to hold great promise, both economically and in terms of total yield. Mussel culture is an important commercial industry in parts of the world, with Spain being one of the leading producers. Washington seems to be among the leaders in North America as far as interest and research in mussel culture, and two small scale culture operations currently exist in Island County, with a larger operation possibly forthcoming.

Raft culture appears to be a much more efficient method for obtaining mussels than harvest of "wild" populations. Where wild populations have been relied upon for harvest, the tendency has consistently been to over-exploit the resource. In addition, losses of mussels due to predation is much lower for raft culture than for wild populations. Conversely, raft culture does not remove the wild food supplies of mussel predators, such as starfish, snails, and crabs, thus minimizing impacts to these predators. Growth rates of raft-cultured mussels are also higher than growth rates in wild populations as raft mussels are continually submerged and not subject to the crowding found in wild populations. Mussels cultured on rafts grow to marketable size in 13 months in Seabeck Bay in Hood Canal, and may grow faster in some other areas in the state. This time period is much shorter than the two to four years required for oysters to reach marketable size; if mussel culture became extensive in occurrence growth time would be expected to increase as a result of competition for food among the mussels.

The fast growth rate of mussels is largely a result of their efficiency both in filtering sea water for food and in converting phytoplankton and detritus to animal matter. It has been estimated that a raft culture of mussels can remove 35 to 40 percent of the food contained in the water flowing past the mussels, and can yield one of the greatest amounts of protein per unit area of any type of animal husbandry known (see Table 2-3). The total yield of meat produced can be as high as 410,000 pounds of meat per acre per year.

In addition, mussels are of extremely high quality in comparison to most meats. For example, one pound of beef contains 0.13 pounds (59.1 grams) of protein, while mussel meat contains 0.14 pounds (65.3 grams). Mussel meat also contains one-fourth the calories, one-sixteenth the fat, and three times the carbohydrates of beef. Mussels also have high content of several vitamins and minerals.

The limiting factor to mussel culture in the U.S. at present may be their marketability. While mussels are popular in most parts of the world, Washingtonians are overwhelmingly unfamiliar with the orangish meat. Mussels are, however, quite tasty and with careful marketing, this problem could be overcome.

OYSTERS
SOLD HERE

Another problem in culture is obtaining juvenile mussels to grow on the ropes which hang from culture rafts. Small mussels can be transplanted from rocks to the ropes, but this is a labor intensive method, and therefore costly. Natural populations of the pelagic larvae can be allowed to settle on the ropes, but usually a host of other animals which compete for space on the ropes with the mussels (and which must eventually be cleared by hand) also settle. The other alternative is to induce spawning of mussels in a laboratory, letting the larvae settle on ropes which can be transferred to a raft. Once again, however, this increases the cost of the culture operation.

The major environmental impact of intensive raft culture of mussels is the large amount of phytoplankton and detritus they comsume. The mussels will in essence be competing, as oysters do, for the food resources of other filter feeding animals and their predators. This will primarily be a problem in large-scale operations or where several smaller scale operations occur in close proximity. Other impacts include the accumulation of organic matter (from feces) on the substrate below the rafts, conflicts with navigation or recreational boating, and reductions the rafts cause in the esthetic quality of a particular area.

Clams

Several clams occurring in Washington, especially the hardshell clams whose wild populations are now commercially harvested, have the potential to be farmed. The seeding of intertidal beaches to produce littleneck clams is already a reality in San Juan and Jefferson counties on a limited scale. If this operation is viable economically, it is certain the techniques will be applied to other beaches and other clams. Clams which are likely candidates include native and Japanese littleneck clams, butter clams, cockles, soft-shell clams, and possibly horse clams, and scallops. As with oysters and mussels, raft culture is also a possibility with these clams.

Salmonids

Salmonid culture is the only other major type of mariculture currently practiced in Washington. The need for culture of salmon and trout has arisen primarily from the loss of spawning and rearing habitat as a result of dams, river bed alternation, and pollution, in combination with past overfishing. The result has been a threat to a resource of high economic, as well as social and cultural, value.

Hatcheries present a slightly different aspect of mariculture in that organisms are cultured only for a portion of their life history and are then released into the wild. Only a few hatcheries in Washington occur at the mouths of stream or rivers within the

Table 2-3 COMPARISON OF ANNUAL YIELD OF CULTURED INVERTEBRATES AND NORI (PORPHYRA) WITH THAT OF CATTLE ON PASTURELAND AND OFFSHORE FISHING

AREA	PRODUCT	ANNUAL YIELD IN FRESH WEIGHT (Kg per Hectare) (lbs. per Acre)
Pastureland	Cattle	6-308
Continental Shelf	Groundfish	25-75
Humboldt Current	Anchovies	375
Japan	Porphyra (Raft-culture)	7,500
Malaya	Cockles	12,500**
Japan (Inland Sea)	Oysters (Raft-culture)	58,000**
Philippines	Mussels	125,000**
Spain	Mussels	300,000**
U.S. (Puget Sound)	Salmon (Pen-rearing)	250,000-1,250,000*

** not included weight of shell
* estimated yield

From Carefoot, T. 1977. Pacific Seashores: A guide to Intertidal Ecology. University of Washington Press, Seattle. 208 p.
and

Novotny, A.J. 1975. Net-pen culture of Pacific Salmon in marine waters. Mar. Fish. Rev. 37(1):36-47.

narrow strip mapped as coastal zone. The majority of hatcheries occur farther upstream and away from marine waters. However, it is vital to bear in mind that chum, chinook, pink, and coho salmon and trout, are very dependent upon the coastal zone primarily for feeding after release from all hatcheries.

Hatcheries appear to be an economic benefit to the fishing industry. It has been reported recently that every dollar spent in hatchery-rearing and releasing coho salmon smolts returns seven dollars through the capture fishery. However, not all these dollars are returned to those making the initial investment in rearing and releasing; this complicates the economics involved, especially as the role of private industry is regarded. However, all non-Indian hatcheries in Washington are currently government-owned and operated; legislation prohibits private concerns from releasing artificially reared fish into public waters.

Some species of anadromous fish spend one or more years in freshwater before migrating into marine waters. Hatchery-rearing of these fish (e.g., coho and chinook salmon, and steelhead trout) must include more sophisticated holding tanks to accommodate them for an entire year, increasing the cost of production. Species such as chum and pink salmon, which migrate into estuarine areas shortly after hatching from eggs, are consequently easier and less expensive to rear.

Some of the impacts of hatcheries are difficult to assess. A major concern is the extent to which hatchery-reared fish compete with the already diminishing wild fish for food resources. The issue is complicated as competition occurs not only in streams, but also along the entire marine shoreline of the state. Another impact involves the diversion of stream water into hatcheries. Although these waters are returned to the stream, this often occurs at a point downstream from the point of diversion. Thus, a stretch of the stream receives a reduced water flow. In the case of hatcheries located on fairly small streams, a large precentage of the flow (greater than 50 percent) may be involved, which would affect the value of this stretch to invertebrates, fish (including wild anadromous fish which are unable to move to upstream spawning areas), vegetation, and wildlife.

Attempt to control predation on hatchery fish (while still in the hatchery) affects several species of wildlife residing near hatcheries. Major predators, such as river otters or Great Blue Herons, are in some cases shot as they are capable of consuming a

large percentage of the fish present. It is unknown to what extent populations of these predators are affected by such actions, however, these same species may later benefit from feeding on hatchery-reared fish which have been released into the wild.

Waters flowing from hatcheries into streams or rivers normally contain moderate amounts of organic debris resulting from fish feces and overfeeding. This organic debris can in some situations result in water quality problems in the receiving stream or river. As a result, many hatcheries in Washington are currently installing treatment facilities to remove these wastes.

Land use practices in areas upstream from hatcheries can have a great impact on the success of rearing fish. For example, logging activities and residential construction may increase siltation in rivers and streams. This siltation can cause deposition of as much as two to four inches of silt in some hatchery rearing ponds in a 24-hour period following heavy rains. If siltation occurs when fish are just emerging from their eggs, mortalities can be extremely high. Other types of pollutants entering the water upstream from hatcheries, such as street runoff and industrial effluents, can also affect the survival of hatchery-reared fish.

Private interests are, however, currently involved in culturing salmonids in totally enclosed rearing pens. These enclosed pens occur in protected unpolluted water just offshore from intertidal areas. Culture requires obtaining juvenile fish from hatcheries, and artificial feeding.

Coho and chinook salmon both appear to be conducive to pen rearing. Based on culture experiments in Puget Sound by the National Marine Fisheries Serivce, yields of one to five million pan-sized salmon (0.25 kg) per hectare per year are considered possible (see Table 2-3). Accelerated coho salmon (a fast-growing strain of coho salmon developed through genetic engineering) can be reared to market size in 18 months under proper conditions.

The main sources of pollution resulting from pen rearing of salmonids are fish excretion and respiration, and excessive feeding practices. Water quality is apparently not significantly altered, thus, the major impact is on the benthic community under-

Table 2-4 INDUSTRIAL PRODUCTS CONTAINING ALGAL DERIVATIVES

COLLOID	SEAWEEDS DERIVED FROM	EXAMPLES OF USES AND PRODUCTS
Agar (or agar-agar)	Red algae	Jelly packing to preserve meats and fish; culture base in bacteriological works; sizing of fabrics; lubricant; leather finishing; ice cream; cream cheese; cosmetics; hand lotions; plywood and linoleum manufacture; malted milks
Carrageenan	Red algae	Toothpastes; ice cream; gels, stabilizing emulsions; hand lotion; pie fillings; jellies; puddings; shoe polish; clarification of beer, honey and wines
Algin (or alginic acid)	Brown algae (especially kelps)	Foods (most of those listed above); rubber materials; paper products; adhesives; cosmetics; pharmaceutical products

neath the pens. A definite accumulation of organic matter will occur on the sea bottom. A study on the effects of pen rearing of salmon in Puget Sound showed mats of a sulfide-reducing bacterium (Beggiatoa) present on this layer of organic matter. The benthic community was reduced and dominated by a polychaete worm (Capitella capitata), which is known to be an indicator of organic pollution.

An alternative to either hatchery or pen rearing of fish is the construction of artificial spawning channels. This would not only help offset the damaging losses of spawning areas which have occurred, but could help stem the continued decline of wild fish stocks. Some preliminary research in this vein has yielded encouraging results, however, the cost of such activity may be prohibitive.

Seaweeds

Farming of seaweeds is financially the most important type of mariculture on a world-wide basis. The culture of seaweeds as foods has grossed $750,000,000 per year, while seaweed by-product industries gross about $500,000,000 per year. Yet there is virtually no culture of algae in Washington; there is some limited research on the potential viability of such an industry.

Algae is harvested for a variety of uses, the major use (world-wide) is as a food. Most algae contain some, although usually limited, amounts of useable proteins and carbohydrates. Some algae possess large amount of vitamins, such as vitamin C, minerals (such as iodine), or trace elements. Substantial quantities of indigestible matter make algae a good source of roughage; algae have been compared to lettuce and celery in this respect. Nori, or laver (Porphyra) is extensively cultured in Japan as food, and is reportedly the single most valuable mariculture item in the world. In relation to other algae, Nori has high percentages of digestible protein and carbohydrates. Several species of nori occur in Washington waters, along with a large number of other edible algae.

Other uses of seaweeds include use as fertilizer, animal fodder or a source of chemicals. The value of seaweeds as fertilizer lies in their content of phosphorous, and a broad spectrum of other mineral elements. When blended with fish, seaweed becomes an especially effective liquid fertilizer and is among the most promising seaweed products for local production and use. Seaweed fertilizers are currently produced on the east and west coasts and have a long history of use and tremendous future potential. As a fodder, seaweeds are most useful when added as a supplement to standard foods to stretch food supplies for cattle, sheep, horses, and pigs.

Seaweeds also contain many chemicals which are commonly used in the production of a wide variety of industrial products. Culture of seaweeds to obtain these chemicals is perhaps the greatest incentive for farming in Washington at present. Seaweeds contain substances called colloids which are primarily used as emulsifiers or gels. These colloids are also significant in soil conditioning when seaweeds are added to sand or clay soils. These colloids, or gels, add substance and increase moisture-holding capacity of the soil. Red algae contain the colloids

agar and carrageenan, while brown algae contain algin (alginic acid). The diversity of products in which these substances are used is astounding (see Table 2-4). Since recent talk regarding the presence of additives in food and drink has made reading lists of ingredients popular, have some fun taking note of those products which contain algal derivatives (which so far at least have not proved harmful in any way).

During 1971, the economic value of the colloid industry was set at $100,000,000. The value in 1978 was probably much higher, owing to inflation. There has also been an increased demand since that period, which has probably further raised its value.

The seaweeds of Washington have a very limited capacity to withstand harvest of natural populations, although natural stocks are harvested successfully in other areas of the world (including California). It is highly unlikely that such a harvest would be economically feasible in Washington. Direct harvest might be undesirable except on a small scale anyway, as seaweeds are of such great value to many commercially and recreationally important organisms. Therefore, culture is the most promising technique for exploiting the algal resource. Both the State Department of Natural Resources and the University of Washington are involved in studies on the feasibility of farming red algae (Iridaea and Gigartina, respectively) for their colloids, along with exploring different techniques of farming algae. The most promising brown algae for culture to produce colloids in Washington may be bull kelp and giant kelp. Some work in oceanic waters off the coast of California to culture a different species of giant kelp than which is most common here shows promise. The technique involves transplanting young kelp plants to artificial substrates thereby supplementing the harvest of natural stocks. California has a large industry based upon the harvest of kelp for colloids. Table 2-5 lists both brown and red algae considered to have considerable potential for culture.

The culture of seaweeds for production of colloids has the advantage over culture for food in that seaweed can be grown in the presence of many types of pollution. In fact, some research on the East Coast has indicated that controlled amounts of sewage effluent may actually stimulate seaweed growth. Seaweeds incorporate nutrients supplied by the sewage, and thus, in addition to growing faster, act as a filter to lessen the impacts of sewage to other areas. Experiments indicate two red algae (Neoagardhiella and Gracilariopsis) could be stimulated to attain growth rates ranking them among the fastest growing plant crops in the world.

Other Species

While most of the mariculture research in Washington has concentrated on a relative few species, many others will probably be scrutinized in the future for their culture potential. In addition to the clams and algae mentioned, other potential culture species are abalone, shrimp, octopi, and crabs. Mariculture could concentrate on only a part of the life cycle, such as raising young to be released into the wild, or could involve culture throughout the entire life cycle. Culture could also occur entirely on land.

A variety of fishes other than salmonids might also benefit from culture activities. Success has been proclaimed by the Soviet Union in using nets to provide artificial spawning substrate for herring. Rearing of juvenile flatfish later released to marine waters has met with success in England, and may be feasible for economically important sole and flounder. Many fish of commercial value in Washington probably have a strong likelihood of being successfully farmed, if economics necessitate such activity.

Problems Associated with Mariculture

Some forms of pollution, rather than being incompatible with mariculture, may be used to benefit such activities. The use of sewage effluents to stimulate algal growth has already be mentioned. With improved technology in the future, sewage may also be used to stimulate production in food organisms as well.

Research has also looked at the plausibility of using thermal effluents to stimulate mariculture. Some success has been achieved culturing trout in such situations. The feasibility of planting warm water strains of kelp and eelgrass near thermal effluents also has shown promise.

Despite the great potential for mariculture, some drawbacks are evident. Mariculture often creates competition for food and nutrients with wild populations of plants and animals. As discussed in relation to mussels, this competition can be quite severe. Culture of other species, such as many fish, can create the need to provide artificial food or the need to begin a new fishery or culture to produce food resources. This process can not only be very costly, but can be extremely difficult as well.

By crowding organisms together in "unnatural" densities, incidences of disease, fungi, or parasites can be increased to the point where high mortalities occur. Prevention can then involve costly monitoring of populations as well as corrective action when necessary. The attraction of predators or herbivores to culture areas is also a problem. Control of these animals not only costs money, but in some cases, involves the destruction of problem species. Some potential culture species, such as crabs, engage in cannibalism. This problem may be so difficult to deal with as to make culture of such species unfeasible.

Mariculture creates potential conflicts over uses of coastal areas. Most food organisms must be grown in relatively pollution-free areas. Sewage or industrial effluents, street runoff, marinas, pulp and paper mills, activities which increase siltation (dredging, logging, etc.) and a variety of other forms of pollution are incompatible with mariculture. Even too much mariculture may conflict with itself, if competition for food or nutrients becomes so severe that the time of maturation is increased to the point where culture no longer is economically feasible. Thus, consideration must be given to spreading out of competing mariculture activities.

Finally, mariculture competes for other uses of water surface. In open water areas, this includes navigation and recreational boating, recreational or commercial fishing space, private or public access across culture sites, as well as the esthetic value people may attach to unaltered sea surface.

V. INACTIVE AGRICULTURE (No. 24)

This classification includes agricultural fields left fallow for a period of time and undergoing a process of invasion by a variety of plants, such as shrubs and broadleaf trees. These areas support wildlife populations and also are highly picturesque contributions to the coastal zone landscape.

Inactive agricultural fields have increased wildlife use as succession gradually recreates natural ecosystems from cultivated areas. Old barns are used by Barn Owls, swallows, bats, and mice as roost and nest sites. Red-tailed Hawks are also common in these old fields and are a familiar bird of prey to many rural residents. Red-tail populations have been shown to be more productive (each nesting pair having a higher number of young) in areas surrounded by fallow fields than in actively farmed crop or pastureland. This is likely due to increased habitat for small mammal prey of the Red-tails in old fields.

Table 2-5 RED AND BROWN ALGAE OF POTENTIAL USE FOR MARICULTURE OPERATIONS IN WASHINGTON STATE

	COLLOID
RED ALGAE	
Ahnfeltia gigartinoides	Agar
A. plicata	Agar
Gelidium purpurascens	Agar
Gigartina papillata	Carrageenan
G. exasperata	Carrageenan
Gracilaria sjoestedtii	Agar
Gymnocongrus linearis	Carrageenan
Iridaea cordata	Carrageenan
I. flaccida	Carrageenan
Neoagardhiella baileyi	Carrageenan
BROWN ALGAE	
Bull kelp (*Nereocystis leutkeana*)	Algin
Giant kelp (*Macrocystis integrifolia*)	Algin
Honey ware kelp (*Alaria marginata*)	Algin
Feather boa (*Egregia menziesii*)	Algin
Sea cabbage (*Hedophyllum sessile*)	Algin
Sugar wrack (*Laminaria saccharina*)	Algin
Brown algae (*Sargassum muticum*)	Aglin

Nonforested, Vegetated Uplands

3

NONFORESTED, VEGETATED UPLANDS (No. 3)

The coastal zone has extensive areas of nonforested, vegetated uplands. These areas are covered by grass or shrubs and may include bluffs and riparian vegetation not contiguous with forested areas. Nonforested, vegetated uplands provide extremely important wildlife habitat. Birds, mammals, amphibians and reptiles use these areas for nesting, burrowing, resting, feeding, and cover. Fish benefit from riparian vegetation which shades streams, thus reducing water temperatures.

Includes:
- Grassland (No. 31)
- Shrub (No. 32)
- Riparian (No. 33)
- Bluff (No. 34)

GRASSLAND (No. 31)

Grasslands are all open, ungrazed upland areas with grasses as their dominant vegetative cover.

Includes:
- Meadows (No. 311)
- Beach Grassland (No. 312)
- Open Grassland (No. 313)

MEADOW (No. 311)

I. INTRODUCTION

Meadows are areas of saturated soil dominated by grasses and forbs, generally occurring along river or stream drainages. Trees and shrubs are characteristically lacking, but may occur at the transition to adjacent forested habitats.

Only at Willapa Bay in Pacific County were meadows of mappable size encountered. All the sites occurred inland from, and adjacent to, salt meadows. Meadows are distinguished from salt meadows by the lack of inundation by saline waters, and the dominance of plant species with freshwater wetland or upland affinities. Meadows are distinguished from freshwater marshes by the lack of standing water at any time. Elsewhere throughout the coastal zone, small meadows occur along streams and rivers, but due to mapping restrictions, were included within the riparian habitat.

II. SIGNIFICANT BIOLOGICAL FEATURES

Common plant species in the Willapa Bay meadows include slough sedge, common rush, Pacific silverweed, cow parsnip, and several grasses. Swamp sandwort, under consideration for listing as a Washington State rare or endangered species, may occur in swamps, freshwater marshes, and meadows in Pacific and Pierce Counties.

Wildlife use and potential disturbances of meadows are similar to those discussed for salt meadows (see narrative no. 625). However, because meadows in the coastal zone are relatively small, they are particularly vulnerable to disturbance.

Elk make extensive use of these areas for feeding, and are a characteristic feature of Willapa Bay meadows. Other characteristic species include river otters, beaver, deer, meadow mice, and Marsh Hawks.

Activities which alter a meadow may have adverse impacts on dependant wildlife, and may also impact streams flowing through it. Streamside meadows are essentially herbaceous riparian communities. The Riparian Narrative (No. 33) discusses significant features and impacts relevant to streambank vegetation.

BEACH GRASSLAND (NO. 312)

I. INTRODUCTION

Beach grasslands occur throughout Washington's coastal zone, typically associated with spits and sand or gravel beaches. The beach grassland plant community is similar to that found on sand dunes but basic differences between the two types include the lack of typical dune topography and generally smaller area of beach grasslands.

Outstanding examples of extensive beach grassland habitat can be found on Gibson Spit (Clallam County, Figure 312-1), Dungeness Spit (Clallam County), and Protection Island (Jefferson County). Less extensive, but perhaps more familiar beach grasslands rim much of the shoreline of inland waters. These areas are generally narrow strands which were often not mapped in the Coastal Zone Atlas due to mapping constraints.

II. SIGNIFICANT BIOLOGICAL FEATURES

Plant Community

Because typical dune topography is lacking, the beach grassland plant community is less diverse than that discussed for sand dunes. Specifically, dune hollows and their associated wetland communities are not developed in beach grasslands, and only species characteristic of dry sites are present. On extensive sites, beach grassland topography is characterized by broad, flat areas with infrequent gently rolling mounds. Figure 312-2 illustrates a typical beach grassland.

A dune wildrye-dominated foredune is present just above high water at sites with moderate to open exposure and may be the only zone in many areas where beach grasslands occur in narrow bands. Beyond the foredune or high water line, the plant community may contain any of the species listed below:

Hemlock-parsley Conioselinum pacificum
Beach morning glory Convolvulus soldanella
Salt grass Distichlis spicata
Dune wildrye Elymus mollis
Red fescue Festuca rubra
Beach peavine Lathyrus japonicus
Tall peppergrass Lepidium virginicum
Rosy plectritis Plectritis congesta
Seashore bluegrass Poa macrantha
Black knotweed Polygonum paronychia
Weeping alkaligrass Puccinellia distans
Nootka rose Rosa nutkana
Dune tansy Tanacetum douglasii
Giant vetch Vicia gigantea
Yellow sandverbena Abronia latifolia
Yarrow Achillea millefolium
Silver bursage Ambrosia chamissonis
Seaside amsinckia Amsinckia spectabilis
Beach strawberry Fragaria chilioensis
Glehnia Glehnia leiocarpa
Gumweed Grindelia integrifolia
Sea purslane Honkenya peploides
Thrift Armeria maritima
Northern wormwood Artemesia campestris
Fat-hen Atriplex patula
Bighead sedge Carex macrocephala
Sand-dune sedge C. pansa
Field chickweed Cerastium arvense

Plant cover varies from very dense to very sparse, and large areas of bare sand may be present. Mosses (notably Rhacomitrium canescens) and lichens often colonize bare sand. Drift logs are generally present just above the high water line, and may cover a large part of the area mapped as beach grassland, particularly when spits are built up on a point of land. Excellent examples occur at King Spit and Battle Point, both in Kitsap County. These "driftwood" areas are a familiar and popular beachcombing zone throughout the coast.

Animal Communities

Like the plant community, the fauna of beach grasslands is similar to but not as diverse as in sand dune communities. The extensive wetland areas of dunes and expansive sandy areas are generally lacking in beach grasslands and wildlife associated with these dune zones are rare on beach grasslands. Species which do occur are those associated with the beach fringe or foredunes.

Narrow strands of beach grassland (foredune) and drift log strips are used by a variety of beach edge species and may support breeding populations of some animals. Raccoons, striped skunks, crows, Killdeer, and Song Sparrows are characteristic species. Raccoons and skunks forage along the shoreline and use the beach grassland as a travel route between the beach and uplands. Crows usually forage on the beach, but also scavenge within the beach grassland strip. Killdeer and Song Sparrows forage here and both may breed in this habitat. Killdeer are ground nesters, and Song Sparrows require shrubs such as Nootka rose for nesting.

Where beach grassland occurs on islands, additional species often nest in this habitat. Glaucous-winged Gulls, Pigeon Guillemots, and Black Oystercatchers may be present in these protected locations. For example, the largest known Glaucous-winged Gull nesting colony on inland waters occurs on the beach grassland on the east spit of Protection Island in Jefferson County.

Several shorebirds occur in beach grasslands during high tides, especially in those locations along preferred feeding areas. For example, beach grasslands on spits is often an important resting area for shorebirds. Sanderlings, Black-bellied Plovers and other shorebirds forage in adjacent marsh and mudflats at low tide, and return to the beach grassland when feeding areas are submerged. Tall plants provide cover and some feeding also occurs in this refuge above tidal waters.

Birds of prey also frequent these areas, especially where shorebirds are abundant and in the more extensive beach grasslands where voles are also preyed upon. Marsh Hawks and Short-eared Owls were the most frequently observed birds of prey during our studies. Peregrine Falcons, Merlins, and Snowy Owls are also noted to occur.

Other species which have been noted in beach grasslands during our studies include the following:

Common Flicker: Flickers were often observed feeding in beach grasslands on the ground as well as on drift logs. These woodpeckers are especially abundant in more extensive beach grasslands such as at Gibson Spit (Jefferson County).

Horned Lark: Horned Larks were observed only in more extensive beach grasslands. They may nest in these areas.

Western Meadowlark: Meadowlarks were observed only at more extensive beach grasslands and in beach grasslands adjacent to salt marshes.

American Goldfinch: Occur in both extensive and narrow bands of beach grassland.

Savannah Sparrow: Common in beach grasslands and are probable nesters at more extensive sites. Known to breed along Crockett Lake on Whidbey Island (Island County).

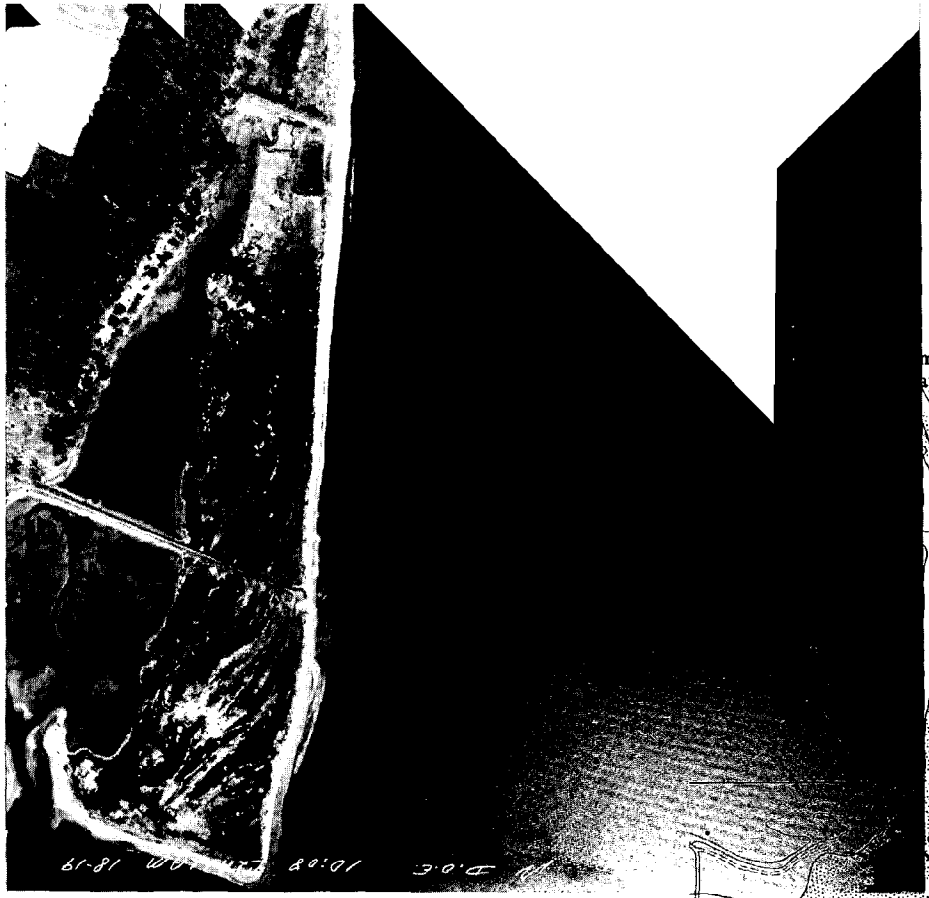
White-crowned Sparrow: Fairly common in beach grasslands, but not as regularly observed as Savannah and Song Sparrows during our studies.

Golden-crowned Sparrow: Only observed in more extensive beach grasslands during our studies.

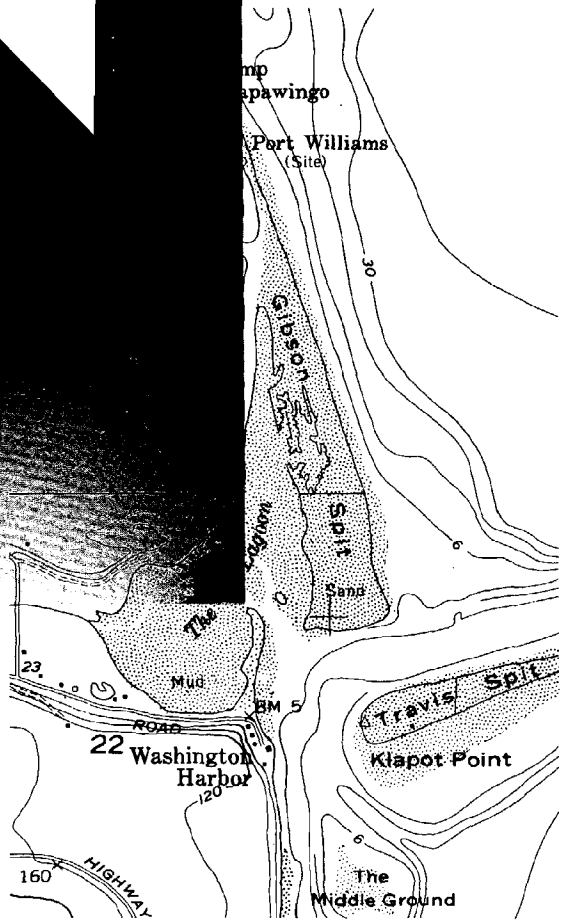
Townsend's Vole (meadow mouse): Often observed in beach grasslands, especially beneath drift logs.

Coyote: Like raccoons, coyotes forage along beach grass at the shore's edge where they hunt voles.

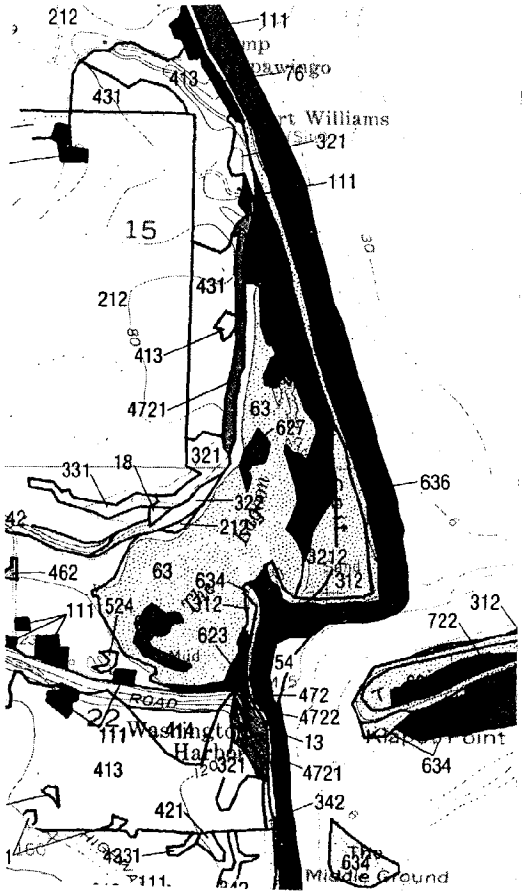
River Otter: Otters use beach grasslands as landing sites where they roll, play, and possibly feed on large fish they have brought ashore. Beach grasslands identified as otter habitat are most often on spits or between coastal freshwater marshes and saltwater. Many sites are included as critical areas mapped in the Coastal Zone Atlas.



Gibson Spit, Clallam County
aerial photo.



U.S. Geological Survey Map



Coastal Zone Atlas
Land Cover/ Land Use Map

Natural "Bulkheads"

The beach grassland plant community plays a major role in the stabilization of the substrate on which it occurs by binding the substrate with roots and stems, and precipitating windblown sediments. This function is particularly important, as most beach grasslands are regularly subjected to disturbance by wind and waves. Where beach grassland occurs as a fringe between the beach and upland, this buffer effect is invaluable as a natural breakwater, dissipating wave energy.

Recreational Value

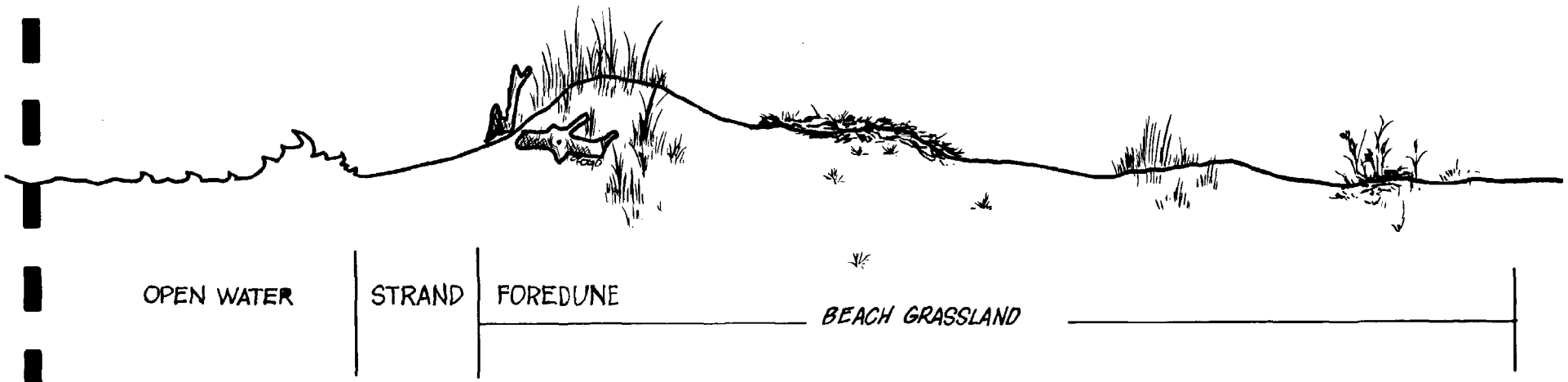
Beach grasslands are enjoyed by many persons who search for driftwood, shells washed in by waves, or by those seeking solitude. Drift logs form a maze along the beach in many locations and provide a natural elevated walkway for a child or surefooted adult. Paths are sometimes worn in the vegetated portion of beach grasslands in more popular areas such as Dungeness Spit (Clallam County). However, many beach grasslands are entered only when the tide forces the beachcomber to higher ground. Like the shorebirds, we benefit from this fringe of vegetation as a refuge from the tides.

III. IMPACTS

Beach grassland plant communities are very vulnerable to disturbance. Activities that remove plant cover, allowing the penetration of wind and waves, may lead to the development of large bare areas. For example, the beach grassland at Dungeness Spit receives heavy recreational use, and impacts are apparent. A well-travelled trail leads out through the grassland, clearly marked by the lack of vegetation, and lowered elevation due to erosion of sand.

Because substrate, plant community, and function are similar to those described in the Sand Dune Narrative, readers are referred to that narrative (No. 722) for further information on impacts. Refer also to the Spit Narrative (No. 74).

FIG. 312-2



OPEN GRASSLAND (No. 313)

I. INTRODUCTION

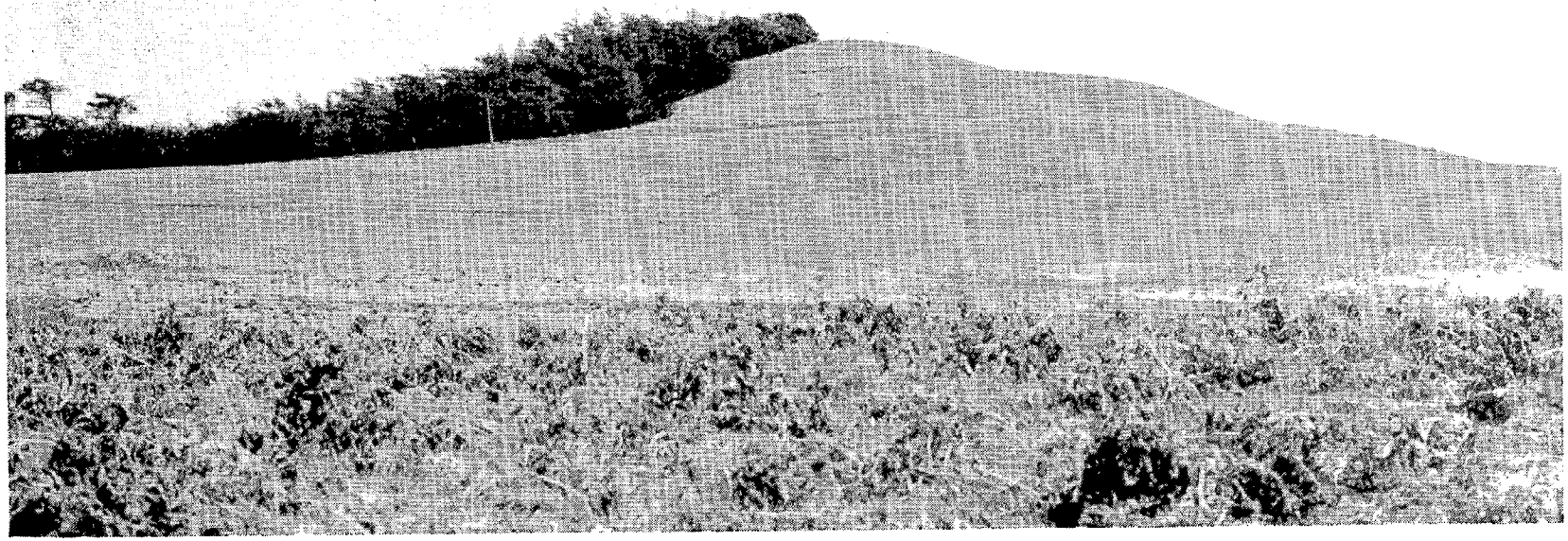
Two very different plant communities are included in this class. Both are dominated by grasses and superficially similar, however they differ in many respects, including wildlife use, community development, and plant species composition. The two types are:

Weedlots

These frequently occur in urban and other developed areas, and only occasionally in areas distant from cities and towns. Those in remote areas are generally short-lived, being quickly succeeded by shrub or forest communities; they are often developed for housing, having been originally cleared for that purpose. Urban weedlots, however, are often persistent, being far removed from seed sources of successional shrub and tree species.

Natural Grasslands

Rarely occur in the coastal zone, primarily in the rain shadow of the Olympic Mountains, including the San Juan Archipelago, Fidalgo Head in Skagit County, and at Deception Pass, Fidalgo Island. The Fidalgo Head grassland is within Washington Park and is subjected to heavy recreational use. Sites in the San Juan Islands are generally less subject to human disturbance. The largest of these is at Cattle Point on San Juan Island, covering approximately 255 hectares (630 acres) in the coastal zone. This site is within American Camp National Historical Park and is home for a large number of the "San Juan Rabbits". Natural Grasslands also occur on numerous small islands throughout the San Juan Archipelago including Goose Island, Castle Island, and North Peapod Rock. These sites are frequently used as nesting sites by marine birds. Because of their limited size, these areas have often been mapped as rock island or rock



island with grass cover. Other natural grasslands occur on bluffs and have been mapped as grass bluffs or as bluff. Examples include Beckett Point and the west side of Whidbey Island. Natural grassland also occurs on Protection Island in Jefferson County, a valuable wildlife area.

While weedlots are a product of human disturbance, natural grassland is a unique habitat which requires our careful attention. Plant communities include many spectacular wildflowers, uncommon plants, and some species proposed as rare and endangered. Wildlife associated with these areas also includes several uncommon species, and in the San Juans, these grasslands are critical feeding areas for Bald Eagles, an officially threatened species. These natural areas have been and are being altered or destroyed in many ways. We must recognize their special values and identify methods to ensure their continued existence.

II. SIGNIFICANT BIOLOGICAL FEATURES

Characteristic Plant Species

Weedlots

Composed of opportunistic plants, i.e. those that produce large amounts of seed with adaptations for wide dissemination by wind or animals. These plants are capable of fast growth, tolerant of a wide range of environments, and establish quickly after disturbance. Species include common dandelions, hairy cats-ears, and thistles. All three are members of the sunflower family, and are very

successful weeds in western Washington. Their seeds are largely wind disseminated, although birds, including goldfinches, also contribute to their dispersal.

Grasses include orchard grass, velvet grass, hairgrass, fescue, and cheatgrass. Garden escapes often establish in weedlots, and may persist for several years. Examples include foxglove, bouncing bett, Deptford pink, and daffodils. Shrubs may be present, commonly Scot's broom and Himalayan blackberry.

Natural Grasslands

Data for coastal grasslands in the San Juans, where they are best developed, are scarce, but not totally lacking. Much of the plant community information in this narrative is taken from studies done in the Tacoma Prairies in Pierce and Thurston counties. This information is pertinent, but the coastal grasslands differ in several significant ways: 1) Tacoma Prairies are not strictly coastal. 2) Tacoma Prairies receive higher amounts of yearly precipitation. 3) San Juan grasslands are on islands; plant and animal species differ as a result of this isolation.

Many grasses, both native and introduced, dominate these sites and include Idaho fescue, Kentucky bluegrass, soft brome, cheatgrass, little and sliver hairgrass, and blue wildrye.

Wildflowers are abundant, often creating a dramatic seasonal display of color, and including several unusual species more typical of eastern and southern floras. A partial listing includes death camas, Leichtlin's and common camas, eriophyllum, manrood, broad-leaved and dark-throat shooting star, smallflower prariestar, seapink, checker lily, and rosy plectritis.

Several uncommon plant species have been reported from dry, open sites on Saturna Island, British Columbia which is a part of the San Juan Archipelago. These species are expected to occur in the American San Juans as well. Included are spring-gold, scalepod, tiny mousetail, Lindley's microseris, and meconella (Meconella oregana) a species under consideration for rare or endangered status. A disjunct population of brittle cactus occurs throughout the San Juan Islands, primarily in open grassland and exposed rock habitats. The presence of this desert species

reflects the dry conditions in the Olympic rainshadow, and is a significant feature of the San Juan Islands.

Another uncommon species, California buttercup, has recently been reported from grasslands on San Juan, Lopez, and Fidalgo Islands, at Deception Pass, and Fidalgo Head. California buttercup is an indicator species of coastal prairies and was previously unreported in Washington. This species can be expected to occur in other dry, open sites such as rock outcroppings and cliffs as well as in grasslands.

Characteristic Animal Species

Weedlots

Fauna associated with weedlots varies considerably according to location. Many sites are close to or within urban areas and have a restricted fauna. As with plant species, many introduced animals and those tolerant of human activities are present. These species include Starlings, House Sparrows, Robins, and voles. Weedlots in more rural or natural areas will be similar to natural grasslands. These areas are usually short-lived and, therefore, have a shorter time span for occupancy by animals. However, many of the comments in the following dicussion will apply to weedlots in outlying areas.

Natural Grasslands

The unique features of natural grassland plant communities are reason enough to identify these sites as extremely valuable coastal habitats. However, these areas also support a variety of animals, many of which are uncommon or rare elsewhere in western Washington.

Natural grasslands might be viewed as having a lack of diversity; there is a lack of trees and shrubs; only grass provides a ground cover. Thus, there are a small number of animal species restricted to or primarily associated with grasslands. For example, a 1930's bird population study in a San Juan "meadow" area reported the following species: Savannah Sparrow, White-crowned Sparrow, Song Sparrow, Western Meadowlark, Brewer's

Blackbird, Chipping Sparrow, Yellow Warbler, Killdeer, Orange-crowned Warbler, Common Nighthawk, American Goldfinch, Robin, Violet-green Swallow, Barn Swallow, Common Flicker, and Bewick's Wren. Of these, only Savannah Sparrows, meadowlarks, Killdeer, and nighthawks are known to nest in grasslands. Recent studies have also noted the occurrence of the following nesting birds: Horned Larks, Vesper Sparrows and Skylarks, the latter having spread from Vancouver Island where they were introduced. Mammals include blacktailed deer and rabbits. As is often the case where a small number of species are present, there are large numbers of individuals of most of these species. In the case of the European rabbit, they appear to completely dominate the open grasslands of San Juan Island.

Although there is a lack of structural diversity, coastal natural grasslands are important wildlife habitat for several reasons:

1) They increase overall diversity of coastal habitat: Natural Grasslands provide open areas which diversify the edge of both forested uplands and the marine environment. Birds of prey are particularly abundant here and include those which normally forage and nest over natural grasslands such as Marsh Hawks and Short-eared Owls, and species which are common in open woodlands and dense forests. This is due to the abundance of prey available and the presence of forests nearby. Great Horned Owls, Cooper's Hawks, and Red-tailed Hawks, therefore, can forage at the edge and over open areas of grasslands, while having roost and nest trees available nearby.

The coastal location of the grasslands makes them available to another group of species not usually associated with interior grasslands. Birds such as Bald Eagles which prey over water and land are present, and other marine foragers

such as the river otter, frequently come ashore at natural grasslands just above the water's edge. The resulting effect of the presence of natural grasslands in the coastal zone is much like the presence of an oasis in the desert only in reverse. Since this habitat is rare, it is as valuable an addition to the coast as trees are to the desert.

2) Unique habitat: Natural grasslands are rare in western Washington, being more like dry areas east of the Cascades. Brittle cactus reflects these conditions as does the occurrence of birds more commonly associated with deserts and more extensive grasslands. Thus, both Swainson's Hawks and Burrowing Owls are known to occur in San Juan Island's natural grasslands. Other uncommon open country species, such as the Rough-legged Hawk, Vesper Sparrow, and Horned Lark, also occur.

Burrowing Owls are rare in western Washington due to limited habitat and are thought to be declining in eastern Washington due to destruction of sagebrush deserts. These light brown, long-legged owls, are named for their habit of nesting in burrows. In eastern Washington the nest site might be a ground squirrel burrow enlarged by a badger. Although they are thought to be migrants in western Washington, it is possible that Burrowing Owls use rabbit burrows as nest sites in the San Juans. This possibility should be investigated further to learn more about preservation of this rare species. Burrowing Owls have also been observed at Nisqually Flats in 1967, near Bellingham (1917), south of Tacoma (1904), in the Grays Harbor vicinity in the winter of 1941, and near Mora in Clallam County (1926). The recorded sighting at Mora was made by the early ornithologist J. Hooper Bowles. He suggested the presence of a coastal race of Burrowing Owls since it was darker than eastern Washington birds (dark plummage is typically associated with several coastal subspecies, i.e., Peregrine Falcons and Merlins).

3) Presence of "San Juan Rabbits": European rabbits (Oryctolagus cuniculus) were introduced to several of the San Juan Islands at varying times in the past and are now abundant, especially at the extensive natural grassland at Cattle Point on San Juan Island. Considered a nuisance by many landowners, the rabbits also severely impact plant communities. However, the rabbits support a large number of birds of prey. This fact, combined with other features of coastal grasslands discussed above, has created one of the most valuable areas in the coastal zone for hawks, eagles, and owls. The following were observed feeding on rabbits at American Camp during a recent study on San Juan Island:

Turkey Vulture
Goshawk
Sharp-shinned Hawk
Cooper's Hawk
Red-tailed Hawk
Rough-legged Hawk
Golden Eagle
Bald Eagle
Marsh Hawk
Prairie Falcon
Peregrine Falcon
Great Horned Owl
Snowy Owl

4) Use by nesting birds: When open grasslands occur on small islands, they are often used as nest sites by marine birds, particularly Glaucous-winged Gulls. Many of those sites have been mapped as rock islands (713) or grass covered rock island (7131), and more detailed discussions of nesting is provided in narratives for those categories. On mainland sites, (including the larger islands in the San Juans), grasslands are also used by ground nesters such as Common Night Hawks, Vesper Sparrows, Savanna Sparrows, and on San Juan Island by Skylarks.

Marine birds which nest in grasslands are primarily restricted to smaller islands where predation and human disturbance is minimal. Glaucous-winged Gulls place their two or three eggs in a grass or seaweed nest on the ground. They sometimes nest on pilings, roof tops, or on rocky outcrops on larger islands, but most nesting is in large colonies on grass covered islands. Where soil is deep and firm enough for excavation, burrow nesters, such as Rhinoceros Auklets, nest in grasslands, particularly along bluffs.

BURROWING OWL

Many of the seabird nesting islands are protected, being part of the USFWS National Wildlife Refuge System. Many also have status as Wilderness areas which affords more complete protection from human disturbance. Ironically, Protection Island in Jefferson County, with its large seabird populations (an estimated 17,000 pairs of Rhinoceros Auklets nest here making it one of the largest known auklet colonies in North America), is not protected. A portion of the island is in State Game Department ownership, however, the majority of the seabird nesting sites and the largest gull colony in the inland waters are outside the boundaries of the Game Department land. Building lots have been sold within the gull colony; houses, an airstrip, and a marina are already present on the island. The island has no adequate water supply and is, therefore, not suitable for development. It is, however, a very valuable seabird island in need of protection. Unfortunately, present uses include destruction of auklet nesting burrows by trampling and automobiles, and picnicking in the gull colony.

Many areas in the coastal zone are intolerant of development, but Protection Island and other seabird nesting areas are especially sensitive. As stated, many seabird islands are part of refuges or set aside as Wilderness. Development is not allowed on those islands and in many cases, access is strictly controlled. Protection Island should be carefully considered for similar status. (Refer also to the Rock Island Narrative, No. 713.)

TABLE 313-1

Observations during our study have also revealed the value of southern San Juan Island grasslands to birds of prey. The following were observed between Eagle Point and Cattle Point during one hour periods:

SPECIES	18 Aug. 77	28 Aug. 77	20 Sept. 77	7 Oct. 77	16 Nov 77	17 Jan. 78
ADULT BALD EAGLE	2		1	1	3	1
IMMATURE BALD EAGLE	7+		2	1	4	10+
RED-TAILED HAWK	1	2	4+	3	2	8
COOPER'S HAWK	1					1
UNIDENTIFIED BUTEO	1			1	1	
FERRUGINOUS HAWK		1				
ADULT GOLDEN EAGLE			1		1	
IMMATURE GOLDEN EAGLE			1	1	1	
ROUGH-LEGGED HAWK			1	2		
TURKEY VULTURE			1			
MARSH HAWK				1		
AMERICAN KESTREL				1		
UNIDENTIFIED EAGLE						1
MERLIN						1
TOTALS	12+	3	11+	11	12	22

* REMARKS: RAVENS AND CROWS ALSO FREQUENTLY OBSERVED. SWIFTS, SKYLARKS, SWALLOWS, FLICKERS, KILLDEER, AND NORTHERN SHRIKES WERE ALSO OBSERVED DURING THESE SURVEYS. GREAT HORNED OWLS WERE OBSERVED IN ADJUCENT WOODS.

During the first National Bald Eagle Census in 1979, eight Bald Eagles and three Golden Eagles were observed on San Juan Island at American Camp The National Park Service reports that 43 Bald Eagles were observed within this open grassland area the week before the count.

III. IMPACTS

Natural Grassland is a rare land cover type in western Washington. Fortunately, grasslands at Cattle Point (San Juan Island), Iceberg Point (Lopez Island) and on several small islands in the San Juan Archipelago are included in federal, state, and county ownership as parks or other protected status.

Elsewhere alteration and destruction of natural grasslands is happening in several ways:

Development

At Eagle Point, San Juan Island, a housing development is encroaching upon the grassland. Housing and recreational development also threaten grasslands on Protection Island. Both areas are very valuable wildlife areas and cannot tolerate human disturbance. These two examples stand out as very damaging and yet easily avoided coastal development projects.

Agricultural Use

The area around Sequim, Clallam County, referred to as "prairie" by Archibald Menzies who visited this area with Captain George Vancouver in 1792, is now agricultural land which in turn, is being encroached upon by housing development. Cultivation of these areas destroys natural grasslands, and even limited grazing alters community composition by continual removal of palatable species. Agricultural activities and developments will also impact adjacent natural grasslands through the introduction of weedy species and increased physical disturbance due to foot, motorbike, and other traffic.

Mechanical Disturbance

Mechanical disturbance is widespread in natural grasslands and can have severe impacts on plant and animal communities. For example, a portion of the grasslands in Pierce County are used by the U.S. Army as a practice range. Activities include gunnery practice, digging foxholes, and driving vehicles throughout the area. All these activities destroy the grassland plant community and expose bare soil which is subsequently colonized by weedy species.

A significant portion of the Pierce County grasslands have been invaded by exotic species as a result of these disturbances. Natural grasslands elsewhere are often subjected to similar kinds of disturbance by cars, motorbikes, and other off-road vehicles.

Introduction of Alien Species

The outstanding example of this kind of disturbance is the presence of European rabbits in the San Juan Islands, particularly at Cattle Point on San Juan Island. This native of Europe was introduced to the islands at varying times in the past and in the presence of suitable habitat has become incredibly abundant. The result has been detrimental to many species of plants and animals, but is beneficial to several others. (See comments in Significant Biological Features section of this narrative.)

The impact of rabbits at Cattle Point is expressed in many ways:

a. Rabbit warrens occur throughout the grassland. Large excavated areas with much exposed soil result.

b. Browsing is severe and it is obvious during the growing season which plant species are preferred (the majority of them) and which are not (notably death camas, which is toxic, filaree, bracken fern, nettles, and thistles.

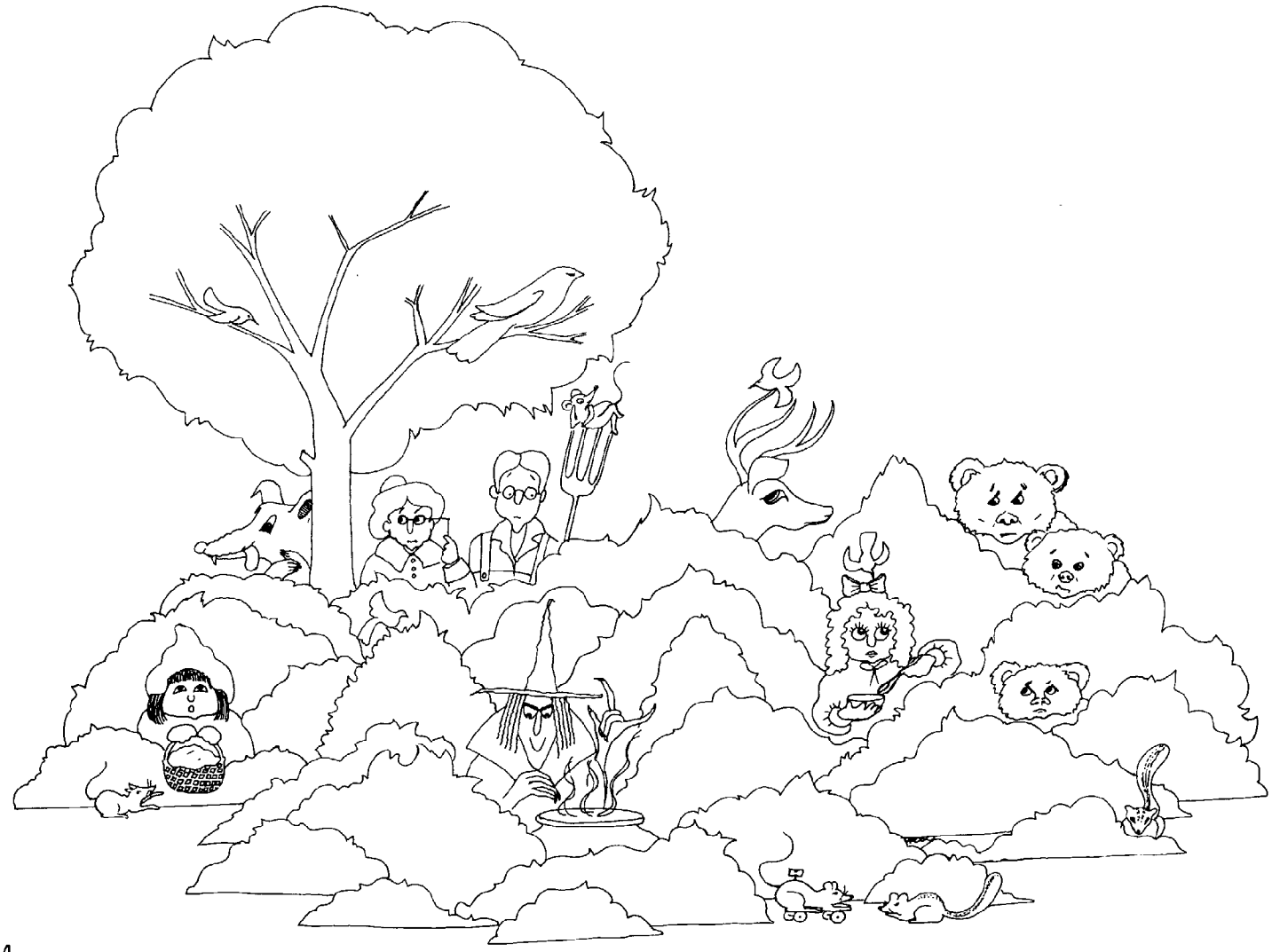
c. A particularly astounding measure of how much plant material is consumed by the rabbits is illustrated by the density of feces in the grassland. In some areas, droppings and the unpalatable filaree are the only ground covers.

The effects of the rabbits on the plant community are further illustrated by comparing the Cattle Point plant community with a grassland on an undisturbed site. Just off Cattle Point is Goose Island, a Nature Conservancy owned biological preserve supporting a natural grassland community. Comparison of the floras of these two sites reveals a much higher occurrence of introduced and/or weedy plant species in the disturbed community on Cattle Point. This is well illustrated by the abundant bracken fern present in the Cattle Point grassland. Although bracken fern is grazed when young, the mature fronds are unpalatable and are, therefore, ungrazed. Grazing on the palatable grasses and herbs, the rabbits are favoring the growth of bracken fern by increasing the availability of light, water, and nutrients, through a reduction in the density and cover of competing species.

The Goose Island flora includes the native Kentucky bluegrass and Idaho fescue, and a spectacular display of wildflowers, absent or less common in the Cattle Point grassland. These include gumweed, Hooker's onion, checker lilies, cow parsnip, star-flowered Solomon's seal, and rein orchid.

d. Vulnerability - The grassland community has a very simple structure, easily disrupted by disturbance. This, in combination with the relative scarcity of natural grasslands, should alert planners and decision makers to the need for caution when considering activities which may impact or destroy our coastal grasslands.

Rabbit warren, south end of San Juan Island, San Juan County.



SHRUB (No. 32)

I. INTRODUCTION

Shrubs are classified as upland areas in which the dominant vegetative cover consists of woody perennials up to 20 feet in height.

Shrub habitats are found throughout the coastal zone. We have divided shrub into three categories, successional shrub (No. 321), coastal shrub (No. 322), and shrub/ exposed rock (No. 323). Successional shrub, an early stage in the development of a climax forest, is the most frequently encountered shrub type in the Northwest. The abundance of this type refects the number of forested and eventually to be forested areas within the coastal zone.

Coastal shrub is a climax community restricted to limited areas adjacent to salt water primarily in the Sitka spruce zone along the Washington coast and is also at other exposed sites in northern Puget Sound.

Shrub on exposed rock is primarily restricted to where thin soil layers occur along rocky shorelines. The cover type is rare in the coastal zone; its greatest frequency is on the San Juan Islands.

Shrub communities have many functions in the coastal ecosystem. All types provide food, cover, nesting sites, and resting areas for large numbers of wildlife. Shrubs are a major browse source for deer, the primary game animal of Washington. Successional shrub communities prepare the soil for new forest seedlings by adding nutrients through shrub litter and decomposing plants. Coastal shrub prevents extensive soil erosion along steep areas of coastline and stabilizes areas near sandy beaches.

Historically, shrub areas were created, and at times maintained, by wildfires which spread through forested areas. Grasses and other herbaceous species would cover burned areas and eventually a shrub layer developed. Indians learned to manage their environment to maintain browse for game and berry patches for human consumption by intentionally setting fires. Today most areas of shrub result from clearcutting and burning forested areas. Shrubs also develop in disturbed areas of clearings such as abandoned agricultural fields.

II. SIGNIFICANT BIOLOGICAL FEATURES

Shrub communities have the same general structure whether located on rocky islands or in forest clearings. Species composition may vary widely, but the interactions of flora and fauna within the shrub community are similar. Differences in canopy cover affect the amount of herbaceous cover on an area. A forest clearing will have much herbaceous cover while in dense thickets, it may be completely lacking.

The ground layer of shrub communities may be covered with grasses and other herbaceous species. Small mammals, birds, and lizards use the ground level of

shrub communities for cover, burrows, nests, and forage on the herbaceous and shrub vegetation. Omnivores like the deer mouse eat shrub seeds, berries, and insects.

The shrub layer is used by small birds which forage for insects, berries and seeds on the shrubs and ground. Insects feed on the plants and in the process pollinate the plants by carrying pollen on their bodies from plant to plant. Deer and black bear browse the shrub layer for new growth and berries respectively.

Above the shrub layer raptors hunt for small mammals and birds which may leave shrub cover for a fatal instant. Sharp-shinned hawks forage among bushes for sparrows, mice, chipmunks, and large insects.

Shrub dominated habitat has a high productivity level. Shrub browse supports many deer in Washington and a great diversity of other wildlife species. Shrub leaf litter and the nitrogen-fixing capacity of some shrubs provides many minerals necessary for the growth of forests. A shrub community is not only an agent acting against soil erosion, it actually contributes to the formation of a new organic layer in burned or clear areas.

Interrelationships With Other Habitats

Shrub habitats are often closely related to other habitats because of their somewhat patchy occurrence. Successional shrub is a seral step in succession and is often an interdigitation of forest and grassland. Coastal shrub has a variety of possible associated habitats from sandy beaches to coniferous forests. Shrub/exposed rock can be thought of as island of vegetation surrounded by a sea of rock.

Many wildlife species which use shrub habitat derive the benefit of the edge effect of two adjoining habitats. For example, black bear browse on shrub but prefer coniferous forest nearby for cover. Raptors may perch on forest trees and hunt over areas of grass and shrub.

Commercial/Recreational/Esthetic Benefits

Shrub communities can be an aid to the silviculture industry. Shrubs supply needed nutrients for seedling growth, preparing new organic layers of soil and preventing soil erosion.

Shrub browse encourages wildlife species such as deer, bear, and birds for hunters to utilize and wildlife watchers to enjoy. Shrub habitat adds diversity to the landscape which increases wildlife species diversity to be appreciated by all.

III. IMPACTS

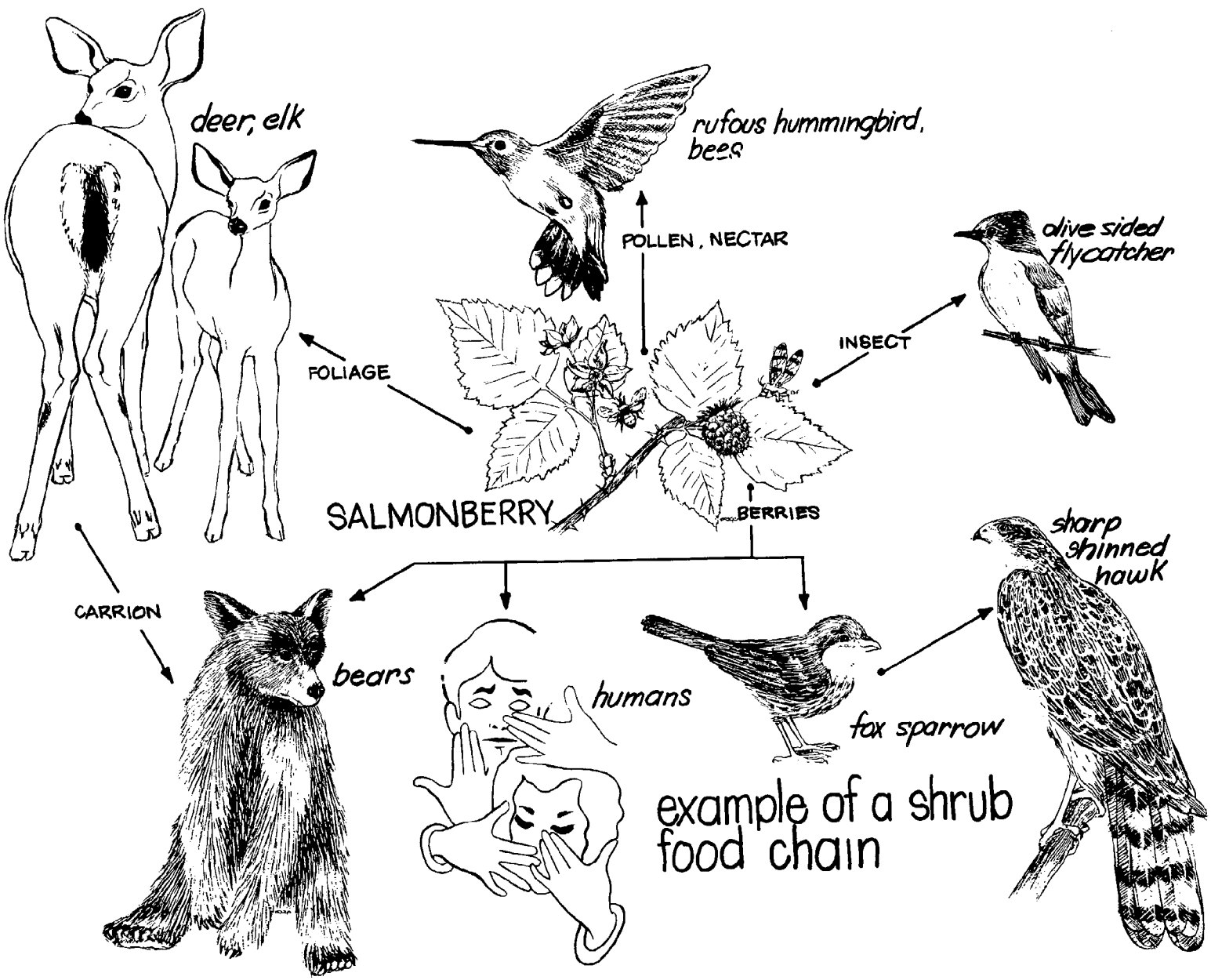
- Clearcutting and slash burning forest practices encourage growth of shrub communities.

- Destruction of fields such as in housing developments decreases area for shrub communities.

- Artificial control of shrubs by spraying with substances such as the recently banned 2,4,5-T to kill alder, vine maple, and salal may do much more harm than good. Without the nutrients supplied by shrubs, artificial fertilizer must be used for forest seedling growth and other controls for soil erosion must be used.

- Many shrubs have been introduced by man for control of erosion and/or ornamental reasons. Some of these exotic species such as Scot's broom and gorse have spread rapidly and are now excluding native shrub species.

- Shrub areas throughout cities and suburbs encourage urban wildife. Developers and planners could enhance the quality of living in these areas by incorporating areas of native shrub communities to attract wildlife as part of development plans. Shrub species which have high wildlife value are suggested for these plantings and include: elderberry, blackberry, serviceberry, snowberry, blueberry, and salmonberry. Shrubs add to the habitat diversity of the city and increase it species diversity. Refer to the Urban Narrative (No. 1), section No. 11, for further discussion of incorporating native vegetation into residential areas.


deer, elk
rufous hummingbird, bees
POLLEN, NECTAR
olive sided flycatcher
INSECT
FOLIAGE
SALMONBERRY
BERRIES
CARRION
bears
humans
fox sparrow
sharp shinned hawk
example of a shrub food chain

SUCCESSIONAL SHRUB (No. 321)

I. INTRODUCTION

Successional shrub is an early seral stage in the developement of a climax forest and occurs throughout the coastal zone. Major locations of successional shrub are clearcut forest areas. They develope when conditions for successional advancement exist in areas of herbaceous ground cover. Successional shrub supports many species of wildlife and prepares the area for new forest seedlings with nutrients from its litter. Historically, successional shrub areas were maintained by wildfires. Massive clearings soon were covered with a herbaceous layer which was followed by shrub communities. Indians manipulated successional shrubs with fire for maintenance of berry patches and browse for wildlife which they hunted. Modern man promotes the developement of successional shrub communities through clearcutting and burning during logging processes, forest fires, and by abandoning fields.

II. SIGNIFICANT BIOLOGICAL FEATURES

Successional shrub is a highly productive community. The habitat diversity resulting from interdigitation of two habitats, forest and grassland, with shrub, results in high species diversity. Successional shrub is an important factor in nutrient recycling. Rich contributions of nitrogen and other minerals are yielded through litter and the nitrogen fixing capacities of some shrubs such as Mountain Balm and Scot's Broom. Shrub is important in the formation of a new organic layer which is necessary for forest regeneration.

Community Structure

Definite patterns for post-fire succession exist but they differ for different sites and conditions. Vigorous regrowth of herbs, grasses, and shrubs frequently occurs in the first few years following the fire. Successional species composition depends on species propagule availability, to what degree the understiory of shrubs was damaged, soil conditions and even chance. The vegetation of a logged and slash burned area begins succession with mosses and liverworts,

while on unburned surfaces, weed-brush development starts immediately after cutting trees. In burned areas weedy species may monopolize cover immediately; some original species may persist and others die out. During the early stages of succession, there is a gradual increase in herb species diversity; the percentage of the total cover by herbs gradually decreases. Shrub species gradually increase in both frequency of occurrence and percentage of total cover. The shrub vegetation overtakes the herbaceous species unless checked by fire or dominated by forest regeneration.

In the spruce zone along the western side of the Olympic Peninsula, dense shrub communities dominate areas following fire or logging. Salmonberry, red elderberry, and huckleberry are common species to invade these disturbed locations. Forests of red alder, Douglas fir, hemlock and spruce eventually replace the dominant shrubs.

Fields created by habitat destruction in developing locations are often covered with native and exotic successional shrubs. Willow species often invade large open moist areas eventually yielding to early successional trees of cottonwood and alder.

One of the most ubiquitous exotic shrubs is Scot's broom. Originally from Europe, Scot's broom has spread rapidly along the coast and interior of the western states. It can be considered a pest species, but it is also beautiful and is purposely planted along freeways for beautification and ease of care. Faunal species found in broom communities include deer mouse, masked shrew, house mouse, meadow vole, Rufous-sided Towhee, and White-crowned Sparrow. Gorse, also from Europe, has spread along the coast. Gorse crowds out native vegetation and burns with a very hot fire which was an obstacle in contolling the 1936 fire in Bandon, Oregon.

Gorse communities are found on the western side of Whidbey Island and in a small patch on Orcas Island. Large communities of gorse occur along the Long Beach Peninsula near Willapa Bay.

Successional shrub provides nest sites, cover, and food for many species of wildlife ranging from hummingbirds to deer and black bear. Early seral plant communities following clearcutting provide concentrations of food such as trailing blackberry, huckleberries, and salmonberry for berry eating rodents, birds, and bears. Seed eating rodents and birds are also provided for. Fresh slashings attract bark beetles, longhorned wood borers, and click beetles which attract the predatory checkered beetle and insectivorous birds and mammals. Pollen and nectar feeding butterflies, bees, wasps, and hummingbirds also forage in shrub areas. Deer and elk browse on shrub foliage.

Characteristic Fauna

Ground Layer

The ground layer is used for nesting, burrowing, feeding, and escape routes for small inhabitants.

Pacific Jumping Mouse

This omnivorous nocturnal mouse feeds on seeds, fruits, and insects. It hibernates from November until April. This six-inch mouse utilizes a home range of one to two acres.

Mountain Beaver

These are classified as the most primitive living rodent alive today. Mountain beaver prefer dense thickets and forests, feeding on herbaceous plants and shrubs such as swordfern, vine maple, and rhododendron. They also harvest shrubbery in late summer and autumn. They use the ground for cover, making extensive tunnels, runways, and burrows.

Deer Mouse

These highly adaptable creatures can survive abrupt changes in vegetation. They feed on seeds, nuts, acorns, and insects, and store food for hard times.

Townsend Chipmunk

These animals are examples of an edge effect species, using trees in coniferous forest for cover, but feeding on the ground in nearby shrub.

Mountain Quail

These birds occur in logged areas and prefer brush habitat. They eat seeds of fireweed, thistle, poison oak. They are ground nesters making a leaf-lined hollow among the brush.

Fox Sparrow

This sparrow has a brilliant musical song. It forages on seeds and berries of cutover shrubs such as elderberry, gooseberry, huckleberry, salal, and ceanothus. It builds its feather-lined cup nest on the ground or bush.

Juncos

Juncos are the most numerous birds occupying cutover forest land in the Douglas fir region. After three to six years when shrubs have become dominant, the junco population density may increase two to three times that of a virgin forest. Their diet changes through the year. In spring, they eat small beetles and seeds to meet the high protein requirements of raising young. In summer, juncos eat seeds of weeds and grasses and later western raspberries and strawberries. Fall and winter diets consist of Pacific madrone and Douglas fir seeds.

Rufous-sided Towhee

This towhee uses heavy brush for cover and feeds on the ground by scratching and kicking in the leaf litter for seeds. Their nests are placed on the ground or on a low shrub.

Shrub Layer

The shrub layer provides nesting sites, food, and cover.

Rufous Hummingbirds

The rufous is the most abundant hummingbird in Washington. Hummingbirds require nectar-producing flowers for food; red-flowering currant and salmon berry on logged over lands and burns are favorites of the bird.

Bushtit

These tiny insectivorous birds travel in flocks through shrubs and small trees. The long woven sock-like nest is placed in tall shrubs, often ocean spray.

Swainson's Thrush

This thrush prefers dense brush in or by shaded deciduous and mixed tree growth, again reflecting the benefits of edge habitats. Foraging is done on the ground in spring and early summer, but as the berries and fruits mature, the birds feed higher above the surface. Dense deciduous brush or willow and rhododendron are commonly occupied. Mud must be available for lining the nest which is placed in shrub or a small tree.

Black-tailed Deer

Deer depend on the existence of shrub-brush areas for foraging. Deer are yet another species that rely on adjoining habitats, using the forest for cover and shrub areas for browsing. Deer can improve their own range. Moderate browsing of shrubs induces sprouting, thereby increasing the volume of available forage and actually raising the carrying capacity of a range. Palatibility and nutritive value of sprouts is higher than unbrowsed twigs and regular pruning prevents plants from growing out of reach.

Black Bear

Bears also make use of edge locations. The cover of the forest and the berries of shrub areas are both important to black bear survival. Bears on Long Isand in the Willapa National Wildlife Refuge are strongly associated spatially with clearcuts covered with salal, huckleberry, and evergreen huckleberry. The availability of juxtaposed food and cover areas on the island are the ultimate factors allowing high densities of bears in local areas.

Aerial

Raptors use the air space above successional shrub to hunt for shrub inhabitants.

Sharp-shinned Hawk

This small hawk forages close to the ground among shrubs for sparrows and other small birds as well as mice, chipmunks and large insects.

Relationship With Other Habitats

Successional shrub is by definition closely related to other habitats. Shrub is part of a natural continuum which begins with liverworts and climaxes with forests only to eventually repeat the cycle. Successional shrub community composition may well determine what future communities will or will not take control of an area. Vine maple, blackberry, and mountain balm all contribute organic litter for future communities, but extremely dense thickets of mountain balm or Scot's broom can retard new species from entering the community.

Many shrub inhabitants rely on the ecotonal portions of their habitat for food and cover. The shrub community offers rich sources of berries and seeds; the forest is better cover. Greater species diversity is found in areas where two habitats intergrade. It must be pointed out that although this heterogeneity of habitat attracts many species, there are still those highly dependent on pure stands of successional shrub.

Successional shrub supports many birds and mammals that wildlife watchers enjoy and hunters use. Berry patches provide many families with an extra food source and a chance to feel they are participating with nature. Most important, a successional shrub community is a point of reference that generations can watch evolve into forest and begin to appreciate the ecological process of succession.

Commercial/Recreational/Esthetic Values

Successional shrubs can aid the silviculture industry by supplying litter and nutrients to the soil, enriching it for new seedlings. When shrubs and herbs are killed chemically, the soil must be artificially supplemented with fertilizer for the growth of seedlings.

Shrub also supports game animals which are important economically as well as recreationally and esthetically. Many nongame species also thrive in successional shrubs and are a source of enjoyment for many people.

GORSE

III. IMPACTS

Historical Changes and Trends.

For centuries fire has been a major factor in determining the direction and rate of plant succession. Wildfires started by lightening or Indians cleared vast areas of land. Indians used repeated fires to perpetuate fields of huckleberry for collection of berries for food. They also used fire to improve the browse for game which they hunted.

Modern man has now replaced wildfires as the major land clearing force. The aftermath of logging leaves new areas for colonization of early seral vegetation and accompanying fauna. Areas of clearcutting and some slash burning allow an eventual successional shrub stage to thrive.

Several exotic species of shrub have been introduced or escaped from cultivation by modern man. Many native successional shrub species are overrun by the exotic species (e.g., gorse or Scot's broom), which can become so dense they become semi-permanent communities.

Destruction of fields and brush areas in developing areas reduces habitat required by shrub species. Sizeable patches of shrub throughout populated areas would enhance city and suburban living by providing song birds and small mammals to watch. Perhaps tools of land clearing should be adopted to enhance shrubs that are favorable to wildlife. Controlled burning, and mechanical brush cutting would stimulate growth of favorable forage on areas not adapted to timber production.

COASTAL SHRUBS (No. 322)

I. INTRODUCTION

Coastal shrub is a climax community occuring in areas adjacent to salt water in the Sitka spruce zone along the outer coast and exposed sites in Puget Sound. Wind, sand, and salt spray create a harsh environment in which succession is halted at the shrub stage. Larger forms of vegetation cannot resist the environmental forces which prune coastal shrub into its characteristic asymmetric shape.

Coastal shrub stabilizes soil by preventing erosion on bluffs and shifting sand on level areas near sandy beaches. Man has purposely introduced shrubs, such as lupine, to stabilize unstable coastal areas along the western coast of the United States.

II. SIGNIFICANT BIOLOGICAL FEATURES

Community Structure

Patches of coastal shrub communities are found along the Strait of Juan de Fuca, Puget Sound and the outer coast. Saltwater spray makes coastal shrub a unique community by influencing plant

distribution, plant morphology and nutrient cycling. Areas initially stabilized by grasses have succeeded to shrub coverage by such species as salal, evergreen huckleberry, rose, and lupine.

Shrub communities on the coast are extremely dense thickets pruned in height by strong wind and sea salt. Salal is the most common coastal shrub in Washington and Oregon. Other coastal shrub species include evergreen huckleberry, waxmyrtle, kinnikinnick, salmonberry, hairy manzanita, snowberry, rose, oregon grape, and lupine. Occasional small Douglas firs, lodgepole pine, cedar, and Pacific madrona, wind pruned to shrub height, are found in the shrub community.

Strong onshore winds influence the composition and form of vegetation by dessicating foliage, transporting salt spray and abrading plants with sand. Salal, manzanita, huckleberry, and madrona are particularly well suited species to these environmental demands having strong leathery leaves that can better resist dessication and abrasion. Deformed shrubs nearest the sea show results of saltcutting and dessication. These same shrubs supply protection for taller shrubs growing inland from them.

The characteristic shape of coastal shrub is asymmetrical with branch development of the seaward side inhibited by harsh environmental forces. Coastal winds cause more rapid transpiration on the windward side of shrubs leading to dessication of leaves and twigs. Wind suppresses windward and upper shoots and mechanically breaks woody flora. Sandblasting by wind carried sand particles may reduce ground vegetation, but does not effect coastal shrub height to a great extent. Wind borne salts have a great effect on vegetation growth. Salts become airborne through the bursting of bubbles of seawater in breaking waves. The deposition of high concentrations of these salts cause necrosis and death of leaves, twigs, and plants through high accumulations of chloride in the plant tissues. Mechanical abrasion to shrubs by leaves and twigs beating against one another form small abrasions which are the primary points of salt entry. Chloride ions are then translocated to apices of leaves and twigs. The differential deposition and translocation of chloride ions from salt spray leads to the death of seaward leaves and twigs resulting in the asymmetrical growth of coastal shrubs and trees.

The coastal shrub community on Partridge Point on Whidbey Island demonstrates wind effects. All the vegetation on the slope is wind pruned to 18 inches in height including a few Douglas firs which would normally grow to 200 feet in optimal coastal forest conditions. Shrub cover consists primarily of snowberry and includes Nootka rose, Oregon grape, and bracken. The sparse understory is composed of checker lily, thistles, sheep sorrel, and yerba buena.

Characteristic Fauna

Coastal shrub provides food, cover, nesting, burrowing, and perching sites for many species of wildlife.

European Rabbit

This introduced rabbit has thrived in the San Juan Islands, making extensive burrow systems throughout the grassland and shrub areas. The rabbits use shrub mostly for cover and feed on the open grassy areas where many become prey for the abundant San Juan bald eagle population and other birds of prey.

Striped Skunk

This omnivore is very common along coastal areas and uses the edges where brushland mixes with mixed woods and grasses. The striped skunk feeds on mice, eggs of ground nesting birds, insects, berries, and carrion. It dens in ground burrows, beneath abandoned buildings, boulders or wood or rock piles. The skunk is important as a controller of small rodents and insects. Skunks are also trapped for their fur.

Shrub Layer

mammals

Black-tailed Deer

This common herbivore occupies several types of habitat where there are browse plants. Coastal shrub is used by deer as part of their range that also includes grassland and coniferous forests. Black-tailed deer feed mostly on shrubs and twigs; they also include grass and herbs in their diet.

birds

White-crowned Sparrow

This black and white crowned sparrow is abundant near salt water especially where there are shrubs or small trees. The sparrow requires nearby water, damp grass-covered ground, and bushes for cover and nest sites. Foraging for seeds is done mostly on the ground. The Puget Sound region has its own subspecies of White-crowned Sparrow Zonotrichia leucophrys pugetensis, familiarly known as the "Puget Sound Sparrow."

Savannah Sparrow

The Savannah Sparrow is found on beaches and salt marshes. Preferring open areas for foraging, the sparrow uses shrubs for perching, again reflecting the usefulness of juxtaposed habitats. Savannah Sparrows have been observed nesting near coastal shrub patches on Whidbey Island.

Aerial Layer

birds

Merlin

This small falcon is a fairly common migrant in western Washington and is often found along saltwater shorelines in spring and fall where it feeds on shorebirds. The Merlin prefers edges of shrub habitat opening onto clearings where small prey birds are accessible.

Marsh hawks

Marsh hawks prefer broad open areas for hunting along the edges of cover habitat. Nests are placed in brush or tall grass bordering open areas.

Interrelationships with Other Habitats

Coastal shrub, because it usually occurs in small patches, is closely involved with many habitats that surround it. Coastal shrub is often juxtaposed to beaches, and may be by grasslands or forest. Coastal shrub often occurs on bluffs (see Narrative No. 47). Close association of coastal shrub with other habitats invites many wildlife species to take advantage of shrub edges. Many different types of edges or habitat associations are possible which attract a diversity of species.

Black-tailed deer, having a wide range of habitats, may use many of the different possible combinations of habitat edges involving coastal shrub. Deer may use a bordering coniferous forest for cover and browse on coastal shrub vegetation or browse in associated grasslands.

The edges of sea and land are also important to wildlife. Common crows which scavange beaches for clams and seabird eggs may use coastal shrub for resting areas. Raccoons forage along the beach for crabs, sandfleas, clams, and use shrubs for cover. They also eat berries from the coastal shrubs.

Commerical/Recreational/Esthetic Benefits.

Coastal shrubs are important soil stabilizers on steep bluffs and older sand dunes. Without the benefit of these shrubs, soil erosion could interfere with established roads and recreational areas. Valuable coastline property could be jeopardized.

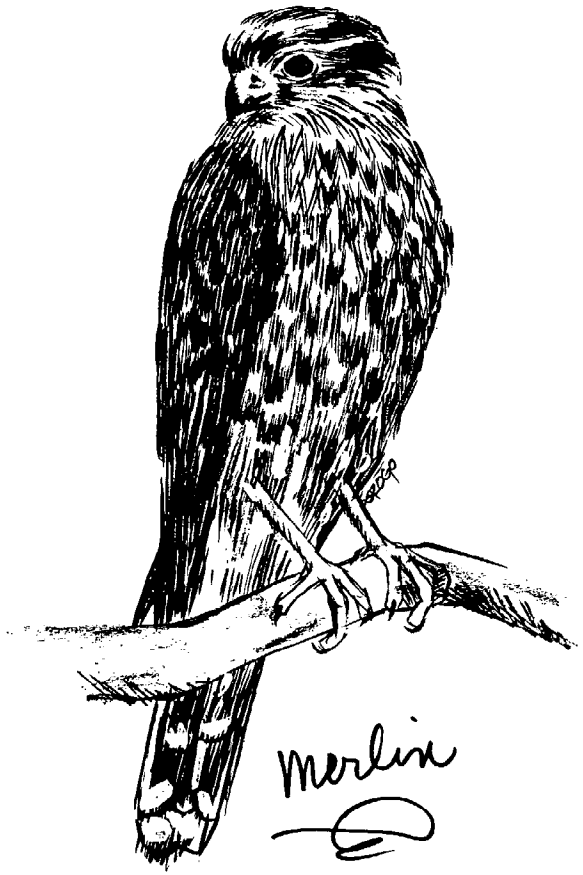
Many species of wildlife utilize coastal shrub and its edges with other habitats, providing wildlife watchers with yet another unique habitat in which to appreciate animals. Coastal shrub adds a dramatic profile to the coastline vegetation. Its windblown asymmetric growth reminds the observer of the strength of natural forces of the maritime environment.

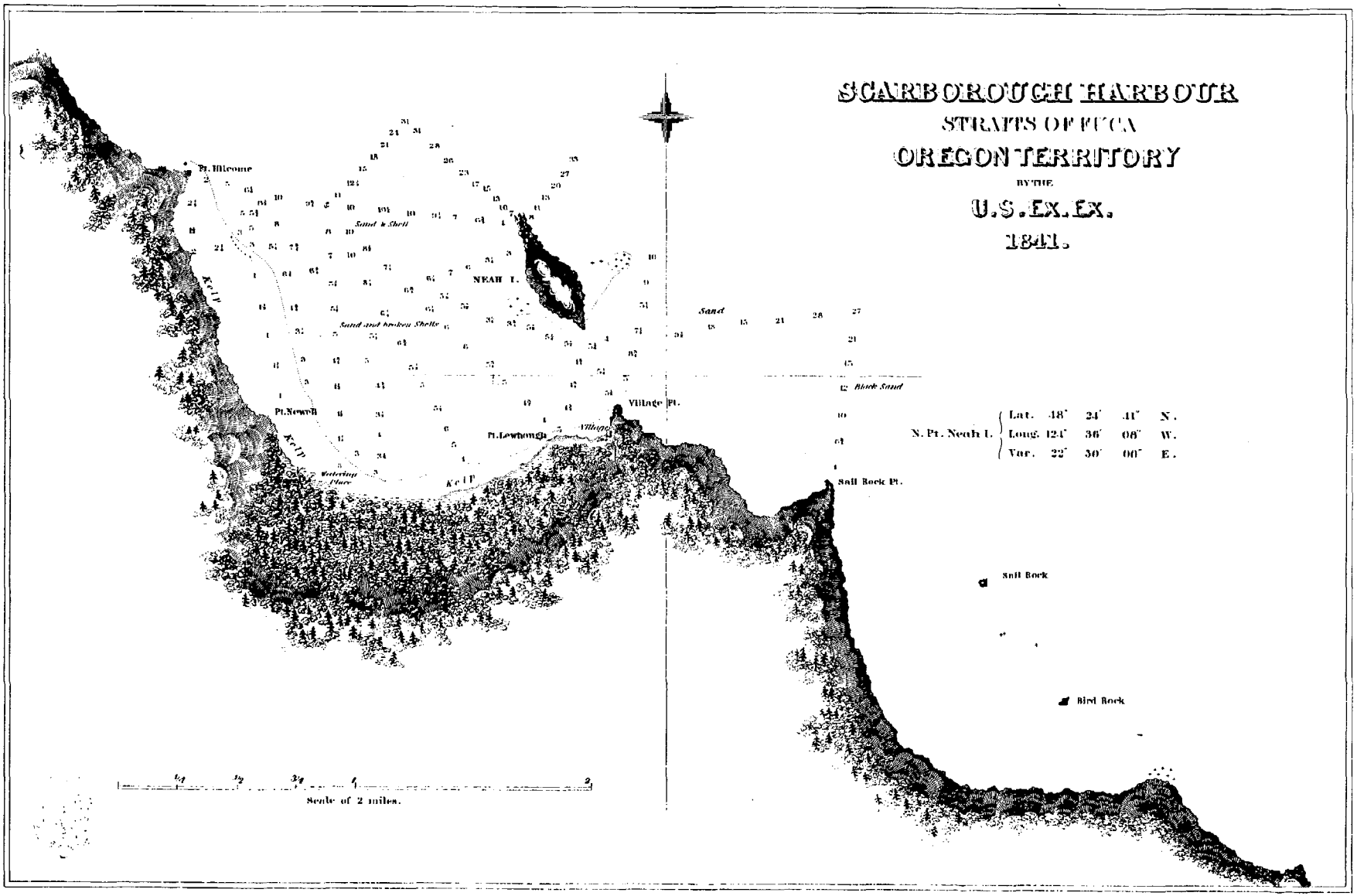
III. IMPACTS

Coastal shrub is nature's soil stabilizer along many bluffs and areas of sand initially stabilized by grasses. Man has occassionally introduced shrub species such as bush lupine to prevent soil erosion in steep areas along the coast.

Coastal shrub located on easily erodible areas should be protected. It has an important function and removal (mechanical or by spraying) could result in severe erosion, resulting in an expensive restabilization project.

Shrubs may be introduced to unstable areas such as a natural means of harnessing the changing coastline in areas where development deems such curtailment necessary.



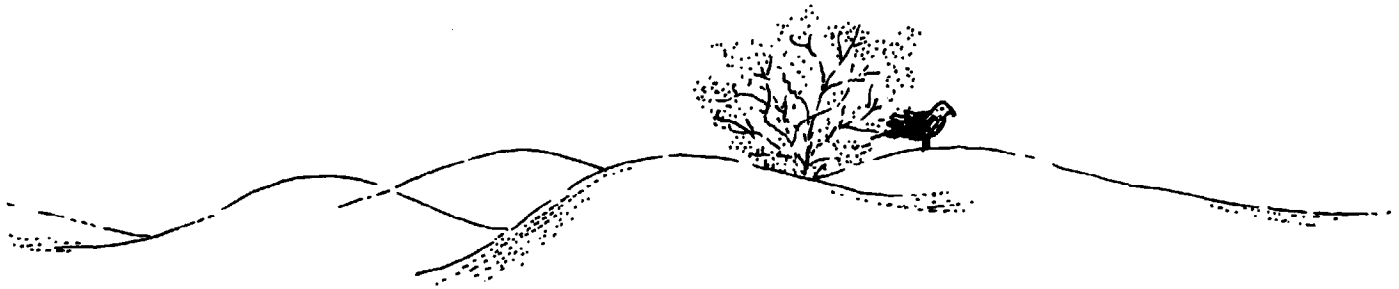

SCARBOROUGH HARBOUR
STRAITS OF FUCA
OREGON TERRITORY
BY THE
U.S. EX. EX.
1841.
N. Pt. Neah I.
Lat. 48° 24′ 41″ N.
Long. 124° 36′ 08″ W.
Var. 22° 30′ 00″ E.
Pt. Hilcome
Kelp
Sand & Shell
NEAH I.
Sand and broken Shells
Sand
Black Sand
Village Pt.
Pt. Newell
Pt. Lewhough
Village
Watering Place
Sail Rock Pt.
Sail Rock
Bird Rock
Scale of 2 miles.

SHRUB/EXPOSED ROCK (No. 323)

Shrub/exposed rock areas are extremely rare due to limited amounts of exposed rock in the coastal zone. They occur primarily in the San Juan Islands. The largest mapped area of shrub/exposed rock occurs along the northeastern end of Massacre Bay on Orcas Island. Shrub species noted in San Juan Island exposed rock areas were ocean spray, snowberry, myrtle boxwood, and baldhip rose.

Exposed rock communities are subject to the severe environmental conditions of wind and salt spray. Shrubs provide additional habitat and protection for wildlife in these stressful areas. As coastal rock areas succeed from bare rock to shrub to trees, they support larger numbers of individuals and species.

Shrubs in exposed rock areas are used by birds and small mammals for cover, nest and burrow sites, and as food resources. Characteristic animals of this habitat include Song Sparrow, White-crowned Sparrow and European Rabbit.



COMMUNITY SUCCESSION

Succession on rock is very slow. The first plants appearing on rock substrate are lichens. Then windborne mosses and herbs follow, developing a thin soil layer in deep cracks of rock. This early vegetation must resist severe dessication caused by water runoff and evaporation. Eventually, enough soil is formed to support shrub growth followed by a climax vegetation of conifers on the exposed rock.

Vegetation supported by thin layers of soil on rock can easily be destroyed by fire. When a community is destroyed by fire, erosion then washes the soil away and the slow regeneration process must begin again.

Shrub/exposed rock areas often intergrade with other habitat types. Thus, small areas of shrub on rock were often mapped as part of other rock habitats. Refer to the Rock Outcrop (No. 711) and the Conifer/Exposed Rock (No. 443) Narratives for more information on this intergradation of rock outcrops into shrub and forest areas. Additional information about shrub communities is found in the Shrub Narrative (No. 32).

Figure 33-1

Riparian zone and stream
as depicted in Coastal Zone Atlas.
The watershed encompasses this zone
and surrounding terrestrial and aquatic
areas draining into the stream system.

RIPARIAN (No. 33)

This narrative includes:

Riparian Shrubs	331
Riparian Forest	46
Coniferous Riparian	461
Broadleaf Riparian	462
Mixed Riparian	463

INTRODUCTION

Riparian zones were mapped throughout the coastal zone along rivers and streams of varying sizes. Riparian vegetation appears as strips of predominantly broadleaf tress and shrubs along larger rivers. Small streams were often not defined as a map unit, but their presence is suggested by a band of riparian vegetation. This zone is depicted in Figure 33-1 and is identified as: No. 331, Riparian Shrub or No. 46, Riparian Forest. Riparian forests are further divided into No. 461, Coniferous Riparian; No. 462, Broadleaf Riparian; and No. 463, Mixed Riparian Forest. (Refer to appropriate shrub or forest narratives for information specific to each cover type, for example, see Conifer Narrative No. 41 for details related to coniferous riparian forests.)

We chose to combine small stream and riparian zones for two reasons, one of which involved constraints of mapping and printing small, narrow polygons (individual mapping units which define each cover type displayed). The second reason is that stream and adjacent riparian vegetation interrelate as an inseparable unit which is part of a larger drainage basin, the watershed. A small, intermittent stream and associated riparian vegetation may constitute one entire watershed. Larger streams and rivers may flow for many miles and be fed by several tributaries, lakes, and ponds. The entire watershed may extend far beyond the immediate slopes adjacent to the stream, and in the case of the Columbia and Skagit rivers, sometimes crosses major political boundaries. It is important to recognize that the entire watershed is an ecological unit and that each stream system is influenced by events which are often great distances away. Streams are also affected by the terrestrial community along the immediate stream bank, the riparian zone.

In arid lands, a riparian zone is easily recognized as a band of vegetation restricted to the immediate vicinity of water. In the Pacific Northwest this zone is not so clearly demarcated. We define riparian zones to include all floodplain vegetation as well as vegetation on adjacent hillslopes which shade the stream or directly contribute detritus to the stream. As mentioned, along smaller streams this may include the entire watershed. Mapped riparian areas are often not as inclusive as this broader watershed definition of riparian, except on these smaller streams.

Vegetation within riparian zones is structurally diverse and can be divided into several components which are influenced by the stream and contribute significantly to stream ecology. These components are listed in Table 33-1 and refer to segments delineated in Figure 33-2 which depicts a typical riparian cross section.

Plant diversity is high in riparian areas and is a major contributing factor to the diverse structure along the stream bank. In general, vegetation changes reflect the entire range of adaptations of plants to aquatic and terrestrial conditions. On stabilized bars and immediately along the stream bank, hydrophytes (plants characteristic of wet soils) occur. With increasing distance from the stream bank, water is diminished, and the riparian zone is replaced by typical upland vegetation.

Broadleaf riparian communities are dominated by black cottonwood, red alder, or bigleaf maple in pure or mixed stands. In the southern Puget Sound counties, Oregon ash stands were occasionally noted, although this species most often occurred mixed with one or more of the former. The understory in these stands is usually well-developed, and typically includes a diverse assemblage of shrubs, grasses, and forbs. Western red cedar and western hemlock are dominants in coniferous riparian communities with Sitka spruce often playing a dominant role along the outer coast. Shrubby and herbaceous species in coniferous and broadleaf riparian forest understories are similar to those discussed in the Swamp Narrative (No. 611).

Shrubs include:

- salmonberry (Rubus spectabilis)
- trailing blackberry (R. ursinus)
- Himalayan blackberry (R. discolor)
- nootka rose (Rosa nutkana)
- red elderberry (Sambucus racemosa)
- vine maple (Acer circinatum)
- devil's club (Oplopanax horridum)
- swamp gooseberry (Ribes lacustre)
- stink currant (Ribes bracteosum)

Herbs include:

- smallflowered woodrush (Luzula paniuflora)
- false lily of the valley (Maianthemum dilatatum)
- foamflower (Tiarella trifoliata)
- fringecup (Tellima grandiflorum)
- mother-of-thousands (Tolmiea menziesii)
- bishop's cap (Mitella spp.)
- stinging nettle (Urtica dioica)
- skunk cabbage (Lysichitum americanum)
- lady fern (Athyrium felix-femina)

These species generally occur in addition to those understory shrubs and herbs mentioned in the Broadleaf Forest Narrative (No. 422) and the "Moist Coniferous Forest" section of the Conifer Narrative (No. 413).

Riparian shrub communities are characterized by several species of willow (Salix spp., including S. lasiandra and S. sitchensis), ninebark, twinberry, red-osier dogwood, and hardhack. Intermixed with these species may be young broadleaf or coniferous trees, and directly adjacent the streambed, cattails, nettles, skunk cabbage, small-fruited bulrush, rushes, burreeds (Sparganiun emersum and S. eurycarpum), slender boykinia, and other herbs are usually abundant.

The diverse plant communities, presence of water, structural diversity, and a coastal location combine to make Pacific Northwest riparian areas extremely valuable zones. Riparian habitat in estuarine areas of larger rivers has been replaced in several urbanized locations by port facilities such as along the Duwamish waterway. Agriculture has also modified riparian vegetation on floodplains and deltas of large rivers such as the Snohomish, Skagit, Nisqually, Puyallup, and Palix. The historical trend has resulted in a loss of riparian vegetation. As these area are lost, remaining areas become more valuable for wildlife use, recreation, flood control, erosion control, and the overall contribution of riparian vegetation to stream ecology. These values, impacts and other features of riparian vegetation are discussed in the following sections. The reader is also advised to consult the River and Stream Narrative (No. 51) and suggested literature at the end of this section.

SIGNIFICANT BIOLOGICAL FEATURES

Riparian zones provide significant habitat to a wide variety of terrestrial and aquatic wildlife. This is primarily due to the presence of and interactions with water which supports greater plant biomass, faster growth, and a greater plant diversity than drier sites in the vicinity. The diverse communities associated with riparian areas are dependent on maintenance of healthy stream systems just as the quality of stream communities requires intact riparian vegetation. Riparian vegetation benefits from adjacent rivers, streams, ponds, and lakes and in turn contributes significantly to the energy supplied to these aquatic systems.

Several key features of riparian vegetation and watersheds as a whole which define and perpetuate these valuable communities are discussed below. Refer to other wetland narratives [e.g., No. 5; see especially the River and Stream Narrative (No. 511-515)] for additional information and dependent species.

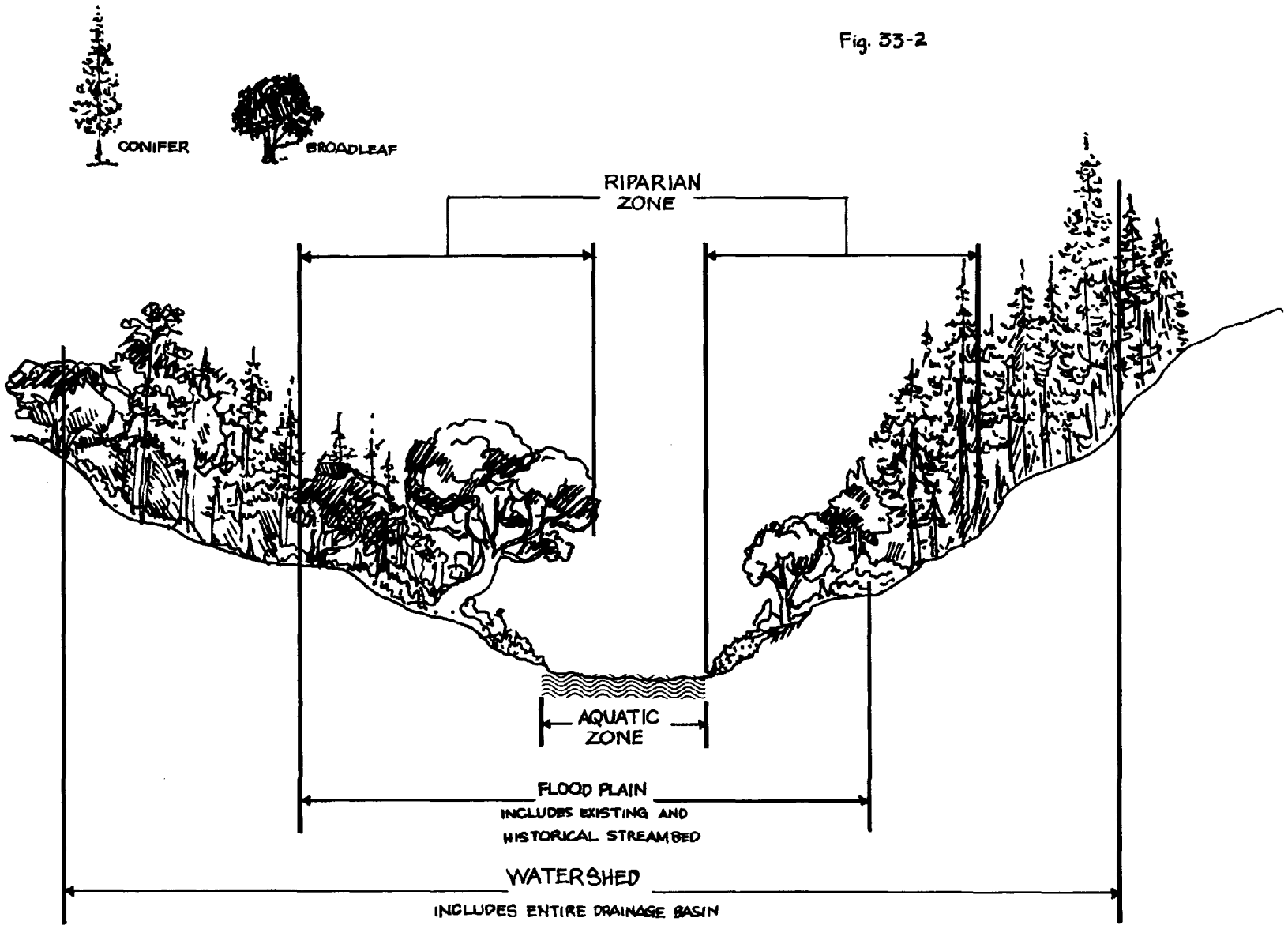
Productivity and Contribution to Stream Ecology

The gravitational movement of materials in drainage waters from terrestrial to aquatic ecosystems is the major link between land and water in the biological world. The tremendous plant biomass produced in Northwest forests and in riparian zones plays a major role in this linkage. Primarily, this involves the transfer of dissolved organic matter and particulate matter (detritus) from riparian zones and the entire watershed to

TABLE 33-1 RIPARIAN VEGETATION

Segment	Component
Floodplain, hillsides (particularly on smaller streams)	Canopy, stems, shrubs and other subcanopy vegetation, snags
Above ground and above the stream channel	Canopy and stems, snags. May include much of hillside vegetation on smaller streams.
Streambank	Roots of riparian vegetation, fallen logs, herbaceous and shrubby vegetation.
Stream Channel	Fallen logs and other large debris derived from riparian vegetation. Detritus and dissolved organic matter also derived from riparian vegetation.

Fig. 33-2


CONIFER
BROADLEAF
RIPARIAN ZONE
AQUATIC ZONE
FLOOD PLAIN
INCLUDES EXISTING AND HISTORICAL STREAMBED
WATERSHED
INCLUDES ENTIRE DRAINAGE BASIN

the stream system. This transfer of organic matter to streams is the major source of energy for most coastal streams and accounts for as much as 99 percent of the energy input in small forest streams. The remaining energy contribution is derived from photosynthesis within these streams by mosses, algae, and aquatic vascular plants. The terrestrial input remains as the chief contributor of energy in heterotrophic (dependent on food produced outside the stream) streams.

Organic matter enters stream food chains in various forms, including leaves, needles, twigs, bark, branches, flowers, and fruits. Plant remains fall into the stream and are washed through the soil and add appreciably to the input of dissolved organic matter which enters the stream directly. Much of this matter is used by various organisms within the stream, but considerable quantities are carried downstream and may amount to more than 60 percent of dissolved and particulate organic matter entering the stream. This export of nutrients and organisms moving downstream contributes to lower reaches of the stream, lakes, and estuarine productivity.

One example of how this organic matter enters aquatic food chains is presented in Figure 33-3. In this example, leaves falling into the stream are skeletonized by shredding insects such as caddisfly larvae. This process produces fine particles of organic matter (detritus) which is consumed by collectors such as midge larvae. These insects are then consumed by one or a series of predators. Adult insects emerge from the stream and may become prey of Cedar Waxwings and other wildlife. Larvae and adults are also consumed by stream predators including sculpins and trout. Sculpins and trout are in turn prey of other wildlife and man.

Within each step of this food chain, several other organisms and processes are involved. They have evolved balances between the amount of organic matter entering the stream, and the amount consumed, exported, and processed (converted to carbon dioxide [CO_2] during biological processes). Balances also exist between the various kinds of organisms through which organic matter first enters food chains. Overall water quality depends on maintenance of these balances within stream systems and surrounding terrestrial communities. Status of a stream's water quality should, therefore, be monitored in recognition of the relationships between particulate and dissolved organic matter and associated micro- and macro-organisms within the system.

Riparian zone and watershed quality will both affect and reflect the health of the stream environment. It should be monitored in terms of a stream's water quality and the status of the system as a whole. We are just beginning to understand the factors which affect stream systems and how to respond to alterations induced by man. For example, we know that logging to the edge of streams has severe impacts on trout and salmon. Buffer strips are now recognized as being important to stream quality and are often being maintained. Riparian vegetation mapped in the Coastal Zone Atlas are a part of this buffer strip and a key feature in the maintenance of stream and water quality.

Edge Effects

Much of the diversity inherent in riparian communities is a product of the continuous edge effects resulting from the streambank transition from water to land and the vegetation associated with each medium. The physical and vegetational changes along this transition zone (depicted in Figure 33-4) create a diversity of foliage strata, and the edges between each provide an abundance of niches for animals. Species will be present which normally occur in each type, plus those which feed in one and nest or seek cover in another.

Birds are especially numerous in riparian areas. For a given number of acres of habitat, riparian areas support higher population densities than any other forest habitat type. This is also true in those riparian forests which lack structural diversity. Homogeneous cottonwood riparian areas in the Southwest contain some of the highest avian population densities per unit area in the continental United States.

Pacific Northwest deciduous forests are known to have high bird diversity and our conifers support a higher number of breeding individuals per unit area than in any other coniferous forest region in North America. Northwestern riparian forests represent a natural or inherent edge where these two forest types and their associated species mix. The resultant habitat diversity and the presence of larger numbers of certain species influenced by our coastal location (e.g., Bald Eagle winter feeding and roost sites largely in riparian areas) add greatly to the value to birds of riparian forests in Washington's coastal zone.

Riparian zones also support mammals which benefit from edge effects along streambanks. Aquatic mammals, such as river otters and mink, move along streams and from the water to shore where riparian vegetation acts as a protective buffer zone and as a source of terrestrial prey. The importance of riparian areas to these mammals is apparent inland and is valuable to river otters along the coastal zone. During our studies, 24 percent of river otter landing sites were adjacent to a riparian shrub or forest community.

Terrestrial mammals are often more abundant along streams where they drink and feed near the cover and forage provided by riparian vegetation. Movement of terrestrial mammals may be along the stream, in which case the function of riparian vegetation may be mostly as a protective corridor. Movement is also between upland, riparian, and stream edges and varies with species. In general, larger mammals have larger daily and seasonal ranges and will make use of a greater variety of habitats. Smaller mammals may reside only within the riparian zone, or in a restricted portion of the zone along the stream.

Recent studies along the lower Columbia River revealed that the highest number of species and greatest abundance of reptiles and amphibians are found in riparian areas, in the immediate river edge habitats.

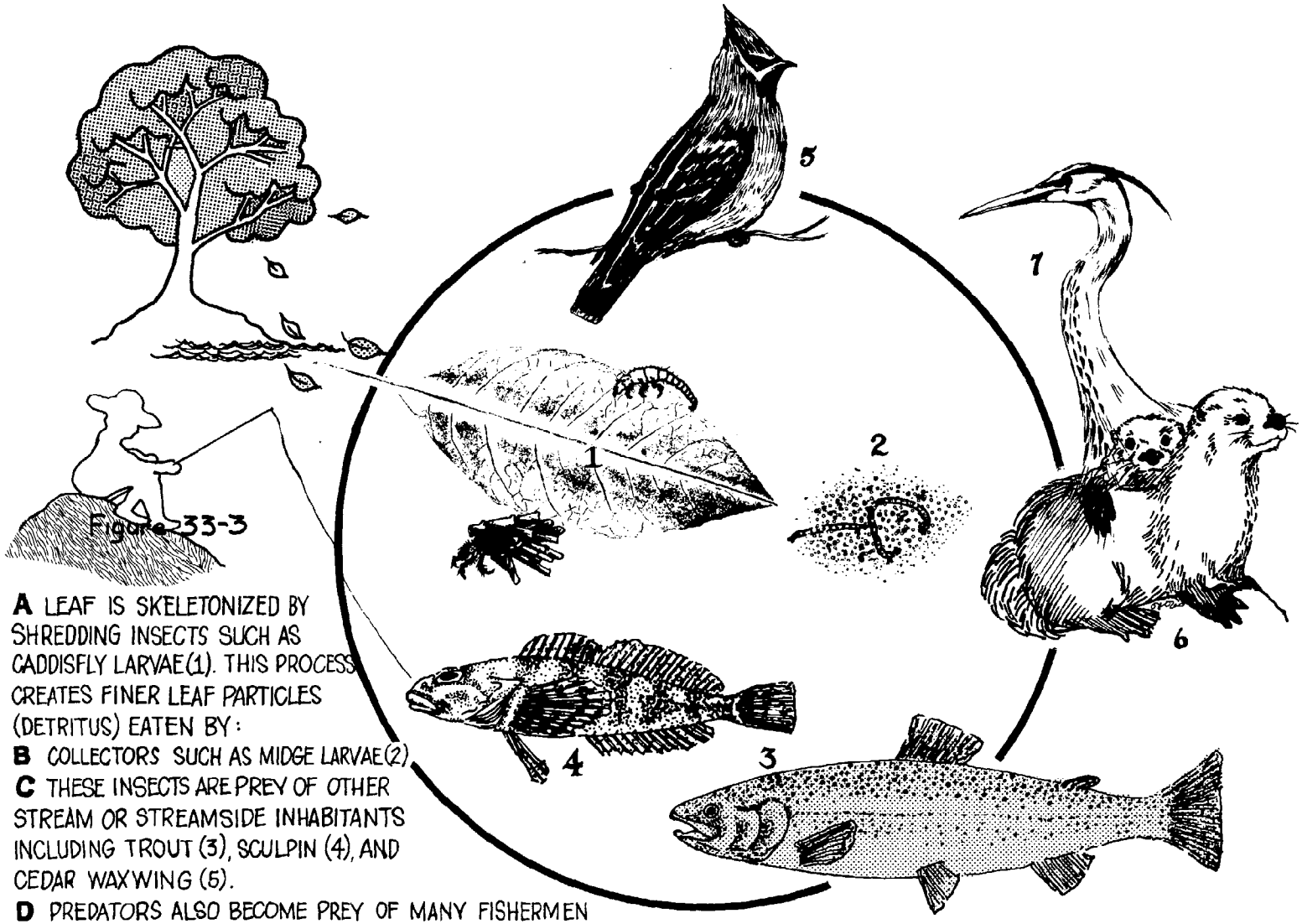


Figure 33-3

A LEAF IS SKELETONIZED BY SHREDDING INSECTS SUCH AS CADDISFLY LARVAE(1). THIS PROCESS CREATES FINER LEAF PARTICLES (DETRITUS) EATEN BY:

B COLLECTORS SUCH AS MIDGE LARVAE(2)

C THESE INSECTS ARE PREY OF OTHER STREAM OR STREAMSIDE INHABITANTS INCLUDING TROUT (3), SCULPIN (4), AND CEDAR WAXWING (5).

D PREDATORS ALSO BECOME PREY OF MANY FISHERMEN ALONG THE STREAM. OTTERS (6), GREAT BLUE HERONS (7) AND SEVERAL OTHER PREDATORS BENEFIT FROM THE CYCLE WHICH BEGAN AS A LEAF FALLING INTO THE STREAM.

Use as Corridors

Man has historically used rivers and riparian areas as travel routes. Among the best known examples of early use in this country was by explorers and fur trappers. Trappers could move along natural water pathways, but the river route wasn't chosen strictly for logistical reasons. The furbearing animals sought for their higly prized pelts also lived in or along these streams. Early day trappers also hunted terrestrial animals such as deer and elk which fed along the river bank or used the riparian strip as a travel corridor between summer and winter range.

Trappers are still active today and provide a living reminder of earlier American heritage. Likewise, the furbearing animals and other wildlife of streams and riparian zones still depend on these areas as travel routes. The value of streams and adjacent riparian zones is apparent for aquatic species such as beaver which forage ashore and retreat to the water. Trapping records indicate that terrestrial mammals are also dependent on aquatic areas and riparian areas. For example, more than 50 percent of all raccoons trapped in one year in Skagit County were reported from the vicinity of streams, lakes, or marine shorelines. Another species dependent on streams and riparian areas for travel is the river otter which moves often between freshwater and the marine environment. Streams are major routes of travel, but riparian areas are also used as places to come ashore and as a pathway by these amphibious mammals.

Thermal Protection

Riparian vegetation contributes significantly to the food base of aquatic organisms which ultimately become prey of several commercially and recreationally valuable species. Trout and salmon (collectively referred to as salmonids) are among these species and, like other fish, they also derive thermal protection and cover from vegetation in the riparian zone.

Direct solar radiation is the principal source of heat that raises water temperatures (which is also affected by a stream's surface area and flow). Several studies have shown that riparian vegetation directly controls water temperatures, which must be maintained at levels suitable for spawning, egg and fry incubation, and the rearing of resident and anadromous salmonids. Other wildlife also benefit from thermal protection, including the Olympic salamander which inhabits shaded streams in some portions of our coastal zone.

Escape and Nesting Cover

The roots of riparian trees and shrubs often extend into a stream where they provide cover for fish and amphibians. Roots also stabilize streambanks. Erosion is modified and undercut banks form in higher frequencies and last for longer periods than in areas where riparian vegetation is removed. These undercuts are prime habitat for young salmon and stream dwelling trout.

Riparian vegetation is also manipulated by some species to provide cover or a nest site. Examples are varied and reflect some of the more intriguing examples of animal architecture:

Beavers may burrow into streambanks for a den site, but the familiar dams and lodges are constructed of riparian vegetation such as alder and willow.

Muskrats also burrow in streambanks and may even share the lodge of a beaver. They also construct lodges of their own, but they use marsh or nonwoody riparian vegetation such as cattails and rushes for construction of their dome-shaped houses.

Bushtits are examples of birds which may use riparian vegetation as nest material and a nest substrate. Their long, hanging gourd-shaped nest provides essential cover for eggs and nestlings. Nests were observed during this study in riparian areas suspended from the branches of low shrubs such as hardhack.

Snags in riparian areas also provide nesting cover for birds such as the brilliantly-colored Wood Duck. Wood Ducks nest in natural cavities or abandoned Pileated Woodpecker nests from five to 40 feet above ground within about 200 yards of the water's edge.

Erosion, Sediment, and Flood Control

Riparian vegetation provides a natural aid in stabilization of streambanks which is an important feature in erosion control. Roots of riparian vegetation bind the soil along rivers and streams. If vegetation is removed, streambanks quickly erode. Increased stream sedimentation is one result which can have severe impacts on salmonids, particularly in gravel used to spawn in.

Riparian vegetation also acts as a filter and interceptor of sediments, surface runoff, and large debris which could enter the stream from sites away from the river bank. Trees and shrubs physically block larger debris, while all riparian vegetation modifies surface runoff which is a major transporter of find sediments. Vegetation removal within the watershed increases runoff which raises water levels throughout the stream system. It can also lower baseflow during summer months. Removal of riparian vegetation destroys the final buffer zone along the streambank allowing debris, increased flow, and increased sediments to enter the stream. The results have severe impacts within the immediate areas and downstream.

Buffer Zones

Coastal forests were described as being particularly valuable because of their proximity to marine waters (see the Forest Narrative, No. 4). Coastal riparian forests provide yet another dimension for wildlife as reflected in their value as buffers in estuarine areas. For example, waterfowl feeding at the mouth of a small stream are screened from possible disturbances where riparian buffers occur. Harbor seals, river otters, and Great Blue Herons also benefit from these protective buffers. These and other species may remain feeding, resting, or nesting along the water's edge if protective buffers of riparian and coastal edge forests are maintained.

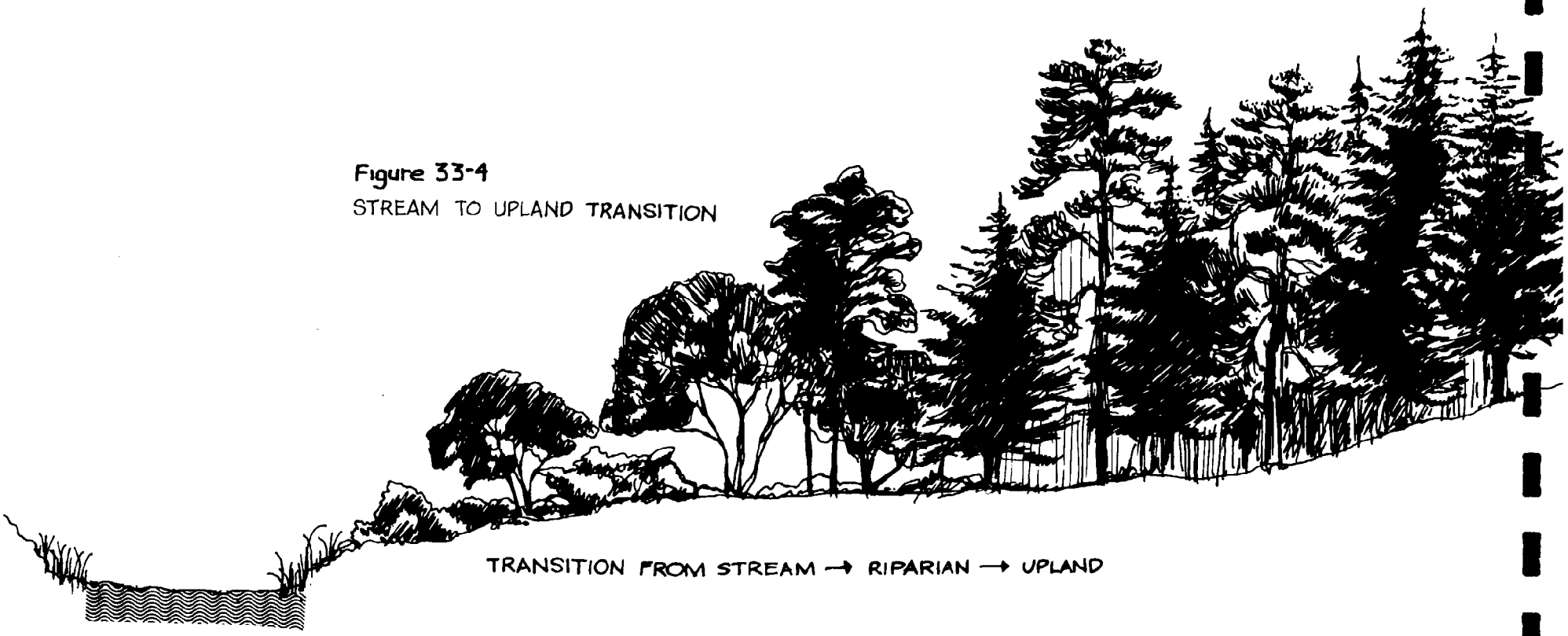


Figure 33-4
STREAM TO UPLAND TRANSITION

Bald Eagles also require protective buffer zones around the nest site and along the many rivers and streams where they feed and roost. Bald Eagle studies have revealed the importance of these buffer strips and the following recommendations are a part of the recent findings along the Nooksack River:

- The use of vegetative buffer zones is an effective management tool for the protection of wintering Bald Eagles. Existing vegetation along the river should be protected and new buffer zones should be selected to include big-leaf maples, black cottonwoods and Sitka spruce.

- A restriction of logging practices along the wintering grounds and roosting areas is essential in order to maintain prime eagle winter habitat. Forestry practices on wintering grounds are not compatible with Bald Eagles and should be controlled.

- Human activities should be restricted beyond the range of flight distances of wintering Bald Eagles. A thousand foot (300-meter) activity restriction zone would mitigate disturbances to most Bald Eagles. This restriction zone should be realized for all land management practices which are potentially threatening to winter perches, roosting, and feeding sites.

- See The Forest Narrative (No. 4) for a summary of Bald Eagle Management Recommendations which includes nest site guidelines.

Commercial and Recreational Values

Conflicting uses and economic considerations make watersheds the focal point of many difficult environmental decisions. Recreational values are considerable and are often not fully appreciated in riparian land use decisions. Both commercial and recreational values are difficult to assess since they involve a complex of direct and indirect benefits from stream productivity, flood control, erosion control, and esthetic values.

Riparian vegetation has been removed in many areas and replaced by or intermingled with agricultural activities, housing, "flood control" dams, power dams, port facilities, and other urban features. These streamside or floodplain activities represent considerable investments and often involve major portions of cities and towns. Preservation of riparian vegetation and wise management of upstream watersheds is essential to the very survival of these communities. For example, water quality within the Cedar River watershed is carefully controlled to provide the city of Seattle its drinking water. Likewise, lower Snoqualmie River inhabitants obtain some measure of protection from natural flood controls in the upper North Fork Snoqualmie watershed. Wise management decisions in these areas require control of logging, retention of riparian vegetation,

minimal floodplain habitation and recognition of natural forces which modify streamflow such as the maze of beaver ponds and meandering streams in the upper North Fork of the Snoqualmie.

Other economic values in all stream zones require our consideration of the contribution of riparian vegetation to the stream system. Some examples of commercial and recreational benefits include:

- Salmon and trout production is greatly enhanced by preservation of riparian vegetation. These fish are our most highly valued recreational and commercial species.

- Aquatic and terrestrial mammals and birds often reach higher densities or exhibit a more diverse assemblage in riparian areas than in adjacent uplands. Most of these species provide considerable recreational values through hunting, trapping, and nonconsumptive uses.

- Wildlife populations in habitats adjacent to riparian areas are benefitted by the presence of riparian vegetation.

- Recreational values in riparian areas are considerable and include esthetic enjoyment, camping, hiking, and wildlife viewing.

- Riparian vegetation improves and maintains water quality necessary to support economically valuable species, and to provide water supplies for human consumption.

- Riparian vegetation is a natural streambank stabilizer which reduces costly erosion problems. It also modifies surface runoff which contributes to natural features of flood control and filtering of sediments which would otherwise enter the stream. These benefits directly influence stream productivity.

- Riparian vegetation acts as a natural buffer zone for floodwaters, accommodating stream overflow without suffering damage.

- Floodplain riparian areas provide natural valley storage for floodwaters; vegetation removal or land use changes increase downstream flooding.

IMPACTS

Aldo Leopold succinctly stated, "A prudent technology should alter the natural order as little as possible." Riparian areas, and wetlands in general, require the attention implied in his statement perhaps more than other areas. Riparian vegetation and associated bodies of water are integrated systems. Alter one and others are affected. Wise management, therefore, requires a consideration of both the aquatic and terrestrial communities which comprise the many watersheds which flow within our coastal zone. Maintaining intact riparian areas, altered as little as possible, is a part of this management scheme.

Specific impacts which affect riparian vegetation and its role in watershed ecology include:

Logging and Other Clearing

Logging and associated road building activities should be restricted in riparian zones. A buffer of riparian vegetation acts as a sediment filter and modifies surface runoff which results from logging adjacent forest. Increased sedimentation is especially harmful to salmonids which may be killed directly or indirectly if suspended sediment concentrations are high and persistent. Fish may be lost when silt accumulates on gill filaments, but greater losses usually occur when sediments cover streambeds and reduce the flow of water within gravel. This reduced flow of intragravel water restricts the supply of oxygen to incubating eggs and may act as a physical barrier to emerging salmonid fry.

Removal of riparian vegetation also diminishes or destroys the value of the area for wildlife as discussed in preceeding sections. (See the discussion in the Significant Biological Features section on the importance of edges, cover, and buffers.) In general, a minimum buffer of 200 feet from the wetland edge is recommended, however, width of buffers varies considerably and may encompass a much wider area. Legal considerations are especially important in coastal riparian forests because of their value to the officially threatened Bald Eagle. Streambank alteration in some cases is also regulated by legal constraints of the Forest Practices Act and the Hydraulics Code of Washington.

Grazing

Livestock are frequently allowed to graze within riparian areas and impacts which result include: loss of vegetative shade along small streams, soil compaction and instability which increases stream sedimentation, trampling of streambanks, and direct removal of vegetation which would filter the increased sediments resulting from the presence of livestock. These disturbances compound erosion problems during times of high water and increased current flow.

Flooding

Dams are sometimes built to control floods in lower reaches of a stream system. Others are are built to produce hydroelectric power. In each case the riparian zone is covered with water. Ironically, riparian vegetation and associated features of the watershed are naturally efficient flood controllers. Costly water projects which submerge these areas eliminate a costless aid in flood control and destroy acres of riparian habitat, valuable timberland, and prime recreation areas. Hydroelectric dams also flood riparian areas and create a new zone along the reservoir where land and water meet. However, water levels fluctuate greatly and riparian vegetation is difficult to establish. These areas present a challenge to management agencies which seek the means to compensate for lost riparian areas.

Housing and Other Urban Activities

Much development has already occurred within riparian areas. By definition, these areas are within the floodplain and are often inundated by recurring flood waters. This is a natural occurrence which is accelerated by increased runoff in upstream locations altered by man. Consequences are extremely costly and involve diking, dam construction, emergency relief operations, loss of property, and loss of lives. The tragedy is that these costs can be avoided through wise land use planning which involves management of entire watersheds. President Carter's floodplain management guidelines state, "Evacuation is preferred over structural elements."

Among the undeveloped areas which can benefit from current knowledge of riparian, stream, and watershed ecology are small streams which do not pose serious threats from flooding. Small coastal streams can and have been viewed as models for larger watersheds as management strategies are applied. Thoughtful development will maintain natural values of riparian zones along these streams and provide an instructive base for larger systems.

Riparian Enhancement

Several streambanks in the coastal zone have already been cleared of riparian vegetation for a variety of reasons. In those areas where clearing has taken place, an opportunity exists to enhance stream and streambank environments. Plantings of native trees and shrubs stabilize the bank, provide wildlife habitat, improve water quality, and offer an esthetically pleasing riverbank environment.

The following plants are suggested for reintroduction of streambank vegetation:

Willow

a. Probably the easiest woody species to plant successfully.
b. Have rapid and luxuriant growth, providing early cover.
c. Extremely dense network of small roots, providing excellent soil binding qualities.
d. Excellent browse for deer, elk, smaller mammals, and grouse.
e. From the fish standpoint, one of the best because it tends to hang out over the water.
f. Since they are relatively short-lived, they do not get so large as to fall from their own weight and thereby tear out the bank.

Snowberry

a. Provides excellent food and cover for many terrestrial and avian vertebrates.
b. Has excellent soil binding roots.
c. Relatively easy to start from cuttings.
d. Avaliable from many local nurseries.

Vine maple

a. Excellent food and cover for most wildlife.
b. Excellent soil binding roots, particularly in the upper 4 inches of soil.
c. Difficult to start from cuttings.
d. Available from many local nurseries.

Red-stem dogwood

a. Excellent wildlife food and cover.
b. Good soil binding roots.
c. Easy to start from cuttings.
d. Available from many local nurseries.

Wild rose

a. Good wildlife food and cover.
b. Good soil binding qualities.
c. Reproduces by suckers.
d. Will form thickets when well established.
e. Available from many local nurseries.

Oceanspray

a. Grows almost anywhere, including rocky areas.
b. Good soil binding roots.
c. Fair browse for deer and elk.
d. Available from many local nurseries.

Hardhack

a. Provides dense cover.
b. Does well in riparian situations.
c. Available from several local nurseries.

Evergreen blackberry

a. Excellent winter cover for smaller wildlife.
b. Provides food for many terrestrial and avian species.
c. Excellent soil cover against rain and water currents.
d. Not as beneficial to aquatic life as terrestrial.

Hazelnut

a. Excellent soil binding roots.
b. Important food for small mammals and some birds.
c. Grows well in rock crevices.
d. Available from many local nurseries.

Tall Oregon-grape

a. Good soil control.
b. Good wildlife food and cover.
c. Available from most local nurseries.

Oregon myrtle

a. Excellent wildlife food and cover.
b. Makes an excellent stream bank control plant.
c. Available at some local nurseries.

Red elderberry

a. Excellent food and cover for hundreds of birds and mammals.
b. Grows easily in riparian situations.
c. Available at some local nurseries.

Ninebark

a. Easily propagated from cuttings.
b. Good wildlife food and cover.
c. Roots hold top soil layers well.
d. Available from several local nurseries.

Service berry

a. Excellent food and cover for many birds and mammals.
b. Forms extensive thickets.
c. Available from some local nurseries.

Mock orange

a. Good food and cover for wildlife.
b. Available from many local nurseries.

Snowbrush

a. Excellent evergreen cover and fair browse.
b. Important point is that its roots are nitrogen-fixing.
c. Available from some local nurseries.

Huckleberry, blueberry

a. Excellent food and cover for wildlife.
b. Forms thickets.
c. Available from many local nurseries.

Hawthorne

a. Excellent food and cover for upland game birds and many mammals.
b. Can form dense thickets.
c. Available from some local nurseries.

Alder

A special mention should be made here for alder because of its mixed blessings. It produces excellent cover while young and many birds feed and nest amongst its foliage. It also has the extremely valuable ability to fix nitrogen in the soil - an especially desirable quality on barren soil. It is also a very agressive pioneer species - one of the first woody plants to start in disturbed areas. Its greatest liability, however, is its tendency to topple into the river when it gets over six inches in diameter due to its shallow root system, and tearing out that part of the bank.

Literature

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Johnson, R. Ray and Dale A. Jones (Tech. Coordinators). 1977. Importance, preservation and management of riparian habitat: A Symposium. USDA Forest Service General Technical Report RM-43, Rocky Mtn. Forest and Range Exp. Sta., Fort Collins, Colorado 80521.

Stalmaster, Mark. 1976. Winter Ecology and Effects of Human Activity on Bald Eagles in the Nooksack Valley, Washington. Unpublished M.S. Thesis. Western Washington State College, Bellingham.

Several other references are available on specific impacts within riparian areas -- readers are advised to consult current literature and legal regulations pertaining to development in riparian areas.

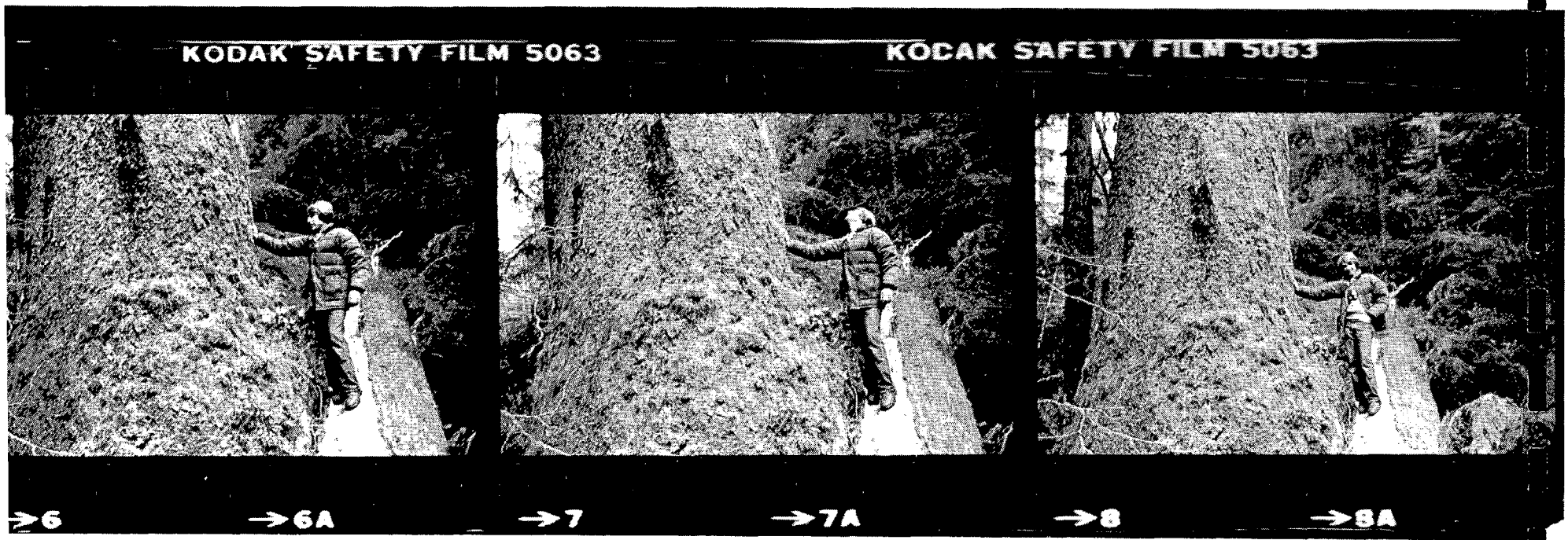
No. 331 Riparian Shrub

See Riparian Narrative No. 33 and
Shrub Narrative No. 32.

BLUFF (No. 34)

Refer to the Forested Bluff Narrative (No. 47) for discussion of all bluff classifications.

4 Forested Uplands



FORESTED UPLANDS (No. 4)

I. INTRODUCTION

Coastal forest, a subdivision of the lowland Pacific Northwest forests for which this area is famous, includes the following communities:

41 Coniferous Forests dominated by Douglas fir, western red cedar, Sitka spruce, western hemlock, and lodgepole pine in pure or mixed stands:

42 Broadleaf Forests largely consisting of red alder forests, but stands dominated by aspen, madrona, and paper birch also occur in the coastal zone:

43 Mixed Forest dominated by a mixed canopy of coniferous and broadleaf species, is common due to logging and other disturbances. Mixed forest typically has very diverse vegetation with corresponding high animal diversity:

44 Open Woodland dominated by a mix of coniferous and broadleaf species (Douglas fir, Garry oak, and madrona typically) on dry exposed sites such as southern shores in the San Juan archipelago:

45 Disturbed Forest includes any forest community that has been altered by disturbance including Clearcut, Burn, Selective Logging, and Grazed Forest:

46 and 47 Riparian Forests and Forested Bluffs are discussed in separate narratives including all riparian and bluff classifications, however, much of the information in the following forest narrative is relevant to these land cover types.

Forest cover is the primary vegetative type in the coastal zone. Distribution of major coastal zone forest types is presented in Table 4-1. While each type differs in plant species composition and wildlife use, many ecological principles apply to all forests, and are discussed in this section.

Table 4-1 DISTRIBUTION OF MAJOR COASTAL ZONE FOREST TYPES

			Whatcom	Skagit	Snohomish	King	Pierce	Thurston	Mason	Jefferson	Kitsap	Island	San Juan	Clallam	Grays Harbor	Pacific	
BROADLEAF	FOREST	Alder	X	X	X	X	X	X	X	X	X	X	X	X	X	X	Early successional stage on moist and scarified sites. Increased since settlement.
		Aspen						X	X				X				Restricted to small, isolated patches. Formerly more extensive.
		Birch	X														Decreased since settlement.
		Madrona				X				X					X		On dry, shallow sites. Particularly abundant on Vashon Island.
CONIFER	FOREST	Mixed Second Growth	X	X	X	X	X	X	X	X	X	X	X	X	X	X	Most abundant forest type.
		Mixed Old Growth	X							X	X	X	X	X			See table 414-1 for specific sites.
		Douglas Fir Seral Stages	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
		Douglas Fir Old Growth											X				See table 414-1 for specific sites.
		Hemlock/Douglas Fir Seral Stages	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
		Hemlock/Douglas Fir Old Growth		X								X	X	X			See table 414-1 for specific sites.
		Hemlock/Spruce Seral Stages												X	X	X	Western half of Clallam County and outer coast.
		Hemlock/Spruce Old Growth												X		X	See table 414-1 for specific sites.
		Cedar Old Growth														X	See table 414-1 for specific sites.

Pacific Northwest forests are unique among forests of the world for several reasons:

Community Composition - A comparison of our flora with those of other areas of the world with similar climate (e.g., Chile, New Zealand, France) reveals that nowhere else have coniferous forests developed to such an extent in terms of size of dominant individuals and development of the forest community. Broadleaf or mixed forests are dominant elsewhere, but in the Pacific Northwest are characteristically seral. The cause of these unique features is a complex series of climate events spanning approximately 25,000,000 years, resulting in optimal conditions for the development of coniferous forests. Present conditions (specifically, high amounts of precipitation concentrated in the winter, and mild temperatures) allow for growth during fall, winter, and spring, giving our evergreen coniferous species an advantage over the deciduous broadleaf species. Other factors favoring conifers over broadleaf species include shade tolerance, longevity, recovery after fire, growth rate, and disease resistance. Age, height, diameter, and shade tolerance of some western Washington trees are presented in Table 4-2.

Shade Tolerance

VTol = Very Tolerant
Inter = Intermediate
Tol = Tolerant
Intol = Intolerant

Table 4-2 AGE AND SIZE ATTAINABLE* BY SOME WESTERN WASHINGTON FOREST TREES AND RELATIVE SHADE TOLERANCE OF THESE SPECIES

	AGE (Years)	DIAMETER (cm)	HEIGHT (m)	SHADE TOLERANCE
Lodgepole Pine	250+	50	25-35	Intol
Douglas Fir	250+	150-220	70-80	Intol
Western White Pine	400+	110	60	Inter
Grand Fir	300+	75-125	40-60	Tol
Sitka Spruce	800+	180-230	70-75	Tol
Western Red Cedar	1,000+	150-300	60+	Tol
Western Hemlock	400+	90-120	50-65	VTol
Red Alder	100	55-75	30-40	Intol
Bigleaf Maple	300+	50	15	Tol
Madrona	150	100	30	Inter

*On optimum sites, age and size generally much greater.

Productivity - Our coniferous species have the genetic potential to grow to tremendous sizes, and because the climate of our area allows this potential to be realized, they comprise the largest standing biomass of any plant formation. Outstanding rates of production for both coniferous and broadleaf forests have been reported in the coastal zone.

Coastal forests are further distinguished by their juxtaposition with the marine environment. This allows for use by birds and mammals requiring both terrestrial and marine habitats. The marine and upland habitats should be considered an integrated system at least within the 2,000 feet mapped in the Coastal Zone Atlas, however, disturbances much farther inland may have heavy impact on the coastal zone (e.g., logging has been shown to increase siltation in estuaries).

Coastal forests have been heavily impacted since the arrival of the early settlers to this area in the mid 1800's. Logging and landclearing were necessary activities in the early days, and were concentrated in coastal areas. Land within the coastal zone is still considered particularly desirable for homesites, and the development of large urban centers is presently one of the heaviest disturbances of wildlife habitat in this area.

II. SIGNIFICANT BIOLOGICAL FEATURES

A forest ecosystem is a complex interaction of physical and biological factors, supplying rich and varied wildlife habitat, and capable of perpetuating itself indefinitely. Forest cover provides nest sites (over one-third of the breeding birds in North America live in wooded habitats), feeding areas, roost/rest sites, thermal cover, and migratory pathways. Coastal forests support typical lowland forest animals including elk, deer, bobcat, many small birds, mammals, reptiles, and amphibians, and are unique in supporting several additional species, rare or uncommon inland. Examples include Bald Eagles, Great Blue Herons, Peregrine Falcons, and river otters which all benefit from the coastal zone forest's fringe, or edge, along the marine shoreline.

Community Structure - For a discussion of wildlife habitat, it is convenient to regard the forest plant community as a series of discrete layers illustrated in Figure 4-1. Each layer represents habitat for wildlife. Many species are dependent on a specific feature within a given layer and many other require several strata. For example, many birds forage at the tops of trees and nest near the ground or in cavities lower in the trees.

Canopy Layer

The uppermost layer, the canopy, is occupied by trees which characterize the particular forest type (canopy coverage refers to the density of this layer). The amount of light penetrating to lower layers is inversely proportional to the canopy coverage, and is a significant factor in determining the composition and density of the understory. Canopy coverage may vary seasonally, as in an alder forest, or remain constant in forests dominated by conifers or madrona.

The canopy layer is one of many starting points for food webs in a forest ecosystem. The energy stored in leaves, branches, flowers, fruits, cones, and seeds passes through many consumers, eventually becoming detritus which is recycled back through the ecosystem.

Insects are the primary consumers in the canopy layer, and are a key link between the plant and animal systems. Grazing and sucking insects are most active in the spring and summer, but are present throughout the year. Vertebrate herbivores include squirrels, which eat cones and small amounts of bark. Herbivorous birds are mainly granivorous (seed eaters); for example Red Crossbills eat conifer seeds. Some birds also feed on leaves or buds in the canopy layer.

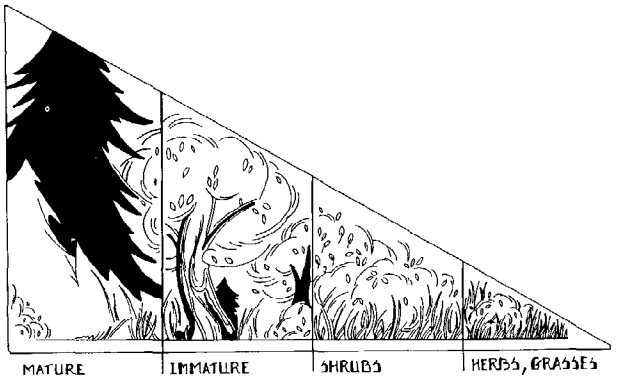


Figure 4-1: FOREST LAYERS/SUCCESSIONAL STAGES

Each layer forms a discrete level within the forest, but much overlap occurs. Within a given forest tract, each layer will be present although species composition and density at each level will vary considerably from site-to-site. Note that if each panel is viewed as a separate unit, the various layers also represent successional stages leading to a mature forest. Bare ground and herbaceous plants gradually are encroached upon by shrubs. Small trees (subcanopy) invade and eventually grow or are replaced by other, larger trees. Thus, the mature forest represents a blend of all these earlier successional stages and plants and animals from each will be present. The result is a diverse assemblage of forest inhabitants.

From these primary consumers, the food web expands to secondary consumers, namely predatory insects, spiders, and insectivorous and omnivorous birds. A number of birds including chickadees and flycatchers are common during part or all of the year in coastal zone forests. They feed primarily on the insect population present in the canopy layer and consume significant numbers of those which are forest pests. Mammals also consume insects in the canopy layer and are primarily represented by forest dwelling bats.

Predatory birds and mammals are the next step in the food web, and some of our most spectacular and least abundant wildlife are in this group. Birds of prey which hunt in the canopy layer or prey on organisms which do, include Great Horned Owls, Spotted Owls, Cooper's Hawks, and Sharp-shinned Hawks. Predatory mammals are not abundant in the canopy, but include squirrels which occasionally consume eggs of canopy nesting birds. Martins and fishers are rare carnivorous mammals which may be restricted to the Olympic Penninsula in the coastal zone. Both are members of the weasel family which spend a portion of their hunting activities in trees where squirrels are among their prey.

Figure 4-2 is a diagrammatic representation of a food web within the canopy layer. Eight categories of consumption are involved in this system including the energy flow going out to other habitats and forest layers. Some significant features of this food web deserve emphasis:

a) This is a relatively simple system operating within one layer of the forest, yet supporting many species and individuals, some of which roam far beyond the immediate area and use a variety of habitat types;

b) Within each category of consumption, there are many species represented, each having particular habitat requirements and exhibiting unique foraging behavior. For example, warblers prey on insects in forests. There are several species of warblers and each feeds at a different height in the canopy as illustrated in Figure 4-3.

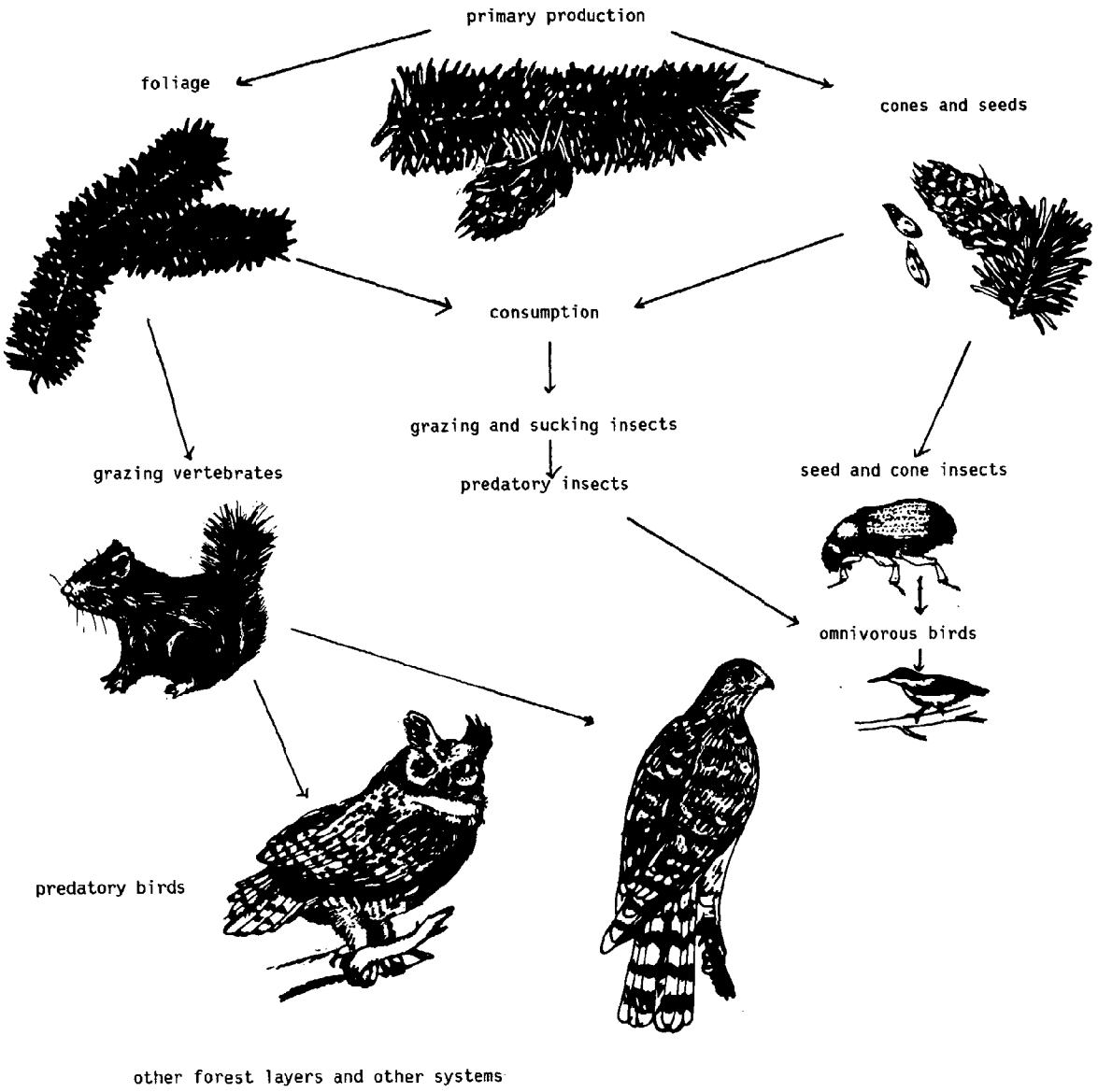
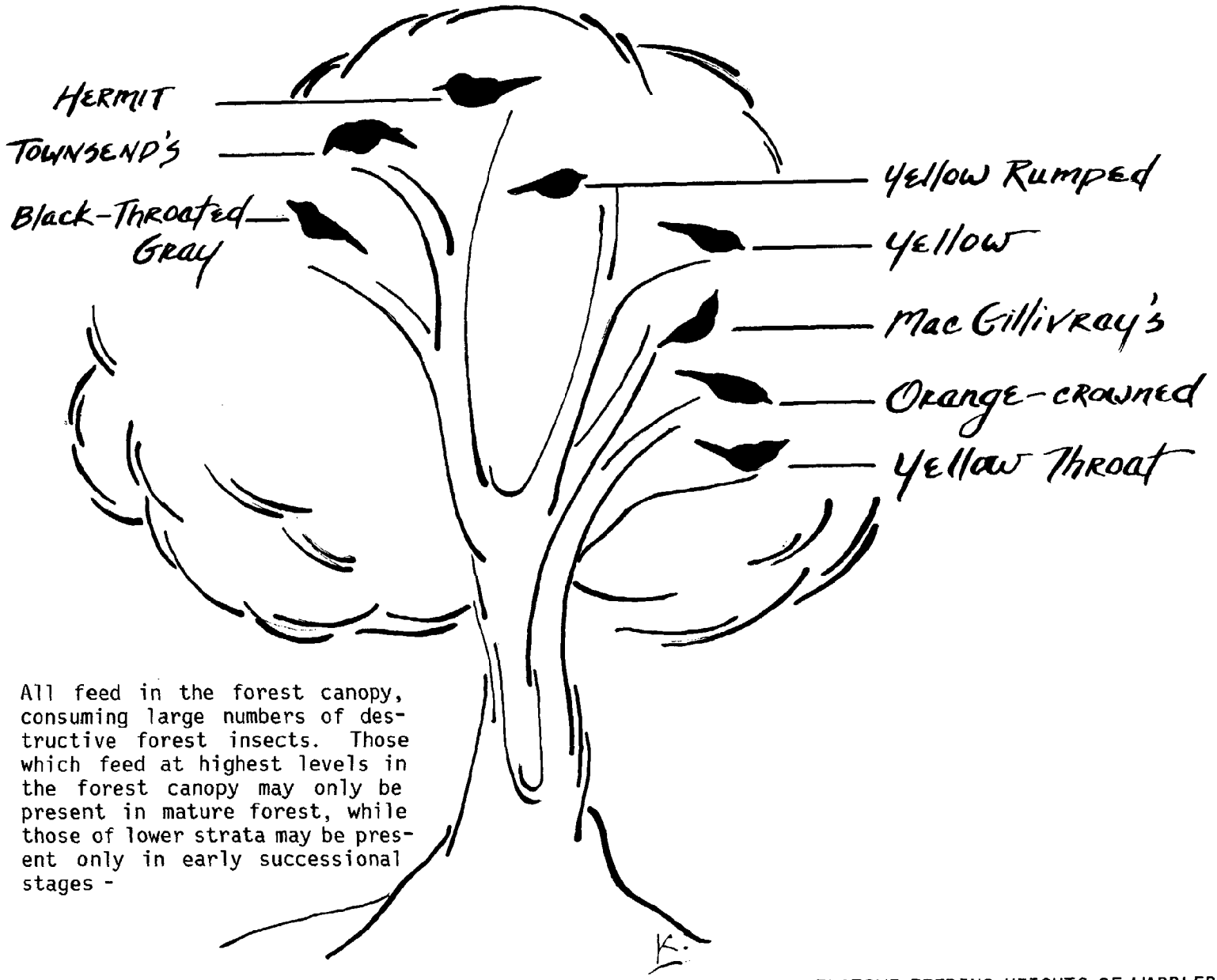


Figure 4-2 Forest Canopy Layer Food Web



All feed in the forest canopy, consuming large numbers of destructive forest insects. Those which feed at highest levels in the forest canopy may only be present in mature forest, while those of lower strata may be present only in early successional stages -

Figure 4-3: RELATIVE FEEDING HEIGHTS OF WARBLERS

The upper canopy of mature forests, larger trees in young woodlands, and snags provide roost and nest sites for many species. Large birds are especially dependent on these trees which support bulky nests that are often reused from year to year. For example, Bald Eagles reach highest Washington nesting densities in coastal forests, and the lack of large trees for nesting and roosting is possibly becoming a limiting factor for their continued existence. Great Blue Herons also nest in coastal forests in colonies which are reused for several years.

As with many plants in the understory, most animals below the canopy are dependent on tree cover in this layer for thermal protection. Thus, both deer and elk are dependent on the canopy layer in the summer to provide a cool retreat and in winter as moderating cover from colder, open areas. Throughout the coastal zone, cleared land does provide forage, but adjacent forests must be present as cover for deer and elk. Forest also provide forage, and in some areas the added cover of the forest canopy has shown to be so important that deer use is higher in forests than in open areas such as recently logged land.

Subcanopy and Shrub Layer

This layer is composed of shade-tolerant shrubs, lower branches of canopy species, and trees that will dominate the next successional stage, but have not yet reached the existing canopy layer.

Several of the shrubs in this layer produce seeds and berries eaten by many animals including thrushes, grouse, Band-tailed Pigeons, and Townsend's chipmunks. Shrubs and small trees also provide browse for deer, elk, and other herbivores. Shrubs which produce seeds and berries are present in all forests, but are most abundant in early stages of succession when forests are in the process of regeneration. Wildlife is also abundant at this stage, a time when many of our most common plant species dominate the forest community.

As the forest matures, the subcanopy changes in many ways. Many berry producing shrubs disappear, but they are replaced by other species tolerant of shade beneath the canopy. Likewise, many birds and mammals of more open shrub or young forest land are joined or replaced by additional species. Many are adapted to conditions only present in the shaded subcanopy of mature forests. These species include several of our least common and rare forest dwellers such as the Spotted Owl.

As trees grow taller, additional space in the subcanopy creates new habitat for forest wildlife. Low branches, shrubs, cavities in trees, and airspace between the ground and canopy layers are forage or nest sites. Especially important in the subcanopy are tree trunks and snags which provide foraging substrate as well as escape and nesting cavities for woodpeckers, owls, and many other birds as listed in Table 4-3. Cavities are also used by mammals including Douglas squirrels northern flying squirrels, and several bats.

As can be seen in Table 4-3, a wide variety of birds require cavities as nest sites. Snags, mature trees, dead limbs, fallen logs, and crevices in live trees also provide natural cavities. They also provide perching, feeding, nesting, and roost sites for wildlife. Woodpeckers are especially dependent on snags and other dead wood. They excavate holes for nest and roost sites which, when abandoned, become nest and roost sites for many birds incapable of excavating. Without suitable habitat and without woodpeckers, there would be extreme competition for existing natural cavities. The shortage of nest sites would then reduce populations of cavity nesters.

In Europe, where forests are intensively managed, there is a lack of snags and mature trees. Because many cavity nesters consume large numbers of destructive forest insects, Europeans have attempted to attract these species by installing nest boxes. The hope is to provide artificial nest sites for birds which will decrease insect populations in the forest. However, most woodpeckers will not use nest boxes, so the kinds of birds attracted will be limited to those unable to excavate their own holes. If we maintain mature coastal forests, and a diversity of snags and mature trees scattered in all forests, woodpecker and other cavity nesting bird populations will be maintained. Thus, wildlife will benefit, many uncommon species will be preserved, and forest insects will be controlled by natural predators.

Herb and Ground Layer

The forest floor is covered by mosses, lichens, fungi, ferns, and many flowering plants. Herbaceous species include many well known wildflowers such as trillium, western springbeauty, calypso, bleeding heart, fringecups, and coral root. Decaying logs and other detritus are often abundant. Much of this decaying plant matter is consumed within the forest, but significant quantities are washed into aquatic systems. Recent studies indicate that this terrestrial contribution may be the most important source of detritus in food webs in coastal waters, even exceeding the contribution of salt marshes.

Mushrooms are typically abundant on the forest floor and many fungi form mycorrhizal associations with vascular plants, including the trees dominating our forests. These symbiotic relationships benefit the trees involved by extending their root systems and supply nitrogen and other nutrients.

Understory in the old growth western red cedar forest on Long Island, Pacific County.

Fungi are also an important food source for a large number of animals, in some cases providing over 70 percent of the annual dietary volume. Fairy cups, puffballs, conchs, and mushrooms are all consumed by shrews, deer, flying squirrels, chipmunks, beaver, and Douglas' squirrels. Grouse and quail, both gamebirds, also eat mushrooms. Animals which consume mushrooms are important in disseminating the spores of fungi, and may play a significant role in the reintroduction of fungi to early seral stages. As the forest matures, this reintroduction of mushrooms is beneficial to developing trees due to the symbiotic relationship between the two. Thus, wildlife that consume mushrooms may be important to the development of forests; this leads to a more complex relationship between:

1) The trees which benefit from the presence of mushrooms that extend root systems and supply nutrients. Trees benefit from wildlife which disseminate these mushrooms;
2) Mushrooms benefiting from trees which provide shaded habitat and plant litter required by fungi. Mushrooms benefit from wildlife which disseminate their spores to new habitats;
3) Fungus-consuming wildlife benefit from mushrooms as a source of food, and from trees which provide cover, breeding habitat, and mushroom habitat;
4) Humans enjoy all three of the above and the symbiotic relationship between forests, fungi, and wildlife that helps perpetuate the forest ecosystem.

In general, knowledge of the importance of fungi in the forest food web is limited, but appears to be much more important than previously realized. Thus, it is good judgment to consider possible consequences of widespread major changes to fleshy fungus habitats with resultant changes in the fungal flora.

The ground layer of forests varies considerably in different forest types and successional stages. Species and numbers of individuals present are among the variables, but throughout coastal forests this layer supports ground nesting birds, and forest dwelling reptiles, amphibians, and mammals. Some mammals, such as deer, may forage on twigs and leaves higher in the canopy, but overall mammal use in forests is primarily restricted to the ground and herb layer. Mountain beavers, an important prey of bobcats, burrow where soil layers are well developed. A wide variety of other small mammals including deer mice, shrews, moles, and shrew moles also inhabit the forest floor.

Table 4-3

CAVITY NESTING BIRDS

Species	Nest in Cavities	Sometimes Nest in Cavities	Excavate Cavities	Comment
Red-breasted Sapsucker	x		x	Uses snags or live trees.
Hairy Woodpecker	x		x	Nest in live trees, reuses hole year after year.
Downy Woodpecker	x		x	Doesn't usually reuse old cavities. It has been estimated that 300 snags of 6 inches or more in diameter are required to maintain Downy Woodpecker populations in an area of 100 acres.
Western Flycatcher		x		Sometimes nest in cavities.
Violet-green Swallow		x		Use varity of cavities and crevices.
Tree Swallow	x			Prefer natural cavities, usually near water.
Purple Martin	x			Nest in woodpecker holes, also cavities in old pilings.
Black-capped Chickadee	x			Common in deciduous forests.
Chestnut-backed Chickadee	x			Common in conifers, nests in old woodpecker holes.
Red-breasted Nuthatch	x		x	May excavate their own cavity.
Brown Creeper		x		Generally nest between loose bark and trunk of large dead tree. May nest in cavities.
House Wren		x		Use a variety of cavities.
Winter Wren		x		Nests in root tangles and crevices.
Bewick's Wren		x		Use variety of cavities including woodpecker holes and knotholes.
Western Bluebird	x			Uses natural cavities or old woodpecker holes.
Starling		x		Introduced, adapted to urban areas.
House Sparrow		x		Also introduced, common in urban areas. Both House Sparrow and Starling exclude native species from cavity nest sites.

Table 4-3

CAVITY NESTING BIRDS

Species	Nest in Cavities	Sometimes Nest in Cavities	Excavate Cavities	Comment
Wood Duck	x			Near water, also use nest boxes.
Bufflehead	x			Near water, little known about breeding status in W. Washington.
Hooded Merganser	x			Near water.
Common Merganser		x		Near water.
Peregrine Falcon		x		Known to nest in tree cavities, although most often reported as cliff nester. Has been reported that hole-nesting population of this endangered species may have disappeared with the felling of the mature trees on which they depended.
Merlin		x		Usual site is in stick nest.
American Kestrel	x			Often uses flicker holes.
Barn Owl		x		Cavities are among their natural nest sites.
Screech Owl	x			As with many cavity nesters, owls are often dependent on woodpecker holes.
Pygmy Owl	x			
Spotted Owl	x			Nest in holes of living old growth conifers; may also be present in mature second growth.
Saw-whet Owl	x			Prefer old flicker or woodpecker holes.
Vaux's Swift		x		Nests in tall hollow snags in burned or logged areas.
Common Flicker	x		x	Nest in dead trees or limbs.
Pileated Woodpecker	x		x	Large dead trees with few limbs preferred. Pileated woodpeckers may use same tree for several years but excavates a new nest hole. The cavities are then available to other cavity nesters. Cavity excavated is large, therefore available to the largest and often least abundant cavity nester.

Local species composition is determined by many factors including soil moisture and vegetative cover. For example, dry sites such as the open woodlands near Beckett Point in Jefferson County provide habitat for Western fence lizards, while many forests with a dense canopy provide moist habitat on the forest floor for woodland salamanders. Insularity is also important in determining species present as discussed in the Rock Island Narrative (No. 713) and as reflected by the presence of the few species of terrestrial mammals on the San Juan Islands. Some island have a very large number of introduced rabbits, but there are few other kinds of mammals present on the islands as compared to the mainland.

Forest Structure and the Forest Community

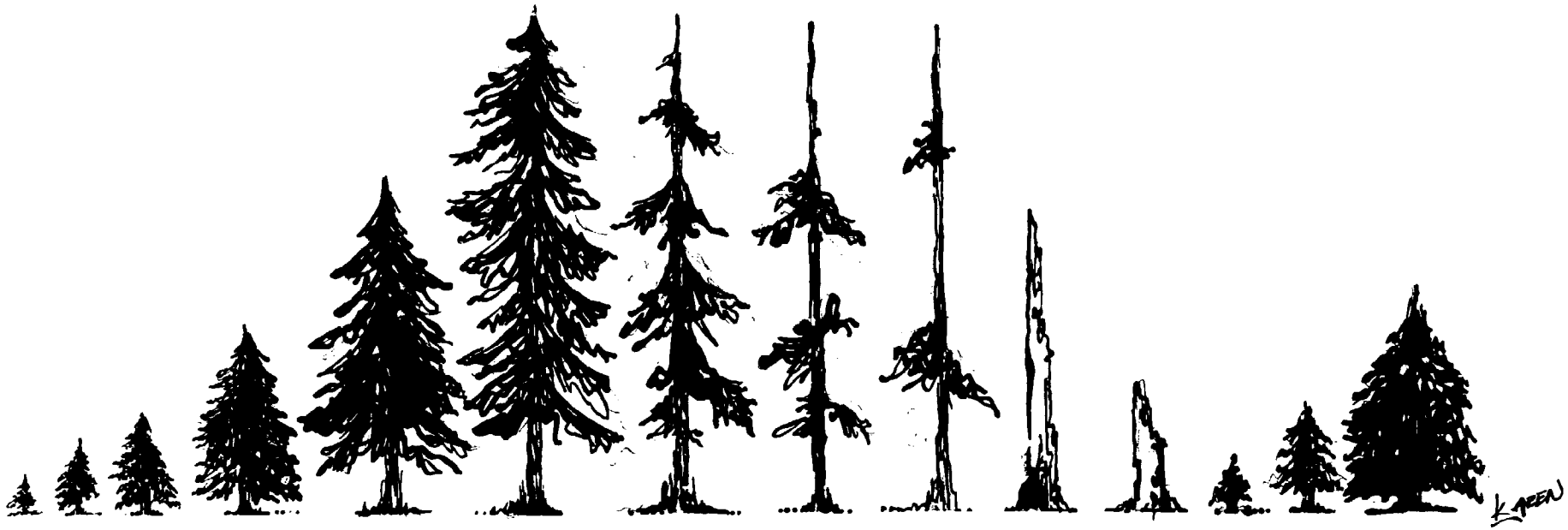
The preceding discussions of forest layers (canopy, subcanopy, herb and ground) point out the importance of various structural features of the forest community. In general, community complexity and diversity of plants and animals of any one forest is largely related to the number of strata present. Complexity of the community refers both to the various layers and the presence of snags, fallen logs, dead limbs, and other features of the forest which provide niches for wildlife. The canopy layer is always present in a forest community, but any or essentially all of the understory, snags, and other structural features may be absent, depending on the stage of development. Animal diversity at such sites will be limited by lack of suitable cover, food, rest, or nest sites.

The levels of a forest and overall complexity develop with succession as illustrated and discussed in Figure 4-1. Each layer changes as the dominant trees grow taller, and these layers become a part of the mature forest community. Thus, a mature forest will contain all layers and have higher faunal diversity than forests in younger successional stages due to an increased number of available niches. Faunal diversity is but one measure of the value of a given forest to wildlife however, and several additional factors should be considered as discussed below.

Management of our highly productive coastal forests should consider their support of a wide variety of highly evolved communities. These plant and animal communities vary greatly as expressed by the number of forest cover types mapped in the Coastal Zone Atlas (Conifers, Broadleaf, etc., and various successional stages). We have mapped only general land cover types, each of which can be divided into several plant communities supporting unique assemblages of flora and fauna. For example, the coniferous forest types include Douglas fir/hemlock, spruce/hemlock/cedar, Lodgepole pine, and Douglas fir/western white pine associations as well as various successional stages within each. Plant species vary considerably between these forest types. Wildlife populations also vary, especially with successional stages as illustrated in Figure 4-5.

The plant and animal species which occur in each forest community are not random assemblages. They have evolved together and have adapted to food and other habitat requirements satisfied within a given association of plants and animals or a specific stage in succession. Thus, each forest type and each age class supports a unique forest community. One forest type may have more species than another or have a more diverse assemblage of those species. However, numbers of plants and animals present do not account for the kinds of species represented. Therefore, it is important to maintain a variety of forest communities within a given area to maintain a variety of plants and animals which are adapted to each type.

Some species are tolerant of greater changes within the forest environment than others. In general, these are our more common and least threatened species and include many of those associated with disturbed or early successional stage forest. Others are highly adapted to a particular forest type, are rare, and often threatened by habitat alteration; they may be dependent on snags, mature forests, or a particular geographical region. Among these uncommon species is the Spotted Owl, adapted to one of our least common and highly threatened habitats, old growth forests.



Life Cycle of a Coniferous Tree

Figure 4-5

The habitat requirements of plants and animals vary greatly from one species to another. Within a given forest type, these requirements may be met at one stage in succession and not at others. Forest birds provide an excellent example of the diverse requirements as illustrated by the species associated with a Douglas fir throughout its life cycle. Some birds remain throughout its life cycle, although their relationship to the tree may change. For other species, niches become available at varying points in succession. Cavity nesters appear only at certain stages, while some birds drop out of the forest as the trees mature. In general, the least common birds are those dependent on the mature tree. To provide suitable habitat for these and the variety of other forest birds, suitable habitat must be available.

Importance of Forest Size

As forest size increases, both the number of wildlife species and the number of individuals comprising the community increases. The home ranges of seven forest-dwelling birds are presented in Table 4-3, illustrating the amount of forested area which may be required by a breeding pair of each species.

Table 4-3

TERRITORY SIZE OF BIRDS WHICH MAY BE PRESENT IN COASTAL FORESTS

Species	Home Range/Territory in Acres
Red-tailed Hawk	1,050
Cooper's Hawk	557
Blue Grouse	4.2
Great Horned Owl	525
Pileated Woodpecker	320-600
Common Raven	2,320
Winter Wren	2.5

Thus, a forest of only 2.5 acres might support a Winter Wren. A much larger, relatively undisturbed forest of 557 acres is required to support a pair of Cooper's Hawks. Those species requiring larger territories are becoming less common in heavily populated areas of the coastal zone due to decreasing habitat and fragmentation of existing forests. Species requiring mature forest are likewise becoming scarce due to lack of suitable habitat.

Forest-dwelling species, in addition to requiring a certain amount of space for their daily activities, may also benefit from or require a buffer zone of forest to reduce competition with edge species, and as protection from disturbance. For example, the tiny Winter Wren may occupy but 2.5 acres of a forest and yet be absent from a 2-3 acre forest tract. This may result from a lack of forest buffer in this forest fragment. The wren may also be excluded from the small forest by edge species which become more abundant as forest size decreases. Studies on the east coast have revealed that the increase in forest fragmentation and decrease in average size of forest tracts due to urbanization has led to population reductions and near extinction in several areas. Those species which have declined are typically inhabitants of the forest interior while those increasing are edge species and those tolerant of human activities.

Because the Winter Wren has one of the smallest home ranges of any forest bird, it might be assumed that 2.5 acres would be a minimum forest fragment. Planners might then be alerted to maintain forest no smaller than that to insure survival of some forest wildlife. However, in some coastal situations, smaller forest tracts, and occasionally a single tree, are critical habitat for nest or roost sites of a given species. For example, farm woodlots and scattered clumps of a very few trees in open areas are often critical habitat for birds of prey.

In general:

- large tracts of forest land are more valuable to wildlife than small patches;

- small patches of forest are most vauable when a corridor of forested or other natural vegetation connects them to larger, undistrubed forests;

- size of forest required by each species varies considerably. Large (often rare) species require larger forest tracts;

- size of forest is related to buffer effects which also vary considerably for each forest type, its relationship to other cover types, and species present. Each species may require a certain buffer width, but these data are not available for many wildlife (Refer to Bald Eagle management guidelines below for buffer zones recommended for this threatened species);

- wetland areas are enhanced by forest buffers in many ways and the required size of surrounding forest varies from site to site. A minimum of 200 feet beyond the wetland edge has been recommended in many cases;

- refer also to the Bluff, Riparian, and River and Stream Narratives for discussions of the value of forest as buffers.

BALD EAGLE MANAGEMENT GUIDELINES

(U.S. Fish and Wildlife Service 1977 Guidelines. Guidelines are being revised and current recommendations should be consulted.)

GENERAL: The purpose of these guidelines is to maintain the environmental conditions that are required for the survival of Bald Eagles in the Pacific Northwest. The emphasis will be on preventing human disturbance to eagles, particularly during the nesting season. The ultimate objective is to preserve at least present populations of eagles in Oregon and Washington.

Thus, certain human activities which are likely to disturb eagles are specified in the following sections as recommended restrictions. Although these guidelines are based on available ecological information, one cannot predict with certainty the effects of a given amount of disturbance on a particular pair of eagles. Therefore, even strict adherence to these guidelines does not guarantee continued eagle use of an area. Whoever make specific land use decisions will need to take into consideration variations in topography and the behavior of individual eagles, so that these general management guidelines can be tailored to suit local conditions.

For management purposes, the following guidelines are divided into sections on Nesting, Feeding, and Roosting. Except as otherwise noted, the guidelines apply to both public and private lands.

1. NESTING: Bald Eagles often use alternate nests in different years. The following guidelines apply equally to all nests used by any particular pair of eagles, even though a nest may not have been used for raising young for one or more years. These guidelines would apply also to any tree-nesting Golden Eagles in the forested parts of Oregon and Washington.

   Eagle-nesting territories are here divided into primary and secondary management zones. Within each, certain human activities have been found to disturb the nesting process. These disturbances are defined by the restrictions recommended for each zone.

   a. Primary Zone: This is the most critical area immediately around the nest.

      (1) Size: Except under unusual circumstances (e.g., where a particular pair of eagles is known to be tolerant of closer human activity), the boundary of the primary zone shall not be less than 330' (five chains) from the nest. The size should be adjusted by the actual use of the area around the nest tree, to include frequently used perch trees. Where isolated groups of trees are likely to blow down, the primary zone should not be less than 20 acres, and the opinion of a qualified forester should be obtained in order to take measures to minimze that likelihood.

      (2) Recommended Restrictions:

         (a) The following human activities are likely to cause disturbance of eagles, and therefore should not occur within the primary nesting zone at any time:

            1. Major land uses such as logging; the development of new commercial and industrial sites; the building of new homes; road and other construction; and mining.

            2. Use of chemials toxic to eagles. These include DDT, other persistent organochlorine pesticides, PCB, mercury, lead.

         (b) In addition, certain human activities are likely to disturb eagles during the critical period. The critical period is the time between the arrival of adults at the nest site and three weeks after the fledging of any young. In the Cascade Mountains, the critical period will usually fall between March 1 and August 15; in the

valleys and along the coast, between February 1 and July 31; and in the Kalamath Basin, between January 1 and July 31. During the first twelve weeks of the critical period, eagles are most vulnerable to disturbance.

The following human activities, therefore, should be restricted during the critical period:

1. Human Entry into the primary nesting zone.

2. Low level aircraft operations.

However, if a pair of eagles chooses to establish a new nest in an area already receiving human use, the human activities occurring at that time can continue, except the use of toxic chemicals. Any expanded human activity should be avoided.

b. Secondary (Buffer) Zone: The purpose of this zone is to further minimize disturbance.

(1) Size: The size of the secondary zone will be determined by local topography and resulting visibility from the nest. It shall lie outside the primary zone and be approximately circular, with a minimum boundary of 660' (ten chains) from the nest. If disturbance would be clearly visible from the nest in a particular direction, the secondary zone should extent ¼ mile (20 chains) in that direction.

(2) Recommended Restrictions:

(a) Certain human activities of a permanent nature are likely to disturb eagels, and they should not, therefore, occur within the secondary zone at any time. These include the development of new commercial and industrial sites, the building of new homes, the building of new roads and trails facilitating access to the nest, and the use of chemicals toxic to eagles (see above).

(b) Certain human activities have time-limited effects but are likely to disturb nesting eagles. Therefore, human entry into the secondary zone should be avoided during the critical period. Examples of this kind of disturbance are logging (including selective cutting), mining, low-level aircraft operations,

use of firearms, camping, and picnicking. Occasional and limited human intrusion, such as solitary hiking, bird watching, and fishing, will not be disturbing in most cases.

If a pair of eagles chooses to establish a new nest in an area already receiving human use, the human activities occurring at that time can continue, except the use of toxic chemicals. Any expanded human activity should be avoided.

(3) Additional Management Recommendations:

(a) On public land, close land and water access to nest. Post boundary only if necessary to reduce travel near the nest. Signs should not mention eagles or eagle nesting.

(b) On private land, the owner might voluntarily agree to protect the secondary zone; or if the integrity of the zone cannot be otherwise preserved, it should be acquired by easement or by exchange, by either a private or public conservation agency. Easements should be for ten years and be renewable.

c. Potential Nest Sites: A small but significant percentage of a bald eagle population nests in new habitat every year. Therefore, to satisfy the future nesting needs of bald eagles, it is essential to preserve suitable habitat in addition to that which is being presently used. Therefore, the following guidelines are recommended:

(1) In potential or traditional eagle habitat, where no nest now exists, for every 320 acres less than ¼ mile from a river, lake larger than 40 acres, or tidewater, leave four to six over-mature trees in the stand with an open view of and clear flight path to the water, in an area free of human disturbance. These should be the largest trees in the stand and preferably have dead or broken tops. In addition, four to six mature (80-year old) trees should be left to provide nesting sites over the long-term (50-100 years).

(2) Old Nests: Since eagles have been known to reoccupy a nest unused for several years, do not remove old nest trees, even though they have been seemingly abandoned. Trees in the surrounding primary zone should also be protected until the nest is destroyed by the elements.

2. FEEDING: The objective of this section is to allow eagles access to and use of feeding areas by instituting measures to eliminate or minimize human disturbances which prevent eagles from using such feeding areas. The following measures should be instituted by public land-managing agencies and are recommended for use on private lands:

   a. Eliminate the use of chemicals toxic to eagles in the watersheds of lakes and rivers where eagles feed. These include DDT and other persistent organochlorine pesticides, PCB, mercury, and lead.

   b. Prohibit clear-cut logging within 200' of the shoreline of such feeding waters.

   c. Discourage the construction of buildings within ¼ mile of the shoreline of feeding waters.

   d. Maintain, restore if necessary, or manage fish populations or other primary food supplies to sustain eagles.

   e. Limit fishing, recreational boating, water-skiing, and other human disturbance if adversely affecting eagle use of the feeding water.

   f. Along rivers where water flow is controllable, maintain flow rates which will not cause loss of shoreline roost or perch trees through shoreline erosion.

3. ROOSTING:

   a. Within ¼ mile (20 chains) of existing nests, outside the primary and secondary zones, save three to five old-growth trees for potential roost and perch trees during the breeding season.

   b. Any winter eagle nesting concentration should be brought to the attention of the landowner or land-managing agency, the U.S. Fish and Wildlife Service or State Wildlife Department, so that a public or private conservation agency can preserve the roost, by purchase, easement, or land exchange if necessary, subject to the availability of funds. There should be no logging within a communal roosting area. There should be no other human activity during the period of eagle use until specific management recommendations have been made.

   c. Along rivers where water flow is controllable, maintain flow rates which will not cause the loss of shoreline roost or perch trees through shoreline erosion.

Other Benefits of Forest Cover

In addition to providing wildlife habitat, forested areas perform several functions:

Floodplain forests provide valuable protection from flood damage by accomodating storm overflow; this is the least expensive and simplest way to moderate flood damage.

Upland forests throughout the coastal zone prevent erosion and loss of soil nutrients, thus conserving fertility. The presence of forest cover influences soil characteristics, increasing the rate at which water reaching the ground surface infiltrates and replenishes groundwater supply. In this role, forests act as watersheds which maintain water supplies.

Forested areas can significantly reduce wind velocity and alter wind flow patterns, influencing the microclimate of specific areas.

As natural noise barriers, it is estimated that a 100-foot width of woodland vegetation can absorb 6-8 decibels of sound.

Forested areas may improve air quality by filtering dust, ash, and other pollutants from the air.

Interrelationships with Other Cover Types

The "edge effect" - high biological diversity where habitats meet - is especially pronounced at the interface of forested and aquatic or wetland habitats. Examples of birds that require this situation include Osprey, Marbled Murrelets, Kingfishers, and Bald Eagles. All these species nest or rest in trees and feed in marsh, tide flat, or open water habitat.

Woodlands adjacent to agricultural fields and open grassland provide cover and food for many birds and mammals. Farm woodlots, and occasionally single trees or snags, are essential roosting and nest sites for

birds of prey that regularly feed over open water, including the rare and endangered Peregrine Falcon. These woodlots are particularly important on large river deltas (for example, the Skagit and Dungeness Rivers) and marshes where tree cover is limited and shorebirds and waterfowl are abundant.

Large undisturbed and unbroken forests are important corridors for daily and seasonal movements of many wide-ranging, uncommon, or secretive species such as cougar and elk. Many birds and large mammals may be excluded from small, isolated patches of coastal forest if corridors and adjacent forests are lacking. Many other factors also contribute to the presence of a given species in a forest tract.

Commercial, Recreational, and Esthetic Values

The high productivity of Washington's coastal forests is reknowned, and was a major incentive for the early settlement of the Pacific Northwest. The lumber industry continues to be a major contributor to the economy of western Washington and is dependent on coastal forests in many counties. Coastal forests also provide a variety of other commercial and recreational persuits which are dependent on maintenance of forest cover types. Local extinctions of birds and destruction of plant communities are occuring over large areas of eastern United States coastal forests due to human encroachment.With forsight and careful planning, Washington's coastal forets will continue to support wildlife, commercial activites, and the many recreational persuits which make the Pacific Northwest a unique place to live. Many persons enjoy hunting, bird watching, mushroom gathering, cutting their own firewood, or a quiet walk in the woods. These values must also be considered in decisions affecting developement within our coastal forests.

III. IMPACTS

Major disturbances affecting Washington coastal forests including logging, fire, grazing by domestic animals, and residential developement. Because they are so widespread, each of these disturbances were mapped separately, and the following discussion is arranged according to the classification system used in the Coastal Zone Atlas.

DISTURBED FOREST (No. 45)

CLEARCUT (No. 451) and SELECTIVE LOGGING (No. 453)

Logging practices generally have a profoundly destructive impact on the structure and composition of a forest ecosystem. Removal of the dominant individuals so alters the equilibrium that relatively rapid successional stages must occur until the plant community readjusts to the altered environment. Clearcuttin causes succession to revert to its initial stages by removing essentially all tree cover, and destroying much of the understory community (see Figure 451-1).

Current practices after logging include piling and burning slash to improve conditions for conifer regeneration. This activity has been shown to further impact impact the understory community.

Studies performed along the British Columbia coast demonstrate that residual coniferous forest species are more abundant on sites following logging with little burning than severely disturbed sites where species of early

Figure 451-1. A recent clearcut in Pacific County.

successional stages, e.g., red alder and wood groundsel, are characteristic. In addition, the sudden and complete removal of vegetative cover creates radical changes in environmental conditions; insolation, soil temperature, evaporation, and erosion all increase drastically. The impacts of these changes are often realized in habitats removed from the logging site. Increased siltation in streams, rivers, and estuaries have been linked to logging practices, as have increased water temperature and reduced oxygen levels in streams following clearcuts in the watershed. Detrimental effects on fish populations may be severe; an approximately 75 percent reduction in the cutthroat trout population in streams following logging has been reported from British Columbia and workers there felt it reasonable to assume long-term effects as a result of altered food resources. Refer to the River and Stream Narrative (impact section) for further discussion on logging impacts.

Effects of logging on other wildlife are essentially a reversion to early successional stages following a loss of habitat and species associated with the logged forest. It is important to note that wildlife are not displaced when a forest is clearcut, they are lost. This is due to the conditions in surrounding forests which do not allow additional species to "move in." Forest species from other areas will, however, recolonize the logged area as the forest matures, beginning with those of early successional stages.

Selective logging, usually the removal of all merchantable conifers, leaves young conifers, madrona, alder, and other broadleaf species standing. The net effect is a change in canopy composition, a decreased number of conifers, and a relative increase in broadleaf trees. Wildlife and the understory community are generally not so severly disturbed as in clearcut operations, although felling and skidding may cause considerable damage to the residual stand.

A recent study has shown that overall, birds are more abundant in unlogged forests and slightly more diverse than those in selectively logged forests. Those species which are most adversely affected due to reduction in habitat are wildlife which forage in tree foliage (e.g., warblers and kinglets) and those which glean insects from branches and tree trunks (e.g., nuthatch and Brown Creeper). Hole nesting birds and those which place their nests in branches of trees are also impacted when forests are selectively logged. Removal of mature trees poses a threat to existing or potential nest sites for birds with bulky nests such as eagles, as well as Pileated Woodpeckers, owls, and other cavity nesters.

Species which may benefit from tree removal are those which feed in air spaces between the trees and include swallows and some flycatchers. Ground foragers will increase as well as a number of early successional stage inhabitants, depending upon density of shrub cover. The dense salal which often increases following many selective logging operations may tend to reduce populations of these groups, especially ground foragers.

BURN (No. 452)

Burned sites were rarely encountered in the coastal zone. Due rapid revegetation, areas recently affected by fire were generally mapped as early successional forest.

Controlled burning is a common forest management technique, and areas mapped as clearcut may also have been burned. Literature concerning the effects of fire is voluminous, most of the work having been performed by or for the logging industry to define the effects of slash burning. Major effects and impacts of fire on forest ecosystems are summarized in Table 452-1.

OUT FIGHTING FIRE
THE WIND CHANGED
BROUGHT IT RIGHT DOWN
THE HILL
RUNNING
WE KNEW
IT WAS CATCHING US
WE LAID DOWN IN A SMALL
CREEK
WITH JUST OUR NOSES
STICKING OUT

ALL KINDS OF ANIMALS
IN THERE WITH US
SQUIRREL AND
DEER

R. BENSON

GRAZED FORESTS (No. 454)

Grazed Forests generally have an undisturbed canopy layer, although the shrub, herb, and ground layers are typically impacted by grazing and trampling. The degree of impact depends on the type of animal and amount of grazing pressure. Where pressure is heavy, understory vegetation and its associated animal community may be severely impacted.

Table 452-1 MAJOR IMPACTS OF FIRE ON FOREST ECOSYSTEMS

moisture relations	lowers infiltration rate, decreases absorptive capacity, increased runoff, increased erosion, increased possibility of flooding, retards re-establishment of vegetation
texture	altered by destruction of duff, mineral soil exposed to baking
temperature during burn	temperatures may be severe - 1,841°F. at surfaces; if not severe, some seeds stimulated by heat
temperature after fire	increased due to lack of plant cover or duff; blackened soil surface absorbs heat, often enough to kill or stress seedlings
fertility	large amounts of nutrients available in ash which may be either washed away, or replenish soil
acidity	ash incorporated in soil decreases acidity, making conditions unfavorable for conifer growth
organic content	loss of organic content has been sighted as having more significance than all other negative factors combined; soil structure, drainage, aeration, and water-holding capacity negatively affect; habitat for soil-dwelling organisms destroyed; studies in Washington report 75 percent loss after burning, still below 50 percent of normal after two years
animals	destroys soil dwelling organisms; vertebrates variously affected; deer associated with post-fire vegetation; destruction of individual nests and may threaten the survival of rare or local species, e.g., Bald Eagles; ash washing into streams and lakes has frequently killed fish
plants	vegetation following fire varies depending on severity of burn, seed source, soil type, and other factors; succession following burn is usually: moss/liverwort stage --- herbs/short-lived perennials --- shrubs/tree seedlings --- immature forest --- mature forest

Western
Trillium

CONIFEROUS FOREST (No. 41)

INTRODUCTION

Coniferous forest is the dominant vegetative cover throughout western Washington, and is one of the most abundant cover classes mapped in the coastal zone. Further subdivision of this cover type defines four age classes: Regeneration (No. 411), Pole Stage (No. 412), Second Growth (No. 413), and Old Growth (No. 414). Forests dominated by Christmas trees (No. 415) are also included in this class.

In contrast to broadleaf and mixed types, coniferous forests are characterized by a perennially dense canopy, a relatively poorly developed understory, and greater longevity. Wildlife adapted to coniferous forests are a major component of the fauna of the coastal zone.

Before the arrival of European civilization, coniferous forests comprised of huge trees clothed essentially the entire coastal zone. Presently, the character of these forests is quite different, primarily as a result of logging and urban development. Throughout Puget Sound and Admiralty Inlet, old growth coniferous forest has been largely eliminated. In and around urban centers, and generally throughout the coastal zone, early successional stages are more common than previously. This condition is reflected in recent pollen analyses performed in the Puget Sound Basin which indicate that red alder, the major seral broadleaf tree throughout the area, is the most abundant pollen. Likewise, throughout the Puget lowland, where western hemlock is the climax species, large areas are dominated by Douglas fir, the major seral coniferous tree.

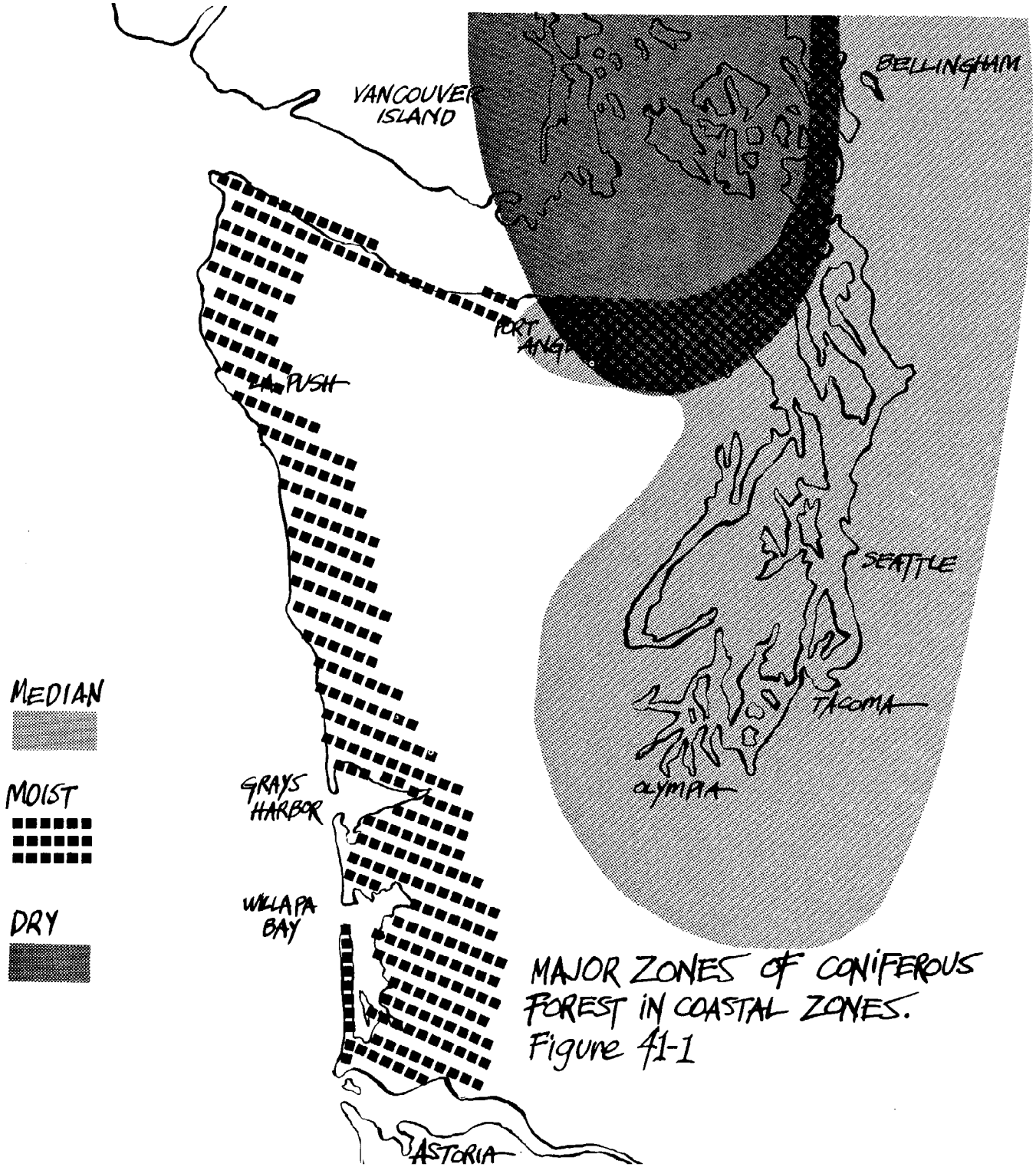
SIGNIFICANT BIOLOGICAL FEATURES

Plant Community

As a result of the environmental gradients within the coastal zone, three major zones of coniferous forest, defined by moisture availability, have been recognized (see Figure 41-1).

1) Moist coniferous forests are characteristic of the outer coast and western half of the Strait of Juan de Fuca. Western hemlock, Sitka spruce, and western red cedar are the dominant coniferous species in this zone. Forest understory is typically dark and lush, with heavy epiphytic growth of mosses, liverworts, and lichens.

2) Dry coniferous forests are found throughout the rain shadow of the Olympic Mountains, including the San Juan Archipelago, the southeast tip of Vancouver Island, the northern half of Whidbey Island, and the northeast corner of the Olympic Peninsula. These forests are dominated by Douglas fir, or a mixture of Douglas fir and lodgepole pine.



MAJOR ZONES OF CONIFEROUS FOREST IN COASTAL ZONES.
Figure 41-1

3) Forests with intermediate moisture regimes, median forests, occupy the shores of Puget Sound and the eastern half of the Strait of Juan de Fuca. Douglas fir, western hemlock, and western red cedar are the characteristic species. Grand fir and western white pine are occasional constituents of these forests, the pine playing a significant role on gravelly soils throughout the Puget Sound area by outgrowing all other coniferous species. On such sites, western white pine may grow to three feet in diameter, while Douglas fir of the same age may reach only one to one and one-half feet in diameter.

Within each of the three major zones, microclimate variation allows the development of several coniferous forest communities. Representative species from each type are presented in Table 41-1.

Productivity

Coastal coniferous forests are highly productive ecosystems. The highest value yet reported, from a coastal Oregon western hemlock forest, is 36.2 metric tons per hectare per year. As a result of this high annual productivity, J. Franklin and C. Dyrness in Natural Vegetation of Oregon and Washington report: ". . . it is not unusual to find closed mature forests . . . which have per-hectare values in excess of 100 square meters of basal area, 800 or 900 metric tons of live above ground biomass, and 2,000 cubic meters of wood volume." With the exception of the old growth western red cedar stand on Long Island, Pacific County, it is doubtful that forests of this size still exist in the Washington coastal zone, but these figures indicate the potential growth of coastal coniferous forests.

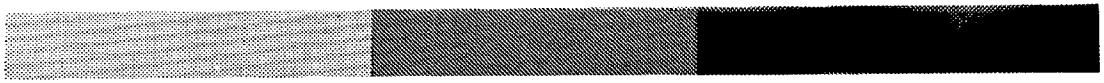
ANIMAL COMMUNITY:

Coniferous forests provide essential habitat for a wide variety of animals. Each species has unique requirements which may limit their occurrence to a specific area, plant community, or to a single successional stage. Other species may occur in all stages, move from one to another in different seasons, or require one stage for feeding and another for cover or nesting. Recent studies also show that some birds may prefer one species of conifer over another. In general, there is an increase in the number of species present in coniferous forests as succession proceeds. This is because more niches become available as the forest matures. This concept is illustrated in the Forest Narrative (No. 4) in Figure 4-5. This figure depicts the life cycle of a single coniferous tree and reflects the more complex changes which occur in the forest as a whole. These changes include the development of the canopy and understory as the forest matures and represent major structural features which determine wildlife present in a given forest. Note that each successional stage and forest type provides habitat for a particular complement of wildlife, unique to that plant community. Maintenance of the variety of animals native to coastal coniferous forests will require maintenance of the diverse plant communities upon which they depend.

See Table 41-2 for representative wildlife of coastal coniferous forests.

Table 41-1 PLANT COMMUNITIES OCCURRING ALONG A MOISTURE GRADIENT IN COASTAL ZONE CONIFEROUS FORESTS

INCREASING MOISTURE



ZONE			
MOIST FOREST	western hemlock Sitka spruce deer fern salal early blueberry red huckleberry Oregon wood sorrel	western hemlock Douglas fir Oregon grape vine maple rhododendron salal evergreen huckleberry	western hemlock Sitka spruce western red cedar sword fern vine maple devil's club salmonberry Oregon wood sorrel lady fern
MEDIAN FOREST	western hemlock Douglas fir salal red huckleberry evergreen huckleberry twinflower vanilla leaf rattlesnake plantain starflower		western hemlock western red cedar Douglas fir sword fern salmonberry Oregon grape red huckleberry enchanter's nightshade bunchberry
DRY FOREST	Douglas fir ocean spray orange honeysuckle hairy honeysuckle snowberry Oregon grape nodding onion grasses		western red cedar grand fir sword fern Oregon grape

TABLE 41-2

COASTAL CONIFEROUS FOREST FAUNA
(Species listed are potential inhabitants; occurrence in a given forest varies according to many parameters.)

SPECIES	RELATIVE OCCURRENCE[1]	REGENARATION 411	POLE STAGE 412	SECOND GROWTH 413	OLD GROWTH 414	COMMENTS[2]
BIRDS						
Great Blue Heron	C		■	■	■	Nest in colonies in large conifers. These colonies are critical habitat for Great Blue Herons.
Goshawk	U			■	■	As with all birds of prey, requires large territory. All birds of prey are protected, they cannot be hunted or killed.
Sharp-shinned Hawk	U	■	■	■	■	Species of special concern (a).
Cooper's Hawk	U	■	■	■	■	Species of special concern (a).
Red-tailed Hawk	C	■	■	■	■	Feeds in open areas, nests in trees. Common in farm woodlots.
Golden Eagle	U		■	■	■	Nests in San Juans; threatened with extinction in Washington (b).
Bald Eagle	C		■	■	■	Threatened species (c).
Osprey	U-R			■	■	Species of special concern (a). Potentially threatened in Washington and probably already threatened in coastal Washington (b).
Peregrine Falcon	R			■	■	Endangered species (c).
Merlin	U	■	■	■	■	Uncommon as nester; species of special concern (a).
American Kestrel	C	■		■	■	Uncommon as nester.
Blue Grouse	C	■	■	■	■	Game bird, edge and clearings.
Ruffed Grouse	C	■	■	■	■	Game bird, edge and clearings.
Marbled Murrelet	C			■	■	Possible nester.
Band-tailed Pigeon	C	■	■	■	■	Game bird.
Barn Owl	U			■	■	Very uncommon, but nests in forests; species of special concern (a).
Great Horned Owl	C		■	■	■	As with other birds of prey, owls are protected.
Pygmy Owl	U		■	■	■	Protected.
Spotted Owl	R			■	■	Requires old growth for nesting. Potentially threatened in Washington (b). May be extirapted from the coastal zone.
Great Gray Owl	R			■	■	Uncertain status-known from Skagit County.
Saw-whet Owl	C		■	■	■	Protected. Status is satisfactory at present in Washington (b).
Common Nighthawk	C	■				Nests on ground in open areas.
Black Swift	C	■	■	■	■	Above trees.
Vaux's Swift	C	■	■	■	■	Nest in snags.
Rufous Hummingbird	C	■				May also nest in older forests.
Common Flicker	C	■	■	■	■	Nests in and creates cavities for other hole nesters.
Pileated Woodpecker	C			■	■	Potentially threatened with extinction in Washington (b). Requires snags, mature trees.
Red-breasted Sapsucker	C		■	■	■	All woodpeckers, crows, and following birds are protected unless noted.
Hairy Woodpecker	C		■	■	■	
Hammond's Flycatcher	C			■	■	Inhabits mature forests.

Western Flycatcher	C		■	■	■	Fly out from perch in tree to snatch insects.
Western Wood Pewee	U		■	■	■	
Olive-sided Flycatcher	C	■	■	■	■	More abundant in younger forests.
Violet-green Swallow	C	■				Swallows also occur and may nest in open, mature conifers. Tree and Violet-green Swallows are hole nesters. Tree Swallows prefer sites near water.
Tree Swallow	C	■				
Barn Swallow	C	■				
Steller's Jay	C	■	■	■	■	Commonly referred to as "blue" jay.
Common Raven	C			■	■	Intelligent-mythical.
Common Crow	C	■	■	■	■	Ubiquitous in coastal zone.
Black-capped Chickadee	C	■				May occur in mature forest, common in broadleafs.
Chestnut-backed Chickadee	C	■	■	■	■	The common chickadee of coastal conifers.
Common Bushtit	C	■		■	■	
Red-breasted Nuthatch	C		■	■	■	Forage along tree trunks, nest in cavity.
Brown Creeper	C		■	■	■	Nest in cavity or beneath loose bark.
House Wren	C	■				
Winter Wren	C		■	■	■	Common on forest floor.
Bewick's Wren	C	■				May occur in open mature forests.
Robin	C	■	■	■	■	
Varied Thrush	C	■	■	■	■	Nest in dense conifers.
Hermit Thrush	C		■	■	■	Migrant and winter.
Western Bluebird	U/R	■				Nest where snags remain in "naturally" regenerating forest; species of special concern (a).
Golden-crowned Kinglet	C		■	■	■	Resident kinglet.
Ruby-crowned Kinglet	C		■	■	■	Migrant and winter.
Bohemian Waxwing	U	■				Migrant and winter.
Cedar Waxwing	C	■				May nest in older forests, in edge and open situations.
Starling	C					Not protected; introduced and increasing especially near developed areas.
Solitary Vireo	C			■	■	Open conifers.
Yellow-rumped Warbler	C		■	■	■	Warblers consume large numbers of forest insects.
Black-throated Gray Warbler	C		■	■	■	
Orange-crowned Warbler	C	■				
Townsend's Warbler	C		■	■	■	
Hermit Warbler	U			■	■	Southwest Washington in mature conifers.
MacGillivray's Warbler	C	■				
Wilson's Warbler	C	■				
Brown-headed Cowbird	C	■	■	■	■	Nest parasite.
Western Tanager	C		■	■	■	Insectivorous.
Black-headed Grosbeak	U	■				
Evening Grosbeak	C	■	■	■	■	Often attracted to bird feeders.
Purple Finch	C		■	■	■	
Pine Siskin	C		■	■	■	Seed eater.
Red Crossbill	C		■	■	■	Bill adapted to eat conifer seeds.
Rufous-sided Towhee	C	■	■	■	■	
Dark-eyed Junco	C	■	■	■	■	Commonly referred to as "snowbird."
White-crowned Sparrow	C	■				Sparrows may also occur or nest in open mature conifers, e.g., San Juan (No. 412 areas) white-crowns are common.
Fox Sparrow	C	■				
Song Sparrow	C	■				

TABLE 41-2 continued

SPECIES	RELATIVE OCCURRENCE[1]	TROPHIC RELATIONSHIP[3]	REGENARATION 411	POLE STAGE 412	SECOND GROWTH 413	OLD GROWTH 414	COMMENTS[2]
MAMMALS							
Dusky shrew (Sorex obscurus)	C	CARN		■	■	■	Shrews are active year round, consume insects on forest floor.
Vagrant shrew (S. vagrans)	C	CARN	■	■	■	■	Ubiquitous.
Pacific water shrew (S. bendirii)	U	CARN			■	■	Wet forests.
Masked shrew (S. cinereus)	R	CARN		■	■	■	Shrews and other small mammals are important in forest ecosystem. Prey of several hawks and owls.
Trowbridge shrew (Sorex trowbridgii)	C	OMNI	■	■	■	■	Large shrew, also eats Douglas fir seeds.
Townsend's mole (Scapanus townsendii)	C	CARN	■				Openings in older forests.
Coast mole (S. orarius)	C	CARN	■				Brushier areas than Townsend's mole.
Shrew-mole (Neurotrichus gibbsii)	C	CARN		■	■	■	Unique to Pacific Northwest.
Little brown myotis (Myotis lucifugus)	*	CARN					*Little known about relative occurrence, habitats, and other life history features of bats in Washington forests. Most species listed were noted to occur in conifers in a recent Oregon study.
California myotis (Myotis californicus)		CARN					
Long-eared myotis (Myotis evotis)		CARN					
Long-legged myotis (Myotis volans)							
Hoary bat (Lasiurus cinereus)		CARN					Bats, like many small birds, are valuable as insect predators. In addition, bats are prey of nocturnal predators including the rare Spotted Owl.
Silver-haired bat (Lasionycteris noctivagans)		CARN					
Big brown bat (Eptesicus fuscus)		CARN					
Pallid bat (Antrozous pallidus)		CARN					
Snowshoe hare (Lepus americanus)	C	HERB	■	■	■	■	Game animal, prey of larger carnivores including bobcats.
Mountain beaver (Aplodontia rufa)	C	HERB		■	■	■	Unique to Pacific Northwest.
Townsend chipmunk (Eutamias townsendii)	C	OMNI	■	■	■	■	In brushy areas of older forests.
Douglas squirrel (Tamiasciurus douglasii)	C	OMNI		■	■	■	Consumes large amounts of mushrooms.

Northern flying squirrel (Glaucomys sabrinus)	C	OMNI		■	■	■	Nocturnal.
Deer mouse (Peromyscus maniculatus)	C	OMNI	■	■	■	■	Ubiquitous small mammal, prey of many carnivores.
Bushy-tailed woodrat (Neotoma cinerea)	U	HERB		■	■	■	Little known regarding status in coastal forests.
Gapper red-backed mouse (Clethrionomys gapperi)	C	OMNI		■	■	■	
Pacific jumping mouse (Zapus trinotatus)	C	HERB	■				Also openings in older forests.
Porcupine (Erethizon dorsatum)	U	HERB		■	■	■	Little known about status in coastal forests.
Red fox (Vulpes fulva)	C	OMNI	■	■	■	■	Edges
Wolf (Canis lupus)	R*	CARN					*Extinct in coastal zone. Potential re-introduction to Olympic National Park
Coyote (Canis latrans)	C	OMNI	■	■	■	■	Edges
Black bear (Ursus americanus)	C	OMNI	■	■	■	■	Game animal.
Racoon (Procyon lotor)	C	OMNI		■	■	■	Edge in older forests, common near water.
Marten (Martes americana)		CARN		■	■	■	
Fisher (Martes pennanti)	R	CARN			■	■	May be present only on Olympic Peninsula in coastal zone. Regarded as rare by the Washington Chapter of the Wildlife Society.
Mink (Mustela vison)	C	CARN					Coastal or freshwater edge.
Long-tailed weasel (M. frenata)	C	CARN	■	■	■	■	
Short-tailed weasel (M. erminea)	C	CARN	■	■	■	■	
Striped skunk (Mephitis mephitis)	C	OMNI	■	■	■	■	Most abundant at coastal edge.
Spotted skunk (Spilogale gracilis)	C	OMNI	■	■	■	■	
River otter (Lutra canadensis)	C	CARN					Coastal or freshwater edge only.
Cougar (Mountain lion) (Felis concolor)	U/R	CARN	■	■	■	■	Cougars may be restricted to Olympic Peninsula and Southwest Washington in coastal zone. Considered rare by Washington Chapter of the Wildlife Society.
Bobcat (Lynx rufus)	C	CARN	■	■	■	■	
Elk (Cervus elaphus)	C	HERB	■	■	■	■	Olympic Peninsula, Southwest Washington. Game animal.
Black-tailed deer (Odocoileus hemionus)	C	HERB	■	■	■	■	Valuable game animal. Also one of the most highly regarded and familiar of "watchable" wildlife.

LEGEND :

1. Relative Occurrence:
   (refers to relative occurrence in Western Washington)
   - C = Common
   - U = Uncommon
   - R = Rare

3. Trophic Relationship:
   - CARN = Carnivore, including insectivores
   - HERB = Herbivore
   - OMNI = Omnivore

2. Comment:
   - (a) species of special concern are those included in the National Audubon's Blue List for 1978
   - (b) status as listed in Washington Department of Game and Ecology. 1975. Marine Shoreline Fauna of Washington, a Status Survey. (edited by Randall L. Eaton).
   - (c) threatened and endangered species are those listed by the United State Fish and Wildlife Service.

REGENERATING CONIFER (No. 411)

INTRODUCTION

Regenerating conifer forest is an early successional stage occurring throughout the coastal zone, although less common than regenerating stands of mixed or broadleaf forest. Stands are most frequently dominated by Douglas fir or hemlock, although occasionally in Mason County and on other dry sites, lodgepole pine may be the dominant species. Stand density varies from open (10' - 20' between trees) to very dense, in some cases forming nearly impenetrable stands. Canopy height of individual stands varies from several to approximately twenty feet. Regenerating conifer stands may develop following such severe disturbances as logging and fire, and often develop following the abandonment of agricultural fields.

SIGNIFICANT BIOLOGICAL FEATURES

Two very different types of stands are included in this class: Open stands are common on moist sites where forest management practices have eliminated broadleaf species regenerating with the conifers. Dense stands are typical of drier sites on which natural regeneration of Douglas fir is rapid and competition from broadleafs less severe. Especially common in Clallam County are logged-off sites replanted with Douglas fir seedlings and managed to yield maximum timber production. On such sites, trees are widely spaced, and the well-developed shrub and herb layers are heavily used as feeding habitat by many wildlife species. As the canopy layer provides more shade, intolerant understory species may be eliminated, but nevertheless a conspicuous understory is present from the earliest stages of forest regeneration. The presence of a well-developed understory is in sharp contrast to the second type of regenerating conifer stand commonly found in the coastal zone. Less intensely managed or natural stands typically develop as dense stands of Douglas fir, hemlock or as mentioned previously, lodgepole pine. Understory development is usually very poor in these stands, a result of the dense canopy cover and the disturbance or land use that generally precedes such a stand. Fire, logging, and agricultural activities often completely destroy the forest cover. Reestablishment of conifers at a site may be delayed until the site is sufficiently developed to support them. Animals, which disperse seeds, and proximity of seed and spore sources and several physical factors affect this reestablishment.

Wildlife Value

The value of a particular site to wildlife varies greatly, depending on location, size, and many other factors. In general, dense stands of regenerating conifers with little or no understory will not support as wide a variety of species as more open regenerating forests. However, these dense stands do provide nest sites, perches, cover, and foraging areas for wildlie. Perhaps of more significance, dense conifer stands and all early successional stages are potential older forests. This point may seem obvious, but coastal forests are rapidly disappearing to other land uses and the value of a particular forest should consider its future as well as current value. Thus, it may be thought economically justified to convert young forests to other uses because of their current low value as timber and wildlife habitat. A longer range evaluation is that these are the highly valued mature coastal forests of the future.

Characteristic Birds and Mammals

A great deal of bird and mammal feeding activity occurs in regenerating conifers. Those areas with snags or a few older trees remaining also provide habitat for trunk foragers, cavity nesters, and birds such as hawks which require a high perch. Open regenerating stands are especially productive. Primarily used as forage sites, they also provide nest and resting sites in shrubby thickets and tangles around fallen logs and stumps.

Breeding species include Fox Sparrows, Bewick's Wrens, and Townsend's chipmunks. Wildlife which are often abundant foragers in regenerating conifer forests include Band-tailed Pigeons, Cedar Waxwings, black bear, coyotes, black-tailed deer, and elk. Birds of prey such as the Red-tailed Hawk are also often present. Representative species of ground and shrub layers are discussed below:

Ground Layer

Vagrant Shrew

Occurs in a wide variety of habitats including regenerating conifers. These tiny [¼ oz. (7.8g)] insectivores tunnel beneath fallen logs and somewhat in the soil layer. Like many other small mammals, shrews contribute significantly to forest ecosystems. They consume numerous insects and in turn are prey of hawks, owls, and other predators.

Deer Mouse

These ubiquitous, large-eared mice are active throughout the year on the forest floor where seeds and insects are consumed.

Coyote

Coyotes very often occur in regenerating forests, especially in more open areas where small mammals and berries are abundant. Long persecuted by humans, the coyote preys on many small mammals considered pests by tree growers.

Common Nighthawk

Nighthawks feed on insects overhead, and are a delight to see and hear in the summer sky. Their swift descent and upward looping flight is accompanied by a whir from their wings and a continuous call of "peent." Their long wings give the appearance of their namesakes, but they are not hawks. Nighthawks are related to whip-poor-wills and other nocturnal, insectivorous members of the family Caprimulgidae. Most often active in the evening, nighthawks are common in open areas and nest on the ground in open regenerating forests.

Common Flicker

The flicker is a woodpecker which feeds mostly on the ground, taking a wide variety of insects including ants. Requires open ground for feeding and older forests for nesting.

Robin

Ubiquitous, robins frequently are observed in regenerating conifers.

Dark-eyed Junco

Juncos are also known as snowbirds and are one of the most abundant land birds in western Washington. They nest and feed on the ground. Ants, beetles, and leaf hoppers are major food items in spring and early summer, while seeds are consumed throughout the rest of the year.

Red-tailed Hawk

Red-tails feed on small mammals which often occur in large numbers in regenerating conifers. They nest in mature forests or woodlots.

Shrub and Canopy Layer

Sharp-shinned Hawk

These small hawks feed largely on birds which are often abundant in berry producing shrubs. Like most other predators which occur in regenerating conifers, they require mature forests as breeding habitat. Sharp-shinned hawks also hunt in mature forests and are adapted to aerial pursuit among the trees.

Blue Grouse

Grouse feed on berries and foliage of shrubs in open regenerating forests and nest and roost in older forests.

Interrelationships with Other Land Cover Types

Regenerating conifer stands are most heavily used as feeding areas, and to be of greatest value, it is important that adequate corridor, resting, nest and cover habitat is accessible. Without their presence, the value to wildlife of a particular site may be greatly reduced. Nearby stands of older forests are important for the cover they provide.

IMPACTS

Managed regenerating conifer stands are often sprayed with herbicides to reduce competition from broadleaf species. While the developing conifers may benefit, value of the site as wildlife habitat may be greatly diminished. Loss of browse and berry-producing plants is primarily responsible for the reduction, with loss of cover a contributing factor. Soil characteristics may also be affected by herbicide treatments, particularly through the loss of plant species with nitrogen-fixing capabilities, and decreased amounts of detritus.

Soil development may also be adversely affected if the nutrient enriching red alder stage is by-passed. It is a current irony in forest practices that broadleaf species are eliminated to benefit conifers. Succession would have also "eliminated" the broadleafs in a longer time period, while naturally fertilizing the soil and ultimately benefiting coniferous growth.

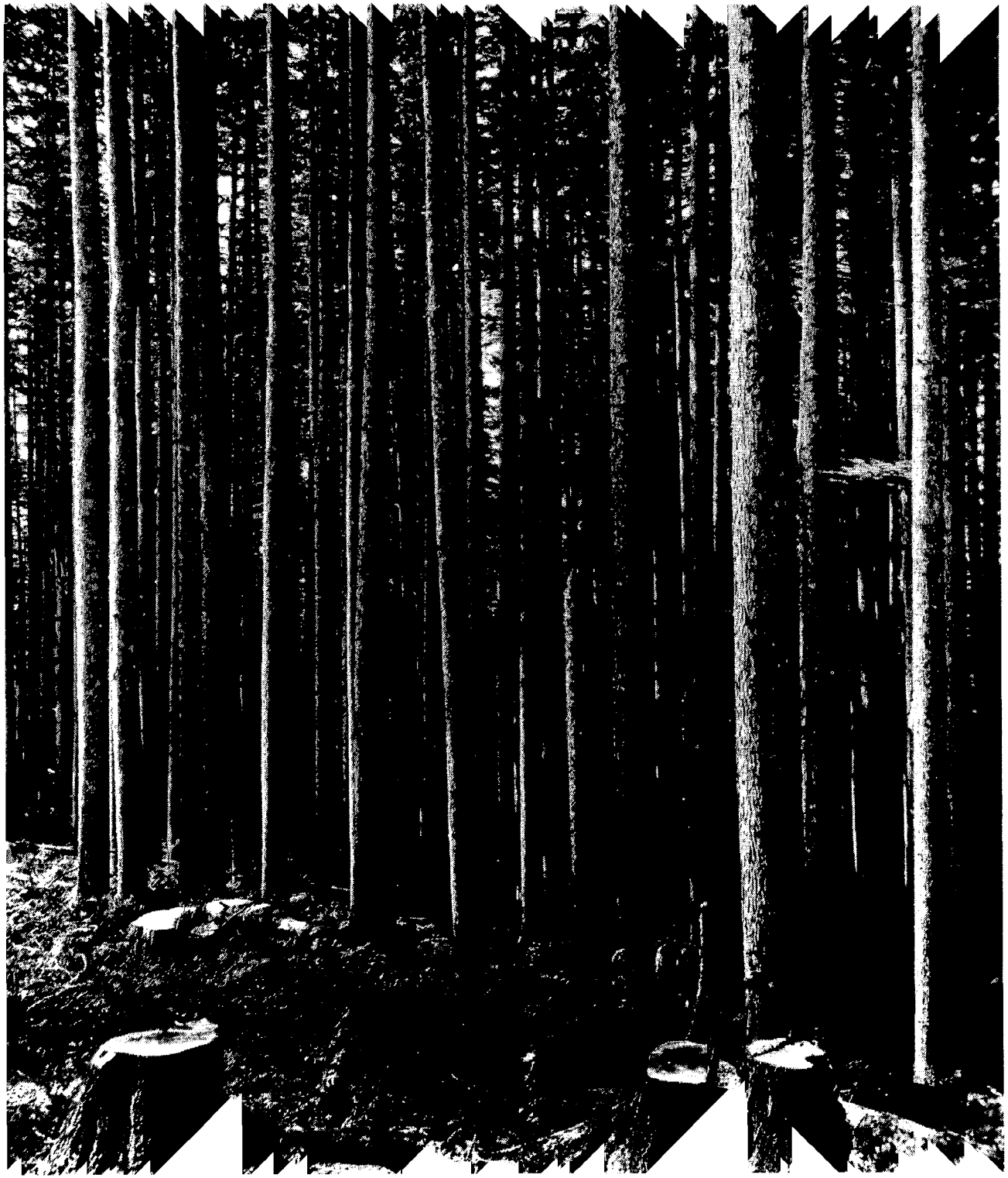


Photo by Darius Kinsey.
Courtesy University of
Washington Photography
Collection.

POLE STAGE CONIFER (No. 412)

INTRODUCTION

Pole stage conifer forest occupies a large portion of the total forest cover found in the coastal zone. Individual tracts vary from less than one acre up to large stands covering hundreds of acres, particularly in Clallam and Mason counties. In sum, this forest class is only less extensive than Second Growth Mixed Forest, and represents a significant wildlife habitat resource.

Forest communities included in this class are very different, reflecting the strong environmental differences found throughout the coastal zone. Over a majority of the area, especially around Puget Sound, Admiralty Inlet, and along the Strait of Juan de Fuca, pole stage conifer stands are dominated by dense, even-aged Douglas fir. On drier sites, notably in the San Juan Islands and gravelly soils in southern Puget Sound, the canopy layer is often less dense, and lodgepole pine may be mixed in with Douglas fir, or be the sole dominant. In the wet outer coast counties, western hemlock forms mixed or pure stands.

Regardless of what the dominant species may be, an even-aged stand of relatively young conifers (approximately 20-40 years), a closed canopy layer, and suppressed understory development are constant characteristics of pole-stage communities. Structure and composition of the understory varies greatly in response to environmental factors and previous disturbances, from a dense tangle of salal and other shrubby species to almost bare forest floor.

Whatever the case, significant change in the understory is delayed until the canopy begins to open up late in this stage. Stand density has been estimated as high as 20,000 trees per acre at twenty years, and decreasing to approximately 75-100 trees per acre at the end of the first century.

Pole stage forest is a relatively short-lived seral stage preceding Second Growth Forest, typically a complex, diverse, and excellent wildlife habitat type.

Heavy logging of our lowland forests during the early part of this century is the primary force responsible for the vast acreage of pole stage present in the coastal zone, and timber production continues to play a prominent role in the creation of these forests. Pole stage forests have always been present as a result of natural disturbances, but impacts which cause forest succession to revert to its earliest stages have greatly increased the acreage. Presently much pole stage coniferous forest is being altered to low density housing and wooded residential use. Such

activity permanently lowers the value of a site as wildlife habitat. For a complete discussion of the impacts associated with this type of disturbance refer to the Urban Narrative (No. 1).

SIGNIFICANT BIOLOGICAL FEATURES

Coastal pole stage conifer forests help fulfill habitat requirements for a wide variety of wildlife. At this stage of forest development, tree trunk and tall canopy cover become available for wildlife use, and many organisms typical of older coniferous forest habitats frequent pole stage stands. At every level in the forest, birds can be observed. Great Blue Herons perch and nest high in the canopy. Golden-Crowned and Ruby-Crowned Kinglets, Pine Siskins, and Western Tanagers forage in the canopy layer, consuming seeds, berries and insects. Wildlife is often less abundant in the understory however, due to a reduction of the shrubs which are so abundant in younger regenerating forests.

The pole stage conifer stands occurring in the San Juan Islands deserve special mention. Due to the general dryness of the area, community structure and composition is frequently different than that found elsewhere. Many of the stands are more open, with a well developed shrub and herb layer. In this respect, they are similar to Second Growth Forest, and value to wildlife is accordingly higher.

Characteristic Species

Ground Layer (Development of the ground layer varies greatly with openness of the canopy, although shrub cover is typically sparse.)

Representative species inhabiting the ground layer include:

Varied Thrush

These resident birds are also known as Alaska robins and are commonly observed in winter at bird feeders and backyards. During the breeding season, they prefer forested habitat and have been observed at this time in coastal pole stage conifers. Most feeding in forested areas occurs on the ground where prey includes beetles, ants, millipedes, centipedes, crickets, and land snails.

Douglas Squirrel

These squirrels require trees for escape, nest building and feeding. However, much feeding activity also occurs on the ground. Fir cones are gathered and consumed on the forest floor and significant amounts of mushrooms are also eaten. It has been estimated that mushrooms comprise as much as 56 percent of the total yearly diet (by volume) of the Douglas squirrel. Mushrooms consumed include Boletes, Suillus species and the Russulas which are very abundant on the forest floor in pole stage conifers.

Black-tailed Deer

Deer often feed in openings, but require forested areas include pole stage conifers for cover. Feeding also occurs here, particularly in more open areas such as pole stage/successional shrub (No. 4121). Deer or their sign were noted on all visits to pole stage stands during this study.

Humans

A significant amount of forest use occurs in coastal coniferous forests, including pole stage. Trees are

well developed and the open understory provides a pleasant forest experience for recreational activity. Commercial activity includes the first stage of timber harvest in coniferous forests, brush picking, and mushroom gathering.

Shrub/Subcanopy Layer

Shrubs are more fully developed in areas mapped as pole stage/successional shrub (No. 4121). This layer is most often reduced in pole stage conifers, therefore, many species found in earlier successional stages are absent. Species using open pole stage forests with a well developed shrub layer include those noted for regenerating conifers. Additional use in pole stage includes nesting by forest birds and foraging in the air space beneath the canopy. Representative wildlife of the shrub and subcanopy layer include:

Saw-whet Owl

Owls and some hawks hunt in the air space beneath the canopy of coniferous forests. Although much feeding is on ground dwelling rodents and large beetles, they are included in this layer to emphasize the importance of diversity in forest structure. Thus, these small owls require tree cover for roosting, branches in the subcanopy for a perch, cavity for nesting, and a source of prey on the forest floor.

Canopy/Trunk

There is a significant increase in tree height at this successional stage and a corresponding increase in use, particularly by birds, of the canopy and tree trunks. Where snags persist, additional habitat is available, particularly for cavity nesters: woodpeckers, chickadees, flycatchers, and other insectivores which appear at this stage of forest succession as a result of development of canopy and trunk habitat. Representative species include:

Great Blue Heron

Herons frequently perch in conifers and the more mature pole stage forests may support nesting colonies. Most pole stage forests at the coastal edge are used as roosting sites by these impressive birds.

Sharp-shinned Hawks

These small hawks have short, rounded wings and a long tail which are adaptations for hunting small birds in the forest. Hunting may occur at all levels, and nests are platforms constructed of twigs as high as 70 feet up in the canopy (may also be as low as ten feet). Although small, Sharp-shinned Hawks, like other predators require a large territory and nesting may be limited in the coastal zone because of reduced forest zine. Territory size is estimated to be 246 acres. Reproductive success may also be declining due to high levels of pesticides which lowers hatching success.

Bald Eagle

Use of pole stage conifers by Bald Eagles is probably limited to roosting. The large platform nests of eagles require more mature trees. However, pole stage conifers are important, especially at the coastal edge and along clearings, particularly in the San Juan Islands where Bald and Golden Eagles have been observed perched in these forests.

Hairy Woodpeckers

Hairy Woodpeckers are an example of the increase in species associated with the availability of trunk space as conifers reach this seral stage. Hairys are medium-sized woodpeckers, predominantly black and white. The male has a small patch of red on the back of the head. Hairy Woodpeckers feed on the trink and along dry branches where wood-boring grubs and larvae are consumed. They are also known to feed on tent caterpillars. They excavate their own nest hole, usually in a live tree and seldom reuse the same nest site. Other hole nesting birds unable to excavate, such as chickadees and nuthatches, are then able to use the old nest site.

Chestnut-backed Chickadee

Of the two chickadees common in the coastal zone, the Chestnut-backed is more often associated with conifers. They occur here throughout the year most foraging for insect prey occurs in the canopy.

Ruby-crowned Kinglet

These small birds also forage for insects in the canopy, but only occur in winter and during migration. During this time, small insectivorous birds form mixed flocks, which aid each species in predator avoidance and in food finding. Flocks might include chickadees, kinglets, nuthatches, and occasionally a Downy Woodpecker. These mixed flocks consume large numbers of insects.

Brown Creeper

These small wren-like birds forage along tree trunks, and are especially common in pole stage conifers in the San Juan Islands. Brown Creepers have stiff tails which act as a brace as they move along the trunk and branches (usually from bottom of tree upwards) searching for insects in bark crevices.

POLE STAGE/SUCCESSIONAL SHRUB (No. 4121)

This class was developed to accommodate those pole stage sites that are commercially thinned to allow better conifer growth. These sites are not common, but at least small patches occur throughout the coastal zone. In addition to improving the growth of the residual timber, the thinning process opens up the canopy layer, allowing development of the understory due to increased light penetration. Dense shrub layer vegetation produces browse for herbivorous species, and cover and nest sites for many birds. (Refer to the Successional Shrub Narrative, No. 321.)

MATURE SECOND GROWTH CONIFER (No. 413)

INTRODUCTION

In common usage "second growth" refers to forests that have regenerated since the original forests were removed by early settlers. However, forests mapped as Second Growth (No. 413) in the Coastal Zone Atlas are restricted to mature coniferous forests, approaching the size and features of virgin or old growth stands.

Second growth coniferous forests exhibit a well-developed community structure. At this stage in succession, dominant trees are large, the canopy begins to open, shrubs and subcanopy intergrade with ground and canopy layers, and a lush ground cover is usually present. Snags and stumps are more numerous than in previous stages as well as dead limbs, broken-topped trees, and fallen logs. This increase in mass of vegetation and structural diversity creates a corresponding increase in available niches. As a result, second growth forests support significant numbers of wildlife species.

Changes in the structure and species composition of a second growth stand happen slowly. Tree height increases, some trees die, and as the canopy opens, increased light penetrates the coniferous cover which had been so dense during pole stage.

One important change occurring as these forests mature is the development of a rich ground layer covered with organic matter. Ground dwelling species occur where mosses, fallen logs and wet spots create additional habitat for small mammals as well as birds, amphibians and some reptiles. Tremendous amounts of organic matter fall to the forest floor where nutrients flow through detrital food chains much as they do in marine systems. Species involved are not the same and physical transfer of organic matter is different, but there are many similarities. In fact, much of the organic matter produced in coastal forests enters aquatic food chains. For example, most nutrients supplied to coastal lakes and streams are derived from surrounding forests and significant amounts also support marine systems. Known as watersheds, these forests supplying nutrients through flowing water form the base of many aquatic food webs.

The second growth period is a relatively long stage, spanning approximately 150 years, during which time these impressive forests become difficult to distinguish from the virgin forests which once were the dominant vegetative features in the coastal zone.

Second growth conifer forests are relatively uncommon, occuring mostly along the Strait of Juan de Fuca, portions of Hood Canal, San Juan Islands, and along southern Puget Sound in Mason County.

Photo by Darius Kinsey.
Courtesy University of Washington
Photography Collection.

SIGNIFICANT BIOLOGICAL FEATURES

Large stands of second growth conifers are relatively uncommon in the coastal zone. This is attributed to heavy disturbances in the past and the significant commercial value of these older forests.

Second growth forests are highly productive and complex, and are capable of supporting plant and animal species not found in younger forests. Because of their rarity, diverse vegetation, and value as wildlife habitat, areas mapped as second growth should indicate to planners that the area has high biological significance, similar to old growth forests. These areas should be considered for preservation in an undistrubed state.

Interactions of soil, climate, and flora and fauna through the decades have combined to produce an ecosystem that spreads far beyond the phsyical limits of the forest tract. These forests have a strong influence on local climate, drainage patterns and the overall value of a large area as wildlife habitat. One of the major contributions of these older forests to other habitats involves the flow of nutrients derived from decaying trees and other plant matter. Contrary to a commonly held belief, these older forests provide much new life as the decaying processes of the forest accelerate. A decaying forest is not an unhealthy forest. Rather, decay within the forest is a natural process, providing organic matter utilized by many plants and animals within the forest itself and in other habitats.

Organic matter is recycled within the forest and provides a base for the establishment of the lush ground, shrub, and understory layers. The added vegetative diversity as the forest matures provides habitat for wildlife throughout the forest levels. This organic matter is also washed into streams and coastal lakes as well as into marine areas where detritus and nutrients provide a base for aquatic food webs supporting many commercially and recreationally valuable species.

Structural changes at this stage in succession provide significant wildlife habitat. The deep litter layer is occupied by small mammals, while root tangles and stumps offer nest sites for birds. In the subcanopy, branches of shrubs and regenerating conifers provide nest and roost sites and high in the canopy, the large platform nests of Bald Eagles are supported by trees which will grow to 90 meters.

GIANT FAWN-LILY

Mountain Beaver

Characteristic Fauna

Ground Layer

(Nesting, burrowing, also feeding by inhabitants of other strata)

Winter Wren

One of the smallest forest birds, the Winter Wren has a song which has been likened to a bubbling stream rushing over stones. Nests are placed on or near the ground, but a tall overstory such as occurs in these forests appears to be essential for maximum Winter Wren densities. Nests may also be placed in tree root tangles, and roost sites may be in woodpecker holes higher in the trees. Daily ranges of these tiny birds have been estimated to be about 200 feet and home ranges are from one to two and one-half acres.

Dark-eyed Junco

The junco or "snowbird" is one of the most abundant birds in western Washington. Ground nesters and feeders, they require open areas in the forest where seeds, ants and beetles are part of their diet. Juncos breed in coniferous forests and move into more open areas such as parks and residential areas during winter, providing a source of enjoyment to bird watchers during the colder months.

Shrew-Mole

These moles are indeed much like the shrews as their common name suggests. These insectivores, unique to the Pacific Northwest, have broadened front feet used to burrow in the litter layer. Local studies have shown them to be most common in forested areas with high soil organic content and little understory. Their range includes the entire coastal zone of Washington although they have not been reported from the San Juan Islands.

Gapper Red-backed Mouse

These small mammals resemble meadow mice, but occur primarily in dense coniferous forests. They feed on seeds, insects and mushrooms and are in turn a source of prey for owls and carnivorous mammals including bobcats. Small mammals such as red-backed mice represent an important link in food webs of forests and reflect the transfer of nutrients from one habitat to another. Thus,

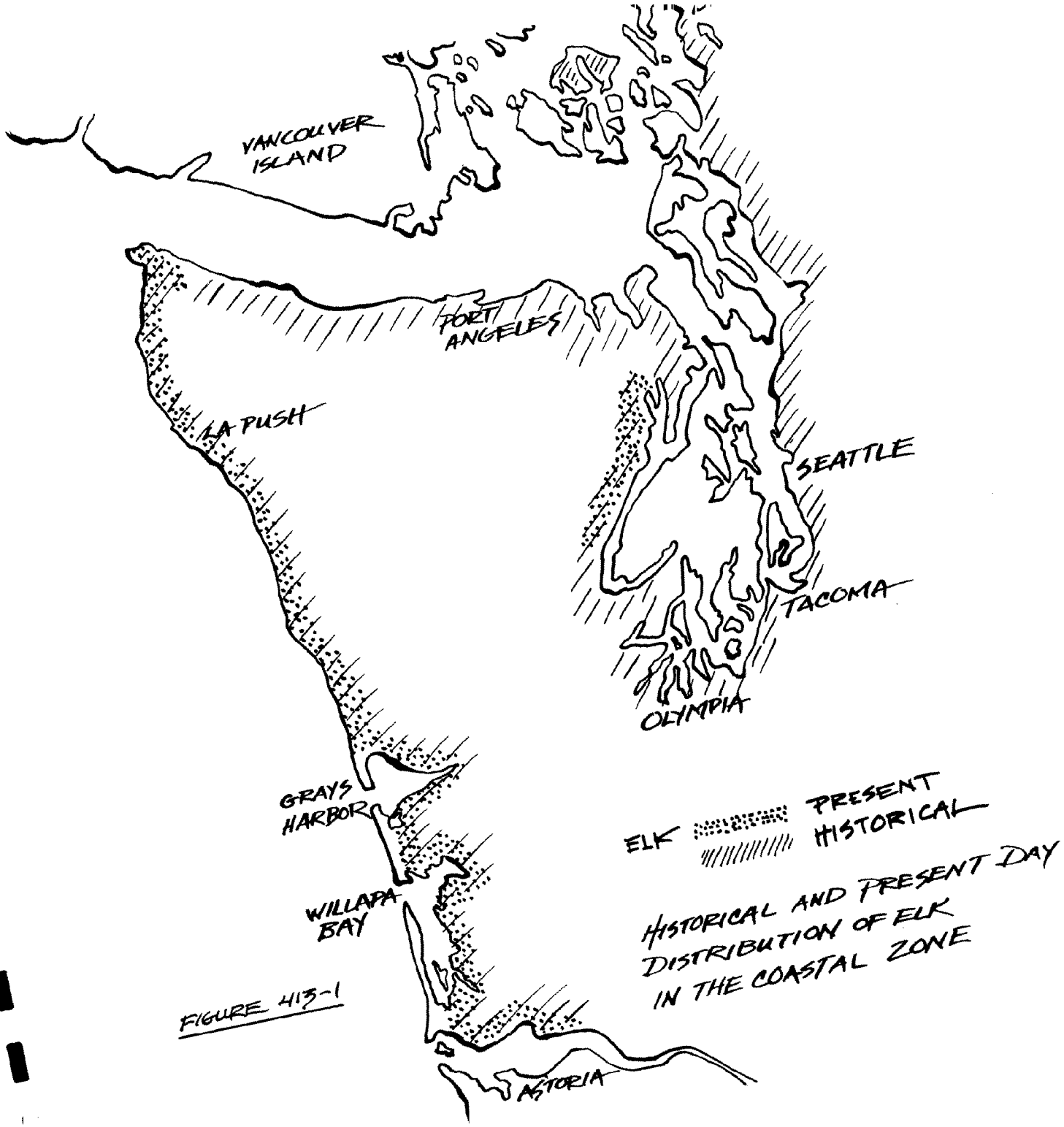
plants on the forest floor are eaten by these mice, which are preyed upon by owls and other predators, migrate great distances from the coastal forest at other times of the year.

Elk

Elk are large relatives of deer which occur in the coastal zone primarily on the Olympic Peninsula and in southwestern Washington. See Figure 413-1 for an elk distribution map. Like deer, elk often feed in more open areas, but require forested areas for thermal and escape cover. Elk are pursued by hunters who value them very highly. More than $32 million were estimated to have been contributed to the state's economy by elk hunters in 1978 alone. Their large size offers a substantial food source to predators other than humans, including cougars and at one time, wolves. Forage plants include sedges, grasses, maple, willow, deer fern, and western hemlock.

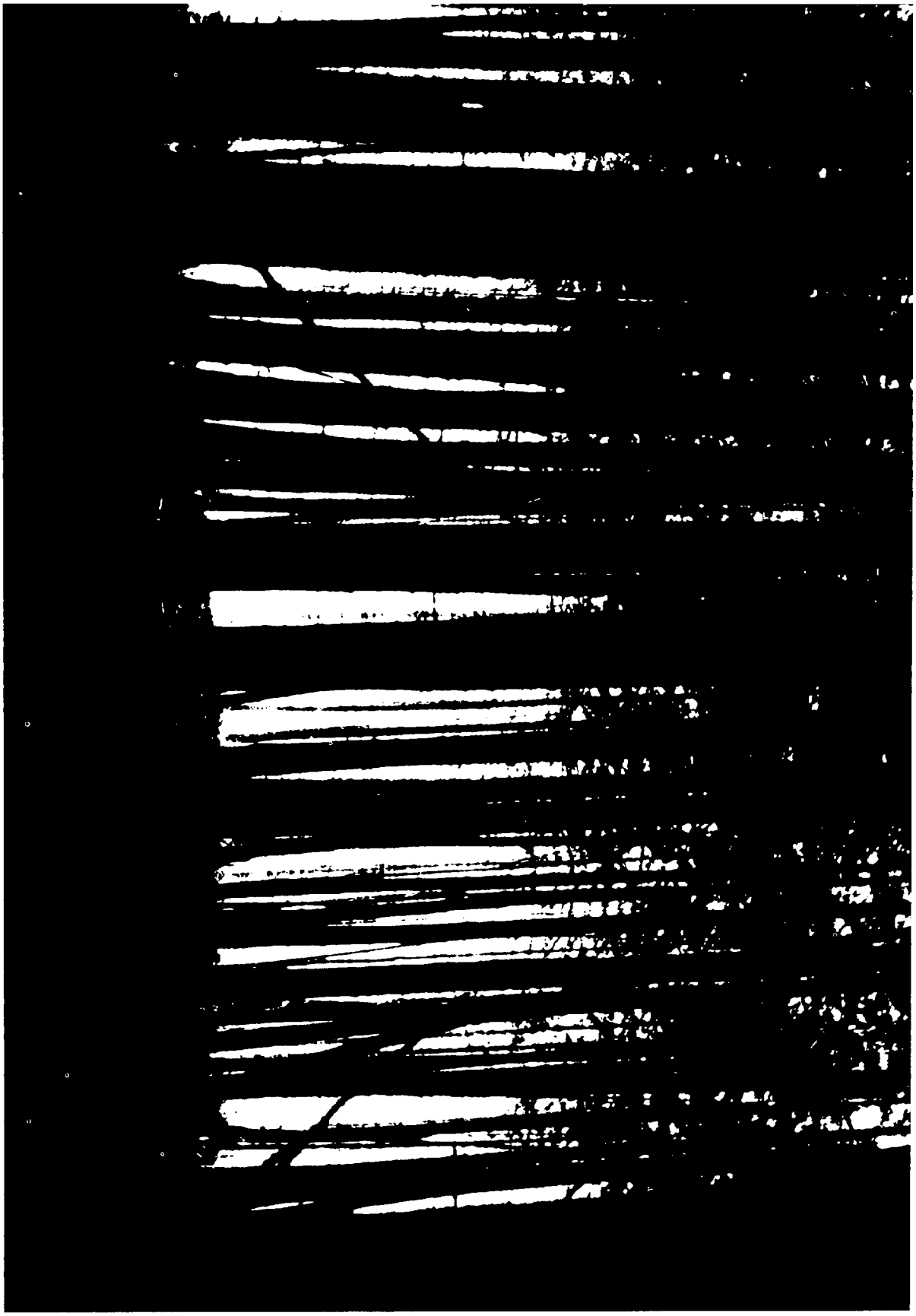
Cougar

These large cats, also called mountain lions and pumas, represent the pinnacle of forest food webs. Because of their large size, territorial requirements, shared position at the top of a food web which include humans, and persecution by man, the cougar is rare today in the coastal zone. Second growth forests offer protected habitat where cougars might continue to persist.



HISTORICAL AND PRESENT DAY DISTRIBUTION OF ELK IN THE COASTAL ZONE

FIGURE 413-1



Amphibians and Reptiles

Moist spots on the forest floor and beneath fallen logs provide habitat for a number of salamanders, some of which live their entire lives away from standing water. These woodland salamanders include the Dunn's salamander of southwestern Washington and the more widely distributed western red-backed salamander. Both these salamanders are lungless. Breathing is through their moist, slippery skin. Eggs are laid beneath rotting logs where the young emerge fully formed. Other amphibians which occur here include the rough-skinned newt which has an aquatic larval stage. Reptiles are limited, but may be represented by the Northwestern garter snake occurring primarily in clearings or at the forest edge in dense undercover.

Shrub Layer

(Provides nest and feeding sites for insectivores and wildlife which consumes seeds, fruit, and foliage. More open areas will offer shrub habitat for some species discussed in younger forests.)

Black-tailed Deer

Deer often browse shrubs in forested areas. Other herbivorous mammals, such as mountain beavers and elk, also forage here.

Townsend's Chipmunk

Chipmunks occupy the shrub layer and are also common in more open shrubland or younger forests. The familiar striped chipmunk is a favorite forest mammals of many a child who would want to take "just one" home. The fascination of children with chipmunks has been reflected many times in popular stories, movies, and cartoons by well-known animators such as Walt Disney.

Subcanopy Layer

(Includes air space beneath the canopy, lower branches of dominant trees, regenerating conifers and broadleaf species in the understory. Branches serve as nest sites, roosts, hunting perches, and forage sites.)

Pygmy Owl

These small owls are sparrow sized, but are known to attack birds larger than themselves. Unlike most owls, they often hunt during the day when birds, including juncos are actively preyed upon.

Red-breasted Sapsuckers

These woodpeckers are common in conifers, and are responsible for the neat rows of holes circling many fruit tree trunks. In conifers, the sapsucker often feeds on cedars. Sap is eaten, but large numbers of destructive forest insects are also consumed.

Western wood Pewee

These flycatchers perch on low branches in open areas in the forest and fly out to catch insects. Their cup-shaped nests are placed on a horizontal branch 20 or more feet above the forest floor.

Steller's Jay

The "Blue Jay" of Western Washington, these birds are a separate species distinct from their eastern relatives. Steller's Jays are often known for their raucous calling when they invade backyards where

they proceed to devour much of the bird seed. However, they are silent at their nest sites in coniferous forests.

Townsend's Warbler

Townsend's Warblers breed throughout the older coastal forests of the Pacific Northwest. Like most warblers, they are summer residents and migrate as far south as Central America in winter. They nest almost exclusively in firs and often feed high in the canopy. Nests also are placed through the canopy from eight to 15 feet or as high as 100 feet. They are distinctively colored with alternating blacks and yellows on the head and throat and have olive-green backs with yellow underparts streaked with black. Warblers consume large numbers of destructive insects; Townsend's Warblers feed on weevils, beetles, spiders and caterpillars.

Canopy and Trunk

(Includes broken tops of trees, canopy, air space in open canopy, and trunks of coniferous trees and snags.)

Great Blue Heron

Heron nests are constructed of twigs and placed near the tops of both broadleaf and coniferous trees. Second growth conifers provide support for their nests as well as roost sites throughout the year.

Bald Eagle

Second growth trees are large enough to support the bulky stick nests of Bald Eagles which also use these areas throughout the year for roost sites. All coastal second growth coniferous forests are potential Bald Eagle nesting habitat. Therefore, careful consideration should be given to any activities which might adversely affect this threatened species. Refer to Critical Area Maps in the Coastal Zone Atlas and other sources for known nest sites and other critical habitat.

Marbled Murrelet

These small seabirds are discussed in marine sections, but are included here because of recent discoveries regarding their nesting habits. Until recently nests had not been found although adults had been observed to fly inland carrying fish to their young, hidden in some unknown nest site. Nests have been discovered, however, including one in a Douglas fir, 135 feet from the ground in a depression lined with moss.

Great Horned Owl

These large owls occur in several habitats, but may nest in second growth conifers in the abandoned nest of a heron or hawk.

Pileated Woodpecker

These large woodpeckers were once thought to be on the verge of extinction like the Ivory-billed Woodpecker which they strongly resemble. However, they have adapted to second growth forests and their substantial workings are frequently observed on both live and dead trees as well as snags and stumps. They feed preferentially on carpenter ants, but also consume other insects which destory trees, staying with one tree until the insects are all taken, thus preventing spread of the insects. Holes excavated by Pileated Woodpeckers for nest and roost sites also offer the same for birds and mammals unable to excavate, including squirrels, owls, Wood Ducks, and Hooded Mergansers.

Red-breasted Nuthatch

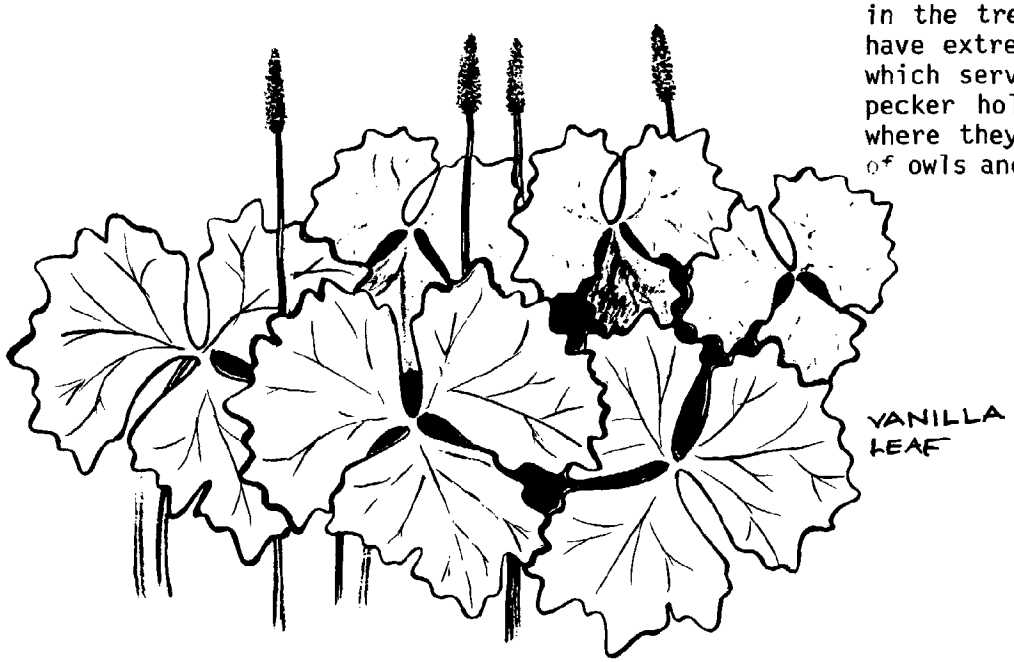
Like the Brown Creeper, nuthatches feed along tree trunks and branches in search of insects. The nasal call of the nuthatch is a characteristic sound within coastal conifer forests.

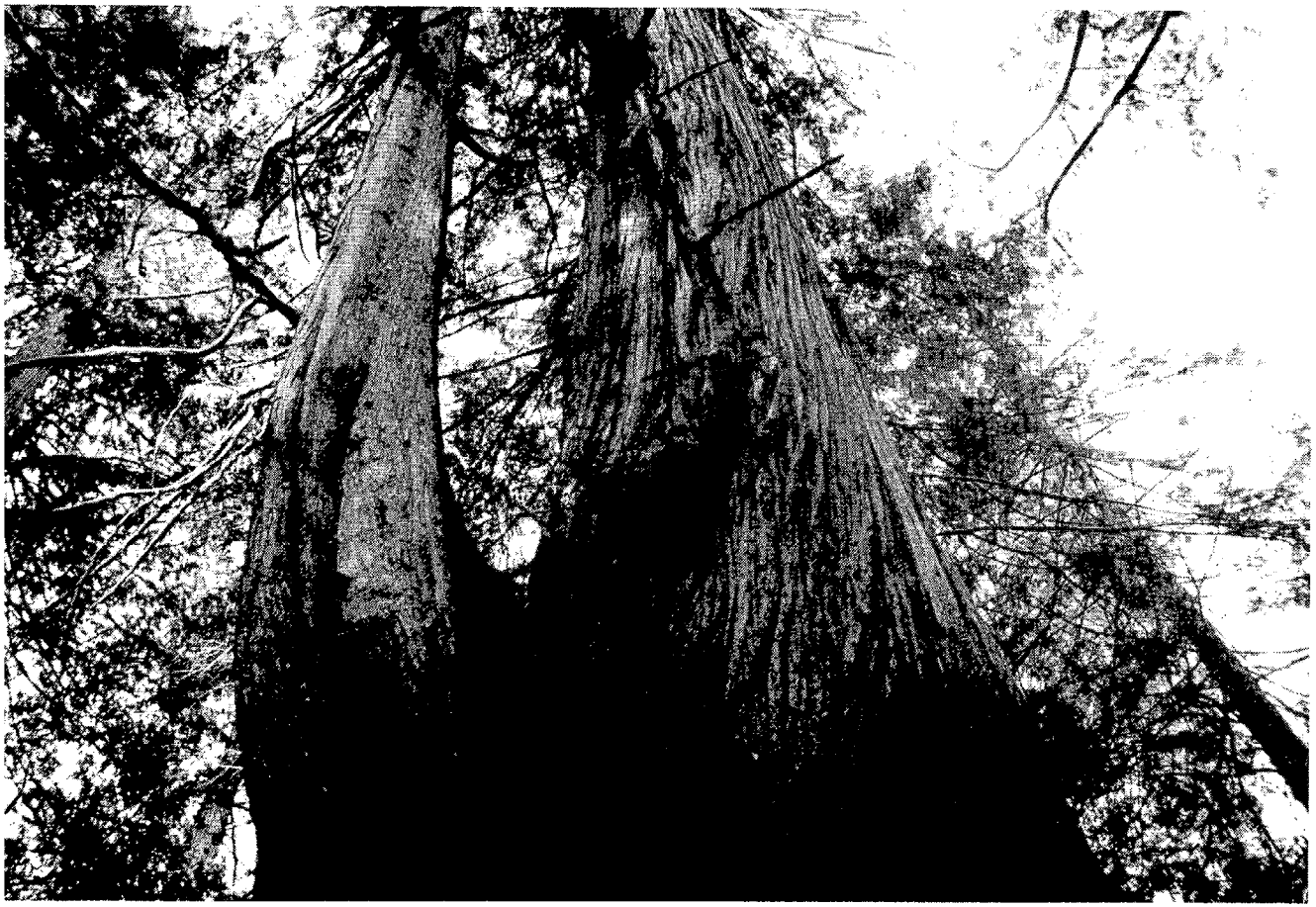
Western Tanager

These beautiful birds are not often see, but are fairly common in both mixed and coniferous forests. The male has an orange-red head, black wings and tail, while the rest of the body is yellow. Their nests are placed high in the canopy. During the breeding season, insect prey includes beetles and spiders.

Northern Flying Squirrels

Flying squirrels are nocturnal inhabitants of coastal forests. A fold of skin between each front and hind leg is stretched to enable gliding from high in the trees as far as fifty yards or more. They have extremely soft, beautiful fur and a flat tail which serves as a rudder. They nest in old woodpecker holes and occasionally feed on the ground where they eat mushrooms. They are, in turn, prey of owls and bobcats.





OLD GROWTH WESTERN RED CEDAR.
LONG ISLAND, PACIFIC COUNTY.

CONIFEROUS OLD GROWTH FOREST (No. 414)
MATURE BROADLEAF/OLD GROWTH CONIFER (No. 432)

INTRODUCTION

Forests of old growth trees are essentially nonexistent in the coastal zone oustide the Olympic National Park Coastal Strip and Long Island in Willapa Bay. Areas mapped as such in the Coastal Zone Atlas are most commonly small stands of second growth conifers or mature broadleaf forests with scattered old growth conifers. Because of their scarcity and value as wildlife habitat, the presence of only a few old growth trees was considered justification for mapping a stand as old growth.

The total area of old growth in western Washington has decreased tremendously. Once the major forest type throughout the coastal zone, isolated stands are now confined to a few locations (refer to Table 414-1) and are lacking in the coastal zone of Snohomish, Thurston, and Mason counties. Fire and other natural disturbances created younger stands prior to Eurpoean settlement, but the majority of virgin timber was felled with ax and crosscut. Fire scars on many old trees and naturally thick, protective bark suggest that remaining trees withstood many fires. These fires helped maintain the open features of old growth forests by periodically removing much of the understory vegetation.

Remaining old growth forests have special value as examples of the potential development inherent in younger forests. Existing old growth stands should be given special consideration before being subjected to any type of disturbance. The dollar value of old growth as timber is a great incentive to log these stands, and was the primary reason for the original European settlement. Presently, for esthetic, biological, and recreational considerations, and out of a sense of respect for those long-lived forests, it is recommended that old growth stands be given highest priority for preservation.

Old growth forests are unique for a number of reasons:

> The tremendous biomass produced by these forests exceeds any biomass figures ever reported in the temperate zone. (Old growth Douglas fir forest recorded at 2,437 metric tons/hectare; average of old growth stands reported is 1,600 metric tons/hectare).

Table 414-1 OLD GROWTH (No. 414) AND MATURE BROADLEAF/OLD GROWTH CONIFER (No. 432) SITES MAPPED IN THE COASTAL ZONE ATLAS

	COUNTY	LOCATION
CONIFEROUS OLD GROWTH (No. 414)	Skagit	Washington Park, Fidalgo Island Deception Pass State Park
	Island	Deception Pass State Park, Whidbey Island Just south of Race Lagoon, Whidbey Island Point Partridge State Park, Whidbey Island
	San Juan	Head of Parks Bay, Shaw Island Skipjack Island North side of Speiden Island East side of Jones Island Northwest and North side of Waldron Island Point Doughty, Beach Haven and just south, Orcas Island
	Clallam	Sequim Bay State Park Agate Head Tongue Point Just east of Eagle Point Just east of Olson Creek North of Rasmussen Creek
	Pacific	Long Island Mouth of Naselle River
	King	Schmitz Park (mapped as Park, No. 191)
MIXED OLD GROWTH (No. 432)	Whatcom	Chuckanut Bay
	San Juan	Bellevue Point, San Juan Island Cattle Point, San Juan Island Jones Island North side Turtle Back Range, Orcas Island Turn Point, Stuart Island Northwest side Waldron Island Sucia Island and Islets in Echo Bay Matia Island Patos Island
	Island	South Whidbey State Park
	Kitsap	South end Blake Island
	Jefferson	West side of Bolton Peninsula
	Clallam	Just east of Green Point

Old growth forests are complex, long-lived communities and represent the climax of forest succession in the Pacific Northwest. Diversity and species richness are generally very high in old growth forests, a reflection of these conditions. For example, nesting and foraging bird use is relatively high as seen in Figure 414-1.

The tall, uneven canopy and characteristically dense understory of old growth forests provide more diverse habitat than do younger forest types. Large amounts of trunk areas are available as substrate for mosses or lichens, or as foraging territory for creepers and nuthatches. Fallen logs provide habitat for small mammals, insects, amphibians and birds, as well as functioning as "nurse logs" upon which conifer seeds germinate and grow for many years before becoming established in the soil.

In the open canopy layer of mixed forests, additional air space is available above the level of the broadleaf species and between the conifers. Swallows, Vaux's Swifts, and the uncommon Purple Martin have all been observed foraging in this space in an old growth mixed forest near Striped Peak, Clallam County.

Snags and broken topped trees are characteristic of old growth forests, and numbers of species which are dependent on them are consequently high. Snags provide habitat for cavity nesters listed in Table 4-2, while large and/or broken topped trees support platform nests of birds such as Bald Eagles. Eagles have been observed nesting or roosting in old growth sites near Crescent Beach on Whidbey Island and just east of Tongue Point in Clallam County. All coastal old growth forests should be considered potential nest sites for Bald Eagles (classified as a Threatened Species by the U.S. Fish and Wildlife Service.)

Old growth forests provide unique wildlife habitat for several uncommon or rare species including the Spotted Owl, which is adapted to old growth conifers. Several other species which have adapted to changes in forest conditions since the arrival of early settlers are probably greatly reduced from previous numbers due to the loss of mature coniferous forests which they originally occupied. Population records for such forest species as owls, Pileated Woodpeckers, cougars, and fishers are lacking, making it impossible to know precisely the effects of old growth habitat loss. However, a study of three coniferous communities in western Washington revealed that more rare birds (those seen less than 11 percent of the time during the study) were seen in undisturbed old growth forest than in earlier successional stages or disturbed old growth.

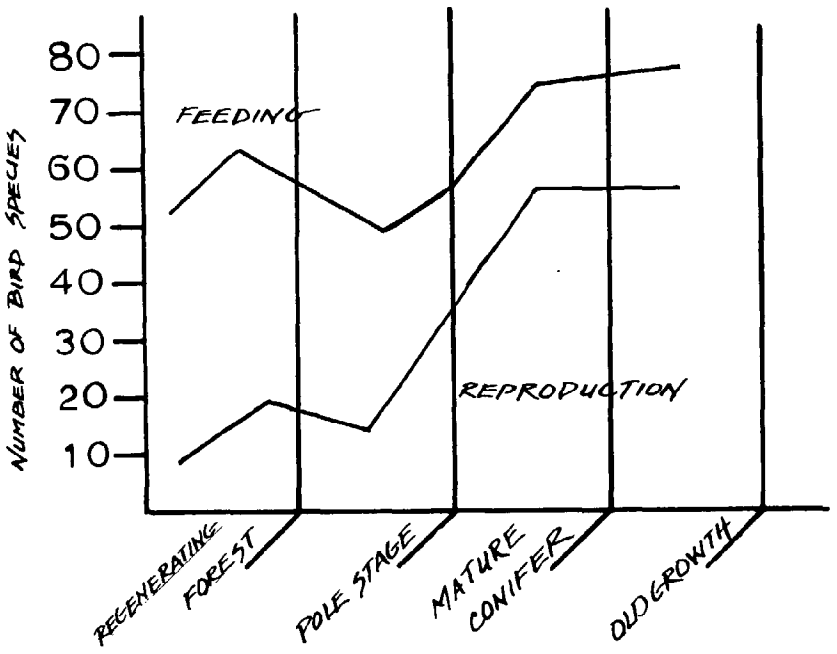


FIGURE 414-1

NUMBER OF BIRD SPECIES USING FORESTS OF VARIOUS SUCCESSIONAL STAGES FOR NESTING AND FEEDING. AS RECORDED IN THE BLUE MOUNTAINS, OREGON.

(Adapted from report by Evelyn L. Bull. 1977. Specialized habitat requirements of birds: Snag management, old growth, and riparian habitat. Paper presented at the workshop on nongame bird habitat management in coniferous forests of the Western United States, Portland, Oregon.)

REPRESENTATIVE SPECIES

Bald Eagle

William Dawson wrote in 1909 - "Fifty years ago they existed in Puget Sound and along the banks of the Columbia in almost incredible numbers. . . Twenty years ago this eagle was still a common site along the shores and waterways of Puget Sound. His white head lighted up the depths of some wood-bound lake as we stepped forth to size up the local bird population, and his majestic flight repeatedly gladdened a tramp along the river trail. Now, all is changed."

Today, the Bald Eagle is officially considered a Threatened Species in the State of Washington. Breeding and wintering populations occur in coastal old growth forests, all of which are known to be used by eagles or provide potential Bald Eagle habitat. It is, therefore, essential to maintain these forests as critical habitat for existing populations and to provide additional habitat where new nesting may occur. It is also important to preserve scattered individual old growth trees which occur in younger forests throughout the coastal zone. These trees provide essential roost sites along beaches, marshes, river mouths and open water where eagles (and other raptors) feed.

Cougar

Although not restricted to old growth forests, the cougar has been greatly reduced or extirpated over much of its former range which included the virgin coastal forests. There is also evidence they preferentially move from one patch of mature timber to another. Like killer whales in aquatic schemes, cougars are at the apex of terrestrial food chains. Unlike the killer whale, cougars have been persecuted by man because we "share" a common need - terrestrial space and an adequate food source. In this way, humans are competitors with cougars and other land predators. In earlier days, the competitive struggles were largely the result of cougar predation on elk, deer and occasionally, livestock. Even more harmful to the cougar's status are the scattered incidents of attacks on humans. The result has been a long history of persecution of these large, wary cats. As the coastal zone became more completely developed, competition for space eliminated most of the cougars which weren't shot or trapped, so that today, the cougar is restricted in the coastal zone, primarily to undeveloped areas of the Olympic Peninsula and southwestern Washington.

In wilderness areas such as the Olympic National Park, cougars serve the useful role of assisting to keep elk and deer within the carrying capacity of their food supply. This natural balance has persisted for centuries and provides a useful model for ecological studies. Outside the park boundaries, elk, deer and cougars are all hunted by man. Their natural habitat is severely altered and populations modified. Remaining wilderness areas, therefore, provide valuable comparisons to monitor the impacts in the landscape occupied by man. Likewise, coastal old growth forests are vestiges of virgin habitat conditions which provide valuable sites for comparison within an otherwise modified coastal zone. They also provide habitat for animals such as the cougar which are retreating more and more to totally undeveloped wilderness areas. Thus, we have the opportunity to maintain small patches of wilderness in the form of coastal old growth forests which may allow the cougar to persist.

Fisher

Unlike many rare mammals, the fisher has probably always been very uncommon. Members of the weasel family (Mustelidae), fishers are somewhat larger than domestic cats (weights from 12-20 pounds reported). They are black, have slender bodies, short legs, and a long bushy tail which tapers toward the tip.

Despite their name, fishers do not feed extensively on fish (1.7 percent of diet) although they are reported to prefer the vicinity of streams flowing through old growth forests. Mammals comprise about 80 percent of their diet which includes squirrels, voles, varying hares, shrews, deer mice and porcupines. Fishers are considered to be the classic predator of porcupines, which they attack head on. Apparently, the fisher has evolved internal defenses against the porcupine's quills, which may be fatal

to other animals. Examinations have shown that little or no inflammation or infection occurs despite the presence of partially dissolved quills lodged in the skin, stomach and muscle of fishers.

Because of natural low densities, requirements of old growth habitat, and perhaps trapping pressure (the latest record in the coastal zone was of a trapped fisher along the Liliwaup River in Mason County). The fisher may be extinct in the coastal zone outside the Olympic National Park coastal strip.

Fishers are now protected in the State of Washington, and that protection must also be extended to preservation of fisher habitat to ensure their continued existence. Remaining old growth and mature second growth forest and undisturbed corridors connecting them to larger forests further inland must be maintained. Given these conditions, fishers may persist in the coastal zone.

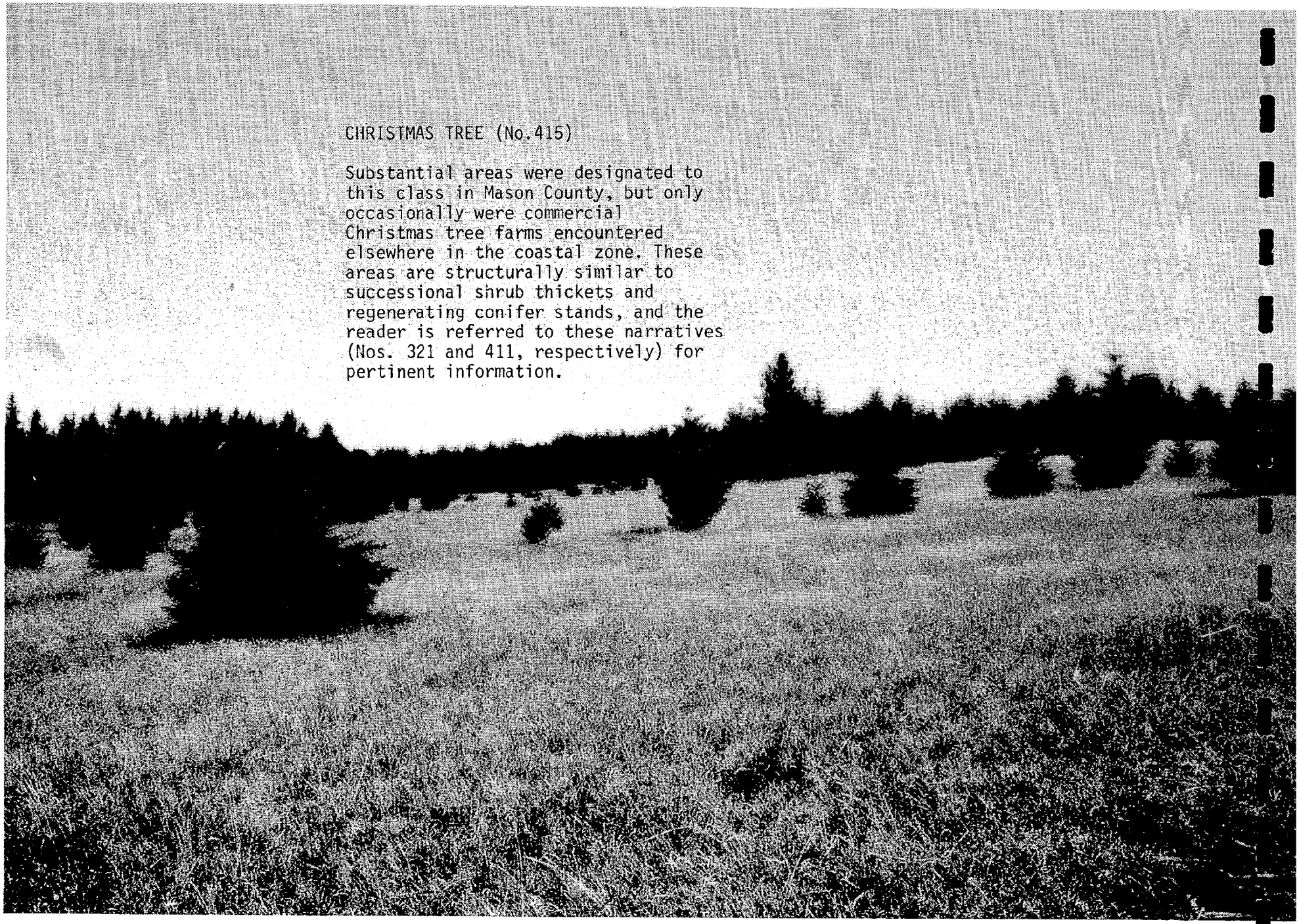
Spotted Owl

The Spotted Owl has been shown to be dependent on old growth forests. It does occur in younger forests, but research suggests that early stages of forest succession provides marginal habitat at best. When patches of old growth are present in younger stands, Spotted Owl observations are often near them. Dependency on old growth is so acute that some researchers suggest that when the last virgin timber goes, so will the Spotted Owl. In this respect, old growth habitat is very specialized for many species, serving as a reservoir for recolonization of other areas as these younger sites become suitable mature forest habitat. Likewise, old growth forests represent the only virgin forests which current generations or our children will ever be privileged to enter.

FISHER

CHRISTMAS TREE (No.415)

Substantial areas were designated to this class in Mason County, but only occasionally were commercial Christmas tree farms encountered elsewhere in the coastal zone. These areas are structurally similar to successional shrub thickets and regenerating conifer stands, and the reader is referred to these narratives (Nos. 321 and 411, respectively) for pertinent information.



BROADLEAF FOREST (No. 42)

INTRODUCTION

The broadleaf forest class is comprised of all forested lands dominated by immature, pole stage, or mature forests of red alder, trembling aspen, paper birch, or madrona. Broadleaf forests differ from conifer forests by the presence of a seasonally leafless canopy (madrona, our only evergreen broadleaf tree is exceptional) generally a better-developed understory, and relatively short lifespan. As a result of the relative shade intolerance and short lifespan of our broadleaf species, the forests they form are seral, developing after disturbance and subsequently invaded and replaced by shade tolerant conifers. Following their establishment, broadleaf forests may be perpetuated by disturbances such as fire, blowdown, and logging which destroy conifer seedlings in the understory and create openings in the canopy layer, allowing sufficient light for the regeneration of broadleaf species.

Red alder, the major seral broadleaf tree in the area, forms extensive forests throughout the coastal zone, characteristically on moist sites. Trembling aspen, paper birch, and madrona forests are comparatively rare.

Since the arrival of the early settlers, there has been a general increase in the total area dominated by broadleaf forest, primarily as a result of logging and landclearing practices. Specifically, an increase in the area dominated by red alder forest is responsible. Birch, aspen, and madrona-dominated forests, historically of limited distribution in western Washington, have decreased in total area primarily due to alteration of suitable habitat, encroachment of residential or commercial development, roads, and other activities related to an expanding populace. The presence of trembling aspen and paper birch in the Puget Sound region has been cited as one of the notable botanical features of the area.

Unfortunately, the classification system used in the Coastal Zone Atlas does not distinguish the four major broadleaf forest types, but approximate locations are provided in the following narratives and Figure 42-1, and site inspections are encouraged when decisions that may affect madrona, trembling aspen, or paper birch forests are being considered.

SIGNIFICANT BIOLOGICAL FEATURES

Plant Communities

Alder Forests

A highly aggressive seral community on disturbed sites, red alder forest characteristically develops following logging, erosion, and other disturbances which expose mineral soil. Full occupancy of such sites may occur within two years, when alders may be greater than seven feet (two meters) in height. Growth rates of red alder during the first 15-20 years have been reported up to five feet (1.5 meters) per year. The lifespan of red alder is 60-100 years, although after approximately 20 years pure alder stands often begin to deteriorate due to the invasion of coniferous species. Stand development is greatest on sites with well-drained, moist soil, as occurs on river terraces and floodplains, but alder will also grow on saturated soils, as exemplified by the extensive alder swamps encountered in Pacific County. Alder forests are absent only from the driest forested areas of the coastal zone.

Paper Birch, Trembling Aspen, and Madrona Forests

Of minor importance in the successional patterns of the region, these broadleaf forest communities are outstanding for their uncommonness in western Washington, and land-use decision makers are encouraged to retain these forests in an undisturbed state whenever possible. Indicated in Figure 42-1 are the approximate known locations of these three forest types in the coastal zone. Some of the stands indicated are quite small, but nevertheless important as seed sources necessary for reproduction. Other locations may exist within the coastal zone, undoubtedly so throughout western Washington as a whole.

Productivity

Because information concerning coastal trembling aspen, paper birch, and madrona forests is essentially non-existent, the following discussions are based on work done in western Washington and Oregon alder forests.

Red alder forests commonly precede the development of coniferous forests throughout the region, and much study has been devoted to determining the role and value of red alder as a species, and of red alder forest communities.

A rapid increase of above ground biomass during the first 15 to 20 years is characteristic of red alder. Figures 42-2 and 42-3 compare the growth in height and volume of red alder and Douglas fir.

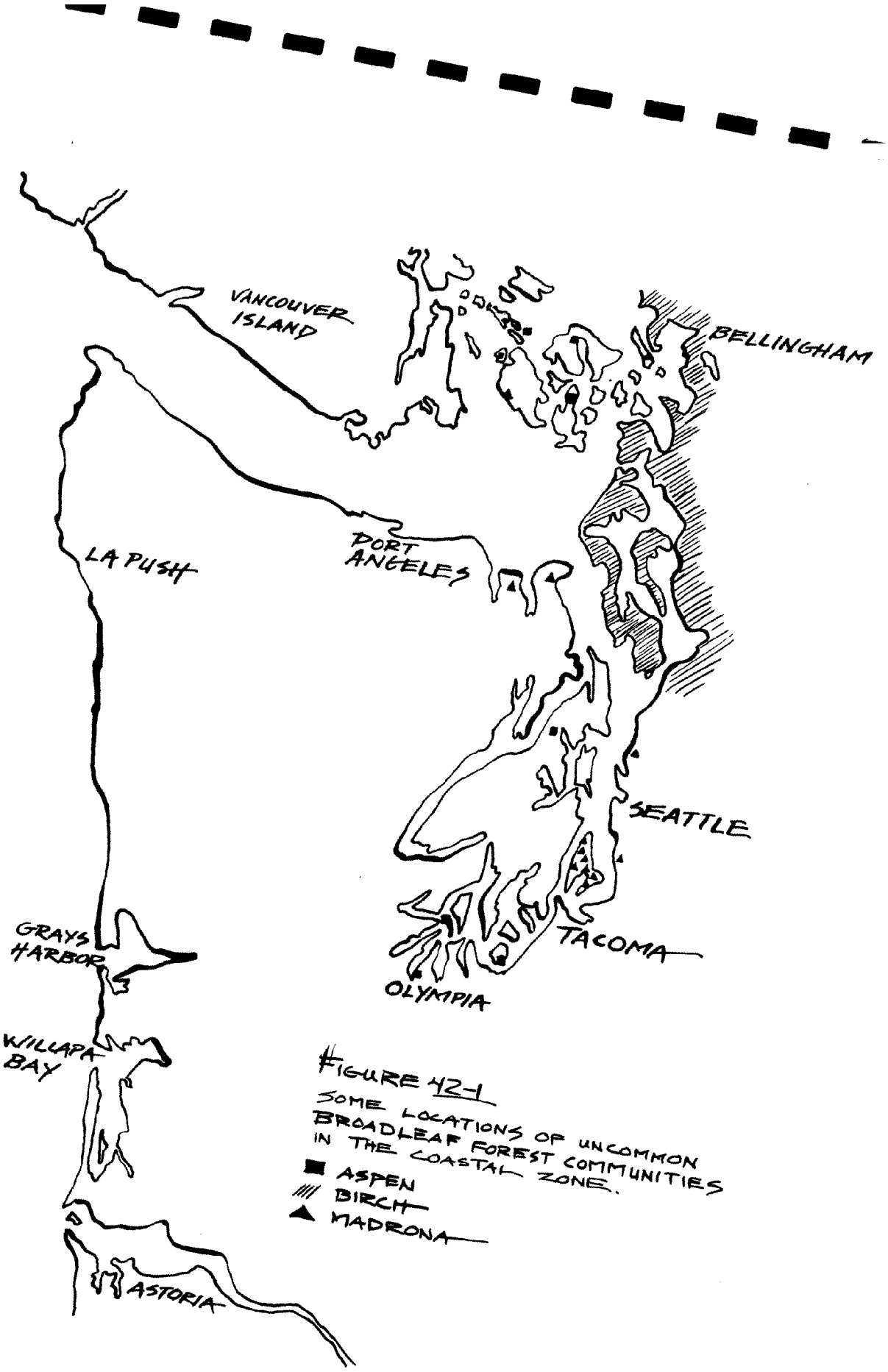


FIGURE 42-1
SOME LOCATIONS OF UNCOMMON BROADLEAF FOREST COMMUNITIES IN THE COASTAL ZONE.
■ ASPEN
/// BIRCH
▲ MADRONA

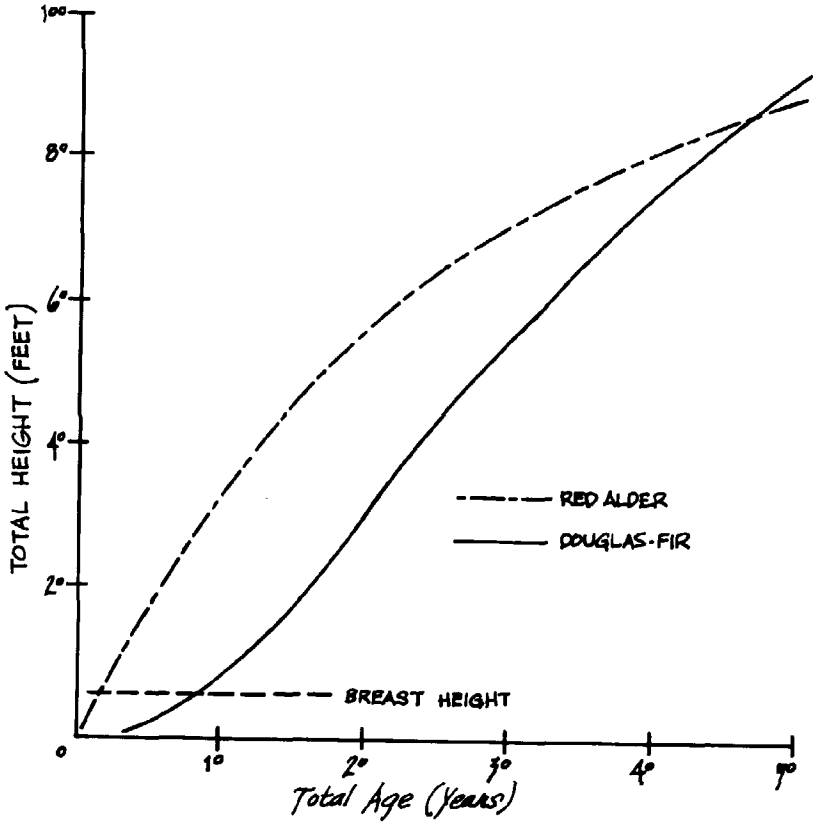


Figure 42-2

Height-age curves for red alder and Douglas fir for 50-year site indices 90 (Worthington et al., 1960) and 105 (King, 1966), respectively. For Douglas fir, total age equals breast-height age + 8.

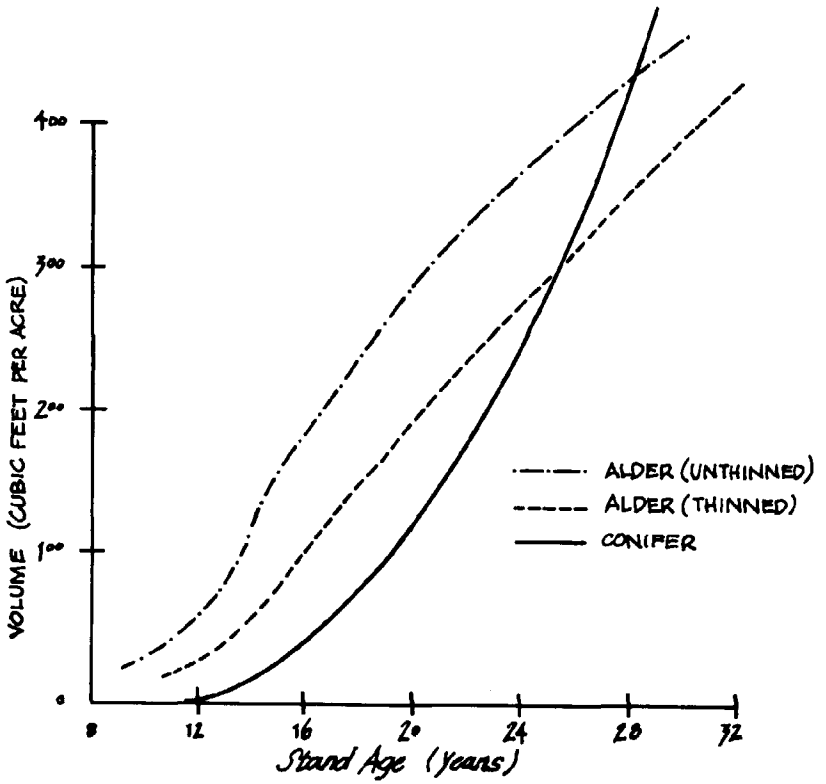
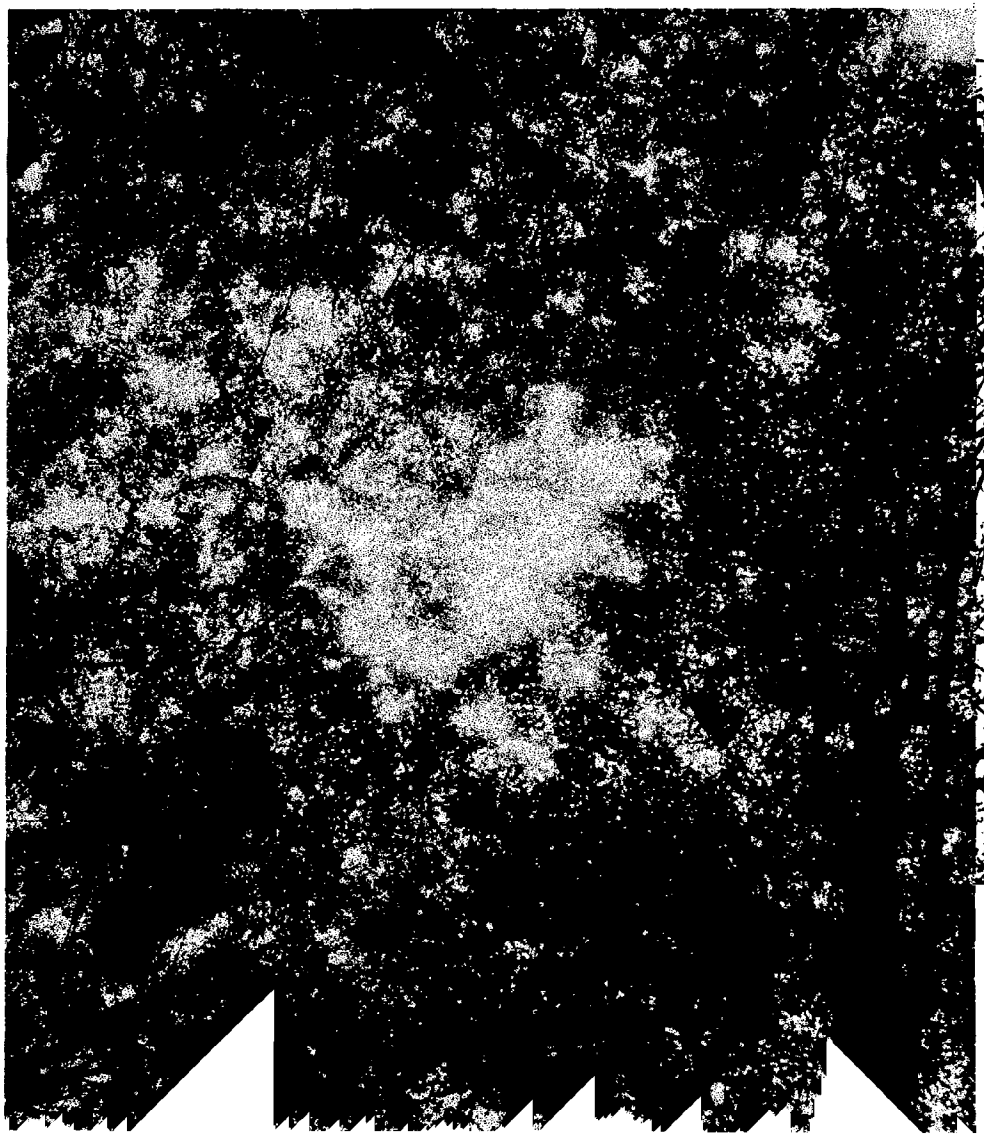


Figure 42-3

Volume per acre for pure alder (thinned and unthinned) and pure conifer stands at Cascade Head Experimental Forest. (Modified from Figure 5 of Bernsten (1961).)

RED ALDER FOREST CANOPY,
SUMMER ASPECT.



RED ALDER FOREST CANOPY,
WINTER ASPECT.

By age ten to 15 years, an annual average net productivity of 26 metric tons per hectare (abbreviated MT/HA) with outstanding values of greater than 30 MT/HA on very productive sites, has been reported. Cumulative productivity figures of 389 and 732 MT/HA from a 20 and 50 year old stand, respectively, are reported. These values, when compared to other temperate forests, are higher than average. Leaf mass alone may amount to approximately 5.5 MT/HA between four and 14 years of age, then gradually decrease.

The ability of alders to add nitrogen to soil has been generally known for some time, and recent studies show that red alder is much more effective in this role than are legumes (alfalfa, peas, beans, Scot's broom), widely known for this trait. The growth of many species commonly associated with red alder is improved because of this contribution, notably Douglas fir. This fact may have particular significance in forest management practices, which previously considered red alder undesirable. Research now indicates it may be economically desirable to manage for alder, rather than eliminate it. Additionally the effects of alder-induced soil properties on one of the major root pathogens of western North America conifers suggest that alder has good potential for biological control. If such a program is employed, biological as well as economic benefits may be realized.

Additional Values

Broadleaf forests in general improve soil fertility and structure by the contribution of large amounts of nutrient-rich litter.

Alder forms the base of a sizable and steadily growing firewood industry in the Northwest, and to a limited extent is used in furniture production.

Alder has been cited as less flammable than coniferous trees and alder forested areas may act as natural firebreaks.

Broadleaf Forest Structure

Except where noted, all four major broadleaf forest types have the following characteristics:

- excepting madrona forests, canopy coverage is seasonally variable, i.e., closed throughout the growing season (approximately April to October)and leafless the remainder of the year (see Figure 42-4).

- understory development in mature stages is characteristically high, with rich subcanopy, shrub, herb, and ground layers. The subcanopy is often comprised of young conifers that will eventually overtop and replace the broadleaf community.

Animal Community

Forest fauna of the Pacific Northwest is generally discussed in terms of the inhabitants of conifers. Douglas fir forests and other coniferous woodlands are the climax plant community over much of the coastal zone and a significant percentage of native wildlife are adapted to those forests. However, broadleaf forests are now more extensive than in early days as a result of clearing the coniferous lowlands. The result is that today broadleaf species and associated wildlife play a major role in the forest ecosystem of the coastal zone. For example, a recent study has shown that numbers of individuals and species of birds inhabiting a western Washington alder forest were comparable to those recorded in other temperate broadleaf forest bird censuses. This indicates that broadleaf forest bird communities in Washington are not improvished because they are isolated from the extensive eastern United States broadleaf forests or because of their relatively recent increase as a major plant community in the northwest. Thus, there are a number of birds adapted to and dependent on broadleaf forests in the coastal zone. Many other wildlife for which trees (broadleaf or conifer) are the primary habitat requirement, are also dependent on coastal broadleaf forests.

A list of potential inhabitants of coastal broadleaf forests is provided in Table 42-1. Species associated with a given forest type or location will vary according to several factors including:

- Plant Community: Little comparative information is available regarding wildlife associated with various broadleaf forest types in western Washington. However, species associated with alder, birch, and aspen are thought to be similar because of comparable moisture and structural features. Wildlife associated with madrona forests will differ as a result of drier conditions and the generally open understory. The large numbers of berries produced by madronas are known to be important food for Band-tailed Pigeons and the Varied Thrush.

- Succession: Broadleaf forests generally mature rapidly and provide an increasing variety of vertical space for wildlife as they grow. Shrubs, trunk space, snags, and leaves in the canopy all provide nesting and forage space. In general, this space is greater in mature broadleaf forest than young stands. The amount of leaf area may be especially important for many species, particularly insectivorous birds. For example, a recent study demonstrated that there is an increase in the proportion of alder leaves present in a broadleaf forest with succession. It was further suggested that alder leaves might be supporting over twice as much insect biomass per unit leaf area as salmonberry and other understory vegetation. Thus, an increase in leaf area with succession increases insects which support warblers, chickadees, vireos, flycatchers and other insectivores. This is especially important during the breeding season when the majority of forest birds feed their young a diet of insects. Many species such as the nectar feeding hummingbirds switch to insects at this time of year to provide protein to their nestlings. Other birds consume insects throughout the year, searching in crevices during winter for their hidden prey.

- Season: Madrona is our only broadleaf tree which does not shed its leaves in winter. Alder and other deciduous broadleaf forests have a marked seasonal change in profile because of the annual leaf drop and subsequent new growth in spring. Many birds migrate great distances to the south during fall, while other wildlife may move shorter distances to adjacent mixed or conifer forests. Several species will, however, overwinter in broadleaf forests and may shift feeding height from canopy to lower in the trees. Some species may shift from coniferous areas during a part of the year and feed in broadleafs. For example, Pine Siskins feed on alder seeds when they first appear in spring, but nest in coniferous forests.

  Very little is known about seasonal changes in madrona forests, but it is intersting to note that one of a very few warblers (the Orange-crowned) which does not necessarily migrate south, is a common inhabitant of madrona forests.

IMPACTS

Disturbances affecting broadleaf forests are discussed in the Forest Narrative (No. 4). In general, disturbances which open the canopy layer and/or destroy regenerating conifers in the understory tend to prolong the life of broadleaf communities.

TABLE 42-1
BROADLEAF FOREST WILDLIFE

BIRDS	Relative Occurrence [1]	SUCCESSIONAL STAGE		COMMENTS [2]
		Immature	Mature	
Great Blue Heron	C		■	Potential nester in mature trees
Bald Eagle	C		■	Mature trees are potential nest sites Threatened species (a)
Sharp-shinned Hawk	U	■	■	Species of special concern (b)
Cooper's Hawk	U	■	■	Species of special concern (b)
Red-tailed Hawk	C		■	As with other hawks and owls, the Red-tail is protected.
American Kestrel	U		■	Cavity nester
Ruffed Grouse	C	■	■	Highly valued game bird
Band-tailed Pigeon	C	■	■	Important game bird
Screech Owl	C		■	Cavity nester
Great Horned Owl	C		■	Like all hawks and owls, protected They can not be hunted or shot
Saw-whet Owl	C		■	Cavity nester
Vaux's Swift	C		■	Cavity nester
Rufous Hummingbird	C	■	■	May be present in older forests
Common Flicker	C	■	■	As with other woodpeckers, excavates cavities which become nests for many species when abandoned
Pileated Woodpecker	U		■	Primarily winter, breeds mainly in conifers Requires snags and mature trees
Red-breasted Sapsucker	C		■	Consumes insects as well as tree sap
Hairy Woodpecker	C		■	Common in conifers but often observed in broadleafs
Downy Woodpecker	C		■	Characteristic woodpecker of broadleafs
Willow Flycatcher Western Flycatcher Western Wood Peewee	C C C		■ ■ ■	Flycatchers snatch insects after flying out from tree tops or perches on shrubs or branches
Olive-sided Flycatcher	C	■	■	
Tree Swallow	C			Cavity nester; near water; other swallows may also be present, feeding over and among trees
Common Crow	C		■	Crows nest in stick nests in tree tops
Black-capped Chickadee	C	■	■	Hole nesters-Common chickadee of broadleaf forests
Chestnut-backed Chickadee	C	■	■	More common in conifers; however, replaces Black-capped in San Juan broadleafs

TABLE 42-1
BROADLEAF FOREST WILDLIFE

BIRDS	Relative Occurrence[1]	SUCCESSIONAL STAGE Immature	Mature	COMMENTS[2]
Hutton's Vireo	U	■	■	Resident
Solitary Vireo	C		■	Vireos move rather slowly among the
Red-eyed Vireo	C		■	foliage in broadleafs, gleaning insects
Warbling Vireo	C		■	
Orange-crowned Warbler	C	■	■	Common in madronas, some overwinter
Yellow Warbler	C	■	■	Species of concern (b)
Yellow-rumped Warbler	C		■	More common in conifers
MacGillivray's Warbler	C	■	■	
Wilson's Warbler	C	■	■	Bushy areas
Northern Oriole	U		■	Along water
Brown-headed Cowbird	C	■	■	
Black-headed Grosbeak	C		■	
Evening Grosbeak	C	■	■	
Purple Finch	C	■	■	
Pine Siskin	C	■	■	
American Goldfinch	C	■	■	
Rufous-sided Towhee	C	■	■	
Dark-eyed Junco	C	■	■	Breed in conifers
Chipping Sparrow	C	■	■	
White-crowned Sparrow	C	■	■	
Golden-crowned Sparrow	C	■		Winter
Fox Sparrow	C	■	■	
Song Sparrow	C	■	■	

additional birds on page 225

MAMMALS	Trophic Relationship[3]	SUCCESSIONAL STAGE Immature	Mature	COMMENTS[2]
Vagrant shrew (Sorex vagrans)	CARN	■	■	Shrews are active the year round; consume
Dusky shrew (S. obscurus)	CARN		■	large numbers of insects and are prey of
Trowbridge's shrew (S. trowbridgii)	OMNI	■	■	owls, and other predators
Shrew mole (Neurotichus gibbsii)	CARN		■	Unique to Pacific Northwest
Bobcat (Lynx rufus)	CARN	■	■	High price of pelts and trapping have led to much concern regarding status of bobcat
Elk (Wapiti) (Cervus elaphus)	HERB	■	■	Limited to Olympic Peninsula and southwest Washington

TABLE 42-1
BROADLEAF FOREST WILDLIFE

MAMMALS	Trophic Relationship[3]	SUCCESSIONAL STAGE		COMMENTS[2]
		Immature	Mature	
Coast mole (Scapanus orarius)	OMNI	■	■	Little known regarding bats in Western Washington. Those listed were noted to occur in deciduous forests in a recent western Oregon study; bats are insectivores.
Little brown myotis (Myotis lucifugus)	CARN			
Big Brown bat (Eptesicus fuscus)	CARN			
Hoary bat (Lasiurus cinereus)	CARN			
Eastern cottontail (Sylvilagus floridanus)	HERB	■	■	Introduced locally common as on Whidbey Island Introduced on San Juan Islands, Most abundant in open areas
European rabbit (Oryctolagus cuniculus)	HERB	■	■	Unique to Pacific Northwest
Mountain beaver (Aplodontia rufa)	HERB	■	■	
Townsend's chipmunk (Eutamias townsendii)	OMNI	■		Introduced in many urban areas
Gray squirrel (Sciurus carolinensis)	HERB		■	Tacoma area south, may be absent in coastal zone?
Western Gray Squirrel (S. griseus)	HERB		■	Introduced, very local as on Crane Island in San Juans
Fox Squirrel (S. niger)	HERB		■	Adjacent to fresh water
Beaver (Castor canadensis)	HERB		■	
Deer mouse (Peromyscus maniculatus)	OMNI	■	■	Ubiquitous; as with many small animals, deer mice are significant prey of other wildlife
Creeping vole (Microtus oregoni)	HERB		■	Prey of owls, hawks, coyotes Occur in forest openings
Coyote (Canis latrans)	OMNI	■	■	
Red fox (Vulpes fulva)	OMNI	■	■	Lowland fox is introduced
Black bear (Ursus americanus)	OMNI	■	■	Valuable game animal
Raccoon (Procyon lotor)	OMNI	■	■	Especially at water's edge
Short-tailed weasel (Ermine) (Mustela erminea)	CARN	■	■	
Long-tailed weasel (M. frenata)	CARN	■	■	
Western spotted skunk (Spilogale gracilis)	OMNI	■	■	
Striped skunk (Mephitis mephitis)	OMNI	■	■	Especially near water
River otter (Lutra canadensis)	CARN	■	■	Aquatic edge only
Cougar (Mountain lion) (Felis concolor)	CARN	■	■	Rare (c)
Black-tailed deer (Odocolieus hemionus)	HERB	■	■	Valuable game animal

TABLE 42-1
BROADLEAF FOREST WILDLIFE

BIRDS	Relative Occurrence[1]	SUCCESSIONAL STAGE Immature	Mature	COMMENTS[2]
Bushtit	C	■		
White-breasted Nuthatch	U	■	■	Limited to Tacoma and south
Red-breasted Nuthatch	C		■	Observed in madronas, this study; generally, uncommon in broadleafs
House Wren	C	■		
Winter Wren	C		■	Common in conifers, also inhabits dense broadleaf forests
Bewick's Wren	C	■		Also referred to as Seattle wren
Robin	C	■	■	*Ubiquitous*
Varied Thrush	C		■	Migrant
Swainson's Thrush	C		■	Summer resident
Golden-crowned Kinglet	C		■	Nest in conifers
Ruby-crowned Kinglet	C		■	Winter resident
Bohemian Waxwing	U	■	■	Winter
Cedar Waxwing	C	■	■	Feed and nest in broadleafs
Starling	C		■	Common near human disturbance

REPTILES AND AMPHIBIANS	SUCCESSIONAL STAGE Immature	Mature	COMMENTS[2]
Rough-skinned Newt (Taricha granulosa)	■	■	Breeds in ponds
Western Red-backed Salamander (Plethodon vehiculum)	■	■	Damp locations
Ensatina (Esatina eschscholtzi)	■	■	
Western Toad (Bufo boreas)	■	■	Near water
Pacific Treefrog (Hyla regilla)	■	■	Near water
Western Fence Lizard (Sceloporus occidentalis)	■	■	Madrona
Northern Alligator Lizard (Gerrhonotus coeruleus)	■	■	Openings
Northwestern Garter Sanke (Thamnophis ordinoides)	■	■	

LEGEND:

1 Relative Occurrence:
- C - Common
- U - Uncommon
- R - Rare

2 Comment:
- (a) Species listed as threatened by USFWS
- (b) Species of concern are those on Audobon Society List, 1978
- (c) Rare status attributed to cougar by the Washington Chapter of the Wildlife Society

3 Trophic Relationship:
- CARN - Carnivore
- HERB - Herbivore
- OMNI - Omnivore

IMMATURE RED ALDER FOREST

IMMATURE BROADLEAF FORESTS (No. 421)

INTRODUCTION

Areas mapped as immature broadleaf forests typically are densely stocked, even-aged stands of young red alder. Immature stands of trembling aspen, paper birch, or madrona are rare (at least in stands large enough to be mapped) in the coastal zone.

Young alder stands are found in every coastal county, best developed on moist sites, and absent only from the driest sites. These stands represent a short-lived seral stage, capable of reaching a height of 40 feet in ten years on good sites. Elsewhere, they may persist for a longer time, but generally begin to display characteristics of mature stages by 20-30 years.

Characteristically developing on disturbed sites with exposed mineral soil, the frequency of occurrence of these young forests has certainly increased since pre-settlement times, as natural disturbances have been augmented by human-caused disturbance (e.g., logging, roadbuilding, filling, and land clearing) creating sites favorable for alder regeneration.

SIGNIFICANT BIOLOGICAL FEATURES

Role of Soil Formation

Immature red alder stands play a major role in the reestablishment of good fertility and structure in degraded soils. The nitrogen accumulating properties of alder are outstanding, and have been the subject of much research. In general, the pattern of accumulation shows high levels during immature stages, decreasing with age and at an inverse ratio to the amount of nitrogen available in the soil.

A study of young (two to 15 years) red alder stands in coastal Oregon found an annual nitrogen increase of 320 kilograms per hectare in the biomass and top 60 centimeters of soil. The same study also reported high amounts of nitrogen in all stands over ten years of age, stands 15 years old growing on sites with 8,000-15,000 kilograms per hectare in the soil and litter.

Reported changes in the physical characteristics of soils under young alder stands include the accumulation of litter and the tendency for a decrease in soil density, extending to a depth of 60 centimeters, as the organic material is incorporated.

Both these changes in soil characteristics are presumed to have beneficial effects on the growth of all coniferous species typically associated with mature stages of red alder forest, although at present this correlation has been substantiated only for Douglas fir and Sitka spruce.

Erosion Control

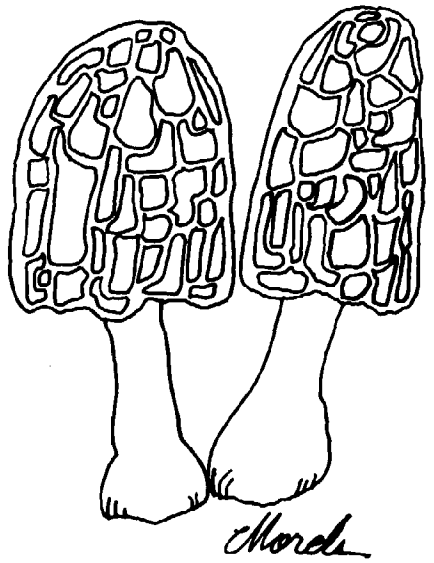
The rapid colonization of bare soil by red alder may significantly reduce erosion, conserving soil and potentially decreasing siltation in streams, rivers, and estuaries.

Plant Communities

Except in the latest stages, immature broadleaf forests tend to be species-poor plant communities, often essentially a monoculture of the dominant species.

A typical stand may be so densely stocked with red alder that easy passage between the young trees is impossible, and understory vegetation limited to smattering of pacific blackberry and mosses. In immature madrona stand on a burned-over site in San Juan County, the only understory vegetation noted during an early spring reconnaissance were scattered mossy patches, and morels.

With increasing age, soil development and natural thinning of the overstory allow the establishment and development of the rich understory typical of mature broadleaf forests.



Wildlife

Young broadleafs generally grow rapidly and a dense, but low canopy quickly provides feeding area for many birds. Several species will become more common as the understory and canopy develops in the mature broadleaf forest. Among these are the warblers, which migrate to broadleaf forests from wintering grounds in and to the south of Mexico. Warblers occurring in young broadleafs include:

Wilson's Warbler

A bird of dense thickets or the understory of older forests, the Wilson's Warbler is a small, yellow bird with a black cap (less distinctive or lacking in female). Their bulky nests are placed on the ground, often near the base of trees. Speaking of all the wood warblers, W. Earl Godfrey states:

> "Collectively, they destroy vast numbers of insects."

Orange-crowned Warblers

The orange crown of this warbler is usually concealed, and the bird is generally quite inconspicuous. They nest on the ground or in low bushes and were often observed in madronas during our studies. The food of the Orange-crowned Warblers is mainly insects, but berries are also eaten.

MacGillivray's Warbler

The MacGillivray's Warbler has a gray hood with olive upper-and yellow underparts. They forage close to the ground and place their small, cup nest in shrubs.

A number of other birds may also be present, but again, there tend to be more species present in mature broadleaf forests. Mammals which occur may include deer, elk, and several other species listed in Table 42-1.

230 MADRONA FOREST CANOPY

MATURE BROADLEAF FOREST (No. 422)

INTRODUCTION

Mature broadleaf forests are ubiquitous throughout the coastal zone of Washington. Stand size varies from less than the minimum mappable size to over a hundred acres. The life span of these forests is relatively short, regenerating conifers in the understory reaching the canopy generally within 30 to 50 years after their establishment. Areas mapped as broadleaf forest, if undisturbed, can be expected to be succeeded by mixed or coniferous forests as conifers overtop the broadleaf canopy.

The arbitrary height of approximately 40 feet (12 meters) was chosen as a criterion for distinguishing mature from immature stages, although in practice height was often not a good determining factor. In such cases, stand development, as reflected by the presence of a diverse understory, regenerating conifers, and a less dense canopy layer, was considered more important than absolute height of the canopy layer.

SIGNIFICANT BIOLOGICAL FEATURES

Plant Communities

Broadleaf communities in the coastal zone are generally pure stands of red alder, paper birch, trembling aspen, or madrona. Stands of mixed broadleaf species are uncommon. Several minor broadleaf forest communities, too small to be mapped or mapped very infrequently, were noted during the inventory. These include stands of bigleaf maple, Oregon ash, black locust, willow, and bitter cherry.

Red Alder Forests

Canopy composition is generally pure red alder, although bigleaf maple, western red cedar, and western hemlock are frequent associates in mature stages. Richness of the understory in mature alder forests has been measured by workers in western Oregon, who report it as being better developed than understories in mixed or coniferous forests.

Workers elsewhere report alder understory as being better developed than understories associated with other broadleaf forest types. Two major factors contribute to this phenomenon; the amount of available light in the understory, and soil characteristics of mature alder forests.

The seasonally leafless canopy allows the presence of plant species in the understory capable of rapid growth and developement in the spring, before the alders leaf out and reduce the amount of light penetrating to the understory. A prime example of such a species is salmonberry, a common member of the shrub layer in alder forests. Salmonberry leafs out and flowers by mid-April, when red alder is just beginning to burst its buds, and is able to complete much of its yearly growth prior to the full developement of the canopy layer.

High amounts of nitrogen in the soil under a red alder canopy are characteristic, and attributable to the ability of alder (unique among native northwest trees) to incorporate atmospheric nitrogen into the forest ecosystem. Amospheric nitrogen is fixed by symbiotic root bacteria and assimilated into plant tissue during the growing season. After alders lose their leaves in the late fall, decomposition of litterfall is an important mechanism leading to increased soil nitrogen content and improved soil texture.

Two recurring understory themes were noted in alder forests throughout the coastal zone; 1) a dense thicket of salmonberry, with a poorly developed herb layer, and 2) dominance in the understory of sword fern, with shrubs widely scattered and the herb layer well developed. The salmonberry-dominated understory generally occurs on moister sites, the sword fern-dominated sites are more common on slopes and other better-drained sites.

Wildlife of Mature Red Alder Forests

Mature alder and associated broadleaf species support a wide variety of wildlife and continue to be a major constituent as conifers begin to dominate. Cavity nesters are especially dependent on older broadleafs, woodpeckers working the trees even after they have fallen to the forest floor.

The lush understory is valuable as food and cover for deer and elk, which are our most sought forest game animals. The understory is also prime habitat for a number of other birds and mammals which consume seeds and berries produced by shrubs including those listed in Table 422-1.

Table 422-1 Examples of Wildlife use of Shrubs and Ground Cover Plants in Broadleaf Forests

PLANTS	WILDLIFE USE
Mosses	Nest material
Lichen	Nest material, eaten to some extent by elk and deer
Salmonberry	Hummingbirds feed on nectar; berries eaten by many species: Swainson's Thrush, Robin, Song Sparrow, Cedar Waxwing, White-crowned Sparrow, Humans
Thimbleberry	Berries eaten by Swainson's Thrush, Band-Tailed Pigeons, Ruffed Grouse
Salal	Fruits and leaves eaten by Ruffed Grouse and Band-tailed Pigeons; foliage eaten by mountain beavers.
Snowberry	Fruit eaten by Ruffed Grouse, Purple Finch, Evening Grosbeak, Hermit Thursh, Varied Thrush, Swainson's Thrush, Rufous-sided Towhee, black bears; foliage eaten by deer, and provides nest/cover for many species in the shrub layer.
Elderberry	Known for its wine-making possibilities, elderberries are eaten by Band-tailed Pigeons, Ruffed Grouse, Common Flickers, Stellar's Jays, Song Sparrows, Cedar Waxwings, and Pileated Woodpeckers.

234 MATURE ALDER FOREST UNDERSTORY

Representative species of alder forests include the following:

Ground and Shrub Layer

Pacific tree frog

The tree frog is a familar amphibian. They are our smallest frogs and may be either green or brown. They require water to complete early life stages (egg to tadpole), but adults are often observed on the moist alder forest floor.

Rufous Hummingbird

Hummingbirds feed on nectar of fuchias in your garden and salmonberries in natural habitat. Other hummingbird flowers include honeysuckle, currant, and mint. Hummingbirds and "their" flowers are an example of coevolution of traits which are advantageous to both plant and animal. The hummingbird is attracted to bright red, tube-shaped flowers, which often have features that restrict access to the abundant nectar to all but the slender-billed hummingbird. This structural adaptation of the flower allows feeding, while facilitating transfer of pollen via the bill tip or feathered parts of the hummingbird.

Black-tailed Deer

The deer hunter, wildlife watcher, and perhaps everyone in western Washington appreciates this, one of our most familiar and valued wildlife. Deer thrive in the coastal zone, foraging on a variety of understory plants in alder forests. Forage plants include mountain balm (also known as buck brush), wild-cherry, thimbleberry, elderberry, dogwood, and several grasses.

Deer contribute significantly to outdoor enjoyment and to the state's economy. For example, each deer harvested in 1977 contributed an estimated $1,200 to Washington's economy and deer hunters were a major component of the $139 million contributed by all hunters to the state's economy in that year.

Ruffed Grouse

Grouse are highly regarded game birds with a long history of pursuit. To many persons, they epitomize fall and the spirit of harvesting wild food amidst the changing colors of the season. Others prefer the site of a female with her chicks, or the sound of males drumming in spring. Regardless of consumptive or nonconsumptive desires, a grouse can scare the hell out of anyone who walks

close enough to elicit their rapid, booming flight. Ruffed Grouse will allow a person or other predator to approach closely, relying on their cryptic coloration as concealment.

Swainson's Thrush

This thrush is far more secretive than its familiar relative, the robin. The simple whistled call is often all that betrays its presence in low branches or shrubs where it is a common nesting bird in broadleaf forests. The flute-like song is a pleasant addition to our Northwest woods where the Swainson's Thrush stays until its southern migration in fall. Food includes blackberries, elderberries, salmonberries, ants, caterpillars, and beetles.

Mountain Beaver

Mountain beaver are unique to the Pacific Northwest, occurring along the coast only from southern British Columbia to Marin County, California. They are the only species of the primitive family Aplondontiidae and are actually quite distant in their relationship to their aquatic namesake, the beaver. Mountain beaver are common in broadleaf forests where their open burrows are often seen along gentle slopes of ravines. Food consists of salmonberries, thimbleberry, devil's club, nettles, salal, fireweed, and skunk cabbage. Bobcats are among their predators.

Black-headed Grosbeak

Black-headed Grosbeaks are rather secretive birds which place their loose, shallow nests in a tree fork or shrub. They prefer brushy areas or openings in mature forests as well as lake edges.

Winter Wren

Winter Wrens are one of several birds commonly thought of as a coniferous forest species, but also inhabit mature broadleaf forests. Nests of these tiny, melodic wrens are placed in a cavity on the ground, or among root tangles.

Canopy/Snags

Bald Eagle and Great Blue Heron

Eagles and herons both require mature trees to support their bulky stick nests and are known to both roost and nest in broadleafs. Mature alders and other broadleaf trees are especially valuable in those areas where large conifers are not abundant. Other birds of prey including Red-tailed Hawks will also make use of these older trees.

Common Crow

The black presence and "caw" of the crow is familiar to most coastal residents, and they are one of the most familiar as well as maligned birds throughout their range. Criticized for destroying eggs and nestlings of other birds, crows also consume many destructive insects and serve a valuable role as scavengers. As noisy members of the bird world, they warn other wildlife in the vicinity when danger is near.

Crows frequently use mature broadleaf forests as breeding and communal roosting sites. The bowl-shaped, stick nest may be placed amidst a large colony or in a more isolated treetop location. They fan out each morning to gather the day's fare and may gather at one point to fly as one to their night's resting place. During daily flights of large flocks of crows to and from their colonies, they may chase one another, making erratic looping dives, fly silently, or call continuously. Wherever they appear, they are intriguing and very watchable wildlife, protected by migratory bird legislation.

Black-capped Chickadee

The chickadee is perhaps the best known onomatopoeia in the animal world - the call of the chick-a-dee-dee-dee is unmistakable. Black-caps are the common chickadee of broadleafs where they are abundant throughout the year. Chickadees are cavity nesters which forage on insects in the subcanopy and canopy and are easily attracted to suet feeders.

Chickadees and other small birds are highly regarded wildlife by the many persons who enjoy watching and feeding backyard birds. This represents an appreciative use of wildlife now being recognized for many reasons, such as the estimated 374 million dollars which were spent during 1977 in Washington on wildlife related activities. Thus, wildlife photography, bird watching, purchasing of binoculars, use of bird feed and other appreciative uses are a valuable contribution to our state's economy.

Downy Woodpeckers

Downys are small woodpeckers familiar to many persons, since they will come to suet feeders in the backyard during winter. At this time, they may accompany mixed foraging flocks of chickadees, nuthatches, and kinglets as they quickly move through the trees. Their appearance on a feeder is often surprising to those who regard woodpeckers as always pecking wood. However, female Downys often pick insects from crevices or bark surfaces rather than hammer like their larger relatives or the slightly larger male. They nest in holes in dead bushes or snags.

Starling

Starlings are an example of an introduced pest that has quickly spread throughout the country. Brought to New York from Europe in 1890, they first appeared on the west coast in the 1940's and are now abundant in urban areas along the coast. Starlings are especially adapted to situations near human habitations and nest in a variety of crevices of buildings, bridges, and natural cavities. Because they nest in cavities, they compete with native hole-nesters and have been known to exclude uncommon species such as Purple Martins from former nest sites. They appear to be lacking from extensive patches of woodlands, preferring edges or disturbed locations. For this reason, it is advantageous to maintain adequate stands of trees to prevent intrusion of starlings into areas in which forests are reduced to small fragments (refer to the Forest Narrative No. 4 for more information regarding forest size).

Yellow Warbler

Often mistakenly called a canary, the Yellow Warbler has recently been added to the Audubon Society's list of species of concern (Blue List, 1978) because of a significant decline in nationwide populations as revealed by breeding bird surveys.

Yellow Warblers nest and feed in low trees or much higher in the canopy. Their diet is almost entirely insects such as caterpillars, beetles, weevils, and plant lice.

Trembling Aspen Forests

In 1931, George N. Jones characterized trembling aspen as " . . . common in the Puget Sound area." in his Botanical Survey of the Olympic Peninsula. In contrast, during this study Coastal Habitat Inventory team members mapped or observed trembling aspen stands only in San Juan, Kitsap, Mason, Pierce, and Thurston Counties (see Figure 42-1). All were small, isolated stands, the largest covering approximately 30 acres on Lopez Island in San Juan County. Nearly all occupied moist sites, a few wet enough to be mapped as swamps.

Growth of aspen groves is clonal, producing even-aged stands, which if undisturbed can be expected to be succeeded by western hemlock and western red cedar. Understory vegetation is quite variable, nearly lacking in younger, dense stands, or lush and dense under older canopies.

Wildlife use of aspen forests is similar to that of alder forests.

Paper Birch Forests

Paper birch-dominated forests are very uncommon west of the Cascade Mountains, occurring only in Whatcom and northern Skagit Counties. Formerly much more extensive, the areal extent of paper birch forest in coastal Washinton has diminished due to human activity. Anchored in Birch Bay in 1792, Archibald Menzies, naturalist aboard the H.M.S. Discovery wrote:

> "I landed at the place where the Tents were erected & walked from thence round the bottom of the Bay to examine the natural productions of the Country & found that besides the Pines already enumerated the Woods here abounded with the white & trembling Poplars together with black Birch. In consequence of my discovery of the latter place, the afterwards obtained the name of Birch Bay."

Logging, fire, and agriculture have primarily been responsible or the reduction of birch forests in western Washington.

A recent study of western Washington paper birch forests indicates understory composition and structure similar to alder forests, with the distinction of an open to nearly closed subcanopy of cascara or vine maple often present. Shrubs may include salmonberry, black twinberry, snowberry, osoberry, and red huckleberry. An abundant herb layer is usually present, although in stands with well-developed shrub or subcanopy layers, it may be suppressed.

Wildlife use of paper birch forests is similar to alder forests.

Madrona Forests

A frequent and conspicuous element of the coastal Washington flora along bluffs and in mixed forests, madrona forms pure stands only in San Juan, Clallam, Skagit, Whatcom, Jefferson, and King Counties. Madrona forests are unique among the broadleaf forest

communities of western Washington due to their evergreen canopy and occurrence on dry, often rocky sites. The most extensive madrona forests mapped were on Vashon and Maury Islands in King County, much of the area underlain by porous glacial deposits and excessively well drained.

Despite the evergreen nature of the canopy layer, the shrub layer was dense at the few sites that were visited. At the Glen Cove (Jefferson County) site, snowberry thickets, baldhip rose, Oregon grape, salal, and evergreen huckleberry are abundant. On Vashon Island in King County, several sites with understories of essentially pure, dense salal were noted.

Madrona is a relatively long-lived species with intermediate shade tolerance, able to stump-sprout and outgrow Douglas fir seedlings following disturbance. These characteristics suggest madrona forest may be a very long-lived, if not climax, community, especially at sites with dense, shrubby understories, as on Vashon Island. On the other hand, eventual replacement of madrona forest by coniferous or mixed forest is supported by observations made at Glen Cove. Evidence of past fire, i.e., charred stumps and muliple-stemmed madronas, is present at this site, and information provided by local residents indicates the area was burned approximately 50 years ago. Subsequently, a pure madrona canopy, estimated to be 40 feet in height, has grown up and now dominates the hillside. Growing in the understory however, are Douglas fir and western red cedar saplings, which can be expected to eventually dilute or replace the present broadleaf canopy.

Wildlife of Madrona Forests

Little is known regarding madrona wildlife communities, however, several species were frequently observed in madronas during the course of this study. Birds which feed on berries were especially common, and at times were observed in large flocks, consuming the abundant fruit of the madrona.

Species noted were Band-tailed Pigeons, Varied Thrush, Hermit Thrush, Robin, and Rufous-sided Towhee. Orange-crowned Warblers were also frequently seen in madronas and other insectivores which forage in these broadleaf evergreens include kinglets, Western Flycatchers, chickadees, and Hutton's Vireos.

Black-tailed deer, western fence lizards, raccoons, and mountain beaver were also noted in madrona forests.

IMPACTS

Major disturbances affecting mature broadleaf forests are discussed in the Impacts section of the general forest narrative (No. 4).

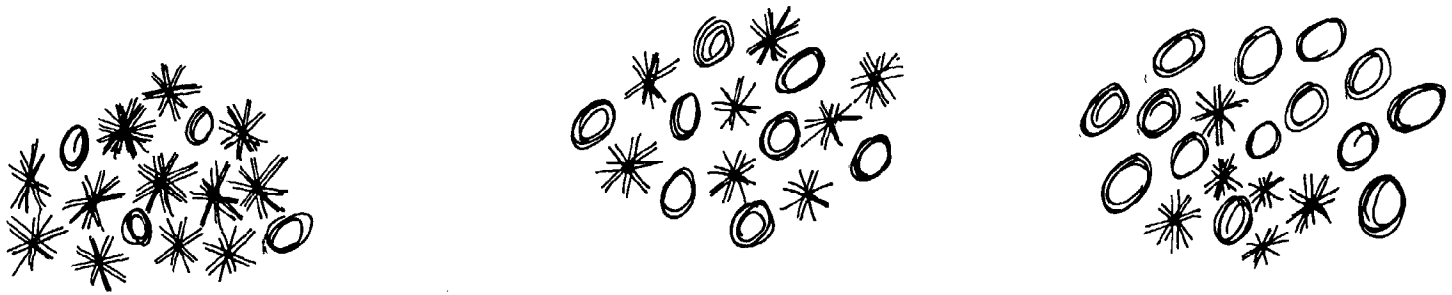
POLE STAGE BROADLEAF FOREST (No. 423)

An intermediate stage between immature and mature fores, this class was used only in Pacific County. A tall canopy of densely stocked red alder and poorly developed understory are characteristic of this stage. Wildlife use is similar to that discussed for mature broadleaf forests, although use of the understory is low.

MIXED FOREST (No. 43)

INTRODUCTION

Forest areas included in this class have a canopy layer formed by broadleaf and coniferous species, with neither strongly dominant, and a generally well-developed understory. Within this broad scheme, individual tracts of mixed forest vary according to the relative numbers of coniferous and broadleaf trees in the stand, and their relative distribution. Illustrated in Figure 43-1 are three possible arrangements.



CONIFERS MORE ABUNDANT
RANDOM DISTRIBUTION

EQUAL NUMBERS
EVEN DISTRIBUTION

BROADLEAFS MORE ABUNDANT
CLUMPED DISTRIBUTION

Figure 43-1 Examples of Relative Numbers and Distribution of Trees Forming Canopy in a Mixed Forest.

Additionally, plant species composition varies throughout the coastal zone in response to environmental factors. Major moisture regimes, described in the Coniferous Forest Narrative (No. 41), largely determine the species composition of a specific site, although local microclimate, soil, and topography are influential. Mixed forests are more abundant that any other forest type mapped in the coastal zone, covering large areas in every county.

A transitional stage in the development of coniferous forest, mixed stands have always been a part of the coastal landscape, but presumably have become more common as disturbance of the pre-settlement forest cover has increased. During this transitional stage, features of both coniferous and broadleaf forests will be intermingled. As a result, mixed forest wildlife communities may be more diverse than those in either pure broadleaf or pure conifer forest as illustrated in Figure 43-2. Species characteristic of conifers or broadleaf and those which are adapted to either woodland type (e.g., deer and shrew-mole) will be present.

Sub-classes of Mixed Forests include: Immature Mixed Forest (No. 431), Mature Broadleaf/Old Growth Conifer (No. 432), Second Growth Mixed Forest (No. 433), and Pole Stage Mixed Forest (No. 434).

SIGNIFICANT BIOLOGICAL FEATURES

Major Plant Communities

The following general mixed forest communities, resulting from climatic differences, were observed during the course of this study.

Throughout the dry forest zone (see Figure 41-1) mixed forests of Douglas fir and madrona are common, particularly on south-facing slopes. Lodgepole pine is often present as a co-dominant. On moister north-facing slopes, or areas otherwise protected from dessication, grand fir, Douglas fir, western red cedar, red alder, and bigleaf maple are the usual components of the canopy layer.

Median zone mixed forests are generally species-rich communities. Douglas fir, western hemlock, western red cedar, grand fir, occasional western white pine, lodgepole pine, and Sitka spruce (i.e., all the common lowland coniferous trees) may be present in the canopy, with red alder, bigleaf maple, madrona, Scouler willow, and several less common deciduous trees providing the broadleaf element. Subcanopy trees and shrubs in the understory include young conifers, cascara, vine maple, Pacific dogwood, hazelnut, salal, Oregon grape, and evergreen huckleberry. Herbaceous vascular plants, epiphytic mosses and lichens, and fungi common to both coniferous and broadleaf forests may be present.

In Pacific County, the only mapped county in the moist forest zone, mixed forests were dominated principally by western hemlock, Sitka spruce, and red alder, usually with a dense understory of salmonberry and red elderberry.

Origin of Mixed Forests

Mixed stands often develop immediately following disturbance (cf. Immature mixed) or as an intermediate seral stage between mature broadleaf and conifer forest (cf. Second Growth Mixed).

Wildlife Use

Due to their ubiquity, mixed forests provide the greatest proportion of the available forested habitat in the coastal zone. Because features of both coniferous and broadleaf forests are present, animal use of mixed forests is high, relative to strictly broadleaf or coniferous forests. For example, in reference to nongame birds of mixed or transitional forests, John Wiens states, "During transitions, when elements of both habitat types are intermixed, species characteristic of both types may be present, leading to an increase in species numbers, density, and biomass."

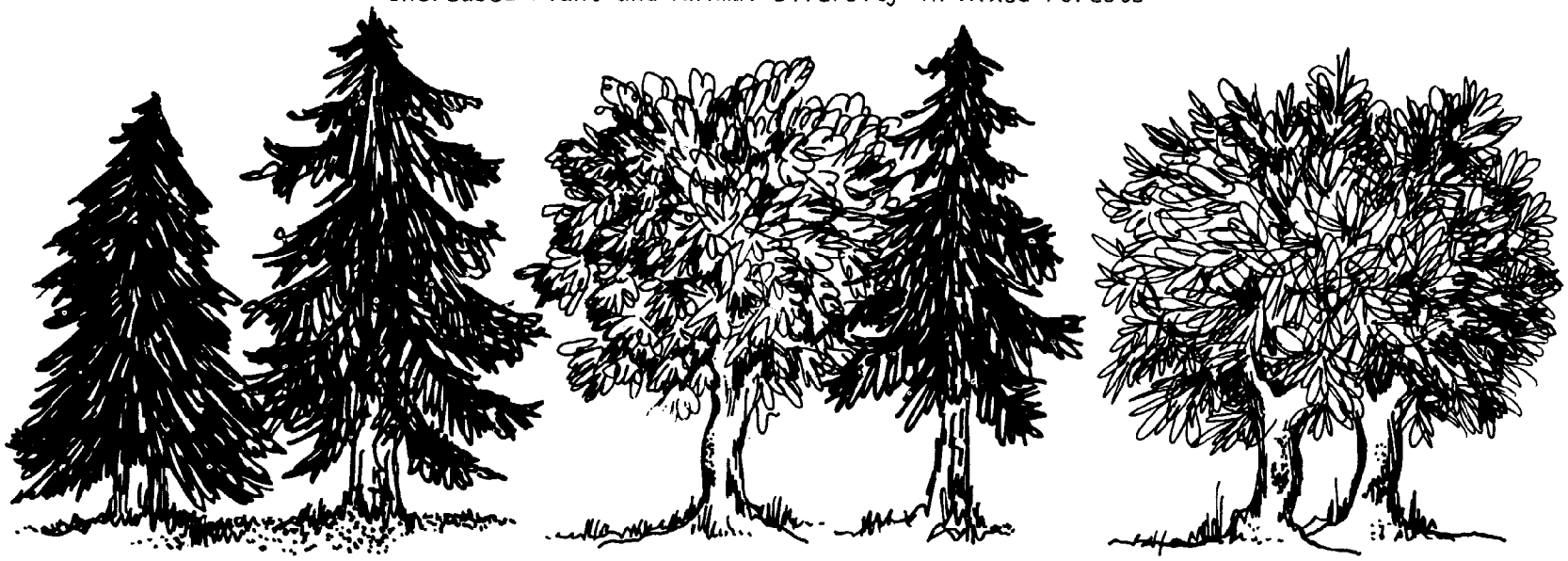
Other Values

Recent studies in coastal Oregon have demonstrated that growth of Douglas fir and Sitka spruce is improved when these species occur in association with red alder (the major broadleaf constituent of mixed forests throughout the coastal zone) as a result of alder's ability to add nitrogen to the soil.

IMPACTS

A general discussion of disturbances affecting all forests, including mixed, will be found in the Impacts section of the Forest Narrative (No. 4). See also specific comments in the following narratives.

Increased Plant and Animal Diversity in Mixed Forests



Conifers,
Representative Species

Douglas Fir
Salal
Hairy Woodpecker
Chestnut-backed Chickadee
Golden-crowned Kinglet
Red-breasted Nuthatch
Brown Creeper
Townsend's Warbler
Douglas' squirrel
Black-tailed deer
Shrew-mole

Mixed Forest,
Representative Species

Douglas Fir
Alder
Salal
Salmonberry
Hairy Woodpecker
Downy Woodpecker
Chestnut-backed Chickadee
Black-capped Chickadee
Golden-crowned Kinglet
Yellow Warbler
Red-breasted Nuthatch
Orange-crowned Warbler
Brown Creeper
Warbling Vireo
Townsend's Warbler
Willow Flycatcher
Douglas' squirrel
Swainaon's Thrush
Black-tailed deer
Shrew-mole

Broadleafs,
Representative Species

Alder
Salmonberry
Downy Woodpecker
Black-capped Chickadee
Yellow Warbler
Orange-crowned Warbler
Warbling Vireo
Willow Flycatcher
Swainson's Thrush
Black-tailed deer
Shrew-mole

IMMATURE MIXED FOREST (No. 431)

INTRODUCTION

Immature mixed forest, an early seral stage, was frequently mapped in areas that had been recently logged. Included in this class are mixed stands of regenerating coniferous and broadleaf trees, often exhibiting a structure and density similar to successional shrub communities. Distinction from the shrub class was based on the presence of tree regeneration. Well-developed strata may be present in some stands, but a lack of regenerating conifers in the understory is characteristic. Succession ordinarily proceeds to second growth mixed forest in the absence of disturbance. Wildlife use is similar to that discussed for open stands of regenerating conifers and young broadleafs. Because the canopy has not developed fully at this point in succession, ground and shrub layers play a major role in providing the abundant berries, insects, and foliage consumed by birds and mammals.

SIGNIFICANT BIOLOGICAL FEATURES

Immature mixed forests typically are a rich assemblage of trees and shrubs, the herb layer sometimes suppressed by the dense overstory. For example, a stand on San Juan Island (San Juan County) had five species forming the canopy layer; Douglas fir, grand fir, western red cedar, red alder, and Scouler willow, and a thick, shrubby understory of ocean spray, bald hip and Nootka rose, serviceberry, coast black gooseberry, red currant and thickets of snowberry. The only herbaceous species noted was sword fern.

Youngest stands, especially those developing after clearcut logging, are a heterogeneous mixture of remnant species from the forest that previously occupied the site, and invading species, e.g., mountain balm (notable for its nitrogen-fixing capacity), willow, fireweed, and wood groundsel. Regenerating trees on such sites are usually Douglas fir, western hemlock, and red alder. A species-rich wildlife community, similar to that discussed in the regenerating conifer narrative, is typical of these young stands. Refer to both the broadleaf and conifer species lists for potential wildlife inhabitants of these young forests.

IMPACTS

Immature mixed forests, when managed for timber production, are often treated with biocides and pre-commercially thinned, both practices aimed at improving conditions for conifer growth. Although developing conifers benefit from these practices, value of the site as wildlife habitat is diminished. Loss of browse and berry-producing plants is primarily responsible for the reduction, with loss of cover a contributing factor. Soil characteristics may be affected by herbicide treatments, particularly through the loss of plants with nitrogen-fixing capabilities (notably red alder, the usual target species) decreased amounts of litter, and possible increased erosion. While short-term gains, i.e., the more rapid development of merchantable timber, may be realized by the early curtailment of alder growth, long-term benefits may be sacrificed. It is a current irony in forest practices that alders are eliminated when young to benefit coniferous species, when succession would also have eliminated them in a longer time period, after naturally fertilizing the soil and ultimately enhancing conifer growth.

MATURE BROADLEAF/OLD GROWTH (No. 432)

Discussion of this uncommon forest community will be found in the Old Growth Conifer Narrative (No. 414). Specific sites where this class was mapped are listed in Table 414-1.

SECOND GROWTH MIXED FOREST (No. 433)

INTRODUCTION

Large tracts of second growth mixed forests are common in every county, this being the most abundant coastal forest class. A diverse, species-rich plant community is characteristic of these forests, typically with well-developed ground, herb, shrub, and subcanopy layers, containing any of the species discussed in the preceeding forest narratives. As a result, wildlife use and value of these forests is great.

SIGNIFICANT BIOLOGICAL FEATURES

Much of the information discussed in the Second Growth Conifer and Mature Broadleaf Narratives (Nos. 413 and 422, respectively) is pertinent to mixed forests, and readers are referred there, keeping in mind the following major characteristics of second growth mixed forests:

- the co-dominance of coniferous and broadleaf species.

- understory development and plant species richness intermediate between conifer and broadleaf forest (as reported from coastal Oregon).

- greater habitat diversity than either conifer or broadleaf forest. Wildlife associated with both types will be present in addition to those which are adapted to woodlands in general. Of special importance is the value of older mixed forests to those species which require snags, large trees for nest support, and other habitat features of mature forests in general.

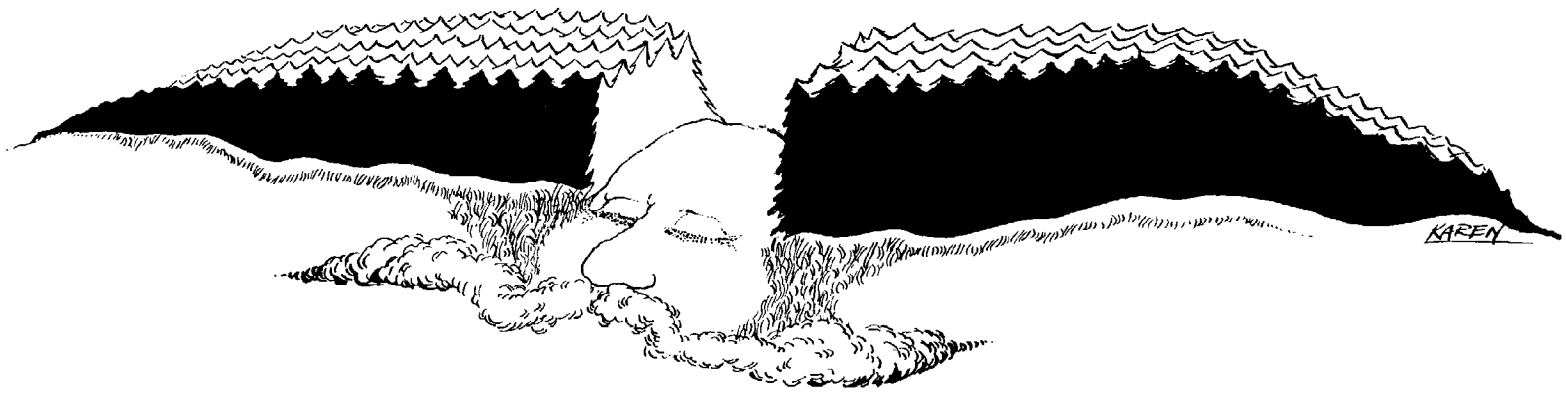
IMPACTS

A common disturbance of mixed forests, especially in areas experiencing rapid growth, is the selective logging of the coniferous trees followed by residential construction. This practice seemed particularly common in mixed forests with madrona as the broadleaf element, perhaps because madrona is a nonmerchantable, but beautiful tree. Where construction does not follow selective logging, these areas may be expected to regenerate mixed or broadleaf stands.

Other common disturbances are discussed in the general Forest Narrative (No. 4).

POLE STAGE MIXED FOREST (No. 434)

An intermediate age class between regenerating and second growth mixed forest, pole stage mixed forest was used only in Pacific County maps. Even-aged stands of relatively young (approximately 20 to 40 years) western hemlock, Sitka spruce, and red alder are included in this class.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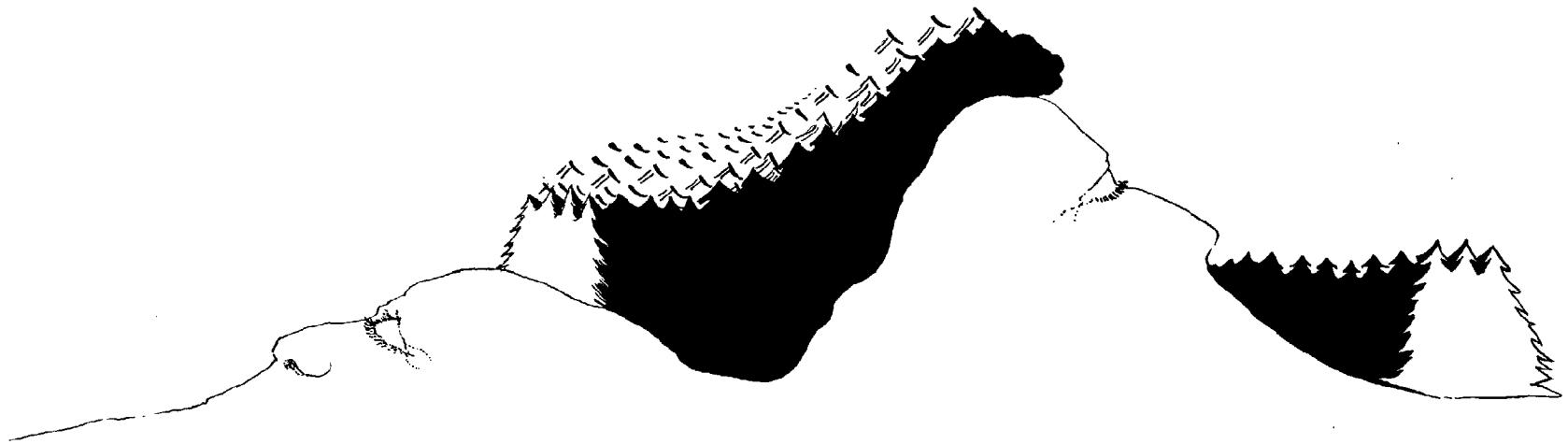
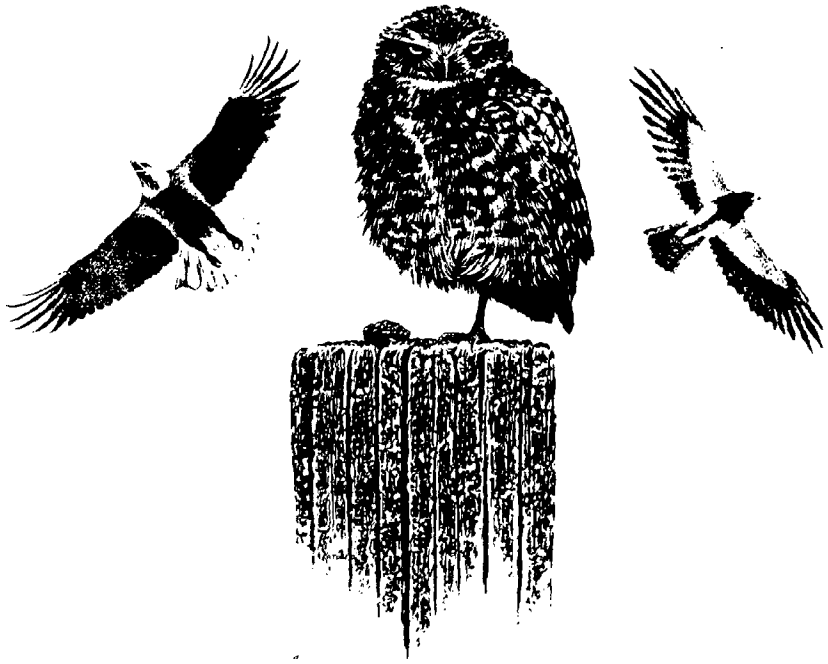


OPEN WOODLAND (No. 44)

Open woodlands are composed of a variety of trees and scattered individual plants which do not form a closed canopy. These areas often occur on dry, exposed sites and usually support a diverse ground cover of grasses and other herbaceous plants.

Includes:

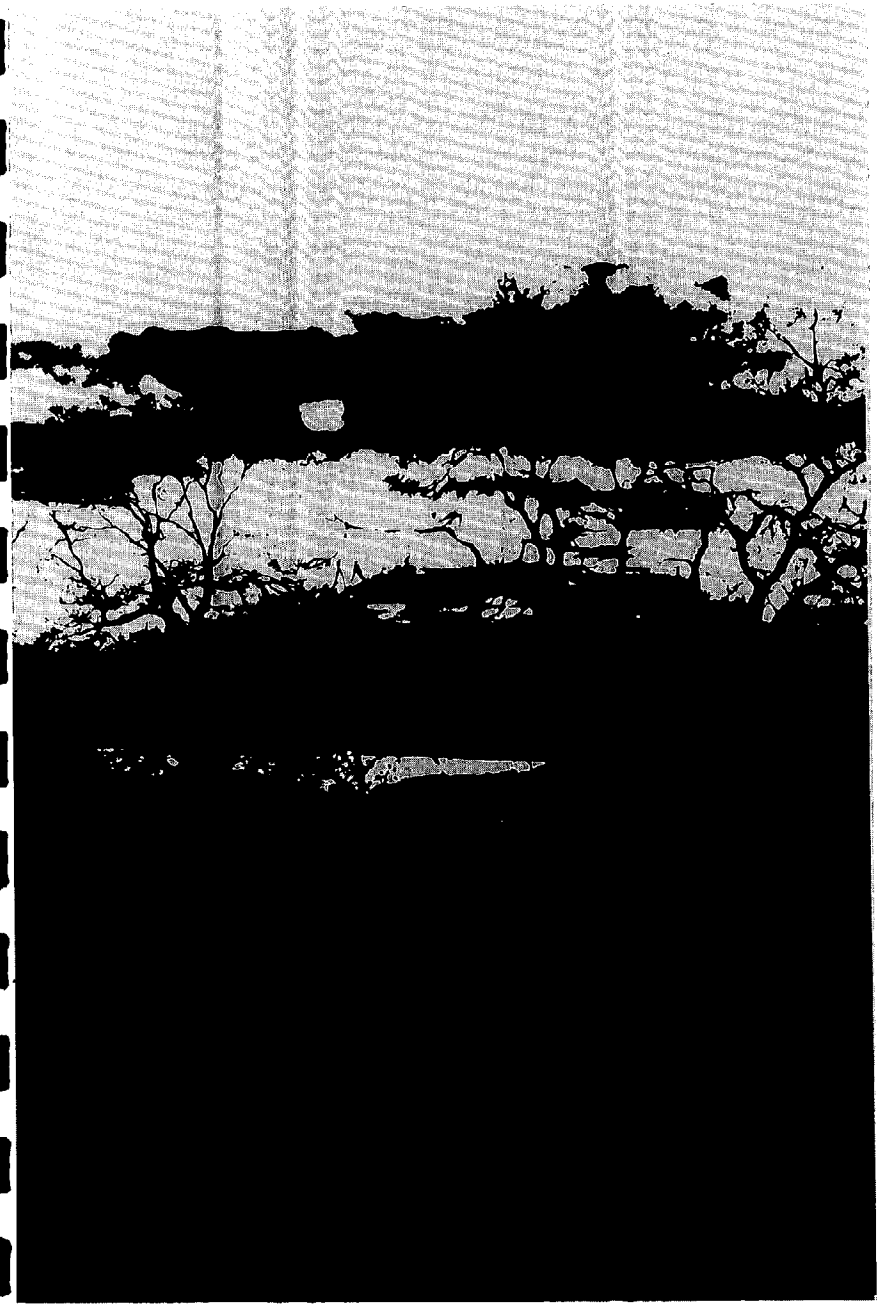
Oak Savannah (No. 441)
Conifer/exposed Rock (No. 443)
Broadleaf/exposed Rock (No. 444)
Mixed forest/exposed Rock (No. 445)



LET THEM LIVE

ALL EAGLES, HAWKS AND OWLS ARE PROTECTED

REPORT VIOLATIONS TO THE U.S. FISH AND WILDLIFE SERVICE
OR THE WASHINGTON STATE GAME DEPARTMENT



OAK SAVANNAH (No. 441)

INTRODUCTION

Abundant in California and Oregon, oak savannah is one of the scarcest habitat types occurring in Washington's coastal zone, reaching the northern limit of its distribution in the San Juan Archipelago, the southern end of Vancouver Island,and adjacent mainland British Columbia. Oak savannah was mapped at only two locations in the coastal zone, the largest approximately 19.3 acres (7.8HA) on the west side of Garrison Bay, San Juan Island, and the second [approximately 8.4 acres (3.4HA)], on Point Disney, Waldron Island. On San Juan Island, the plant community extends into the uplands beyond the 2000' limit of the coastal zone represented in the land cover maps. The Waldron Island site is wholly contained within the mapped zone. In the Puget Sound Basin, similar communities occur inland of the coastal zone near Sequim (Clallam County), Shelton (Mason County), on Whidbey Island (Island County), and south of Tacoma in Pierce and Thurston counties.

At both coastal sites, widely scattered Garry oaks are present in a grassland matrix, with shrub thickets and rock outcrops occurring throughout. Additional trees include Rocky Mountain juniper, madrona, and Douglas fir. Seedlings of these species are present while those of Garry Oak are conspicuously absent. The grassland matrix is essentially the same species rich community mapped elsewhere as open grassland (see Narrative No. 313), containing many spring-flowering annuals and perennials. The presence of trees and shrub thickets, however, is a significant factor in determining the wildlife use of these areas, particularly by birds of prey.

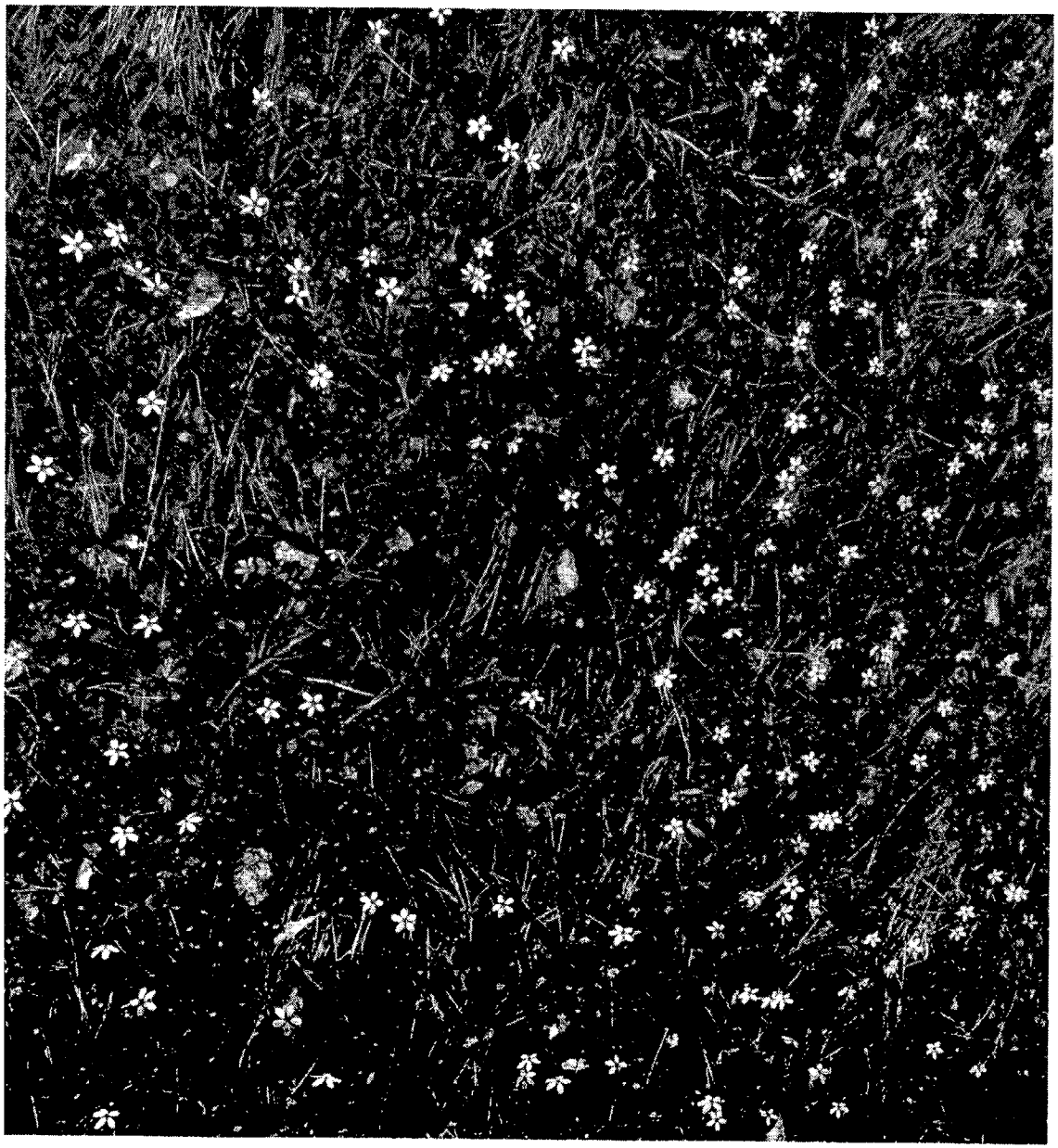
HISTORICAL CHANGES

The presence of Douglas fir, Rocky Mountain juniper, and madrona seedlings does not bode well for the future of our coastal oak savannahs. Encroachment by seral species is well documented in Pierce and Thurston counties, where the extent of prairie and oak savannah have been greatly reduced since European settlement, primarily by the invasion of Douglas fir. When Douglas fir invades oak savannah, it eventually overtops the oaks which are subsequently unable to reproduce in the increasingly shady understory. Eventually, oak savannah is transformed into Douglas fir, or mixed, forest. This phenomenon is also occurring at the San Juan Island site, as evidenced by the relict oaks in the surrounding conifer-dominated stands, and the abundant fir seedlings scattered throughout the oak savannah (see Figure 441-1). Prior to European settlement, both natural and intentional fires periodically burned through the Tacoma prairies, preventing the establishment of Douglas fir and other seral species. After the advent of fire protection, invasion of the prairies and savannahs increased. Whether fire was also a factor in maintaining the oak savannahs on the San Juan Archipelago is not definitely known, but is not an unrealistic assumption.

This same successional scheme appears to have occured at Johns Prairie on the west side of Oakland Bay in Mason County. Here, lodgepole pine dominates a large area, with old Garry oaks scattered throughout.

In the vicinity of Oak Harbor, Whidbey Island, there existed in the past a large area of oak savannah and open grassland. Archibald Menzies, botanist with Captain Vancouver, noted in 1792, "Oak timber more abundant [in this area] ... than any we have explored ... the country to the northward ... abounding with luxuriant lawns, cropt with the finest verdure...". This area is presently altered by urban and agricultural development, and oak savannah is absent from the coastal zone. Although Garry oak stands extend into southwest British Columbia, the only extensive

Figure 441-1



original stand is now occupied by the built-up area of greater Victoria. Nearly all remaining stands are threatened with destruction as landclearing and subdivision proceed.

SIGNIFICANT BIOLOGICAL FEATURES

The occurrence of oak savannah, a plant community reaching its highest stage of development in California, in the generally cool, moist Puget Trough, is in itself a very significant feature. Its presence is primarily the result of the geological history and climate unique to this area.

Garry oak, our only native oak, is a species found only on the driest treed sites in western Washington, reaching the northern limit of its distribution on Vancouver Island and the San Juan Archipelago (see Figure 441-2).

The presence of Garry oak in this area is puzzling, and two theories have been discussed:

A) Garry oak (and many of the herbaceous species occurring in the open grassland) are relicts from the dry warm period following the Vashon glaciation.

B) Oaks, an important food resource of native Americans throughout California and Oregon, were introduced to the San Juans and at other northern sites. Trading parties, intermarriages, and relocation of villages could all have been responsible for the dissemination of Garry oak acorns this far north. Many sites where Garry oak is found throughout Washington are also locations of former native American villages.

Garry oak is a relatively long-lived (to 600+ years), slow-growing tree. A study of the oaks of the Tacoma prairies determined an easy method for estimating the age of the oaks growing there. While recognizing the physical and environmental differences existing at the two sites, the same formula (multiplying the diameter

in inches x 11 = approximate age) was applied to several individuals from the San Juan Island savannah. The results are in Table 441-1.

TABLE 441-1. Estimated Ages of Garry Oaks in San Juan Island Savannah.

Circumference	Diameter	Estimated Age
47½"	15.12"	166 yrs.
64"	20.37"	224 yrs.
66½"	21.17"	233 yrs.
69"	21.96"	241 yrs.
74"	23.55"	259 yrs.
108"	34.38"	378 yrs.
116"	36.92"	406 yrs.
119"	37.88"	416 yrs.
138"	43.93"	483 yrs.
156"	49.66"	546 yrs.

It is probable that the oldest trees in this stand are the progenitors of the younger individuals and first sprouted in the early part of the 15th century.

Garry oaks produce scant crops of acorns every other year which are eaten by a wide variety of animals. Leaves and stems are also a food resource for many vertebrates (see Table 441-2).

Table 441-2

San Juan Islands Birds and Mammals Known to Consume Acorns and/or Oak Foliage.

	Acorns	Leaves, Twigs	Relative Occurrence in San Juan Islands
BIRDS			
Ruffed Grouse	X	X	Status uncertain
Band-tailed Pigeon	X	X	Common resident
California Quail	X	X	Abundant resident
Turkey	X	X	Introduced on San Juan Island
Common Crow	X		Abundant resident
Common Flicker	X		Common resident
Downy Woodpecker	X		Uncommon resident
Steller's Jay	X		Status uncertain
Horned Lark	X		Common in summer
Varied Thrush	X		Uncommon in winter
MAMMALS			
Red fox	X		Introduced - status uncertain
Raccoon	X		Common
Meadow mouse	X		Common
Black-tailed deer	X	X	Common

The oak savannah on San Juan Island is within English Camp National Historical Park, and therefore protected from development. However as mentioned earlier, shrub thickets and seral trees have become established in the savannah. In the absence of fire, it is inevitable that the savannah community will eventually be succeeded by coniferous forest. Periodical burning of the area retards succession by destroying successional shrubs and trees, and burning off the humus layer of the soil (which retards acorn germination).

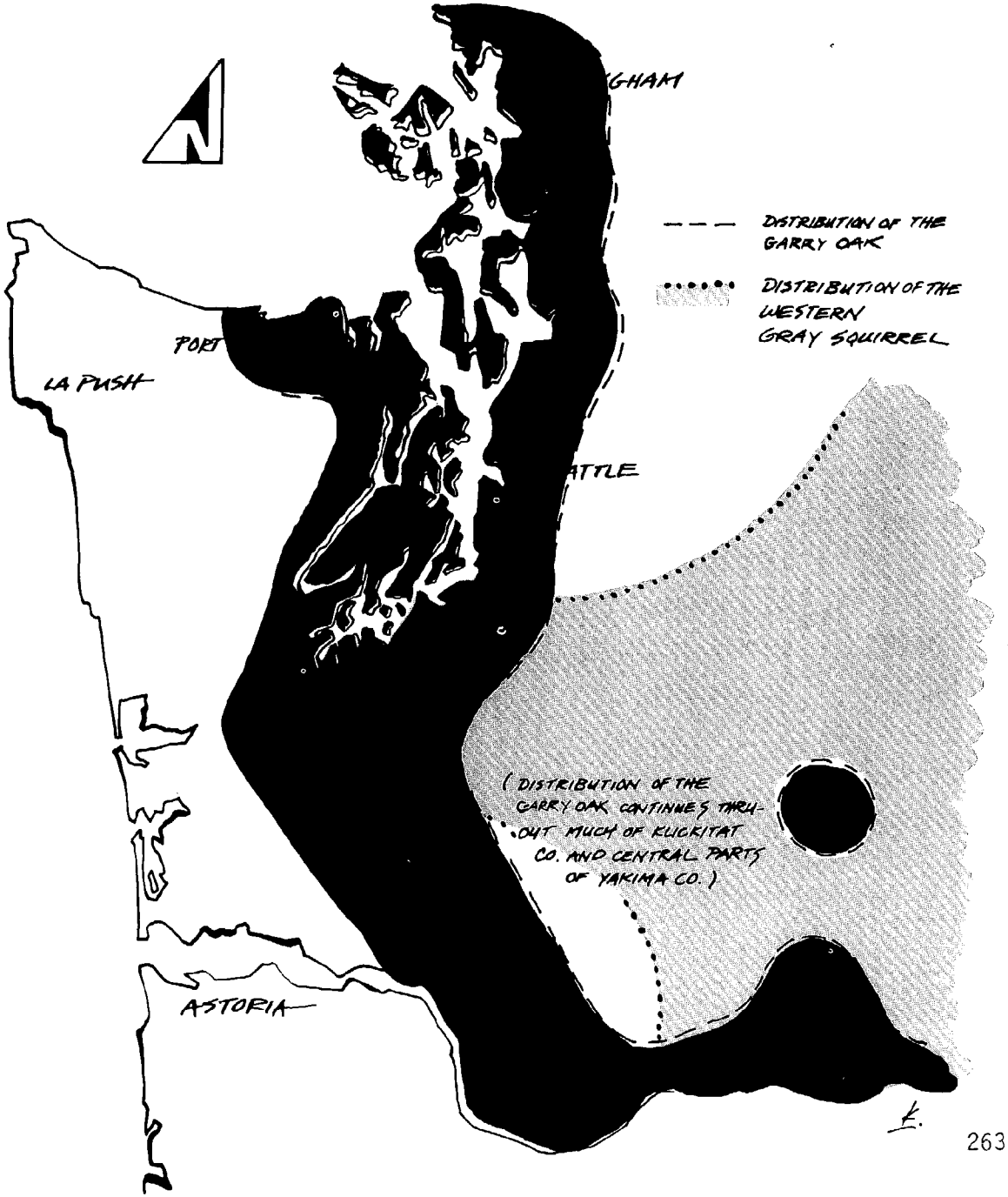
Coastal Washington oak savannah flora is unique due to the absence of two plant species common in the oak savannah communities to the south. Both poison oak and mistletoe are conspicuous elements of more southerly oak savannah communities, but are lacking at both coastal Washington sites. Poison oak has a spotty distribution around Puget Sound, usually occurring close to the shoreline on dry bluffs. Mistletoe, a parasite of Garry oak, is very abundant throughout the Willamette Valley, but is unreported in the Puget Sound area.

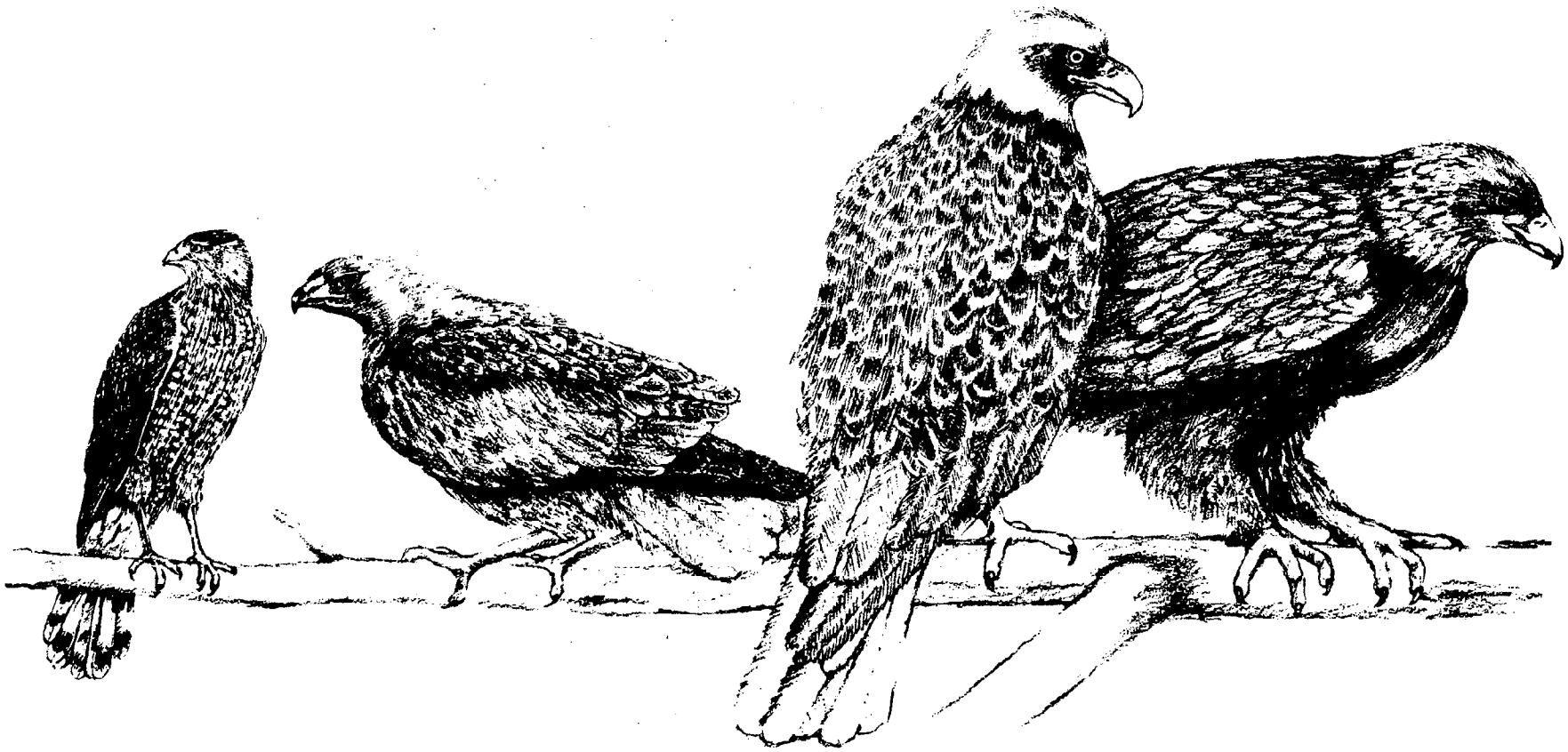
A notable mammal which is absent from the San Juan oak savannahs is the western gray squirrel. Acorns are a staple in the diet of this squirrel; however, the water barrier has limited the number of mammals in the San Juan Islands, among them several other acorn predators. The western gray squirrel probably occurs in the coastal zone, however, along the southern edge of Puget Sound, and inland within the Tacoma Praries area. See map (Fig. 441-2) for the distribution of this uncommon Washington mammal. The more common Douglas squirrel is also thought to be absent on San Juan and Waldron islands.

As a result of characteristically poor acorn crop production, and insect infestation, crown sprouting and root suckering are important means of Garry oak reproduction. Viable acorns are disseminated by animals, notably rodents which cache food supplies in soil or duff. Although these animals do not occur in the San Juan coastal oak savannahs, large birds are capable of transporting acorns long distances. Perhaps these birds are responsible for the original dissemination of oaks in the San Juan Islands rather than early man.

A study of Oregon oak woodlands, which included open, savannah-like areas, found the diversity of avifauna higher than the diversity reported for many other forest communities. It is suggested that the many micro-habitats provide areas with greater food variety and thus can support a proportionally large number of individuals or species. As with most temperate forests, particularly broadleaf forests, there is a sharp rise in bird species diversity in spring due to the arrival of migratory breeders.

Densities of birds (average 550 per 100 acres) during the breeding season were comparable to the deciduous forest types, and higher than eastern oak woodlands. High breeding bird density in the Oregon oaks may be


GHAM
DISTRIBUTION OF THE GARRY OAK
DISTRIBUTION OF THE WESTERN GRAY SQUIRREL
PORT
LA PUSH
ATTLE
(DISTRIBUTION OF THE GARRY OAK CONTINUES THRU-OUT MUCH OF KLICKITAT CO. AND CENTRAL PARTS OF YAKIMA CO.)
ASTORIA



due to the mild winters of the Willamette Valley. Similarily, winters in coastal Washington are relatively mild. Although there is an increase in bird species in the spring, there are also a number of permanent residents (a higher percentage than is found in eastern oak woods). In Oregon, many of the winter residents were found to move to nearby plant communities for breeding. Thus, the oak woods support several species during the winter, including Red-breasted Nuthatches, Varied Thrushes, and kinglets, which then breed in coniferous forests. Potential breeding birds include most species noted for broadleaf forests (see Table 42-1).

Many other species occur in much higher numbers or more regularly in San Juan coastal oak savannahs, particularly birds of prey. This was especially evident on a winter visit to the English Camp oak savannah during this study. The following were observed that day:

Red-tailed Hawks
Cooper's Hawk
Adult Bald Eagles
Immature Bald Eagles
Golden Eagle

The open nature of oak savannah makes it valuable habitat for these species. Therefore, it is important to maintain the savannah for the sake of many animals as well as to preserve this unique plant community.

IMPACTS

It appears that the greatest impact to Washington's remaining coastal oak savannahs is the result of fire control, initiated with the arrival of the early settlers. Fire at one time was the major factor in sustaining oak savannah in Oregon and Washington, but in its absence, successional plant species are encroaching the savannah. Recognizing fire as a necessary and healthy component of the savannah ecosystem is essential for the continued existence of these communities, for if present trends continue, oak savannah will soon disappear from western Washington.

MADRONE/ARCTOSTAPHYLOS (No. 442)

Originally mapped in Whatcom and Skagit Counties, this class was incorported in either the Broadleaf (No. 42) or Open Woodland (No. 44) category in revised maps for those counties. Refer to these narratives for areas mapped as No. 442 in original (1978) editions of the Washington Coastal Zone Atlas.

CONIFER/EXPOSED ROCK (No. 443)
BROADLEAF/EXPOSED ROCK (No. 444)
MIXED FOREST/EXPOSED ROCK (No. 445)

INTRODUCTION

Open woodlands characteristically have a very open canopy, sparse subcanopy and shrub layers, and a well developed herb layer composed of grasses and wildflowers. Dominant plant and animal species are those characteristic of dry sites, including many species which primarily occur in desert conditions in Eastern Washington. Rock outcrops are scattered throughout the understory and insure a permanently open canopy which increases the floral and faunal diversity of these woodlands.

The distinguishing features of exposed rock woodlands result from the dry, open conditions and unique plants and animals beneath the canopy layer. In this narrative, areas mapped as Conifer/Exposed Rock (No. 443), Broadleaf/Exposed Rock (No. 444), and Mixed Forest/Exposed Rock (No. 445) are discussed together. These share much in common with forests of corresponding dominant types (i.e., Conifer/Exposed Rock--Coniferous forest) and readers may refer to three narratives (41) Conifer, (42) Broadleaf, and (43) Mixed forest for pertinent information.

Exposed Rock Woodlands are primarily restricted to dry, south-facing slopes in the San Juan Archipelago. Shallow soils, high levels of insolation, low summer soil moisture, and dry southerly winds are characteristic of these sites. San Juan sites are often quite extensive, forming the upland equivalent of the Archipelago's extensive rocky shoreline.

Where soils are more fully developed, exposed rock woodlands may only form a narrow ecotonal fringe between coastal rock outcrops and more dense forests extending inland. These narrow bands occur throughout the San Juans and infrequently elsewhere in the coastal zone such as along the eastern shore of Hood Canal. Because of the extent in the San Juans, the amount of habitat provided is large enough to attract dry land wildlife which require fairly large territories. Outside of the San Juans, fauna in rock woodlands will be more typical of surrounding forests.

SIGNIFICANT BIOLOGICAL FEATURES

Plant Community

Dominant on coniferous sites are Douglas fir and lodgepole pine with occasional madrones scattered in the canopy. All three species are able to regenerate under the open canopy, although Douglas fir is the most shade tolerant. Thus, broadleaf sites now dominated by madrone, garry oak, or bigleaf maple are likely to be succeeded by Douglas fir. Mixed forests represent a transition or result from disturbance. Rocky Mountain juniper also occurs in exposed rock woodlands in open spots under the canopy or at the forest edge. Characteristic open woodland shrubs include ocean spray, snowberry, shrubby thickets of Garry oak (once thought to be a separate species of oak), and salal.

Herbs on the forest floor include many introduced and native grasses, nodding onion, Leichtlin's camas, deadly zigadenus, and Greene's bogorchid. All these herbaceous annuals and perennials are also found in dry, more open spots throughout the San Juans and are indicative of the interrelationships between open woodlands, rock outcrops, and natural, open grasslands. In many cases, the rocky woodlands are really inseparable from these more open lands. They grade into one another and, on Dallas Mountain on the west side of San Juan Island, form one of the most biologically and esthetically dramatic sites in Western Washington. Scattered trees and patches of woods are clustered on the rocky slopes of Mt. Dallas. Rock outcrops are extensive and support a distinctive flora composed of many mosses, lichens, and wildflowers. (Refer to rock outcrop narrative, No. 711, for a more detailed description).

Rocky Mountain Juniper

The main distribution of this small tree is east of the Cascades in a few locations in Washington and throughout the Rocky Mountains states. The disjunct population on the San Juan Archipelago and other rocky sites in the rain shadow of the Olympics is a remarkable feature of the flora of this area. Rocky Mountain juniper is a very long-lived species, capable of reaching 3000 years. Juvenile leaves of this species are sharp-pointed, awl-shaped, and often long-persistent, but eventually the mature, scale-like leaves develop.

Juniper cones are fleshy, berry-like structures, relished by many species of birds, that stay on the tree through the winter, providing an excellent food supply. Birds are apparently the primary agents for the dissemination of juniper seed, which doesn't germinate successfully until the fleshy covering has been removed by digestion by birds or other animals.

Two additional plant species common east of the Cascades with disjunct populations centered in, or restricted to the San Juan Archipelago include brittle cactus and western blue flag. None of the species are abundant in western Washington, and destruction of their habitat or of individual plants will adversely affect the continued existence of these unique populations.

Fauna

Fauna is similar to that found in coastal forests previously discussed, particularly outside the San Juan Islands. Refer to the Conifer (No. 41), Broadleaf (No. 42), and Mixed Forest (No. 43) Narratives for potential species.

However, the resultant structural diversity and uniquely dry conditions (19 to 28 inches of rainfall each year in the San Juan Islands compared to 37 inches in Seattle) create a correspondingly unique and diverse animal community. Insular conditions restrict numbers of kinds of mammals, and to some extent birds, present at most rocky woodlands in the San Juans. However, several other features of the islands accentuate the habitat conditions to produce the most unique plant and animal community in the coastal zone.

Canopy Layer

Because of the open canopy, there is additional air space between trees for aerial foragers including swallows and birds of prey. Since trees are present, raptors present in rocky woodlands include those of both open country (Golden Eagle) and forests (Accipiters such as Cooper's Hawks which are adapted to chasing small birds in woodlands) as well as the Red-tailed Hawk, which is naturally a bird of savannahs or other open woodlands. Trees provide hunting perches, night roosts and nest sites, while the openings provide hunting territory. This habitat is even more beneficial to Bald Eagles (which forage, roost, and nest in rocky woodlands) since they also feed on fish and birds in nearby marine waters. Along Mt. Dallas, eagles also can be observed during courtship displays above rocky slopes and woodlands. Thus, all San Juan Island rocky woodlands should be considered as prime Bald Eagle habitat in addition to their other unique features.

Ground Layer

Rabbits are most abundant in the San Juans in open grassland or farm land, but also occur in open forests, including the rocky woodlands along Dallas Mountain. Rabbits provide a year-round food source for birds of prey and exemplify the relationships and requirements of predators and prey in open woodlands. Eagles and other birds of prey perch in trees and forage on ground dwellers like rabbits. The rabbits, however, are only the most obvious prey. As mentioned, Bald Eagles also fly out over salt water in search of marine birds and fish. Sharp-shinned Hawks and Merlins probably do not prey on rabbits, feeding instead on small birds from the ground layer, through shrubs and in the canopy where a perch and nest site is also available. At dusk, owls, including Great Horned Owls, may feed on rabbits, but other small mammals such as meadow mice are also taken in hours of darkness. Thus, a wide variety of birds of prey forage in rocky woodlands, many of which are rare species. It is important, therefore, to maintain undisturbed ground layer habitat as well as trees to provide optimum conditions for predators and prey in rocky woodlands. Patches of shrubs, snags, fallen logs, wet places, and scattered areas of dense woods all provide additional habitatfor wildlife and increase the overall diversity of rocky woodlands. The combined features of an open canopy, ground layer prey including rabbits, nearness to rich aquatic habitat and more open terrestrial habitats result in extremely important wildlife value of rocky woodlands. No figures are available, but it is thought that rocky woodlands in the San Juans, particularly along San Juan Island's west shore support one of the most diverse populations of birds of prey in the coastal zone.

The following have been observed in the vicinity:

- Turkey Vulture
- Goshawk
- Sharp-shinned Hawk
- Cooper's Hawk
- Red-tailed Hawk (Common and abundant year-round)
- Rough-legged Hawk
- Golden Eagle
- Bald Eagle (Common and abundant year-round)
- Merlin
- American Kestrel
- Great Horned Owl
- Burrowing Owl (more open areas of Mt. Dallas - a bird of Eastern Washington)

Additional birds which are uncommon in other coastal forests which have been observed in rocky woodlands include:

Ravens: In the coastal zone, Ravens are often observed foraging along the shore for carrion. These large relatives of the Common Crow are typically solitary birds historically looked upon with mythical reverence by Northwest Coast Indians. Many legends revolve around the Raven who also appears in several forms displayed by the highly skilled coast Indian artists.

Western Bluebird: A very uncommon bird anywhere in Western Washington, bluebirds have declined because, as holenesters, they require nest sites which are being lost due to development and expropriation by competitors such as the introduced Starling. They are considered somewhat common summer residents along the west side of San Juan Island.

Common Flicker: Flickers are not uncommon elsewhere, however the combined features of trees for perches and nests, and open ground for foraging make rocky woodlands ideal flicker habitat.

IMPACTS

Rocky woodlands are extremely valuable esthetically and (if these values are separable) as unique coastal plant and animal habitat.

They are also extremely fragile habitats.

Unfortunately, these areas have not been recognized for their social and biological value and set aside as preserves. Currently, private development is threatening some of the most valuable rocky woodlands in the coastal zone. Road construction, off-road motor biking, house construction, and rabbit hunting threaten these areas.

Because soil layers are thin and many plants which occur here are rare, slight disturbances can have devastating impacts. By definition, trees are not abundant with the result that any tree removal may be significant. Shooting, motor biking, and at times, walking through these woodlands may result in disturbance to certain species. Rare plants may be destroyed inadvertently by any of these activities or by collectors.

For these reasons and the importance of rocky woodlands to rare, endangered and threatened wildlife (including plants), we recommend preservation of rocky woodlands, particularly those in the San Juan Islands. This includes a more diverse area along the west side of Mt. Dallas also mapped as rock outcrop, cliff, and shrub.

DISTURBED FOREST (No. 45)

Classes included under Disturbed Forest are:

Clearcut (No. 451)
Burn (No. 452)
Selective Logging (No. 453)
Grazed Forest (No. 454)

For discussions of these disturbances, refer to the Impacts Section of the Forest Narrative (No. 4).

RIPARIAN FOREST (No. 46)

Refer to the Riparian Narrative (No. 33) for discussion of riparian ecosystems.

Bluff Cover Type		Refer to the following narratives for Each Bluff Cover Type
Includes: Nos.	34 Bluff	This Narrative
	341 Grass Bluff	313 Open Grassland
	342 Shrub Bluff	32 Shrub
	47 Forested Bluff	4 Forest
	471 Coniferous Forest Bluff	41 Coniferous Forest
	4711 Regenerating, Coniferous Forest Bluff	411 Coniferous Forest,Regenerating
	4712 Pole Stage, Coniferous Forest Bluff	412 Coniferous Forest, Pole Stage
	4713 Second Growth, Coniferous Forest Bluff	413 Coniferous Forest, Second Growth
	4714 Old Growth, Coniferous Forest Bluff	414 Coniferous Forest, Old Growth
	472 Broadleaf Forest Bluff	42 Broadleaf Forest
	4721 Immature Broadleaf Forest Bluff	421 Broadleaf Forest, Immature
	4722 Mature Broadleaf Forest Bluff	422 Broadleaf Forest, Mature
	473 Mixed Forest Bluff	43 Mixed Forest
	4731 Immature Mixed Forest Bluff	431 Mixed Forest, Immature
	4732 Second Growth Mixed Forest Bluff	433 Mixed Forest, Second Growth
	4733 Mature Broadleaf and Old Growth Mixed Forest Bluff	432 Mature Broadleaf and Old Growth Conifer
	76 Bluff Non-vegetated	This Narrative

INTRODUCTION

Bluffs are a prominent feature along the coast of Washington and vary considerably in height, slope, and vegetative cover. Substrate composition also varies and excludes only rocky slopes which are classified as cliffs or other rock upland habitat. We did not distinguish between bluffs or different heights or slopes except that nonvegetated bluffs are almost exclusively vertical walls. Examples of these steep, nonvegetated bluffs occur just west of Dungeness Spit in Clallam County and near Magnolia in King County.

Vegetative cover on bluffs was mapped according to major plant communities as listed above. Each of these cover types is discussed in a separate narrative (e.g., refer to the Coniferous Forest Narrative for information relevent to Coniferous Bluffs and to the Open Grassland Narative for information concerning Grass Bluffs, refer to the list of relevant narratives for each bluff cover type on page 278 Discussions below are relevant to all bluff categories and are especially applicable to nonvegetated or sparsely vegetated bluffs.

Steep slopes and a coastal location modify, and in many ways enhance, wildlife use of areas mapped as bluffs. Each cover type mapped as part of a bluff, therefore, exhibits slightly different features than if further inland or on flat terrain. Historically, bluffs have been recognized as unstable sites for building or other uses. This has left much of the coastal bluffs undeveloped, even in more populated counties. These undeveloped coastal bluffs are remnants of natural land cover which today provide scenic settings, buffer zones, open space in urban areas, and important strips of coastal habitat for wildlife.

SIGNIFICANT BIOLOGICAL FEATURES

Habitat/Buffer Zone for Wildlife

All areas identified as bluffs provide potential habitat for coastal wildlife in addition to that usually provided by the specific cover type. Bluff vegetation is much like riparian vegetation in this respect, providing an edge situation between the terrestrial and aquatic environment. Nesting marine birds are among the species benefiting from this edge and examples are listed in Table 47-1.

Table 47-1 EXAMPLES OF MARINE BIRDS NESTING IN COASTAL BLUFFS

Species	Nonvegetated	Grass/Shrub	Forested
Great Blue Heron			x
Bald Eagle			x
Osprey			x
Glaucous-winged Gull	x	x	
Common Murre	x		
Pigeon Guillemot	x		
Rhinoceros Auklet	x	x	
Tufted Puffin	x	x	
Belted Kingfisher	x		

Nonvegetated bluffs and those with grass or shrub cover are generally steeper than forested slopes and the steep terrain protects nest sites from most mammalian predators. Burrow nesters excavate holes in loose, but firm soils along these bluffs. Kingfishers and guillemots nest in bluffs throughout the coastal zone, while puffins, murres, and Rhinoceros Auklets are restricted to island locations.

These steep slopes also provide a buffer zone between adjacent uplands and beach or nearshore wildlife. This buffer effect is especially pronounced when bluffs are high or when forested. High, nonvegetated bluffs increase distances between uplands and beaches, while forested bluffs are often long, gentle slopes which create relatively wide strips of natural vegetation along the coast. This strip of vegetation is a visual and noise buffer which also provides habitat for woodland or coastal edge wildlife.

Birds, such as Bald Eagles, which feed in marine areas and nest in trees are among the species benefiting from preservation of forested bluffs. Several species which occur along the beach margin of wooded bluffs also benefit from bluff habitat and buffer effects. These include river otters, coyotes, skunks, raccoons, and weasels. Each of these species has been observed along the base of wooded bluffs where developed uplands might otherwise have displaced them. Steep, forested slopes have often discouraged development from extending to the edge of the shoreline to the benefit of these and other wildlife.

Birds and marine mammals which occur in nearshore waters are partially screened from any development atop bluffs. These species benefit indirectly from the presence of bluffs along their feeding or rest areas.

Bluff Dynamics/Accretion and Erosion

Geological processes involving bluff erosion and subsequent transport of sediment by longshore currents are discussed in detail in the Coastal Drift Sectors portion of each Coastal Zone Atlas volume. The dynamic changes associated with coastal bluffs are mentioned here in reference to wildlife.

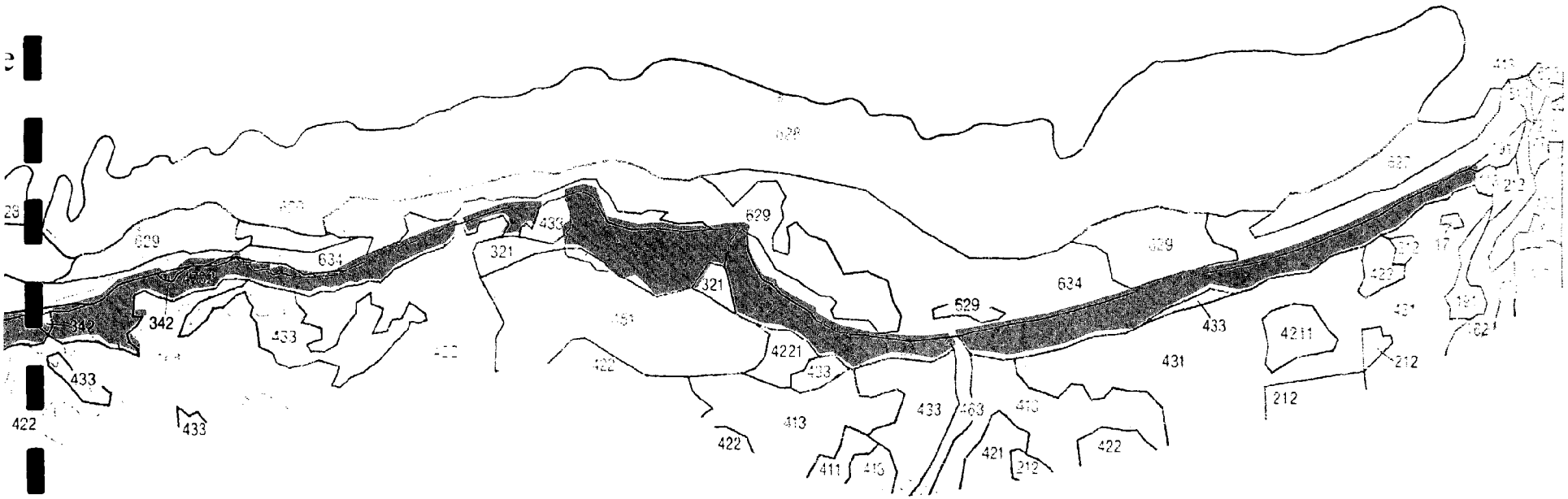
Bluffs, particularly nonvegetated bluffs, are continually eroding due to weathering, wave action, human activities, and, in some cases, activities of other animals. Sediment drops to the base of the bluff where it is gradually transported alongshore by wind and wave action. These sediments provide the substrate for accreting shoreforms such as spits. Dungeness Spit in Clallam County is a prominent example of this process in which bluffs to the west contribute sediments to the five mile long spit. Shoreforms such as Dungeness Spit have created major wildlife habitats along the spit, in

protected waters sheltered by it, and in marshes formed on or adjacent to it. These habitats are dependent on continued erosion and accretion processes, and are altered if erosion is interrupted.

Bluffs are integral parts of shoreline ecology and must be viewed with a broad perspective to protect interrelated habitats. Refer to the Impacts section for more information relevant to human activities which modify bluff erosion and affect other cover types and wildlife.

Corridors

Bluffs were likened to riparian habitats in the preceding section on habitat and buffer zones. Undisturbed bluffs are also analogous to riparian areas in that they provide travel corridors for wildlife. This corridor is especially important in more populated counties in which wooded bluffs are often the only natural vegetation remaining in the coastal zone. Birds and mammals use these bluffs in daily movements and in seasonal migrations. As coastal forests become more fragmented, these corridors offer travel routes which will ensure maintenance of the numbers and diversity of wildlife populations in coastal areas.



Chain Fern growing on a forested bluff in southern Puget Sound.

Chain Fern (Woodwardia fimbriata J. E. Smith)

At several sites throughout Puget Sound bluffs provide suitable habitat for chain fern, a species currently being considered for inclusion on the state rare and endangered species list. This large evergreen fern reaches the northern limit of its distribution in Puget Sound and adjacent British Columbia, where it is usually found on wet, seeping bluffs overlooking salt water. The earliest Puget Sound collection, from the border of a bog near East Hill, Olympia, is the only reported site in Washington not directly adjacent to salt water.

Chain fern sites are designated by a red asterisk on the Critical Biological Area maps in appropriate volumes of the Coastal Zone Atlas. Specific sites are also listed in Table 47-2.

TABLE 47-2. LOCATIONS OF REPORTED CHAIN FERN SITES IN WASHINGTON.

COUNTY	LOCATION	
Kitsap	West side of Bainbridge Island	
Mason	Southeast shore of Hartstene Island	
	Along North Shore Road (State Highway 300)	Largest Washington site - vulnerable to collection for garden use, roadside spraying.
Pierce	Steilacoom	1898 collection - recent efforts to locate this site were unsuccessful.
	Ruston district of Tacoma, along Tacoma Narrows	Vulnerable
Thurston	East Hill	1893 collection - still extant?
	West side of Budd Inlet	

Esthetic Values

Bluffs are extremely variable features which are a part of the scenic value of Washington's coastline. Nonvegetated bluffs are often steep and dramatic uplands rising above the shore while the gentle slopes of wooded bluffs create a gradual transition between the land and sea.

Bluffs also provide much of the remaining natural vegetation in densely populated areas. As development expands, these areas become more valuable for recreational land and urban open space. Wildlife dependence on bluffs also increases as other natural vegetation is lost.

IMPACTS

All land use practices which alter bluff vegetation or interfere with the dynamics of bluff erosion and associated accretion processes may have major consequences in interrelated habitats. Any individual bluff site must be regarded in a broad context in terms of geomorphological and ecological characteristics of the area. Esthetic and recreational values should also be considered in decisions affecting bluffs.

Removal of vegetation at the top of bluffs or along the face of steep slopes is a common practice throughout the coastal zone. Landowners seeking a better waterfront view cut down trees on or along the bluff, only to find that their land begins to erode at a faster rate. Roots of bluff vegetation bind the soil and reduce the rate of erosion. Retention of vegetation and a restricted waterfront view may be a more practical long-range decision and may also eliminate the need to build costly bulkheads to control erosion. Bulkheads and other erosion control structures must be approached in terms of the complete coastal system. Specific sites along the shoreline may be critical to the coastal processes which continually alter the form of bluffs, and to the shoreforms, such as spits and beaches, which receive bluff sediments. Erosion control in one area may well increase erosion elsewhere. This demands that careful investigation of sediments, longshore drift, winds, and other shoreline factors must be made to evaluate proposed erosion control plans.

Ecological factors to be considered in decisions affecting bluffs include the wildlife features discussed in preceding sections. Bluffs are valuable wildlife habitat, providing nest sites, roost areas, corridors, and buffers between upland and nearshore habitats. They are also esthetically valuable areas for waterfront landowners and all residents and visitors to Washington. Consideration of all these geological, ecological, and social features is needed to ensure that bluffs and the larger coastal system retain their associated values.

5 Water

WATER (No. 5)

The water classification includes both marine and fresh water habitats. Water subclassifications are River/Stream (No. 51), Lake/Pond (No. 52), Reservoir (No. 53), Bay/Estuary (No. 54), Impoundment (No. 55), Lagoon (No. 56), Slough (No. 57), Canals and Channels (No. 58), and Open Water (No. 59).

Freshwater habitats including rivers, streams, lakes, ponds, reservoirs, parts of estuaries, impoundments, enclosed lagoons (No. 561) and sloughs (No. 571) have many of the same wildlife species. Birds, mammals, amphibians and reptiles using freshwater and riparian areas are listed in Table 5-1, 5-2, and 5-3 respectively. Freshwater fish species are listed in the River and Stream (No. 51) and Lake and Pond (No. 52) Narratives; marine fish are listed in Beach Substrate Narratives (631-638). Many aquatic animals also use riparian habitat extensively. Refer to the Riparian Narrative (No. 33) for additional information about plant and animal species associated with freshwater.

Table 5-1 FRESHWATER BIRDS IN THE COASTAL ZONE

Species	Lakes/Ponds	Rivers/Streams Most Common Zone: Estuary	Rivers/Streams Most Common Zone: Fresh	Comments
Common Loon	■	■		May breed in Washington on lakes
Red-necked Grebe	■	■		Uncommon fresh
Horned Grebe	■	■		Uncommon fresh
Eared Grebe	■		■	Also protected marine
Western Grebe	■	■		Breeds in east. Wash.
Pied-billed Grebe	■		■	Breeds on lakes
Double-crested Cormorant	■	■		More common marine
Great Blue Heron	■	■		Common
Green Heron	■	■	■	Recent resident
Great Egret		■		Uncommon
American Bittern	■		■	Marsh
Whistling Swan	■	■	■	
Trumpeter Swan	■	■	■	Once near extinction, status has improved
Canada Goose	■		■	Breeds locally
White-fronted Goose		■		Rare on freshwater
Mallard	■	■	■	Ubiquitous, valuable game bird
Gadwall	■		■	
Pintail	■	■		Ducks are generally more common in salt
Green-winged Teal	■	■		water in the coastal zone. Some, like
Blue-winged Teal	■		■	the Wood Duck, prefer freshwater. Be-
Cinnamon Teal	■		■	cause of their location, many coastal
European Wigeon	■	■		freshwater habitats will also have marine
American Wigeon	■	■		species present.
Shoveler	■		■	
Wood Duck	■		■	
Redhead	■		■	
Ring-necked Duck	■		■	
Canvasback	■	■		
Greater Scaup	■	■		Uncommon, freshwater
Lesser Scaup	■		■	Common, freshwater
Common Goldeneye	■	■		
Barrow's Goldeneye	■	■		
Bufflehead	■	■		
Harlequin Duck			■	Nests along rivers; rest of year marine

Species	Lakes/Ponds	Rivers/Streams Most Common Zone: Estuary	Rivers/Streams Most Common Zone: Fresh	Comments
White-winged Scoter		■		Rare in freshwater
Surf Scoter		■		Rare in freshwater
Ruddy Duck	■	■		
Hooded Merganser	■	■		Uncommon throughout western Washington
Common Merganser	■		■	
Red-breasted Merganser		■		Uncommon, freshwater
Bald Eagle	■	■	■	Occurrence varies greatly
Osprey	■		■	Uncommon
Virginia Rail	■		■	Marshy edge
Sora	■		■	Estuarine areas in winter
American Coot	■	■	■	Common
Killdeer	■	■	■	Edges
Common Snipe	■		■	Edges
Spotted Sandpiper	■	■	■	Common in estuary in Fall
Greater Yellowlegs	■	■		Most sandpipers which are migrants in
Lesser Yellowlegs	■	■		western Washington feed extensively on
Pectoral Sandpiper		■		exposed mudflats in estuarine zone of
Least Sandpiper		■		rivers.
Dunlin		■		
Dowitcher spp.	■	■		
Western Sandpiper	■	■		
Wilson's Phalarope		■		Former known western Washington breeding habitat destroyed. Present nesting status unknown.
Glaucous-winged Gull	■	■		
Western Gull		■		Gulls are typically more common in salt
Herring Gull	■	■		water, because of location many occur in lakes in the coastal zone.
California Gull	■	■		Breeds in eastern Washington
Ring-billed Gull	■	■		Breeds in eastern Washington
Mew Gull	■	■		
Bonaparte's Gull	■	■		
Common Tern		■		
Caspian Tern		■		Breeds in Grays Harbor
Belted Kingfisher	■	■	■	
Rough-winged Swallow	■	■	■	Swallows feed over water.
Barn Swallow	■	■	■	
Cliff Swallow	■	■	■	
Common Raven	■	■		
Common Crow	■	■		
Dipper			■	
Long-billed Marsh Wren	■	■	■	Marsh edges
Water Pipit	■	■		
Red-winged Blackbird	■	■	■	Marsh edges

Table 5-2 MAMMALS ASSOCIATED WITH FRESHWATER HABITATS IN THE COASTAL ZONE

Species	Lakes/Ponds	Rivers/Streams Most Common Zone: Estuary	Rivers/Streams Most Common Zone: Fresh	Comments
Pacific Water Shrew (Sorex bendirii)	■		■	Swampy edges
Yuma myotis (Myotis yumanensis)	■	■	■	Closely associated with water. Bats like swallows in the daytime, feed over open water - on insects at night.
Beaver (Castor canadensis)	■		■	
Townsend's Vole (Microtus townsendii)	■	■		Abundant in marshes in estuaries.
Muskrat (Ondatra zibethica)	■	■	■	Common
Coyote (Canis latrans)	■	■	■	At edge - common
Raccoon (Procyon lotor)	■	■	■	Especially abundant in estuaries.
Mink (Mustela vison)	■	■	■	
Striped Skunk (Mephitis mephitis)	■	■	■	
River Otter (Lutra canadensis)	■	■	■	
Bobcat (Lynx rufus)	■	■	■	At edge
Harbor Seal (Phoca vitulina)		■		Rare in freshwater; locally dependent on estuarine areas.
Elk (Cervus elaphus)	■	■	■	At edge - restricted range.
Black-tailed Deer (Odocoileus hemionus)	■	■	■	Common - at edge.

Table 5-3

AMPHIBIANS AND REPTILES
OF COASTAL COUNTIES
(Adapted from Slater, James R.)

Slater, James R. 1964. County Records of Amphibians for Washington. Occ. Papers, Department of Biology, Univ. of Puget Sound, No. 24. pp. 237-242.

Amphibians Species	Whatcom	Skagit	San Juan	Island	Snohomish	King	Kitsap	Jefferson	Clallam	Mason	Thurston	Pierce	Grays Harbor	Pacific	Wahkiakum	
SALAMANDERS & NEWTS																SALAMANDERS & NEWTS
Northern Rough Skinned Newt	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	Taricha granulosa granulosa
Pacific Giant Salamander	■	■			■	■		■	■	■	■	■	■	■	■	Dicamptodon ensatus
Northern Olympic Salamander								■	■	■			■	■	■	Rhyacotriton olympicus olympicus
Northwestern Salamander	■	■		■	■	■	■	■	■	■	■	■	■	■	■	Ambystoma gracile gracile
Long-toed Salamander	■	■		■	■	■	■	■	■	■	■	■	■	■		Ambystoma macrodactylum
Dunn's Salamander														■	■	Plethodon dunni
VanDyke's Salamander								■	■	■		■	■	■		Plethodon vandykei
Western Red-backed Salamander	■	■			■	■	■	■	■	■	■	■	■	■	■	Plethodon vehiculum
Oregon Salamander	■	■		■	■	■	■	■	■	■	■	■	■	■	■	Ensatina eschscholtzi oregonensis
TOADS & FROGS																TOADS & FROGS
Tailed Frog	■	■			■	■		■	■	■	■	■	■			Ascaphus truei
Western Toad	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	Bufo boreas boreas
Pacific Tree Frog	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	Hyla regilla
Northern Red-legged Frog	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	Rana aurora aurora
Cascades Frog	■	■			■	■		■	■	■		■	■			Rana cascadae
Bullfrog	■	■		■	■	■	■	■	■	■	■	■	■	■	■	Rana catesbeiana
Green Frog	■															Rana clamitans
Spotted Frog		■			■	■					■	■				Rana pretiosa

Reptiles Species	Whatcom	Skagit	San Juan	Island	Snohomish	King	Kitsap	Jefferson	Clallam	Mason	Thurston	Pierce	Grays Harbor	Pacific	Wahkiakum	
TURTLES																TURTLES
Western Pond Turtle						■					■	■				Clemmys marmorata
Painted Turtle											■					Chrysemys picta
LIZARDS																LIZARDS
Western Fence Lizard						■	■	■	■	■		■				Sceloporus occidentalis
Northern Alligator Lizard	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	Gerrhonotus coeruleus principus
SNAKES																SNAKES
Rubber Boa	■	■		■	■	■	■	■	■	■	■	■			■	Charina bottae
Northwestern Garter Snake	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	Thamnophis ordinoides
Western Terrestrial Garter Snake	■	■	■			■	■	■	■	■	■	■	■			Thamnophis elegans
Common Garter Snake	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	Thamnophis sirtalis
Western Yellow-bellied Racer											■	■				Coluber constrictor mormon
Pacific Gopher Snake												■				Pituophis melanoleucus catenifer
Sharp-tailed Snake												■				Contia tenuis

KAREN

RIVERS AND STREAMS (No. 51)

Including the Estuarine (No. 511), Pastoral (No. 512), Floodway (No. 513), and Boulder (No. 514) zones.

I. INTRODUCTION

Rivers and streams are distinguished from other water bodies by a definite current. The current varies with valley shape and other geohydraulic features in different streams and in different segments of the same stream. We have used Wolf Bauer's geohydraulic river zone classification system to characterize stream segment types. Four zones are described, proceeding from the coast, upstream to the mountains. Because of the many similarities in ecological structure and effects of certain impacts on stream, this narrative will deal with all stream types. Differences between stream types will be described where applicable.

The estuarine zone (No. 511) of a river is strongly influenced by the marine environment and is distinguished by a branching channel pattern in a broad, flat valley. The stream channel gradient is near zero feet per mile, with the result that weak currents deposit silt and mud in the stream bed. Salt and fresh waters are mixed in much of this zone, creating a unique ecosystem that is discussed in the Estuary Narrative (No. 54).

The pastoral zone (No. 512) has a sinuous channel pattern that meanders through broad valleys with gently sloping walls. Sand and silt are deposited in the stream bed which slopes less than five feet per mile. Oxbow lakes, which are former river channels cut off from the main stream course, typify the pastoral zone.

The floodway zone (No. 513) of a river or stream has a braided channel pattern cutting through a narrow valley with terraced walls. Gravel and sand, forming frequent point bars, are predominant bed material along the stream channel, which drops five to twenty-five feet per mile.

The boulder zone (No. 514) is a single, fixed channel in a steep walled, V-shaped valley. Strong currents flow along steep channel gradients which drop more than 25 feet per mile. These currents transport sediments to lower segments of the stream course, while abrading larger rocks against one another and scouring their surfaces. This scouring action results in a cobble and boulder streambed.

Many streams are so small they have not been mapped in the Coastal Zone Atlas as separate bodies of water, but are included in areas of riparian vegetation. Refer to the Riparian Narrative (No. 33) for discussion of these streams and associated wildlife. Stream size does not dismiss its importance to the watershed ecology; small streams are essential to the production of salmon and trout in the Pacific Northwest.

Rivers are an integral part of the earth's hydrological cycle in which water is a cyclic commodity involving surface water, ground water, the atmosphere, and oceans. They are the primary link between terrestrial and standing water habitats. Nutrients collected from runoff and groundwater are distributed within rivers and transported to other habitats. Rivers carry enriching nutrients to lakes and estuaries, making the latter a highly productive area for fish, oysters, waterfowl, and several other organisms. Rivers also function as spawning and rearing areas for fish and are a source of food for riparian wildlife.

Rivers have been important to mankind throughout history. They have been a reliable source of food and water, and have been used as pathways for Indians and explorers of the Northwest. In 1805, Lewis and Clark canoed down the Columbia River to the Pacific Ocean, on one of the most famous expeditions in United States history.

During the last 100 years, rivers have been altered drastically. Most major cities in western Washington were built in the estuarine zone of a major river. This development has led to almost total destruction of these areas. The city of Seattle has impacted the Duwamish River; Tacoma the Puyallup River; Everett, the Snohomish River; Aberdeen, the Chehalis River; and Hoquiam, the Hoquiam River. Dams have

been built for generating power; reservoirs created for water supply and flood control. Logging, road building, agriculture, dams, and urbanization have led to increased siltation of rivers, changing stream flow and limiting wildlife use. A startling example of altered wildlife use is found in the Columbia River which is now a series of reservoirs. The Columbia supports less than 5 percent of the salmon which once spawned in this largest of west coast rivers.

II. SIGNIFICANT BIOLOGICAL FEATURES

A. Community Structure

1. Community Formation

Rivers and streams in western Washington are relatively short. There are considerable channel variations due to differences in topography of each drainage basin or valley, as reflected in the different stream classes. The river channel is fashioned and maintained by water flowing in it. Major sources of water flowing in a stream channel are surface runoff and groundwater discharge. Gravity and friction direct the water's action upon a given area; topography and geology determine the type of riverscape formed. If the valley is partially blocked by glacial debris, the river may silt and level the valley floor, forming a lake or meandering channels in a floodplain of sand and gravel as seen in the estuarine and pastoral zones. A narrow valley with steep slope forms a fixed channel perhaps down to bedrock as seen in floodway and boulder zones of rivers.

Rivers periodically flood during high runoff periods. Valleys are partially filled and leveled off by the sand and gravel carried by streams, as they meander and shift channels across the floodplain. These natural flood cycles periodically replenish porous soil, providing a plant-accessible water table and a recharge of underground aquifers. Preservation of meandering streams requires stream banks to remain free to be watercut and built up through natural processes. Alterations of floodplains changes these processes and their benefits. Development of these areas for housing involves irreversible and detrimental impacts to the environment.

Floodway and boulder zone stream channels that are cut into bedrock and/or are straight with a steep gradient, form stable shorelines and stream banks. These areas are more suitable to river tract developments, although such development may not be pleasingly esthetic to the public. However, all riparian communities, including floodway and boulder zones, are unsuitable for development because of their importance to wildlife and their extreme vulnerability to alterations.

Cleanwater streams of the estuarine, pastoral, floodway, and boulder zones have similar principal biological components. These components are: bacteria which break down organic matter, particularly dead algae; attached algae and other plants; bottom animals, consisting primarily of insects that feed on algae and other insects; fish which feed on insects; fish which feed on other fish; and birds which feed on insects and fish.

Polluted streams have similar components, but species differ and the relative importance of each of the components may differ. In streams with an artificially heavy load of dissolved organic material, the bacterium Sphaerotilus natans becomes prevalent and occupies most sites formerly held by attached algae. In streams with an increase in water temperature and/or a decrease in dissolved oxygen concentrations, carp or other warm water species replace trout and diptera (flies and mosquitos) replace the invertebrate mayflies and stoneflies.

Current, substrate, and water depth dictate what life forms occupy an area of a stream. Riffles are characterized by shallow water and a fast current, which keeps the bottom relatively clear of silt and provides a firm substrate. Riffles usually provide a great variety of niches for aquatic invertebrates, upon which many aquatic animals feed. Characteristic invertebrates in this area are specialized benthic or periphytic organisms which become firmly attached or cling to the firm substrate. However, fishes, such as salmon and trout, must resist the downstream current and are accordingly strong swimmers.

Pool areas are deeper than riffles and the current is reduced. Silt and other loose materials settle to the bottom creating a softer substrate. Silty bottoms of pools are unsuitable habitats due to scouring by flood waters; however, the silt substrates are favorable for burrowing animals. Stream fish take refuge in these pools and feed in or at the base of rapids. Pool biota is similar to that of lakes and ponds. As streams mature, the distinction between rapids and pools lessens; eventually, a channel is developed in large rivers. The biota of river channels resembles that of rapids except the population distribution is highly clumped because of the scarcity of firm substrates.

Stream bottom type is very important in determining the nature of communities and the population density of community dominants. Species diversity in a stream is proportional to the relative heterogeneity and stability of sediments. Other conditions being equal, sand and/or soft silt supports the fewest numbers of species and individuals of benthic plants and animals. Clay bottom is more favorable than sand. Flat rocks and rubble produce the largest variety and highest density of bottom organisms. A river or stream may have many different substrates throughout its length and the stream biota will vary accordingly.

Habitats created by rivers are highly dynamic. The entire water mass flows more or less rapidly, continually bathing the shore and bottom with new water. Stationary benthic communities are exposed to new water and mechanical effects of currents, while plankton are carried down stream in the same water mass. Drift of stream organisms is an integral feature of stream ecology. Drift is composed of free-ranging organisms and weak swimmers such as floating midge larvae that are eaten by trout.

Flowing water is richer in oxygen than standing water, accordingly, a reduction of respiratory surface is common in stream animals. Current promotes respiration and the organic substances leading to a killing eutrophication are quickly oxidized in the fast flowing water. In areas of rushing water, stones are overgrown with mosses and algae and there is a rich developement of animal life. Abundant is also found in areas of slower current (less than 20 cm/sec) when sediment is enriched with organic materials.

Stream animals have narrow tolerances to many environmental factors. They are especially sensitive to reduced levels of oxygen and any type of organic pollution that reduces the dissolved oxygen supply. Incubation of salmonid (salmon and trout) embryos requires high levels of dissolved oxygen in intragravel water. A decrease in the concentration of dissolved oxygen below saturation can reduce fry size and delay their hatching, resulting in fish less successful in competition for food and cover.

Organic loading and associated depressed levels of dissolved oxygen are common in small streams. However, in intact watersheds, small streams are adept at handling large amounts of natural dissolved organic materials. Stream temperature is also a limiting factor to stream biota. Fish are poikilotherms (cold blooded), which means temperatures can control their activities. Fish have been found to be sensitive to changes in temperatures as small as 0.1°F. (0.05°C.). Such sensitivity enables fish to follow temperature gradients toward preferred ranges. Optimal temperature ranges for salmonids suggested by the U. S. Fish and Wildlife Service are 40-60°F. during migration, 45-55°F. during spawning, and 50-60°F. during rearing periods.

Increases in temperature affect fish by direct heat-induced death, increased metabolic rate and maintenance requirements, increased activity of pathogenic organisms, and decreased solubility of oxygen in water. The greatest effects of thermal pollution are sublethal. Fish have lower and upper lethal temperature limits which are species' specific and may vary at different stages in the fishes' life histories. Young fry and smolts (young salmon ready to leave fresh water for sea water) are more sensitive than fingerlings to temperature changes.

Turbidity and light intensity are also important limiting factors to stream life. These factors limit primary producers such as algae and moss. Turbidity can also interfere with fish ability to locate prey.

2. Trophic Relations

The streams of the Pacific Northwest are among the richest producers of fish in the world. These highly productive streams derive most of their energy for productivity from outside the river system. Natural sources of nitrogen in forest soils and water are the atmosphere (in which nitrogen is transported by electrical storms, precipitation and nitrogen-fixing bacteria), and decomposition and mineralization of decayed bodies and plants. The level of metabolism of a stream is strongly dependent upon the input of nutrients and energy from terrestrial ecosystems. Much of this organic input is used by stream plants and animals during fall and winter, periods of lowest annual temperatures. Forest streams under a closed canopy and estuaries are especially reliant on energy inputs from terrestrial systems.

Detritus enters the stream in the coarse form of leaves, needles, twigs, branches, nuts, flowers, and as soluble organic matter leached from these materials. Coarse particulate matter is colonized by micro-organisms (bacteria, aquatic fungi and protozoans), and is reduced to fine particles. Immature stages (nymphs and larvae) of stream insects usually dominate the macro-invertebrate role in energy transformation.

It has been estimated that a small stream imports over 90 percent of its energy input from terrestrial surroundings. As little as 1 percent of the stream system energy is derived from stream photosynthesis by mosses and phytoplankton. Energy inputs consist of almost equal amounts of dissolved

organic matter and particulate organic matter. Of all the energy imported and produced within a stream, only approximately one-third is assimilated by stream biota and processed to carbon dioxide. Almost two-thirds of the organic input is not assimilated and exported downstream.

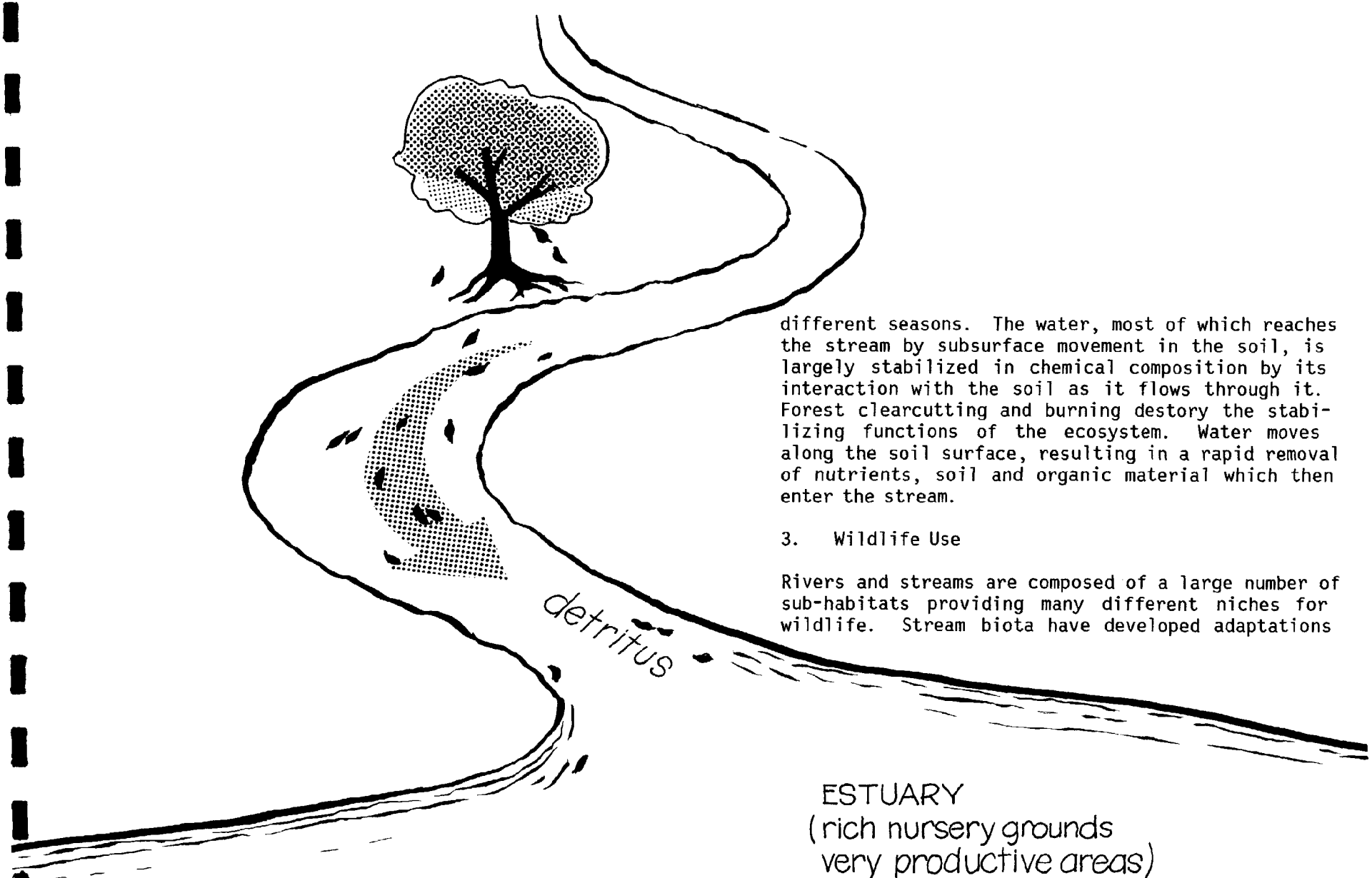
Primary producers of energy in streams are fixed filamentous green algae, encrusted diatoms, aquatic mosses and some vascular plants. Flow discharge regimes exert important controls on the dominance of primary producers in running waters. Sudden floods (called spates) prevent establishment of filamentous green algae.

Smaller streams which are cool and heavily shaded are usually heterotrophic; stream photosynthesis contributes very little to the total energy budget. Larger running water communities exhibit trends toward autotrophy (i.e., they produce their own energy through photosynthesis). The rate of change from heterotrophy to autotrophy is controlled by light, temperature, organic and inorganic inputs and flow, with lesser localized effects by invertebrate grazers of vegetation. Shifts from heterotrophy to autotrophy in streams involves a conversion from typical diatom-moss (e.g. Fontinalis) communities and in some streams watercress beds around springs, to filamentous green algae and beds of rooted aquatic plants.

Many invertebrates important to fish production live within mats of algae which the invertebrates also eat. Chironomid (midge) larvae, copepods and ostracods, for instance, have short life cycles and their numbers respond quickly to changes in the amount of algae food available. Invertebrates can exist in extremely large numbers. An Oregon stream had 160,000 midge larvae per square meter during one summer.

In addition to unused energy in the form of detritus, the stream ecosystem exports energy created within the system in the form of emerging insects and other stream life, such as fish, consumed by air breathing predators. The stream ecosystem contributes nutrients and energy to other ecosystems and continues the cyclic nature of organic matter.

The nutrient function of watersheds involves balancing nutrient input from precipitation and weathering, with output in the stream. Stream water is relatively constant in concentrations of dissolved nutrient elements despite changes in volume of stream water after storms and in



different seasons. The water, most of which reaches the stream by subsurface movement in the soil, is largely stabilized in chemical composition by its interaction with the soil as it flows through it. Forest clearcutting and burning destory the stabilizing functions of the ecosystem. Water moves along the soil surface, resulting in a rapid removal of nutrients, soil and organic material which then enter the stream.

3. Wildlife Use

Rivers and streams are composed of a large number of sub-habitats providing many different niches for wildlife. Stream biota have developed adaptations

to take advantage of the many niches within a stream. One of the more common adaptations to stream life is the ability of some plants and animals to fasten themselves to a firm substrate in swiftly flowing waters. Green algae attach to rocks with long trailing filaments while the caddis fly larva cements its body case to a stone. Other animals have developed hooks and suckers, sticky undersurfaces (e.g., snails), and streamlined or flattened bodies.

Competition among similar species of stream animals has resulted in some species varying the timing of life cycle events. Three similar species of the stonefly genus Nemoura emerge and begin their life cycles at different times; winter, spring, and fall. Seven species of caddisflies (Ryhacpphila spp.) divide their habitat use by each having a different diet and/or having differences in timing of life cycles.

Salmon and trout also have niches separated by seasonal use and habitat type (small streams, rivers, pools, or riffles). Juvenile fall chinook salmon use small tributaries, while spring chinook use larger tributaries and main rivers during their first year. Most lower main river areas are barren of naturally produced salmonids during summer, except for young steelhead, and coho and chinook salmon of the year. Chinook salmon and cutthroat trout juveniles use estuaries before proceeding to the sea, while sockeye salmon and steelhead emigrate directly to the high seas. Chum salmon prefer to spawn in areas associated with a nearby hiding place while coho salmon avoid areas of excess cover. Water temperature also separates salmonids' niches; juvenile and adult chinook salmon tolerate warmer water than other salmonids.

Each fish species has established niches and territories for various stages of its life history. The physical features of a stream exert major control on the abundance of each species, regardless of food supply. Degrading stream environments diminishes food supply and reduces habitats available to fish. Interspecific competition and food supply could limit the size of specific populations, regardless of any increased effort in supplying stream areas with cultured salmonids.

All stream-inhabiting salmon and trout have the following general optimum requirements:

access

Spawning and nursery grounds must be accessible to adult salmonids migrating upstream.

streamflow

The most productive streams have a stable streamflow without extreme flooding or droughts and with adequate water levels in late summer and winter.

substrate

Salmonid reproduction requires clean, stable gravel of one-half to six inches in diameter.

cover

Stream salmonids require cover, such as undercut banks, logs, rubble, substrate, turbulence, overhanging streamside vegetation and deep pools. Cover is used by juveniles for feeding sites and refuges for escape and wintering. Adult salmonids use cover for resting and escape.

temperature

Optimal water temperatures are as follows: 45°-60°F. during migration, 45°-55°F. during spawning and 50°-60°F. during rearing periods.

oxygen

Stream salmonids require high levels of dissolved oxygen (preferrably at saturation concentration) in intragravel and surface waters.

clarity

Stream water must be clear enough to permit photosynthesis. Primary producers support the invertebrate fauna that fish eat. Fish also require clear water to find their prey.

Rivers and streams are one of the more important wetland habitat types used by wildlife. River habitat is used for spawning grounds, nursery and rearing areas, resting areas, cover and as a food reservoir for aquatic animals. Terrestrial animals also use rivers and associated habitats for food, cover, nesting, travel routes, and play areas.

Rivers and streams are primary habitat to the following species: Great Blue Heron, Harlequin Duck, Bald Eagle, Osprey, Spotted Sandpiper, Belted Kingfisher, Dipper, and beaver. Chinook, coho, chum, sockeye, and pink salmon, steelhead and cutthroat trout and dolly varden are all very valuable commercial and/or sports fishes. These fish and others depend on rivers and streams for their continued existence. Several other fish, particularly sculpins, are an abundant and valuable source of prey for other fish, birds, and mammals. Many other species use rivers and streams and their associated riparian habitat. These edge areas provide rich feeding grounds, corridors and cover for river otter, raccoon, mink, muskrat, eagles, herons, and kingfishers.

Many terrestrial animals travel along the streambanks or in the stream. Otters use streambank areas for landing spots, which serve a variety of purposes including feeding, scent marking and play. These traditional marking areas may be used for at least 40 years.

4. Characteristic Species

invertebrates

Invertebrate species vary according to substrate and current flow. The distribution of bottom fauna is often correlated with the distribution of plant detritus on the substrate. In the estuarine zone, there is a gradual change in species composition from freshwater to estuarine invertebrates. As the

Belted Kingfisher

water becomes brackish, crustaceans (amphipods, isopods) appear first, followed by worms (oligochaetes, polychaetes, nematodes) and clams. Information about species occurring in the muddy sediments of estuarine zones is found in the Mud Narrative (No. 638).

Midge (chironomid) larvae •

Midge larvae are a major food source of trout. Adult female midge lay eggs in the streams. As the larvae approach maturity, they pupate and float downstream to a backwater or eddy where they emerge as adults. Midges are extremely vulnerable to fish while floating downstream in pupal form and as adults when trying to break free of the pupal cast on the water's surface. Midges occur in large numbers that respond quickly to changes in food (algae) availability.

fish

Anadromous fish species include chinook, coho, pink, chum and sockeye salmon, steelhead and cutthroat trout, dolly varden, sturgeon and shad. The eggs of these fish hatch in gravel redds (nests) in freshwater streams; the fish spend some portion of their early life in streams before migrating to the sea. Some species stay in estuaries at the mouths of rivers as an intermediate stage between fresh and salt water. The fish feed, grow and develop into adults in the marine environment. After a species specific number of years in salt water, adult anadromous fish return to the streams from which they originated, to spawn. A large number of salmonids are now produced in hatcheries, as a result of destruction of spawning habitat. These hatchery reared fish still have the same basic life history requirements as wild fish, and therefore, require healthy river systems as do natural populations.

Anadromous fish are the major fish species used by commerical and sports fisheries in the Pacific Northwest. Their habit of travelling through freshwater zones and saltwater demands we acknowledge their seasonal use of these areas and manage them accordingly. A summary of the life history of anadromous salmon is found in Table 51-1. Food habits of fish occurring in rivers and streams are listed in Table 51-2. Representative freshwater fish occurring in rivers and streams are listed in Table 51-3.

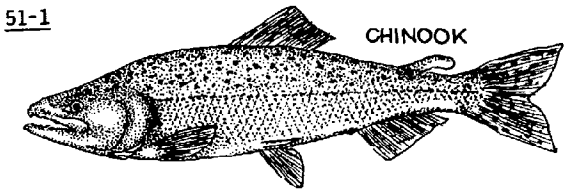
Species descriptions of river and stream fish follow:

Steelhead •

Steelhead (rainbow trout), an important sport fish, has anadromous and nonanadromous races. Steelhead refers to the anadromous race of rainbow trout. Anadromous juveniles spend two or three years in fresh water before downstream migration. Steelhead young then remain in estuaries for 30 to 60 days before entering marine waters, mainly from February to July. Steelhead usually remain in marine waters for one to four years before returning to fresh water to spawn. Females lay 3,500 to 4,000 eggs in their home streams. Unlike salmon, steelhead do not die after spawning and may live to spawn a second or third time.

Food of young steelhead consists of insects, euphausiids, copepods, amphipods, and young fish (sand lance, herring). High seas food of steelhead includes mainly fish and various crustaceans.

TABLE 51-1



CHINOOK

In saltwater, identified by heavily spotted tail and the black lower gumline where teeth project from the jaw. Freshwater spawning colors include brown or olive green with heavy black spotting on back.

Fall Chinook (Oncorhynchus tshawytscha), also called king, tyee, blackmouth, and jack salmon.

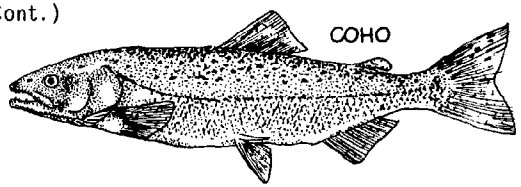
	SMALL TRIBUTARY	LARGE TRIBUTARY	MAIN RIVER	ESTUARY	OCEAN	GENERAL COMMENTS
Mature Adults (spawning)	Some use	30 to 60 days fall months				Adults always die after spawning
Eggs & Larvae (incubation)	Some use	90 to 150 days in gravel winter months				Average number of eggs 4,000 per female. Max. 13,500
Juveniles (rearing)	Some use	60 to 120 days, spring months through summer		30-60 days seaward migration		Limited by loss of natural spawning and rearing areas.
Growth to Maturity					1-5 yrs. 3 yrs. typical	Ranges north to Alaskan waters Some Puget Sound proper
Maturing Adults		Returning to original spawning grounds to complete life cycle, normally at age 4 years				Average weights 20-25 lbs. 126 lb. maximum weight

TABLE 51-1 (Cont.)

Spring Chinook (Oncorhynchus tshawytscha, also call spring salmon, blackmouth, and jack salmon

	SMALL TRIBUTARY	LARGE TRIBUTARY	MAIN RIVER	ESTUARY	OCEAN	GENERAL COMMENTS
Mature Adults (spawning)	Some use	3 to 6 months spring through early fall months				Adults always die after spawning
Eggs & Larvae (incubation)	Some use	90 to 150 days--Fall through mid-winter months.				Average number of eggs 4,000 per female. Max. 13,500
Juveniles (rearing)	Some use	Juveniles tend to spend a full year in fresh water.		30-60 days seaward migration		Limited by loss of natural spawning and rearing areas.
Growth to Maturity					1-5 yrs. variable 3 yrs. typical	Ranges north to Alaskan waters Some Puget Sound proper.
Maturing Adults		Returning to original spawning ground to complete life cycle, normally at age 4 years.				Average weights 20-25 lbs. 126 lb. maximum weight.

TABLE 51-1 (Cont.)



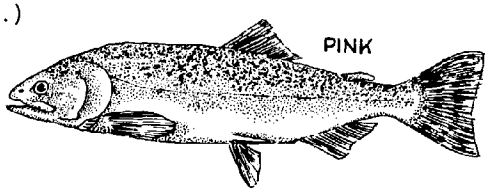
COHO

In saltwater, identified by light spotting on upper part of tail only, and a white lower gumline where teeth project from jaw. Freshwater spawning color is reddish black on head and back shading to red on sides.

Coho Salmon (Oncorhynchus kisutch), also called silver, silverside, and hooknose.

	SMALL TRIBUTARY	LARGE TRIBUTARY	MAIN RIVER	ESTUARY	OCEAN	GENERAL COMMENTS
Mature Adults (spawning)	30-60 days late fall through early winter		Some use especially in side channels.			Adults always die after spawning.
Eggs & Larvae (incubation)	80-150 days winter months					Average number of eggs 3,000 per female.
Juveniles (rearing)	12 to 14 months spends entire year in stream		Some use, extent unknown	30-120 days seaward migration		Populations limited by low summer flow conditions.
Growth to Maturity					Spend 1-2 yrs. at sea 2 yrs. typ.	Ranges north and south in ocean; some in Puget Sound proper.
Maturing Adults	Returning to original spawning grounds to complete life cycle, normally at age 3 years.					Average weights 8-10 lbs. 31 lbs. maximum weight.

TABLE 51-1 (Cont.)



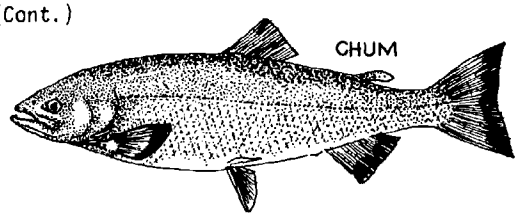
PINK

In saltwater, identified by heavy blotches on tail, tiny scales, and a "rubbery" jaw. Males develop a pronounced humped back as they near spawning time. Freshwater spawning color is brown with a prominent white streak along the belly.

Pink Salmon (Oncorhynchus gorbushcha), also called humpback salmon or humpy.

	SMALL TRIBUTARY	LARGE TRIBUTARY	MAIN RIVER	ESTUARY	OCEAN	GENERAL COMMENTS
Mature Adults (spawning)	Some use	30-60 days early fall months on odd yrs. only.				Adults alway die after spawning.
Eggs & Larvae (incubation)	Some use	90-150 days winter months.				1,500-2,000 eggs per female.
Juveniles (rearing)		Move to sea soon after hatching.		Spends approx. 3-4 months in shoreline areas.		Little if any freshwater growth.
Growth to Maturity					Spend approx. 12 mo. at sea.	Ranges generally north; mature at 2 years.
Maturing Adults		Returning to original spawning grounds to complete life cycle, always at age 2 yrs.				Average weights 5-6 lbs. 16 lbs. maximum.

TABLE 51-1 (Cont.)



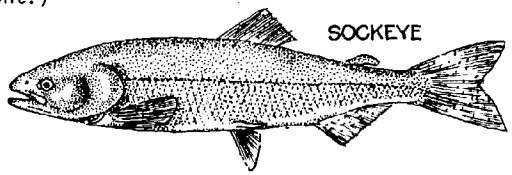
CHUM

In saltwater, identified by a slender caudal peduncle (just ahead of tail), large scales, and often faint grid-like shading on their sides. Freshwater spawning colors include gray or green on the back with purplish mottling along the sides.

Chum Salmon (Oncorhynchus keta), also called dog salmon or fall salmon.

	SMALL TRIBUTARY	LARGE TRIBUTARY	MAIN RIVER	ESTUARY	OCEAN	GENERAL COMMENTS
Mature Adults (spawning)	Some use	Up to 30 days. Late fall early winter months.				Adults always die after spawning.
Eggs & Larvae (incubation)	Some use	90-150 days winter months				Spawns 3,000 to 3,500 eggs per female.
Juveniles (rearing)		Move to sea soon after hatching.		Spends approx. 3-4 months in shoreline areas.		Little if any freshwater growth.
Growth to Maturity					3-5 yrs. at sea variable.	Range north to Alaskan waters.
Maturing Adults		Returning to original spawning grounds to complete life cycle, normally at age 3 or 4 years.				Average weights 11-12 lbs. 25 lbs. maximum.

TABLE 51-1 (Cont.)



SOCKEYE

In saltwater, the slimmest and most streamlined of the various salmon, and they have a soft-toothed mouth and large glassy eyes. Freshwater spawning color red body with greenish colored head.

Sockeye Salmon (Oncorhynchus nerka), also called red salmon, blueback, kokanee or silver trout.

	LAKE TRIBUTARY	LAKE SYSTEM	MAIN RIVER	ESTUARY	OCEAN	GENERAL COMMENTS
Mature Adults (spawning)	2-4 months late summer & fall.	Some shoreline spawning.	Main migration June, July, Aug.			Adults always die after spawning.
Eggs & Larvae (incubation)	90-150 days winter months					Spawns 2,000-2,500 eggs per female.
Juveniles (rearing)		1-3 yrs. spent in lake.	These areas used during seaward migration			Some stay to maturity in lake (kokanee) to 2 lbs.
Growth to Maturity					2-3 yrs. variable.	Ranges generally north to Alaskan waters.
Maturing Adults	Returning to original spawning grounds to complete life cycle, normally at age 3 or 4 years.					Average weights 5-7 lbs. 3-4 lbs. in Columbia River.

Cutthroat Trout •

This important sport fish also has nonanadromous and anadromous races. Anadromous juveniles migrate to the sea during the first three years of life; timing varies locally. Marine bound cutthroat remain in or near estuaries and often move into streams in spring to feed. Cutthroat may remain in the sea for one or more years before returning to their spawning stream in fall and winter. Spawning of 1,100 to 1,700 eggs occurs between February and May.

Prickly Sculpin •

Prickly sculpins are unique in that some populations migrate downstream to spawn in brackish waters. Preferred estuarine and pastoral spawning streams have a boulder, cobble and flat rock bottom with a current flow of about one cubic foot per second. Thousands (25,000 to 30,000) of eggs are laid. Prickly sculpin larvae are mainly pelagic for 30 to 35 days before metamorphosing and settling on the stream bottom. A staggered upstream migration occurs with adults departing before juveniles. Prickly sculpins are an important prey of other fish, birds, and are a favored food of river otters.

Threespine Stickleback •

This stickleback serves as an important forage species for trout and other predaceous fish, and birds, such as mergansers. The threespine stickleback spawns on the bottom sandy areas of shallow streams in June or July. It is tolerant of fresh, marine, and brackish waters.

Candlefish (eulachon) •

This anadromous smelt moves short distances up coastal freshwater streams to spawn from mid-March to mid-May. Most adults die after spawning, but a few may survive to spawn a second time. Candlefish are taken commercially by drift gillnets and used for human and commercially reared furbearing mammal's consumption.

Table 51-2. FOOD HABITS OF RIVER AND STREAM FISH

	Juveniles	Adults
steelhead trout	insects, ephausiids, copepods, amphipods, sand lance, herring	marine fishes (e.g., greenling) various crustaceans
cutthroat trout	aquatic and terrestrial insects, small invertebrates	marine aquatic and terrestrial insects, small fish, crayfish, salmon eggs, dead salmon
chinook salmon	terrestrial insects, crustacea, chironomids, caddisflies, mites, ants	marine fishes (97%) invertebrates (3%) (crabs, squid, shrimp, amphipods)
coho salmon	insects - dipteran larvae, trichoptera, plecoptera, coleoptera, sockeye salmon fry	marine pink and chum salmon fry, herring, sand lance, squid, crustacea
pink salmon	marine copepods, euphausiids, amphipods, dipteran insects, tunicates	marine euphausiids, amphipods, squid, copepods, pteropods
chum salmon	insects	marine diatoms, ostracods, mysids, amphipods, isopods, fish larvae, squid
sockeye salmon	plankton, cottids	plankton, squid, euphausiids, amphipods
prickly sculpin	planktonic crustaceans, aquatic insect larvae	fish, aquatic insect larvae (chironomids and trichopteran), bottom invertebrates (e.g., molluscs)
stickleback	worms, small crustaceans, aquatic insect larvae, fish eggs, and fry	
candlefish	plankton	plankton
starry flounder	barnacle larvae, cladocerans, copepods, marine worms, amphipods	crabs, shrimp, worms, clams, molluscs, small fish, brittle stars

The name candelfish is derived from the past practice of drying these fish and fitting them with a wick after which they may be used as a candle.

Starry Flounder •

This euryhaline species (having a wide tolerance of salinities) is found in lower portions of coastal streams, and in and below the intertidal zone in estuaries and bays. Young starry flounders are most abundant in estuarine areas of rivers. Protected locations, such as Willapa Bay, are used as flounder nursery areas. Starry flounders are taken commercially and for sport and are important prey for harbor seals, river otters, and other nearshore wildlife.

amphibians

Olympic Salamander •

Olympic salamanders are found only in the Pacific Northwest, ranging from mid-Humboldt County, California west of the Cascade Crest northward onto the Olympic Peninsula. They are small (44 to 64mm), chocolate brown above and yellowish orange below with white speckling, especially along the sides.

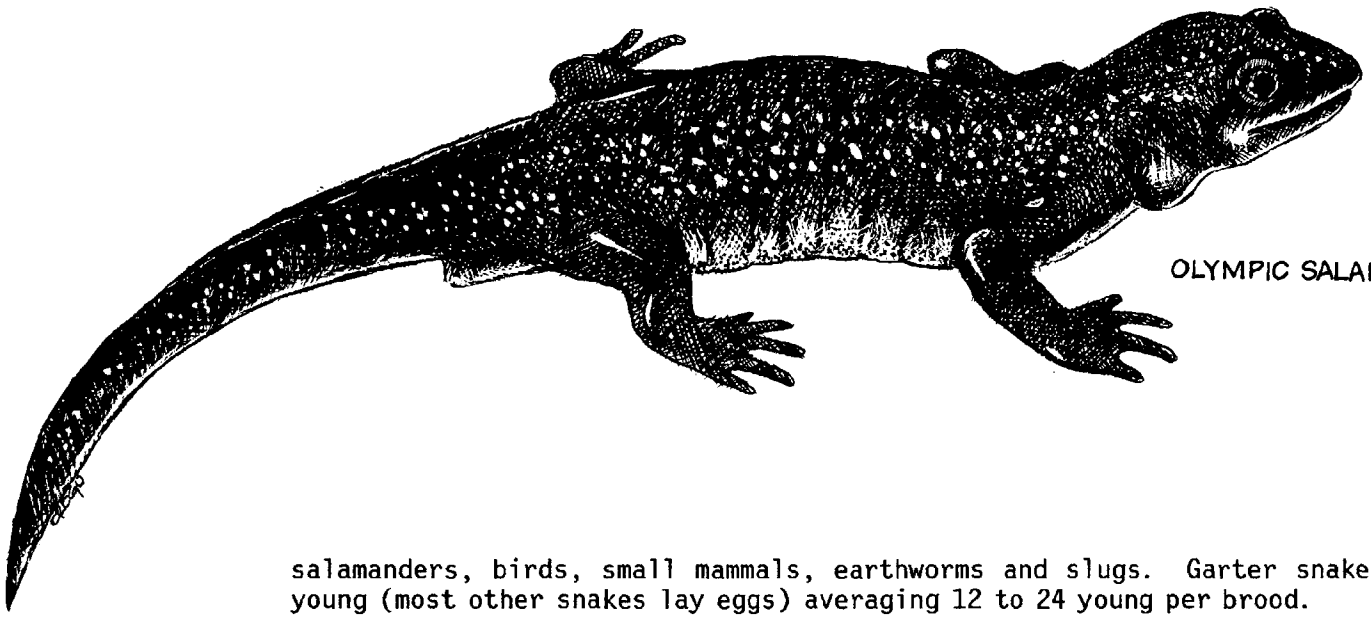
The Olympic salamander's habitat is characteristically one of cold, permanent streams with small, water-washed or moss-covered rocks in and along the edges of running water. Streams with Olympic salamanders usually have dense tree cover, especially during summer months. Abundant understory vegetation, moss, and a thick leaf mat are characteristic of the stream bank. Resting sites are in areas with slow water movement. Olympic salamanders are rarely out of direct contact with water or a saturated substrate. Reproduction is in spring and early summer when the female attaches her seven to fifteen eggs to the undersides of stones and to moss in streams.

Other amphibians that may occur in streams include rough-skinned newt, Northwestern salamander, pacific treefrog, red-legged frog, spotted frog (uncommon), tailed frog, and the introduced bullfrog.

reptiles

Common Garter Snake •

This snake inhabits a variety of habitats near water. Garter snakes are good swimmers and retreat to water when frightened. Their food consists of fish, toads,



OLYMPIC SALAMANDER

salamanders, birds, small mammals, earthworms and slugs. Garter snakes bear live young (most other snakes lay eggs) averaging 12 to 24 young per brood.

Birds

Dippers •

The Dipper, also called water ouzel, is a slate colored bird with white eyelids and a stubby tail. It dives and submerges into streamwater with bobbing motion, searching the bottom for insects, aquatic invertebrates and small fishes. Fast flowing streams with plenty of aquatic life are preferred. Typically a mountain stream bird, the Dipper also uses lowland streams in winter, and has been observed in estuarine areas including Salt Creek marsh in Clallam county. The Dipper makes its nest out of a bulky ball of moss on the rock wall of a stream, often behind a waterfall.

Spotted Sandpiper •

This small sandpiper has round black spots on its under parts in breeding plumage. It is commonly found along freshwater lakes, ponds, and streams during breeding season. The sandpiper uses a leaf-lined scrape near shore or under bush for a nest. During winter, it characteristically inhabits the estuarine zone of rivers and streams and also feeds along marine shorelines. The Spotted Sandpiper eats insects and other small invertebrates.

Bald Eagles •

The Bald Eagle is found along coastal lakes, and rivers and streams where fish and carrion are abundant. It is often seen along rivers where it feeds on spawning salmon. Large concentrations of eagles occur at this time at the Skagit River Eagle Sanctuary and in estuarine areas, such as at the mouth of the Skokomish, Hamma Hamma, Quilcene, and Stillaguamish rivers.

The Bald Eagle requires tall trees for nesting in which mates build bulky platforms of sticks for their two or three young. Protected riparian and estuarine areas are also required for roost sites and as buffers around feeding sites. (See the Forest Narrative, No. 4, for Bald Eagle management recommendations.)

mammals

Townsend vole (Microtus townsendii) •

This large vole is ubiquitous in wet places, becoming especially abundant along salt meadow/marsh in the estuarine zone. Townsend voles make surface runways and extensive underground tunnels in loose soil. They are a main food for Barn and Short-eared Owls, Marsh Hawks, and foxes.

Beaver •

Beavers are known for their stick and mud dams they build across streams to increase their wetland habitat. Their favored habitats are streams and lakes with birch or alder trees on the banks. Preferred foods of beaver are the bark and small twigs of red alder, willow, maple, birch, poplar, and aspen. They store food supplies of branches and small sections of logs under

water near their lodge or stream bank dens. Beavers are important furbearers and water conservationists. The small amount of timber they do destroy is outweighed by their creation of habitat for many valuable fish and wildlife species. For more information on the beaver, see the Beaver Pond Narrative (No. 525).

River Otter •

This beautiful animal is found along streams and lake borders. Although aquatic, it may travel several miles over land to reach another stream or lake.

Otters are relatively asocial animals, although marine populations may be more gregarious. Otters often travel in small groups covering home ranges of 15 miles or more. Otters eat frogs, fish, crayfish, and other aquatic invertebrates. They prefer crayfish and sculpins in fresh water, but switch food preferences to adult salmon in fall and winter during spawning runs.

Otters are valuable esthetically and for scientific research; these curious and playful creatures provide wildlife watchers with hours of enjoyment. They are also an important furbearer in Washington State.

Otters move freely between fresh and salt water, but seem to prefer freshwater areas for reproduction. Thus streams are critical as year-round habitat for some otters, while providing a corridor and refuge for reproduction for others during part of the year.

Raccoon •

The nocturnal raccoon inhabits stream and lake borders where there are wooded areas or rock cliffs nearby. Raccoons are omnivorous, eating fruits, nuts, grains, insects, frogs, crayfish, or bird eggs. Raccoons den in hollow trees, hollow logs, rock crevices or ground burrows. Their home range covers up to two miles. Young have been known to disperse up to 165 miles from their birthplace, but usually disperse less than 30 miles. Raccoons are especially abundant in estuarine areas, where they forage along tidal sloughs and in marshes.

B. Interrelationships with Other Habitats

Rivers and streams are interrelated with many other habitats [refer to the Riparian (No. 33), Salt Marsh (No. 623), Lagoon No. 56), and Bay/Estuary (No. 54) Narratives]. Rivers and streams are also integrated with other aquatic habitats serving as links between habitat types (e.g., between lakes and estuaries). Energy and nutrient exchange occurs across ecosystem boundaries by means of gases, precipitation, surface runoff and ground outflow of water, all containing dissolved nutrients and chemicals. Migrating animals also carry nutrients and energy across habitat boundaries. For example, salmon move from fresh water to estuary to open sea and back to fresh water.

Terrestrial ecosystems provide stream biota with the majority of nutrients and materials necessary for their existence. Toxins, such as heavy metals, radio isotopes, and pesticides, can be transported directly or indirectly via terrestrial ecosystems to aquatic ecosystems by the same pathways of energy and nutrient exchange. Changes in management of an adjoining terrestrial system can change a stream's ecology. Mature terrestrial ecosystems tend toward a steady state where erosion and transport of dissolved substances are minimized. Intact terrestrial ecosystems develop tight nutrient cycles as they mature and lose only small amounts of available nutrients in drainage waters and stream production is adapted to these levels. Disturbance of a terrestrial system can upset natural relationships and accelerate input into adjoining aquatic systems. Heavily polluted aquatic ecosystems, resembling unstable or retrogressive natural systems, result.

Terrestrial vegetation providing shade along streambanks helps regulate stream temperatures. Shade maintains the cool temperatures required for salmonid and other fish production. Streamside vegetation also provides cover necessary for many fish and other wildlife.

Estuaries, one of the most productive ecosystems known, depend on rivers for their maintenance. River flow contains nutrients, such as sulfates, carbonates, phosphorous and nitrogenous compounds, etc., which contribute to estuarine productivity. River water also contains considerable amounts of terrestrially produced organic detritus, a major source of food for many estuarine organisms. River nutrients

may even influence the productivity of the nearby sea as seen in increased algal growth outside the estuarine areas.

The flushing and mixing action of fresh water from rivers and sea water maintains salinity gradients within the estuary. The lowered salinity and flushing action of river water provides an excellent environment for oysters and other invertebrates. Fresh water flushing action rids oysters of damaging parasites and eliminates species that would compete with oysters for food. Hypersaline water limits oyster production by restricting development of gonads.

Estuaries are highly dynamic environments due to the action of river flow and tides. At the mouths of rivers there is often a two-layered water system. At low tide with a high river flow, the surface water is fresh, while the bottom water is quite salty. Under these conditions, true freshwater species may penetrate far downstream. At the same time and location, true marine species may be found in the saline bottom waters of the lower river. Marine species use the fresh upper estuary as a nursery ground for their young. Juvenile starry flounders may stay in the upper estuary two to two and one-half years before going to sea.

River flow is also closely connected to the maintenance of natural channels between barrier islands. The channels connect estuaries to the sea and are important as passages for fish and invertebrates between nursery grounds and feeding areas.

Many animals use rivers and riverbanks as corridors of travel. Otters and raccoons travel along the rivers which provide food including invertebrates and fish. Young beaver follow a river course for dispersion from their birth place and take up residence further up or downstream. Deer, elk, coyotes, bobcat, and other terrestrial mammals also use riverbanks as travel corridors. Rivers can be corridors of recreation and beauty which can lead a canoeist or kayaker through crashing rapids and serene pools as they pass a variety of terrestrial habitat types.

C. Commercial/Recreational/Esthetic Benefits

Rivers provide the base for production of commercial and sport fisheries. Fisheries are a major industry in Washington, and the management of our rivers will largely determine the fate of our fishery resources. As discussed previously, rivers also carry nutrients which enrich estuaries producing oysters, fish, waterfowl, and other commercially and recreationally valuable wildlife. More information on estuarine resources is found in the Bay/Estuary Narrative (No. 54).

Rivers are also used as commercial sources of power and water. The value of dams and reservoirs built for industry and consumptive use must be weighed against the impact they will have on stream and river ecology on a case-by-case basis. However, the total demands and potential capability for our region must be considered before we have irreparably altered all our rivers. We may well have already reached the limits for a balance between river development and wildlife, recreation, natural, and commercial values. For example, the remaining free-flowing rivers in western Washington are few, and the major salmon producing streams have already been largely destroyed or severely altered by dams and other development. The Columbia is the most dramatic example, having only 55 miles free flowing above Bonneville Dam in Washington. The Skagit, Snohomish, Green/Duwamish, Puyallup, Nisqually, Skokomish, Elwha, Chehalis, and Columbia rivers have all been altered severely by dams, urban development, channelization and/or destruction of estuarine marshes. Hatchery salmonid subsidies alone are extremely costly or damaging "replacements" for natural fish runs of undisturbed rivers. Other losses caused by river development are largely irreplaceable and have contributed to the decline of several species, loss of natural recreation areas and reduced commercial productivity in estuaries. We must consider the natural values of rivers and their tremendous contribution to our economy and well-being. The short-term gains realized by logging watersheds, adding another kilowatt, or building a flood "control" dam may not be as valuable when compared to the long-term production of clean water, fish and other wildlife.

The value of a pristine stream to an angler whiling away a pleasant afternoon, or the heart-shaking excitement of a rafter negotiating rapids; or the joy of a child when he first skips a stone over a calm pool must all be measured before river management decisions are made.

Rivers benefit industries and recreationists and also contribute to the function of the global ecosystem. Rivers and associated ecosystems provide rich habitats for wildlife and should be managed with this in mind. Changes in a watershed can affect a river and its biota, as well as the biota of many interdependent habitats.

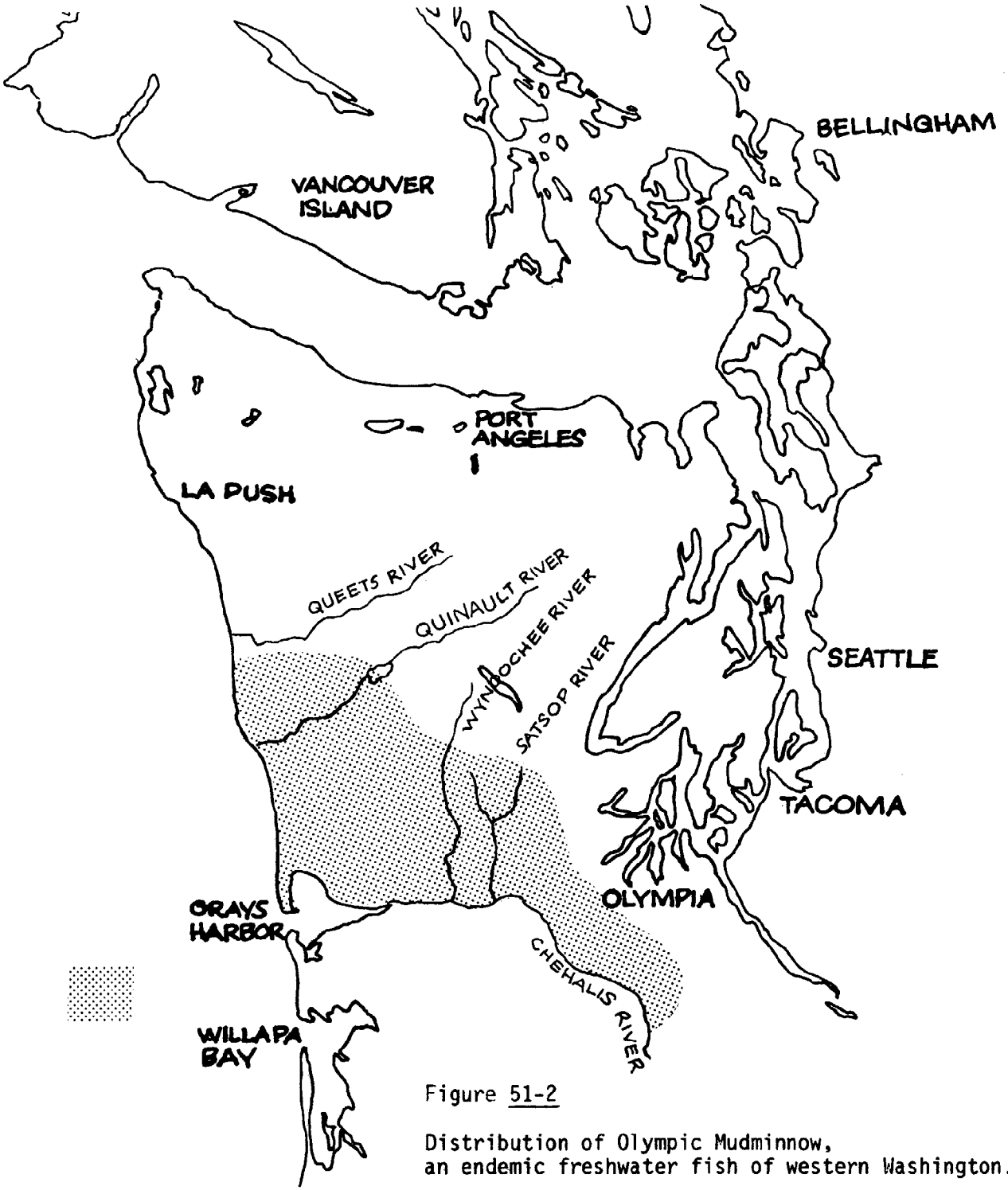


Figure 51-2

Distribution of Olympic Mudminnow,
an endemic freshwater fish of western Washington.

III. IMPACTS

A. Historical Changes and Trends

Historically, rivers have been used as sources of food and pathways for travel. During the past two hundred years in the Pacific Northwest, man has changed his use of rivers and has severely altered river and riparian habitat. Logging, building of dams, reservoirs and roads, urbanization, stream channelization, agriculture and a general increase in human activities have resulted in decreases of wetlands. Watersheds and rivers have been changed from stable to unstable systems.

Fish populations have changed as a result of man's influence on rivers. Historically, summer runs of steelhead in coastal rivers were larger than they are now. Logging has increased stream water temperature and siltation, resulting in a decline in the steelhead population.

Past management of rivers and streams in Washington has been poor. In the early 1950's, a pollution barrier to fish existed in the estuary of the southern branch of the Snohomish River and Everett Harbor. Soda and sulfite pulp mills, fish canneries, meat packing plants, and dairies poured their wastes into the river and harbor. As a result, dissolved oxygen concentrations decreased, and large kills of herring, candlefish, and young salmon were reported.

Other estuaries, such as the Duwamish and Puyallup, have been even more severely impacted. Only valuable, tiny Kellogg Island remains a marsh in the Duwamish estuary. The Nisqually estuary is now threatened by proposed construction, and development is occurring on several other estuaries in Washington.

B. Specific Impacts

Logging

Logging is one of the primary causes of change in rivers and streams in the Northwest. Logging can cause sedimentation of rivers, and changes in temperatures, dissolved oxygen concentrations, nutrient flow, and gravel stability. Logging can also increase river flooding, block fish passages and change courses of streamflow.

Logging and fire destroy the natural mechanical support for soils and remove the soil's surface cover. Eroded particulate matter from the bare soil enters the stream through runoff, increasing the stream sediment load. The sediments, inorganic particles less than 4 mm. in diameter, are transported downstream, altering the physical appearance and morphometry (shape) of channels and basins through scouring and redeposition. Habitats are physically disrupted, turbidity restricts penetration of sunlight, and water chemical relationships are altered.

Sediments in suspension influence fish by blocking the transmission of light which reduces food production. They also damage fish gill membranes resulting in death where sediment concentration is high and exposure is prolonged.

Fish are also affected by bottom sediments which fill the space between the gravel, reducing interchange between surface waters and waters within the gravel bed. This affects the survival of salmonid embryos in the gravel by reducing the supply of dissolved oxygen and inhibiting the removal of waste products and also impedes the emergence of fry. Survival of salmonid fry is impaired by sediments because of loss of escape cover and reduction of aquatic organisms that are fish food. Normally, only 10 to 30 percent of the total eggs deposited by spawning trout and salmon survive to fry stage; their survival is much less when sediment loads are added to the gravel bed.

Clearcutting streamside vegetation can alter stream temperature; this can have drastic effects on salmonid populations. Removal of vegetation increases solar radiation received by a stream, driving water temperatures up. Stream water temperatures in deforested watersheds are higher than in undisturbed watersheds, and diurnal temperature fluctuations are also greater. Removal of vegetation producing colder temperatures at night can also cause mortality of salmonid eggs and larvae. Temperature changes are most significant on small streams that are essential to production of salmon and trout; solar radiation received by small streams may increase six to seven times after logging. Many of these smaller streams receive the least protection from the Forest Practices Law.

Increased temperatures can have many other detrimental effects. Migratory behavior patterns of adults and juvenile fish can be altered by temperature changes. As water temperature rises, an environment is created that favors other fish over salmon and trout. Many of these other fish, including several introduced species, are less desirable to sportsmen. Increases of water temperature also increase the

virulence of fish diseases and the toxicity of chemicals.

Increased runoff from logging and slash burning contributes high volumes of nutrients to streams. Following slash burning, nutrient cation loss increases one and one-half to three times the amount lost from an undisturbed watershed. Deforestation results in large increases in stream concentrations of all major ions except ammonium, sulfate and bicarbonate. Nitrogen, normally conserved in undisturbed areas, is rapidly leached by drainage waters. Undisturbed areas may lose 0.16 pounds of nitrogen per acre of watershed annually while logged and burned areas lose upwards of four pounds per acre per year.

Additional runoff due to logging increases streamflow. In western Washington the minimum streamflow during dry summer months has materially increased, benefitting some fish species. At other times, increased runoff can add to the probability of floods. Floods destroy fish eggs and reduce bottom macrofauna. High winter mortality of trout can be attributed partially to severe floods.

Logging debris (e.g., logs, branches, leaves) also alters streams. Debris can obstruct main drainage channels and delay or block migration of salmonids. Smaller log jams erode the stream beds and fish redds by repositioning of currents. Decomposition of debris lowers the concentration of dissolved oxygen in streams which adversely affect salmonids from embryonic to adult stages.

Fertilizers

Fertilization of agricultural lands, lawns, gardens, and forests with inorganic fertilizers results in an increase of nutrients, especially nitrogen, in drainage waters. Nitrogenous compounds accelerate eutrophication which leads to lower concentrations of dissolved oxygen in rivers and streams.

Road Building

Road building can cause slope failures due to slope loading, back-slope cutting, and inadequate soil drainage. Sediments wash into streams, often blocking streamcourses, especially along small streams. Larger streams are also impacted. For example, most sediments in the Chehalis River are due to logging roads.

Removal of Riverbed Material

Removal of riverbed material reduces spawning areas. It can cause a continuous and excessive bed load movement which destroys the redds in the gravel. Large numbers of salmonid fry and fingerlings are trapped in pockets left by gravel excavations of river banks and are lost when the river recedes.

Dams

Dams built for hydropower and reservoirs restrict fish passage and result in loss of spawning area and changes in water quality. In the Columbia River, almost 10 percent of young fish are lost as they travel over each dam. Siltation also occurs on dammed rivers, restricting water flow which can have dire effects on estuaries.

Flood Control and Channelization

Flood control methods consisting of channel straightening, diking, removal of stream bed material and replacing natural stream vegetation with riprap all reduce the natural pool-riffle character of spawning and rearing areas and limit valuable riparian habitat.

Streams are channelized usually for flood control. The effects of channelization can be severe and long lasting. Channelization upsets the delicate balance existing between volume of runoff and sediment movement within a stream and reduces fish habitat. Experiments on Big Beef Creek in Kitsap County demonstrate some channelization effects. Following channelization, Big Beef Creek experienced accelerated stream bank and dike erosion within the channeled areas. Prior to channelization, 50 percent of chum salmon redds were lost because of gravel instability. After the stream was channelized, 50 percent of the redds were still lost due to streambed shifting and sedimentation as before, thus, channelization did not create better salmonid habitat. Reduction of permanent stream bank cover resulting from channelization reduced the productivity of steelhead trout in the lower portion of Big Beef Creek.

Industrial Effluents

Intermittent and seasonal pollution of lower rivers and estuaries is caused by effluents from agricultural, industrial and sewage disposal sources. Estuaries may develop a build up of sludge and toxic waste, which is limiting and harmful to anadromous and marine fish, shellfish, and bird and mammal productivity.

C. Recommendations

Negative logging impacts can be modified by leaving buffer strips of vegetation along river and stream banks. Leaving a streamside canopy of vegetation shades the stream and minimizes or eliminates increases of water temperature associated with clearcut logging. Maintaining stream buffer vegetation also reduces siltation, maintains dissolved oxygen concentrations, and preserves the esthetic quality of streams. Buffers also aid in deterring forest fertilizers from entering streams.

Vegetation buffers need not be composed of marketable conifers; shrubs and deciduous trees will also act as buffers. In areas where conifers are left, the fish productivity value may equal or exceed the timber value of the trees. Logging problems are acute when clearcutting is done near small streams. Temperature increases can be modified along small stream channels with merely a dense canopy of understory vegetation. Survivial of coho salmon and cutthroat trout have been affected in clearcut watersheds. No significant changes have been seen in fish populations or their habitats when a watershed is patch-cut and buffer strips are left along streambanks.

Timber felling and yarding away from streams is also another method to modify detrimental effects of logging. This method costs two to three times that of conventional cutting, but the benefits are also great. Uphill felling lessens timber breakage, reduces slash that must be burned, enables quicker forest regeneration and reduces the need for expensive creek cleaning. This method reduces the problems streams encounter from logging debris.

Wise management of rivers and streams must include wise management of entire watersheds. Rivers and streams are so intimately interrelated with terrestrial and other aquatic ecosystems that a change in one may have long lasting effects on another. Rivers and streams will continue to be highly productive environments and areas of esthetic value, only if they are managed with the all ecosystems in mind.

TABLE 51-3 REPRESENTATIVE FRESHWATER FISH OF WESTERN WASHINGTON WHICH MAY OCCUR IN COASTAL RIVERS AND STREAMS

Common Name	Scientific	Commercial Value	Comment
River lamprey	Lampetra ayresi		Parasitic; anadromous
Western brook lamprey	L. richardsoni		Nonparasitic; nonanadromous sometimes used as a fish bait
White sturgeon	Acipenser transmontanus	C,R	Common, anadromous - grows to 20 feet
American shad	Alosa sapidissima	C,R	Introduced; locally abundant, anadromous member of the herring family
Pink salmon	Oncorhynchus gorbuscha	C,R	Salmon and trout spawn in streams and rivers throughout the coastal zone. Most populations are anadromous, each species spending a part of its life in freshwater.
Chum salmon	O. keta	C	
Coho salmon	O. kisutch	C,R	
Sockeye salmon	O. nerka	C,R	
Chinook salmon	O. tshawytscha	C,R	
Cutthroat trout	Salmo clarki	R	
Rainbow trout (steelhead)	S. gairdneri	C,R	
Brook trout	Salvelinus fontinalis	R	
Dolly varden	S. malma	R	
Longfin smelt	Spirinchus thaleichthys		Freshwater and marine
Eulachon (candlefish)	Thaleichthys pacificus	C,R	Anadromous, highly valued food fish
Olympic mudminnow	Novumbra hubbsi		Endemic; restricted to Chehalis drainage basin and Olympic Penninsula. See Figure 51-2 for distribution map.
Peamouth	Mylocheilus caurinus	PR	Widely distributed in western Washington; once regarded as sport and food fish
Northern squawfish	Ptychocheilus oregonensis	R	Common and widely distributed

TABLE 51-3 (Cont.)

Common Name	Scientific	Commercial Value	Comment
Redside shiner	Richardsonius balteatus		Common, S. Puget Sound drainages
Longnose dace	Rhinichthys cataractae		Widely distributed
Speckled dace	R. osculus		Common, S. Puget Sound drainages
Longnose sucker	Catostomus catostomus	PC	Marketed as "mullet"
Largescale sucker	C. macrocheilus	PC	Common
Threespine stickleback	Gasterosteus aculeatus		Common
Striped bass	Roccus saxatilis	C,R	Uncommon, introduced and may occur as anadromous fish in outer coast rivers
Yellow perch	Perca flavescens	C,R	Introduced
Coastrange sculpin	Cottus aleuticus		Common; sculpins are prey of salmon and other fish, birds, and mammals
Prickly sculpin	C. asper	R	Common, spawns in estuarine zone
Shorthead sculpin	C. confusus		Recently (1963) recognized as a separate species
Torrent sculpin	C. rhotheus		Common
Pacific staghorn sculpin	Leptocottus armatus		Occasionally enters freshwater, occurs in estuaries
Starry flounder	Platichthys stellatus	C,R	Occasionally enters freshwater, occurs in estuaries

LEGEND:

C = Commercial
R = Recreational
PC = Potential Commercial

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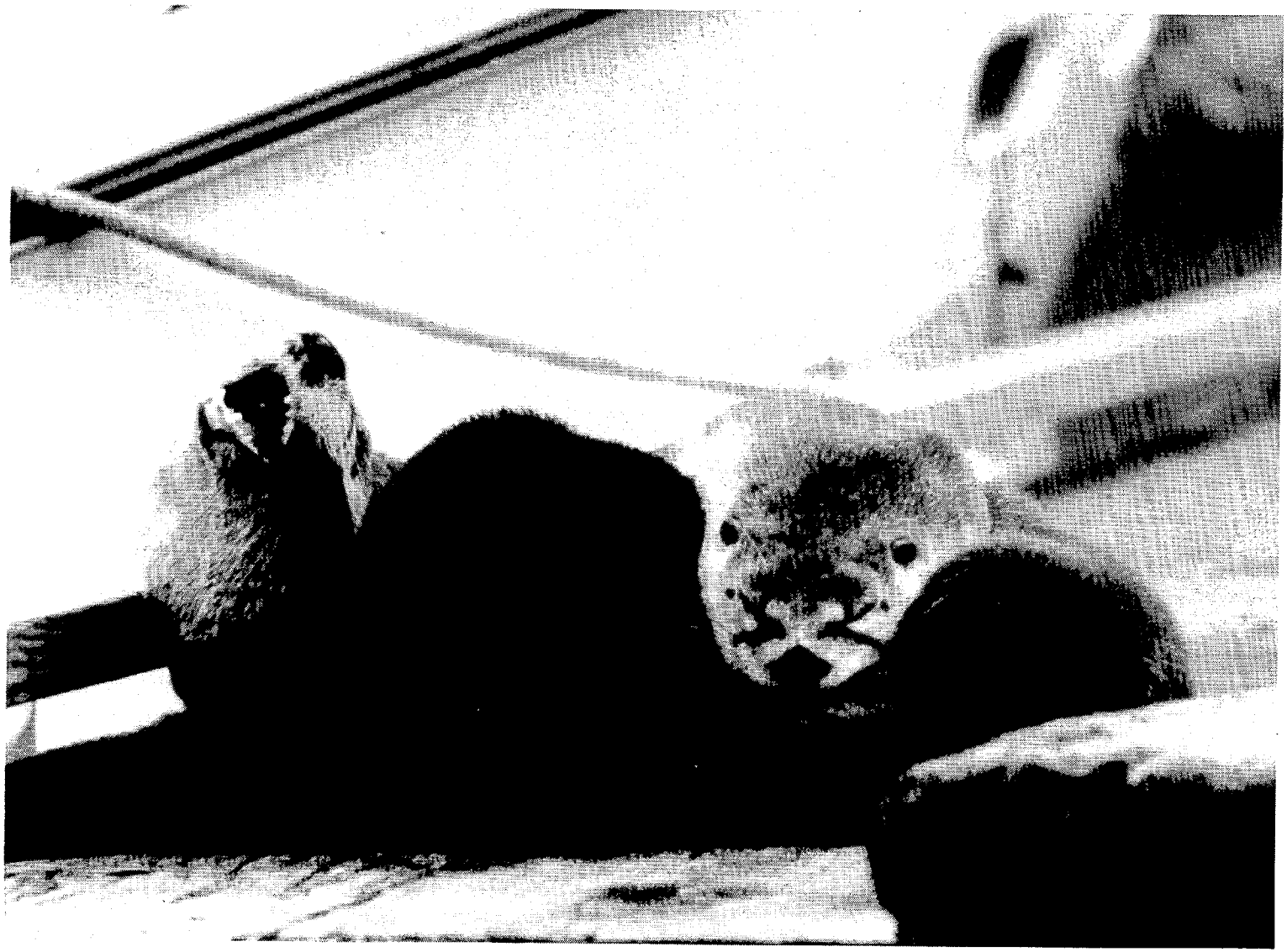


LAKES AND PONDS (No. 52)

I. INTRODUCTION

Lakes and ponds are numerous throughout the Pacific Northwest. Many of these permanent standing water habitats originated as a result of the last glaciation 10,000 to 20,000 years ago. Lakes and ponds occur in localized areas and vary in depth, area, and species composition. We have divided the lake/pond category as follows: Lake (521), Inland Pond (522), Coastal Pond (524), Beaver Pond (525), and Farm Pond (526).

Lakes (No. 521), for our mapping purposes, are bodies of standing water with a surface area greater than 20 acres. Open water areas (i.e., the limnetic zone) are relatively large compared to nearshore zones and are the primary producing regions of the lake. Very few lakes were mapped in the Coastal Zone Atlas (excluding the outer coast), examples include Cranberry Lake on Whidbey Island and Pass Lake in Skagit County. Other lakes in the coastal zone occur on Anderson Island in southern Puget Sound and on Blakely and Orcas Islands in the San Juan Islands.

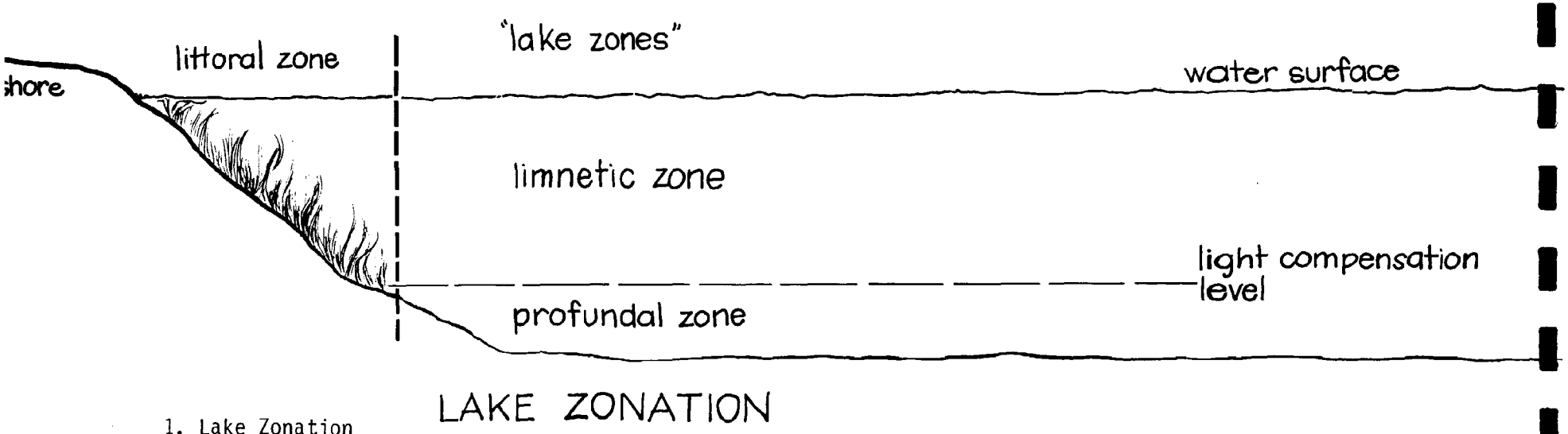
Ponds are typically shallow and lack extensive open water areas. Thus, their primary producing zone is nearshore water (i.e., the littoral zone). Bodies of water mapped as inland ponds (No. 522) and coastal ponds (No. 524) cover less than 20 acres. Inland ponds are situated at higher elevations. Coastal ponds are located along the beach fringe behind drift logs and at the base of shoreline bluffs, or form on river deltas when old stream channels are blocked by levees or natural stream course drifts. Additional related information about coastal ponds is found in the Enclosed Lagoon Narrative (No. 561), since there is much similarity between these two aquatic types.

Beaver ponds, created by the construction of beaver dams, are discussed in Narrative No. 525.

Farm ponds (No. 526) are created by man damming a stream or excavating basins. Stream water is generally detoured around the pond or the pond is formed in a basin without permanent streamflow. The intensity of management of these ponds determines their resemblance to natural pond habitats and the diversity of organisms present. (See Narrative No. 526.)

Lakes and ponds are important to the Pacific Northwest as wildlife habitat, recreation, and as part of watersheds. Although lake and pond classification types may differ in specific functions for human and wildlife activities, all these bodies of water are part of a vast chain of wetlands used by migratory birds.

Lakes and ponds have gone through many changes during the last 100 years. Increased human activities, such as logging, road building, development, and recreation, have altered not only the shorelines, but also the species and chemical composition of lakes and ponds. Some lakes and ponds have decreased in area through siltation, while others through waste disposal have become eutrophic. Other ponds have been changed from a natural state to one that suits private interests, such as the coastal pond near the Port Townsend pulp mill which was reduced by 50 percent and recently converted into a sewage pond.



1. Lake Zonation

Lakes and ponds can be divided into three zones of biological activity. These are the littoral, limnetic, and profundal zones. Due to differences in depth and area, not all lakes and ponds have all three regions.

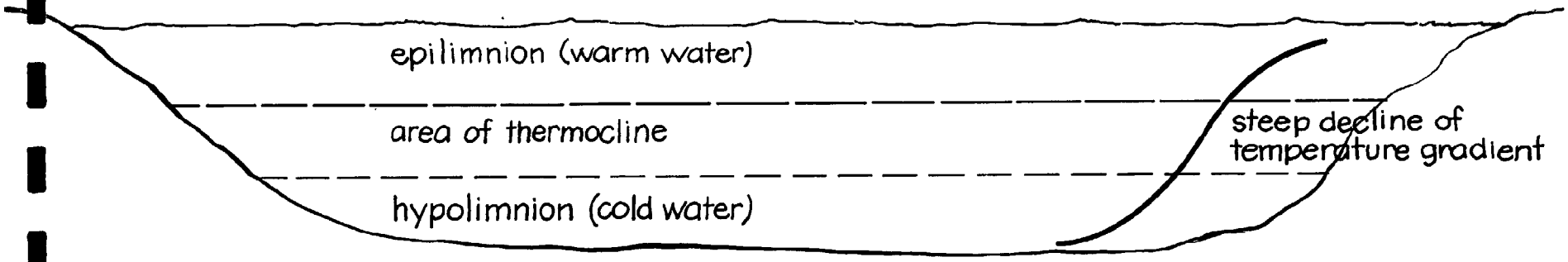
The littoral zone is the nearshore shallow-water region where light can penetrate to the bottom. This zone is occupied by rooted plants in natural ponds and lakes, but is nonvegetated in some managed farm ponds and reservoirs. The littoral zone is the primary producing region of ponds and very shallow lakes.

The limnetic zone includes open water to the depth of effective light penetration, called the light compensation level. At the compensation level, the amount of energy produced by photosynthesis equals that used during respiration by aquatic organisms. The light intensity at this level equals about one percent of full sunlight intensity. The primary producers in the limnetic zone are plankton and nekton (freeswimming organisms). The limnetic zone is absent in small, shallow ponds.

The profundal zone is the bottom, deep water area below the depth of effective light penetration. This zone is usually absent in ponds or shallow lakes.

Each of these three regions of lakes and ponds have unique community structures. The communities do overlap and may vary seasonally or with changes in water level.

STRATIFICATION OF LAKE



2. Stratification

Lakes are usually deeper than ponds, and often become stratified during summer and winter. Temperature stratification occurs during the summer when the top lake waters become warmer than the bottom water. Only the top water then circulates; it does not mix with the cold bottom water. A stratum called a thermocline having a steep termperature gradient is formed between the warmer surface water (the epilimnion) and the colder bottom water (the hypolimnion). If the thermocline occurs below the level of effective light penetration as it frequently does, the oxygen supply becomes depleted in lower waters. Oxygen sources of green plants and surface waters are cut off by the lack of light and noncirculation of water.

The rate of summer lake oxygen depletion depends on the amount of decaying matter and the depth of the thermocline. Highly productive lakes suffer greater oxygen depletion than less productive ones. Fish needing cold waters survive only in poorer lakes which do not become oxygen depleted. Other bottom organisms, such as crayfish, are adapted to seasonal stratification changes and survive.

In shallow lakes having transparent water which allows light to penetrate to the bottom, oxygen may be more abundant in lower levels than surface waters. This is due to colder water being capable of retaining higher dissolved oxygen concentrations.

3. Productivity

Lake and pond productivity is influenced by species composition, nutrient concentrations, temperature, light penetration, water movement, depth, geological age, and other factors. On a global scale, energy variables, such as solar radiation, have a greater affect on lake productivity than does nutrient availability. When lakes are restricted to a certain range of latitude, as in the Northwest, nutrient availability becomes the major factor in determining lake productivity. Total dissolved nutrient concentrations appear to be the most important factor in determining productivity.

4. Depth

Lake morphometry varies in importance to lake productivity. In lakes of similar nutrient and energy status, deep lakes have about the same phytoplankton production as shallow lakes when productivity per unit surface area is compared. Shallow lakes are more productive and have a denser phytoplankton population when production per unit volume is considered.

Primary production is not dependent on the average depths of lakes. There is, however, a close relationship to depth as long as the deeper water does not lose all of its oxygen supply during summer. Deep lakes having a large supply of dissolved oxygen in the hypolimnion (bottom waters) can have as great a production of phytoplankton and other plants as much shallower lakes.

Quantities of fauna from deep lakes are usually as high as those found in some lakes of shallow depth. There is no correlation between areas of lakes and ponds and associated standing crops of fish per acre (biomass). There is a tendency for biomass to decrease with increasing maximum depth of trout lakes, warm water lakes and reservoirs. There are significant increases in biomass as carbonate concentrations increase in these bodies of water.

Efficiency of energy utilization in lakes is directly proportional to average depths. Thus morphometric features of lake basins have decisive influences on rates of secondary production. Primary production is not always proportional to mean depth, but the intensity of conversion (secondary production) and breakdown of organic substances (decomposition) is proportional to average depth.

5. Nutrient Cycles

Nutrient cycles of lakes and ponds are relatively self-contained over short periods of time. Lakes and ponds generally have large supplies of nutrients locked up at any given time in the form of living plants and animals, dead organisms and debris under bottom silt. Terrestrial inputs contribute significantly to long-term balances in lake and pond nutrient cycles.

There are small, rapid changes of nutrients between solid and dissolved states occurring continually. Extensive movement of nutrients between organic matter and water is often irregular with periods of net release from sediments followed by net uptake by organisms of other sediments. Nutrient exchange is highly dependent on seasonal temperature conditions and activities of organisms, but generally the nutrient uptake rate exceeds the release rate in lakes and ponds. It has been suggested it is far more valuable to measure limits of lake productivity not by nutrient concentrations, but by the flux rate of a nutrient, such as phosphorous, being exchanged between sediments and organisms.

Nutrients are released back into the system by decomposers and mechanical processes. Plants also play a role in releasing nutrients. In the littoral zone, rooted plants act as nutrient pumps, collecting nutrients from sediments and incorporating them into their tissues. These nutrients are returned to the aquatic system when plants are consumed, decomposed, or broken down by other means. Blue-green algae are able to fix gaseous nitrogen into nitrates which make the nitrogen available to other organisms.

6. Lake Succession

Newly formed glacial lakes are oligotrophic (poorly nourished). Many of our lakes formed in the Pleistocene are still oligotrophic due to their great depth, the surrounding land being poor in nutrients, or their drainage basin being small. Nutrients have not had the time or opportunity in some areas, to enter the lake in surface runoff. Oligotrophic lakes have a low concentration of dissolved nutrients and clear water with little particulate matter in suspension. Productivity is low with algal growth composed of single-celled diatoms. The water is well oxygenated at all depths and seasons because there is such

limited respiration. Fish such as trout, salmon, and whitefish, which require low temperatures and high oxygen concentrations, thrive in oligotrophic lakes. Oligotrophic lakes contain high quality water and are suited to a variety of uses including fishing and swimming.

Succession of lake form proceeds from oligotrophic to eutrophic (having many foods) as nutrients are added to the lake through runoff and leaching from the soils and rocks of the surrounding drainage basin. Man-made effluents which enter water bodies increase the rate of eutrophication. This results in an increase of concentrations of nutrients essential to plant productivity, primarily that of algae. The process of eutrophication (progressive nutrient buildup) in the lake is accompanied by increases in species diversity of phytoplankton and increases in total algal biomass. As eutrophication proceeds, diversity decreases and the flora becomes dominated by green and blue-green algae.

Progressive enrichment and increased biological productivity accompanied by filling in of the lake basin by inflow sediment and the remains of algae and weeds, decreases lake depth and increases water temperature. The warmer water, increased oxygen demand from bacterial breakdown of decaying matter, and respiration of increased numbers of organisms results in dissolved oxygen deficits in deeper waters. The altered oligotrophic lake eventually becomes eutrophic and is subject to summer stratification.

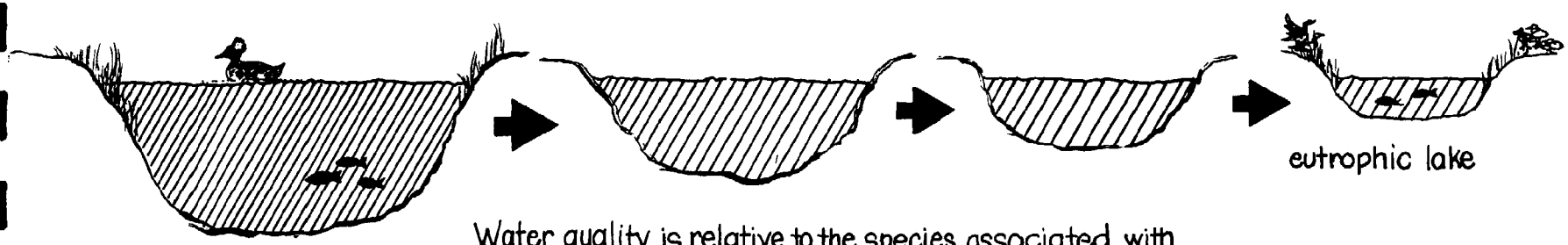
The lake may eventually age to a shallow, warm, turbid, highly productive lake with water of decreased quality and limited usability to humans and cold water fish. Trout, whitefish, and salmon are replaced by warm water forms. In lakes having a continued nutrient supply from the drainage basin, eutrophication will proceed until the lake is filled in. Succession will continue with the establishment of a terrestrial community.

Plant and Animal Communities

1. Littoral Zone

In the littoral (nearshore) zone, plants belonging to two major groups are responsible for primary production. Algae, which may be micro or macroscopic, attached or free-swimming, and vascular plants, which are often discussed according to growth habit. Also referred to as macrophytes, vascular plants may be:

1) Emergent - rooted in the bottom sediment but with stems, leaves, flowers, and fruits above the water surface. Emergent species include mare's tail, arrowhead, and buckbean. In shallow ponds, species which usually occur in marshy of swampy sites may be rooted in the standing water. Examples include common rush, willows, red alder, and water parsley. Species which are rooted in shallow water, but form dense stands, e.g., cattails and bulrushes, were normally mapped as part of the surrounding marsh habitat. However, due to mapping constraints, small marginal bands of marsh were sometimes included within the lake or pond polygon. Emergent vegetation is used for food and cover by wildlife, such as muskrats, ducks, and blackbirds, and acts as a bridge for insects having life histories requiring both water and land.



oligotrophic lake

Water quality is relative to the species associated with a successional stage of eutrophication. It is generally assumed to be high in oligotrophic lakes due to the water's usability by humans and salmonids. However, eutrophic lakes which are productive support a wider variety of species.

2) Floating - rooted in the bottom sediment with leaves floating at the surface, and flowers and fruits often just above the surface - or nonrooted and free-floating. Examples of rooted floating species include spatterdock, fragrant water-lily, water shield, pondweeds, and water-starworts. Dense, solid, or mixed stands of these species are common in the littoral zone of many coastal lakes and ponds.

Free-floating species include one of the smallest flowering plants of the coastal flora (water lentil), the smallest fern (water fern), and two species of liverwort (Riccia fluitans and Ricciocarpus natans). Dense stands effectively reduce light penetration into the water, reducing primary productivity in the shaded water area. Large, floating leaves are used as nesting and feeding areas by red-legged frogs, rough-skinned newts, and many insects. Leaves are also used for egg deposition by invertebrates, cover by fish, and as feeding substrate by blackbirds.

3) Submergent - plants that grow beneath the surface of the water and may be rooted or free-floating. Many species have very thin, highly dissected leaves, an adaption for the exchange of nutrients with water. Submerged plants provide cover and feeding substrate for fish, amphibians, and insects, and are capable of very high productivity. Spiked water milfoil has been the object of control efforts in some lakes with heavy recreational use by fishermen, boaters, and swimmers. Other important plant species in this group are coontail, waterweed, wavy water-nymph, and common and humped bladderwort, and horned pondweed. Two algal species which may be mistaken for higher plants due to their growth form are stonewort and nitella.

Phytoplankton, the nonrooted microscopic primary producers of the littoral and limnetic zones, is composed of numerous algal species. They include desmids, diatoms, and many other single-celled algae as well as filamentous or colonial multicellular species. In nutrient-rich shallow lakes, during warm weather, algal blooms may occur. One to several species may undergo rapid growth and reproduction, often accumulating on the downwind side of the lake.

The littoral zone has a greater variety of animals than the other regions of lakes and ponds. Characteristic animals that rest on or are attached to stems and leaves of plants in nearshore waters include pond snails, damsel fly and dragonfly nymphs, rotifers, flatworms, bryozoa, hydra and midge larvae. Animals found resting on the bottom or beneath silt or plant debris include dragonfly nymphs, crayfish, isopods and mayfly nymphs. Mud burrowing species include dragonfly, mayfly, clams, worms, snails, and midges.

Free-swimming species include diving beetles and many types of Hemiptera and Diptera larvae. Vertebrates almost exclusively restricted to nearshore water are frogs, salamanders, turtles, and snakes. Pond fish use both the littoral and limnetic (nearshore and open) waters. Many fish use the littoral zone for breeding, rearing areas, and cover, and use open water for feeding.

Littoral zone zooplankton include water fleas, copepods, ostracods and rotifers. Insects that use lake and pond surfaces include whirligig beetles and water striders of the families Gerridae and Veliidae.

2. Limnetic Zone

The limnetic (open water) zone of lakes and ponds is also a biologically rich region. The zone is the chief producing region for lakes; it may be entirely absent in small, shallow ponds. Primary producers, phytoplankton, of the limnetic zone include diatoms, green algae, blue-green algae, and dinoflagellates. Although microscopic in size, these phytoplankton may exceed rooted plants in food production per unit

area. Phytoplankton population densities vary seasonally in the northern United States due to changes in nutrient availability, amount of solar radiation and temperature.

Many fish species occur in both the limnetic and littoral zones of ponds, however, some lake fish may be restricted to the limnetic zone. Lake fauna is generally more diverse than that of ponds because of the greater size and presence of all community zones within a lake.

3. Profundal Zone

The profundal (bottom waters) zone is located below the level of light absorption. Because there is no photosynthesis in this zone, the inhabitants are dependent on what drifts down to them from the littoral and limnetic zones. The profundal zone provides nutrients freed from organic debris by decomposers that are then recycled by currents and swimming animals. Profundal zone species include those of bacteria, fungi, blood worms, clams, and phantom larvae.

The great diversity of lake and pond vegetation and open water zones create several niches for a wide variety of wildlife. Each animal has its own requirements for food, space, cover, and is distributed in the lake where those needs are satisfied. Interactions with other organisms, such as competition for resources and predation, continually modify associations; these and other factors have led to unique assemblages of plants and animals (communities) in a given lake or pond.

Fish are spatially segregated by species along gradients of depth, vertical height in the water column, and vegetative structure within a lake. For example, sculpins tend to be bottom dwellers while trout occur at the water's surface. Within a given species there may be spatial segregation according to size classes. Small fish are confined by larger predators to areas of dense cover. Within these areas, competition determines space used by different species.

Fish reproductive strategies also involve habitat segregation. For example, sockeye salmon and longfin smelt eggs are deposited in rivers and their young are limnetic upon entering the lake in spring. Prickly sculpin nest in the littoral and profundal areas of a lake and their young

are epibenthic. Stickleback, peamouth, squawfish, yellow perch, and suckers are bottom spawners in littoral regions. Their young remain in a narrow band near shore using plants for cover.

Several birds and mammals feed on these fish or the vegetation which fish use for refuge. Kingfishers take small fish, such as sticklebacks, which frequently swim near the surface. River otters swim along lake and pond bottoms, feeding primarily on sculpins, crayfish, and other bottom animals, while raccoons are confined to the shallow lake margin. Predation pressures from these species may reduce competition between fish and increase overall diversity.

Birds and mammals use many different shoreline habitats. American Bitterns forage near the lake edge for fish, frogs, and crayfish, and the Red-winged Blackbird nests in emerging cattails. Mallards forage on or near the surface for aquatic plants and small aquatic animals, while scaups dive in deeper waters for bottom dwelling animals and plants. Each lake and pond inhabitant is interrelated, and together they comprise a community typical of others while unique to that location.

C. Characteristic Wildlife

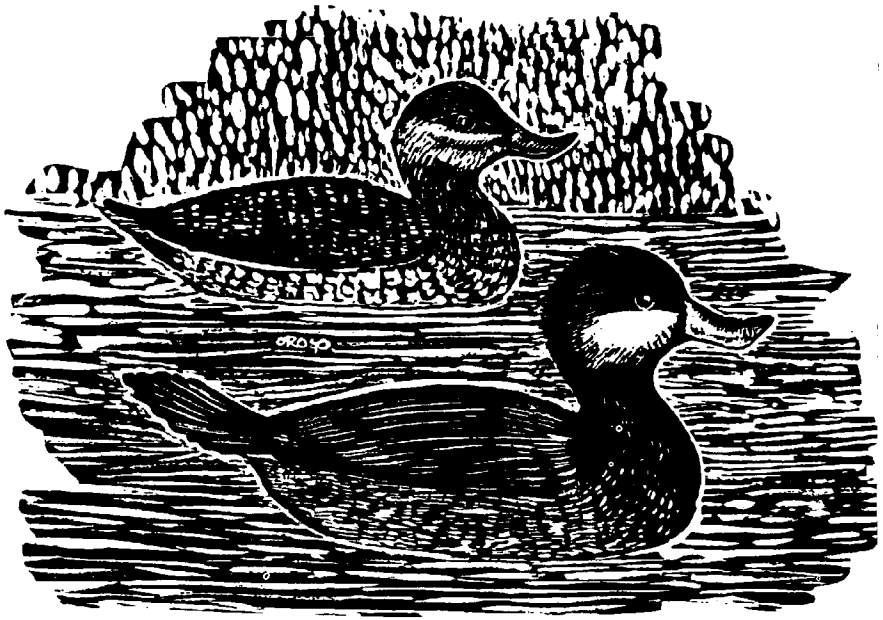
Waterfowl and shorebirds use lakes and ponds for feeding, resting, protection, and breeding. Many furbearers, such as river otter, beaver and mink, rely heavily on these habitats for food, protection, breeding, and rearing areas for their young. Deer and elk use the emergent vegetation and the shoreline trees and shrubs for food and cover. Animals also use quiet pools for thermoregulation and to escape insects during the summer. Frogs, salamanders, newts, snakes, and turtles rely on lakes and ponds for reproduction, feeding, and cover. Numerous freshwater fish species are also dependent upon the existence of lakes and ponds.

Many of the same species requiring freshwater are found in lakes and ponds, rivers and streams. Fish species occurring in lakes and ponds are listed in Table 52-1. Species lists of birds, mammals, and amphibians and reptiles are found in Tables 5-1, 5-2, and 5-3 in the Water Narrative, No. 5. There are some birds which generally prefer lakes over ponds, such as the Common Loon, Lesser Scaup, Osprey, and swans. These and other species are often present or often more abundant on lakes because of the larger surface area and greater food abundance. Some species may also be more abundant in coastal lakes and ponds because of their proximity to marine waters. For example, Bald Eagles are frequently observed at Cranberry Lake on Whidbey Island. Eagles may feed in both fresh and salt water and also benefit from nearby stands of old growth forest.

Lakes and ponds are important to wildlife all year long. In spring, lakes are used for breeding and rearing young and are rich sources of high protein foods needed for the energy demands those activities require. In winter, lakes are used as feeding and sheltered resting areas by wildlife. For example, during one recent cold January day, there were three inches of snow on the ground along Cranberry Lake on Whidbey Island. During that day, the following were observed: 3 Common Loons, 130 Ruddy Ducks, 8 Common Mergansers, 6 Bufflehead, 4 Common Goldeneye, 25 American Wigeon, 15 Mallards, 30 American Coots, 15 Scaup sp., 2 Western Grebes, 4 Pied-billed Grebes, 8 Mew Gulls, and 20 Glaucous-winged Gulls. Along the lake edges, Common Flickers, Varied Thrushes, and a Red-tailed Hawk were seen. Sign of beaver, raccoon, and river otter activity showed they also had used the lake area recently.

Inland and coastal ponds support many of the same species, however, coastal ponds may also have species more related to marine environments due to their proximity to salt water.

During our studies, a coastal pond on Shannon Point, Skagit County, was observed to have 6 Northern Shovelers, 3 Green-winged Teal, 2 American Wigeon, 25 American Coots, 3 Pied-billed Grebes, 8 Bufflehead and 6 Glaucous-winged Gulls and river otter sign one day in November. On a January day's observation, the same pond had 25 Bufflehead, 30 American Coots, 20 Ring-necked Ducks, 4 Mallards, and 1 Great Blue Heron. Several of these species move freely between the pond and adjacent marine waters. For example, a well worn otter path leads between the two aquatic areas. Other species, such as the Pied-billed Grebe and Ring-necked Duck, are more restricted to fresh-water and will be equally common on inland and coastal ponds. Representative species of lakes and ponds include the following:



RUDDY DUCK

Amphibians

Northwestern Salamander

This brown or black salamander inhabits open grassland, woodland, or dense forests under rocks, boards, and logs near water. It spawns in ponds, lakes, and streams during the months of January through July.

Rough-skinned Newt

This, the only newt occurring in western Washington, occurs in grassland, woodland, and forest. They breed from late December to July in ponds, lakes, reservoirs or slowly flowing streams. The newt may be found crawling in the open or hiding under logs, bark, and in rotten wood. Their bright orange bellies and rough skin distinguish them from other salamanders.

Mammals

Pacific Water Shrew

This shrew inhabits wet wooded margins and swamp areas of lakes and ponds. Its hind feet have stiff, bristle-like hairs along their sides as adaptations for swimming. The Pacific water shrew is large for a shrew, having a head and body length of 3.5 to 3.8 inches and a tail up to 3.2 inches long.

Muskrat

The muskrat inhabits marshes, ponds, lakes, and streams among cattails, rushes, water lilies, and in open water. It is chiefly aquatic, but does move overland, especially in autumn. Muskrats feed on aquatic vegetation, clams, frogs, and fish. They build conical marsh vegetation houses which protrude two to three feet above the water. They also burrow in banks. The muskrat is an important furbearer in Washington State.

Mink

Mink are excellent swimmers and occur along streams, lakes, and ponds. They eat small mammals, birds, eggs, frogs, crayfish, and fish. Mink den along stream or lake/pond banks and the male mink may have a several mile range along a stream. Mink are also valuable furbearers in Washington.

Beaver

These fascinating animals contribute to water and soil conservation and create new wetland habitat by their activities of building dams which create ponds. The chiefly nocturnal beaver relies on water for protection. They occur in lakes, ponds, and streams where there is good forage vegetation of black cottonwood, red alder, willow, and birch. They feed on bark and small twigs of trees as well as grasses, cattails, and pond lilies.

Family groups of parents, yearlings, and kits live together and maintain their dams. Beaver have been recorded to move as far as 150 miles or more from their birthplace, but usually move under six miles when driven from the colony at age two or three. Beavers are valuable furbearers, but they are also valuable social animals for study and pleasurable observation. They occasionally cause flooding damage, but dam building may also irrigate surrounding lands and moderate stream flow downstream. See the Beaver Pond Narrative (No. 525) for more information.

Birds

Mallards

This familiar and ubiquitous duck occurs on almost any type of freshwater from park fountains to wilderness lakes. Mallards use irrigated farmlands, and also occur on ponds, lakes, rivers, freshwater marshes and in marine areas. Mallards occur as migrants and residents and are perhaps the most abundant waterfowl that breeds locally.

American Bittern

This freshwater marsh bird occurs around the margins of lakes and ponds where there are cattails for cover. When disturbed, the cryptically colored bittern freezes with its neck upstretched and motionless, thus it is camouflaged against a background of cattails. It uses emergent marsh vegetation for cover, while foraging for aquatic and terrestrial foods, such as fish, frogs, crayfish, mice, and insects.

Pied-billed Grebe

This small, and generally wary, grebe breeds on fresh-water ponds, coves of lakes, sloughs, and slow-moving streams. Breeding areas are mainly those having much shore and emergent vegetation. During winter, they are found on larger lakes or on protected salt water. Grebes have the interesting ability of diving suddenly or increasing their specific gravity and sinking slowly out of sight. Pied-billed Grebes feed on fish such as prickly sculpins, catfish, suckers, and stickleback. They also consume crayfish and a wide variety of insects.

Osprey

The Osprey requires lakes and rivers for feeding and breeding. This spectacular bird of prey hunts by hovering over a lake on beating wings, and plunging feet-first, striking the water surface to catch a fish in its talons. Osprey nest in large dead trees, in or near lakes and also feed in marine waters and nest along the marine shoreline. Osprey are uncommon in the coastal zone and known nest sites require protection. Population declines have been noted in some areas, such as at the mouth of the Columbia River. This area supported 200 pairs in the 1940's, but dropped to only 24 pairs in 1963. Other areas have exhibited encouraging increases and increased public awareness and careful management are needed to ensure the Osprey's survival.

The Osprey was considered as potentially threatened in Washington and probably already threatened in coastal Washington in a 1975 Department of Game and Ecology status report of marine fauna. The following recommendations were based on that report:

- The national ban on DDT established in 1972 should remain in effect. DDT has been linked to egg shell thinning and reduced reproduction in Ospreys and other birds.
- Logging practices should be changed to provide more nest sites. Old dead-topped trees should be preserved and existing nest trees protected. Uneven-aged stands provide more suitable nesting habitat than even-aged stands.
- Artificial snags and nest platforms could be provided.
- A buffer of at least 200 feet should be reserved around nest trees, beyond which all suitable broken top trees and snags should be preserved within two miles.
- Human activity during the breeding season should be restricted from the nest area.
- Public education and cooperative efforts between researchers and the public should be encouraged. Nests could be monitored by local residents who often are, or could be stimulated to be, protectors of Osprey in their area.
- Existing legislation prohibiting shooting of Osprey and other birds of prey should be better publicized. Prevention of these acts will be encouraged through public education programs as well as enforcement.

Known nest sites should be studied to determine population status and trends. Surveys should be conducted to identify potential habitat and to locate existing sites not presently recorded. Report information concerning nests to the Washington Game Department.

Lesser Scaup

Lesser Scaup prefer smaller lakes, ponds, and rivers where they forage for aquatic plants by diving in shallow waters. Scaup nest in a down-lined hollow in grass near fresh water; the limited breeding which occurs in Washington is east of the Cascades.

Trumpeter Swan

Trumpeter Swans were once thought to be on the verge of extinction. Formerly fairly common in the West, they are now a very rare migrant in western Washington. They appear to be increasing; however, they were considered as potentially threatened in the 1975 Department of Game and Ecology status report of marine fauna. These beautiful swans use coastal lakes and ponds, large rivers, and bays which are critical during severe winters when inland lakes are frozen. Coastal areas used by Trumpeter Swans include the Skagit area (Barney Lake, Beaver Lake, Clear Lake, and DeBay Slough), Willapa Bay, and the mouth of the Columbia River. Those areas mapped as critical habitat in the Coastal Zone Atlas for Whistling Swans should also be regarded as critical habitat for Trumpeters.

Common Loon

The Common Loon prefers the solitude of wilderness and large lakes for breeding. They are common along the coast much of the year, however, their spring and summer freshwater breeding range is becoming more restricted with encroaching development. Common Loons have a fantastic maniacal laughing call during breeding season that, for many people, is an embodiment of wilderness. It is a rare and wonderful treat to encounter these birds in their breeding habitat. Common Loons do occur in coastal areas during the summer, apparently as nonbreeders. Their call is heard on our waters, but nesting sites have not been reported.

Bufflehead

This small duck has an uncertain breeding status in Washington. Where breeding occurs, they nest in tree cavities near small ponds and lakes. Buffleheads are common migrants and winter residents on more open waters such as bays, lakes, and rivers of coastal Washington.

Wood Duck

The Wood Duck is one of the most colorful and beautiful ducks in the Northwest. It prefers ponds, small lakes, and slow-moving rivers bordered by deciduous trees, such as cottonwoods and willows. Wood Ducks nest in old woodpecker holes in larger trees near water and also accept nest boxes. When the young are ready to leave the nest, they step out of the tree and fall to the ground where their mother waits to lead them to water.

Ring-necked Duck

These ducks prefer shallow to deep water freshwater ponds, sloughs, and lakes during breeding. In winter, they are found on larger lakes and rivers near marshy shores. Ring-necked ducks are rarely found on salt water and the breeding population status in coastal Washington is unknown.

D. Lake and Pond Relationships to the Watershed

Terrestrial habitats provide lakes and ponds with nutrients in surface runoff that increase their productivity. Rivers and streams which drain into lakes provide lakes with nutrients from distant areas and can also contribute to lake siltation.

Lakes and ponds are used by many species. Adjoining terrestrial habitat provides cover and nest sites while aquatic areas provide food. Aquatic mammals, such as river otter, beaver, mink, and muskrat, require terrestrial and aquatic habitats for fulfilling food and cover needs. Lakes within terrestrial habitats enrich these areas for wildlife use and support many more species than areas without water.

Lakes and ponds and associated wetlands act as corridors as part of migration routes for waterfowl, shorebirds, songbirds, and fish. Many stream animals enter lakes, but their distribution remains near the stream mouth and along the lake shore. Other river and stream fish, such as sockeye salmon and longfin smelt, spawn in rivers and streams and migrate while young to lakes for growth to the adult stage.

E. Commercial/Recreational/Esthetic Benefits

Lakes and ponds offer wildlife and mankind innumerable benefits. Commercially, lakes and ponds support the sporting industries by providing habitat for boaters, divers, waterfowl hunters, and anglers. Fishing in Washington's lowland lakes is a major contributor to the states economy. For example, thousands of people fish on opening day spending considerable sums on fishing equipment, food, gas, and related activities.

The esthetics and recreation enjoyed by the use of lakes and ponds are for many people inseparable. Swimming, fishing, boating, and watching wildlife are just a few of the benefits they offer. Lakes and ponds diversify the landscape and add a unique beauty of their own.

III. IMPACTS

A. Historical Changes and Trends

During the last 100 years, lakes and ponds have undergone many changes. Increased human disturbance has altered their shorelines and the plants and animals which inhabit them. Siltation from logging, construction, and other human activities and added nutrients from fertilizers and wastes have changed many lakes from a pristine oligotrophic state to one of eutrophy.

Beaver ponds decreased in occurrence during the late 1800's due to overtrapping of beaver. Beaver were reintroduced and now have again increased the number of beaver ponds in the Northwest.

Man-built farm ponds have also increased during the last 100 years. During the Great Depression of the 1930's, farmers were encouraged by the federal government to build ponds for erosion control and fish production. Farm ponds enable farmers to change land use patterns by converting new stockwatering areas.

B. Recent Impacts

Ponds, because of their small size, are particularly susceptible to destruction due to lack of legal protection. Present laws provide little restriction on filling in standing waters of less than 20 acres. Ponds are extremely important to wildlife, some of which prefer these smaller waters. Proposed alterations of these small ponds must consider effects they will have on wildlife on a case-by-case basis. Filling of one small pond may seem insignificant, but when the prevailing philosophy of management allows filling of such areas, we may lose vast numbers and acres of these important wetlands.

In recent years, we have become more aware of the value of lakes and ponds and have come to understand more about the impacts some of people's activities have on ecological systems. Efforts have been made to maintain and/or improve water quality and preserve habitat. Continued efforts should be made to safeguard these valuable wetlands from destruction if we are to continue to appreciate them as wild ecosystems.

Human activities have the greatest impacts on lakes and ponds. Use of herbicides, insecticides, and fertilizers, road building, construction, and recreation affect lake and pond communities.

Agricultural use of fertilizer is a major contributing factor to eutrophication of lakes and ponds. Runoff containing large amounts of fertilizer nutrients enters the aquatic system and spurs productivity of algae. Dense algal blooms may result, which deplete the water's oxygen concentration.

Lake Washington is a classic example of the results of eutrophication and is a model for restoration of damaged lake systems. In the early 1900's, Lake Washington become highly eutrophic due to disposal

of raw sewage. In the following years, secondary waste treatment and eventual diversion of wastes from the lake has permitted the lake ecosystem to recover. Lake Washington, once extremely polluted, is now considered to be almost an oligotrophic lake.

Pesticides and herbicides may also enter via runoff of surface waters. Pesticides and herbicides can alter the aquatic community structure and contaminate many organisms which are consumed by wildlife and humans. Herbicides, such as dichlobenil, fenac, paraquate, diquat, and endothall have been applied to lakes and ponds to control submerged aquatic weeds. Herbicides are usually applied only to areas which are managed for fish production or recreation.

Herbicides may persist in active form for several months after application to lakes and ponds. Water depth may be a factor in herbicidal persistence, especially where granular formulations are used for application. Granular treatments made on a volume basis deposit a greater number of herbicidal-bearing granules on soil in deep water than in shallow water. These particles on the lake/pond bottom act as a reservoir supplying herbicide to the water over a time determined by solubility of herbicide, granule strength and other factors. It is important to remember the lake or pond bottom is also the reservoir for nutrients not presently incorporated into tissue and that shallow water plants and decomposers use these nutrients.

Rotenone is used in fishery management to remove undesirable fish in lakes, ponds, and streams. The chemical kills all the fish in the water and after a period, rotenone loses its effectiveness and favorable fish species are introduced. Rotenone also kills lake and pond zooplankton which are important fish food. Zooplankton populations are slow to recover from this poisoning and do not recover to preapplication population levels until several months after the lake has become nontoxic to fish. The impact of poisoning on fish predators should be considered before treatments are applied.

Silting of lakes and ponds is detrimental to their community structure. Silt enters the system carried by surface runoff, and streams and sloughs. Disturbance of land by logging, agricultural practices, and urban/suburban construction all contribute to erosion and eventual siltation of aquatic systems. Siltation of lakes and ponds can change their bottom substrate and, if thickly silted, can cover available nutrients and bottom invertebrates. Continual siltation eventually changes the depths of lakes and ponds. As depth decreases, temperature and chemical stratification of waters may cease, effective light penetration levels may extend to the bottom, and oxygen concentrations may be altered. The flora and fauna also change to adjust to the physical changes of their environment. Eventually, the lake could become entirely filled with silt and terrestrial succession would begin.

Recreational activities also have an impact on lakes and ponds. Power boats, enjoyed by many, do alter the natural environment for wildlife with noise, turbulence and general disturbance.

Housing developments alter shorelines and form barriers for wildlife approach to lakes and ponds. The dumping of sewage into lakes and ponds is extrememly detrimental to the systems. Sewage is a rich source of added nutrients which can produce a eutrophic and dying aquatic system as discussed above.

Table 52-1

Representative Fish of Lakes and Ponds

Common Name	Scientific Name	Comment
Sockeye salmon	Oncorhynchus nerka	Anadromous, significant commercial value. Other salmon may occur in lakes and stream-fed ponds.
Cutthroat trout	Salmo clarki	Anadromous and freshwater
Rainbow trout	S. gairdneri	Common trout of lowland lakes stocked by hatcheries.
Brook trout	Salvelinus fontinalis	Introduced
Longfin smelt	Spirinchus thaleichthys	Freshwater and marine
Olympic mudminnow	Novumbra hubbsi	Not known to occur in areas covered by Coastal Zone Atlas, although distribution extends into coastal zone in Grays Harbor County north of Chehalis drainage.
Goldfish	Carassius auratus	Introduced, locally abundant
Carp	Cyprinus carpio	Introduced
Northern squawfish	Ptychocheilus oregonensis	Common, freshwater and estuarine
Redside shiner	Richardsonius balteatus	Common
Longnose dace	Rhinichthys cataractae	Common
Longnose sucker	Catostomus catostomus	Common
Largescale sucker	C. macrocheilus	Common, also estuarine
Black bullhead	Ictalurus melas	Introduced
Brown bullhead	I. nebulosis	Common, introduced
Threespine stickleback	Gasterosteus aculeatus	Common, freshwater and estuarine
Largemouth bass	Micropterus salmoides	Common, introduced
Black crappie	Pomoxis nigromaculatus	Common, introduced
Yellow perch	Perca flavescens	Common, introduced
Prickly sculpin	Cottus asper	Common

C. Summary

- Major sources of pesticides, herbicides, and fertilizers should be limited and, if possible, diverted from lakes and ponds.

- Activities such as logging and construction should take adequate precautions to reduce erosion and prevent added silt from entering aquatic systems.

- Recreational activities should be encouraged. Water recreation is a source of enjoyment for many people and areas should be included for this purpose. However, it should be noted there are many types of recreation and not all are mutually compatible. Power boaters need space for their recreation as do wildlife watchers who require quiet areas. In some lakes, multiple uses may be possible; in smaller areas, they are not.

- It is of primary importance we preserve some lakes and ponds solely for wildlife. Many species depend on lakes and ponds for their existence and require undisturbed areas.

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BEAVER PONDS (No. 525)

I. INTRODUCTION

Beaver ponds are relatively shallow ponds which vary greatly in size. In addition to the pond, many acres may be flooded by beaver dams which extend available wetlands. Beaver ponds are important throughout the Northwest as wildlife habitat and for natural flood control. The ponds provide the beaver with a safe retreat from predators and disturbance and offer a home to several invertebrates, fish, birds, and other mammals.

Beavers and their ponds have been important for man since the Pleistocene era. Beaver dams and the associated ponds collected rich silt which eventually produced much of the present rich agricultural areas on the North American continent. The fine fur of beavers provided impetus for exploration of the continent and trade in furs began in the 1600's. By the late 1800's beaver had been trapped almost to extinction in most locations and the occurrence of beaver ponds also declined. Beaver were reintroduced to many areas throughout the U.S., including all the western states, and now have good sized populations in the West. Beaver ponds have also increased in number and have again become important wildlife habitat.

II. SIGNIFICANT BIOLOGICAL FEATURES

Community Structure

The development and maintenance of beaver ponds is dependent upon the occurrence of vegetation the beaver uses for food and for building dams. Beavers prefer areas with alder for building dams and alder, willow, and red osier dogwood for food. As beavers work, they bring about many states of plant succession. As willow and alder are felled, additional sunlight reaches coniferous trees, enhancing their growth. The conifers inhibit the growth of new willows and alder and eventually the beaver will desert the pond. After the beavers are gone, the dam begins to decay and the pond fills with the silt and debris that were trapped on the upstream side of the dam. Eventually a meadow is produced with grasses and shrubs. Reoccupation of beaver meadows by beaver may occur within a few years to as much as 20 years depending on the renewal of food trees. Thus beaver ponds go through alternation of use and disuse by beaver as a result of vegetative changes. Use by other species also changes as vegetation develops.

Flooded areas benefit beavers by making standing vegetation more accessible to them. Beavers transport tree trunks many times their size by floating them on the water. Flotation of trees instead of carrying them across land is so preferable to beavers, they will dig channels inland to create corridors to float distant vegetation to the pond.

The trophic ecology of beaver ponds is similar to that of shallow ponds (see the Lakes and Ponds Narrative, No. 52). Beaver ponds are productive systems that can produce larger trout than those found in streams. The ponds are excellent habitat for many fish and other wildlife and thereby increase their production. Beaver ponds differ from other ponds by their alternation between pond and meadow in a relatively short time. The patterns of succession from beaver pond into meadow is similar to other pond succession patterns, but occurs within a shorter time interval. Beaver ponds will remain similar to other productive ponds until the dam which creates them is no longer maintained by beaver.

Wildlife species also change with the cycle of beaver ponds. The creation of a pond floods out voles and shrews inhabiting the margin and forces them to higher ground. Muskrats that may have avoided a fast moving stream move into the calm pond waters. Mink and otter enjoy an increased supply of fish and crayfish with the water body occupying a greater acreage. Where elk occur, they feed extensively on sedges and other herbaceous plants in meadows adjacent to actual dams and in old beaver ponds. Deer and elk that fed on willows, alders, and maples will lose their forage to the beavers activities, but enjoy relief from mosquitos in the new deeper waters during summer. More water plants, such as Potamogeton spp. and lilies grow in the pond serving as food for herbivores. Frogs and salamanders have increased habitat to live and breed in. Trees killed by rising water levels become nest sites for Tree Swallows, Wood Ducks, Hooded Mergansers and nest and forage sites for woodpeckers. Waterfowl use the ponds for resting and feeding and nest in nearby cover.

Interrelationships With Other Habitats

Beaver ponds increase habitat diversity and thereby attract many more species and numbers of individuals than stream areas with ponds. Forest and grassland animals, such as deer, racoons, and elk use the pond for feeding, water and cooling off and use the wooded areas for cover and nesting.

Beaver ponds are closely interrelated with streams from which they are built. Flood water is spread over a greater area than originally shaded by the stream channel and in warmer months solar radiation heats the water to higher than normal stream temperatures. During very hot weather, the temperatures below the impoundment can increase to levels which may cause fish mortality.

Beaver ponds have great effects on surrounding terrestrial ecosystems. In addition to changes in vegetation due to beaver foraging and building activities, development of ponds changes levels of the ground water table in adjacent areas. The rise in groundwater in adjacent lowlands depresses the growth of forest stands by decreasing the aeration of the soil and partially drowning tree roots. The small rise in ground water benefits forest stands on neighboring uplands.

Commercial/Recreational/Esthetic Benefits

Beaver ponds can be extremely beneficial to man. Ponds can prevent flooding by rivers during spring and maintain a stabilized streamflow during dry summer months, improving stream habitat for trout. Ponds act as water reservoirs, fire breaks and through subirrigation increase sedge and grass production on meadows by streams.

Beaver dams divert water, thereby reducing water pressure in streams and decreasing erosion of downstream areas. The dams also catch and reduce loads of soil sediment that streams would normally carry to estuaries or man-made dams.

Beaver ponds increase wetland habitat for wildlife species which are important commercially, recreationally, and esthetically. Trout and furbearers that use ponds are used by anglers and trappers. Ponds provide the wildlife watcher with a rich habitat in which to view animals.

III. IMPACTS

Beavers have traditionally had an important place in North American Indian lore for thousands of years. It was said the beaver helped the Great Spirit to create the earth which was thought to be originally covered with water. Beavers were directed by the Spirit to dive beneath the surface waters and dredge up mud from the bottom to form land masses. Other Indian legends also reflect the industry and engineering abilities of the beaver and their effects on the land.

Since the Pliocene, beaver dams have caused silt laden waters to spread over the valleys of North America. Over thousands of years, deep, level, fertile valleys formed giving this continent some of the richest agricultural land in the world. During primeval conditions, beavers and their ponds have been important factors in opening up forests and maintaining both terrestrial and aquatic ecosystems.

Beaver ponds were a characteristic feature of North America when Europeans arrived. The abundant beaver became the basis for fur trade at first between Indians and Europeans. Beaver pelts became so popular and profitable to trade, Europeans soon started trapping beaver themselves. Beaver and the greed for their pelt value provided impetus for exploring the continent and a new frontier was opened.

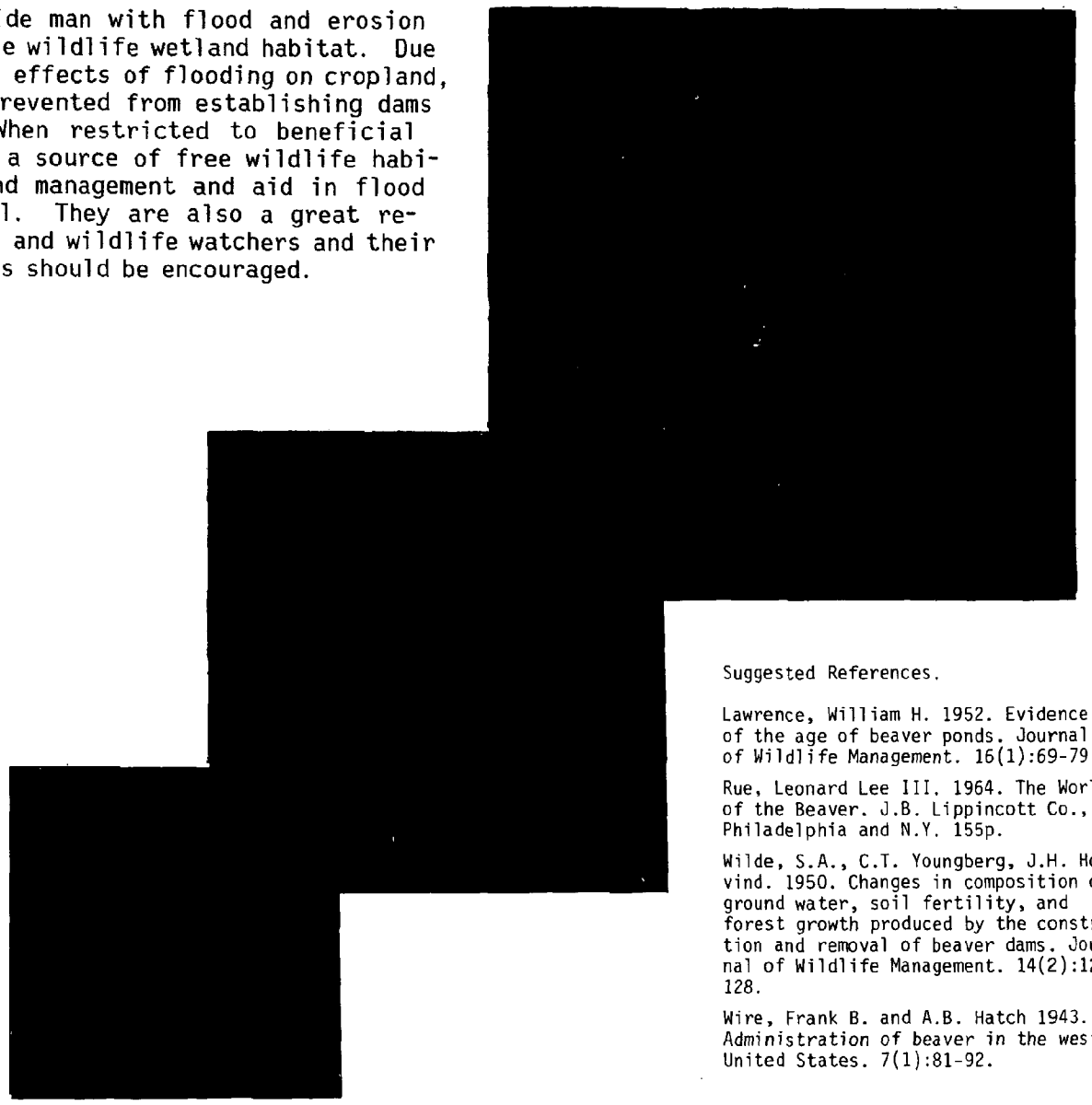
In 1823, the steel trap was invented by Seivell Newhouse, allowing trappers to take tremendous numbers of beaver with ease. During the period from 1853 until 1877, the Hudsons Bay Company alone traded over three million pelts. By the late 1800's the beaver had been trapped near extinction.

Beaver restocking programs began as early as the 1890's in some areas of the country. During the 1920's, beaver were beginning to thrive again. Today in Washington the beaver population again supports the trading and fur industry. During the trapping season 1977-78, approximately 10,000 beavers valued at $176,000.00 were trapped in western Washington.

Removal of beaver dams destroys beaver ponds and their beneficial aspects as wildlife habitat. It has been found that dam removal can actually cause greater damage to neighboring forest stands which have adjusted to rises in ground water than the building of dams and the persuant groundwater changes. Sudden drainage of beaver ponds and flood areas lowers the water table and dries the soil. Drying the soil damages surrounding vegetation with root systems adapted to the moist soil. This shock type of stress is far more limiting to forest areas than the gradual changes an area undergoes with beaver activites.

Overtrapping beavers removes the pond engineers and maintainers. The pond will then deteriorate without the immigration of beavers from other areas.

Beaver ponds provide man with flood and erosion control and increase wildlife wetland habitat. Due to some detrimental effects of flooding on cropland, beaver should be prevented from establishing dams in these areas. When restricted to beneficial areas, beavers are a source of free wildlife habitat development and management and aid in flood and erosion control. They are also a great resource for trappers and wildlife watchers and their development of ponds should be encouraged.



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FARM PONDS (No. 526)

I. INTRODUCTION

Farm ponds occur frequently in rural areas of the coastal zone. These small (one to few acres) man-made ponds are created by damming a stream or excavating basins. Streamwater is generally detoured around the pond or the pond is constructed in a basin without permanent streamflow in order to prevent loss of nutrients and silting of the basin. Farm ponds usually have little water flowing through them and are often artifically fertilized with nutrients and stocked with game fishes and domestic ducks.

Farm ponds are important as water sources for livestock, storage for irrigation water, fire protection, production of protein, and recreation. Farm ponds are also good wildlife habitat, providing resting and feeding areas for waterfowl. The ponds diversify large expanses of farm land and increase wildlife use of these areas.

During the late 1800's, the federal government encouraged the development of farm and ranch ponds for livestock and especially for the production of fish. However, farm ponds did not come into wide use until the 1930's. The Depression provided incentive for farmers to produce new sources of protein. Most important, farm ponds became soil conservers, providing a means of changing land use from wasted croplands to pasture. Areas with new sources of water were opened to use by livestock.

II. SIGNIFICANT BIOLOGICAL FEATURES

Community Structure

The species composition and productivity of farm pond communities are highly dependent on how the ponds are managed by their owners. Farm ponds generally have fewer species than natural ponds. This is partially due to management discouraging rooted vegetation. The variety of organisms in farm ponds used to produce fish is reduced through pond management to favor large numbers of favored species. Stocked fish ponds may have such fish as cutthroat and rainbow trout, largemouth bass, yellow perch, black crappies, and catfish. Invertebrates found in farm ponds include Dipteran larvae, Ephemerida, Odonata, Hemiptera, and molluscs. Elodea is a common waterweed that can become a pest in shallow areas of ponds and is generally controlled in ponds managed for fish. Although farm pond food chain relations resemble those of lakes, ponds are rarely deep enough for the stratification seen in lakes. When stratification does occur during warmer months, there is a layering of the water thermocline with the colder waters remaining on the bottom. Chemical stratification can also occur in deep farm ponds. Hydrogen ion concentrations (pH) decrease toward the bottom as do those of dissolved oxygen. Carbon dioxide is abundant in lower levels of stratified pond water.

Farm pond productivity varies proportionally with the degree to which a pond is managed. Abandoned, unmanaged ponds resemble small natural depression ponds. Farm ponds can be much more efficient at producing energy than unmanaged ponds when they are managed to produce a large biomass of fish. Reducing or preventing introduction of species unnecessary to fish production directs energy into "desirable" fish. Nonfertilized farm ponds stocked with carnivorous game fish, such as trout, can produce 40-150 pounds of fish per acre per year, and artificially fertilized ponds will produce 100-500 pounds of fish per acre per year. These nonfertilized and fertilized ponds produce 9 to 34 Kcal/m^2/yr and 45 to 112 Kcal/m^2/yr respectively.

The production of carnivorous fish, such as trout or bass, requires much more energy than that of herbivorous fish such as carp. Yields are greater when herbivores are stocked rather than carnivores which require a longer food chain. In the Orient, ponds managed for herbivores and detritus feeders produce 1,000 to 1,500 pounds of fish per acre; U.S. ponds managed for carnivorous sport fish produce only 100 to 500 pounds per acre.

Because 90 percent of possible energy is lost when the next higher trophic level uses the one below, food chain length determines the productivity at any one level of the chain. Carnivores (e.g., trout) require at least four steps in their food chain consisting of phytoplankton, small crustacean and insect consumers, small carnivores or detrivores (forage fish) and large carnivores. In comparison, herbivorous fish require only two levels in their food chain; vegetation and herbivorous fish. Thus herbivorous fish are much more efficient to produce although they may not be as desireable to sportsmen or consumers.

Good fish ponds have the following characteristics: a stable water level, an area greater than one-fourth acre, a long shoreline compared to pond volume, a shore which slopes steeply to at least three feet below water level for weed prevention, depth enough to maintain warmer bottom waters during freezing weather and cool waters in the summer, and a permanent drain for restocking and cleaning. Shrub and wooded margins also increase their value to wildlife.

Farm ponds encourage the productivity of waterfowl and other wildlife by providing additional habitat for feeding, resting and in some ponds, breeding. The following birds seen on a farm near Sequim, in Clallam County, reflect the value of ponds to waterfowl. Species observed include some uncommon and rare species: Trumpeter Swans, Ring-necked Ducks, Hooded Mergansers, Buffleheads, Wigeon and Scaup. A farm pond on the Stillaguamish Flats, Snohomish County, was observed to have Canada Geese, scaup and Wood Ducks. Other birds which use farm ponds include Mallards, Barn Swallows, Killdeer, Lesser Scaup, Green-winged Teal, Common Goldeneye and Common Snipe. Farm ponds which attract large numbers of waterfowl and have adequate roost sites nearby may also be visited by birds of prey including Bald Eagles. Mammals using farm ponds and adjacent areas for feeding and water include livestock, skunks, raccoons, river otter, muskrats, deer, and mink. For discriptions of characteristic birds and mammals of ponds, see the Lake and Pond Narrative (No. 52).

Interrelationships With Other Habitats

Farm Ponds, although removed from natural systems more than other ponds, are still affected by and affect other ecosystems. Watershed runoff is a source of water and nutrients for farm ponds as it is for other ponds.

Farm ponds, as part of the migration route of waterfowl, serve as connecting points for all waterfowl habitats. The ponds break up the monotonous acreage of croplands and pasture and provide waterfowl with rest stops along their (1,000+ miles for some species) journey.

Farm ponds also diversify land use for the land owner. The creation of ponds enables the land owner to extend pasture areas with new stockwatering locations or to extend cropland using the ponds for irrigation.

Commercial/Recreational/Esthetic Benefits

Farm ponds are of commerical importance by allowing new uses of land and indirectly controlling erosion. Ponds also increase the potential livestock production of an area. When managed for fish production and privately stocked, farm ponds can be a source of profit for owners. Ponds stocked by the Washington Department of Game must be open for public use and thus become a source of recreation for all.

Farm ponds are important to waterfowl, upland game birds, and furbearers; all have indirect commercial benefits to the sporting industry. Farm ponds add to the esthetics of farm land and increase the number of areas in which to view wildlife. Esthetically, it is nice to know some farm children may still meet at "the swimming hole" on a warm summer day.

III. IMPACTS

History

Farm ponds have increased in occurrence in the last 50 years although the federal government has sought to encourage the public to build them since the 1800's. In 1872, the first federal funds were made available to make free distribution of fish for stocking ponds. Early efforts at boosting farm ponds failed largely to lack of available assistance and expertise on how to build and manage ponds.

During the 1930's, in efforts to conserve badly eroded soil, the U.S. Soils Conservation Service and the Production and Marketing Administration provided farmers with technical assistance and financial aid to build farm ponds. During the period from 1934 until 1949, one hundred times as many ponds were built in the United States as were built during the preceding 200 years. Farm pond popularity grew and during the early 1950's, 38,000 ponds were built per year in the U.S. Farm ponds, although a recent addition of habitat to lowlands, have become important to man and wildlife.

Specific Impacts

Unrestricted livestock use can be detrimental to ponds. Livestock trampling can flatten the shore and muddy the water, resulting in lower pond productivity. Over grazing destroys wildlife food and cover. These problems can be remedied by fencing the pond and piping the water to a nearby stock trough or by encouraging dense shrubs or wooded margins which provide natural fences.

Fertilization of ponds reduces or prevents mosquito production and increases fish production. Productive ponds must be fished at a high enough rate to prevent overproduction which could then result in a eutrophic and eventually dying pond.

Recommendations

Farm pond maintenance should be encouraged. They are important to wildlife and can help land owners with their water needs. Ponds are also a good source for producing protein and sport fish. Farm ponds can be used for all these activities if managed properly.

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RESERVOIR (No. 53)

INTRODUCTION

Inland reservoirs are important in the Northwest as sources of water for hydroelectric power. Those mapped in the Coastal Zone Atlas include manmade water storage areas for industrial or domestic purposes, with the exception of farm ponds. Reservoirs throughout Washington vary in size from a few acres to several hundred acres and are similar to large lakes. They may differ in factors, such as basin geomorphology, and having controlled discharge and resultant fluctuating water levels.

Most reservoirs in the United States have been built in this century. Reservoirs increase habitat for a few waterfowl species, but severely reduce wildlife species diversity in a given area. Vast areas have been flooded and permanently lost due to the development of large water storage projects.

SIGNIFICANT BIOLOGICAL FEATURES

Water Levels and Stratification

Reservoirs are characterized by fluctuating water levels and high turbidity. Reservoir depth has direct effects on temperature, stratification, circulation, and dilution of nutrients. Depth has

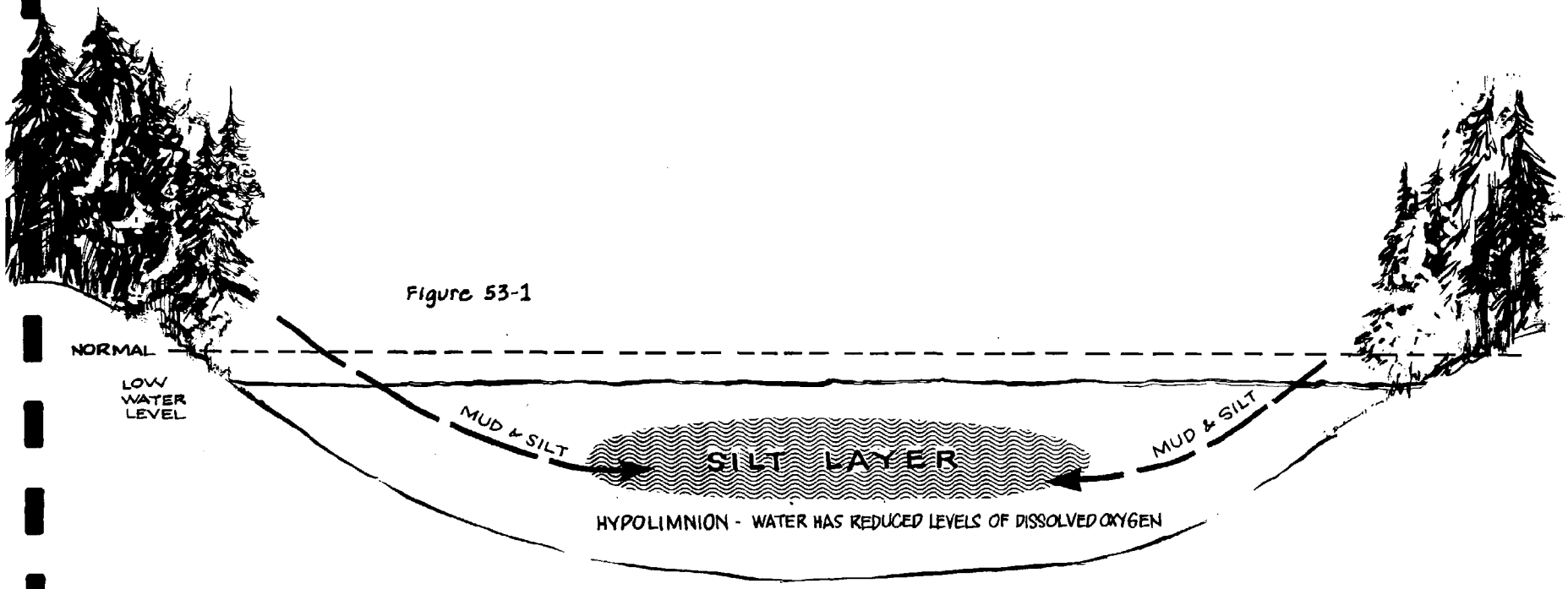


Figure 53-1

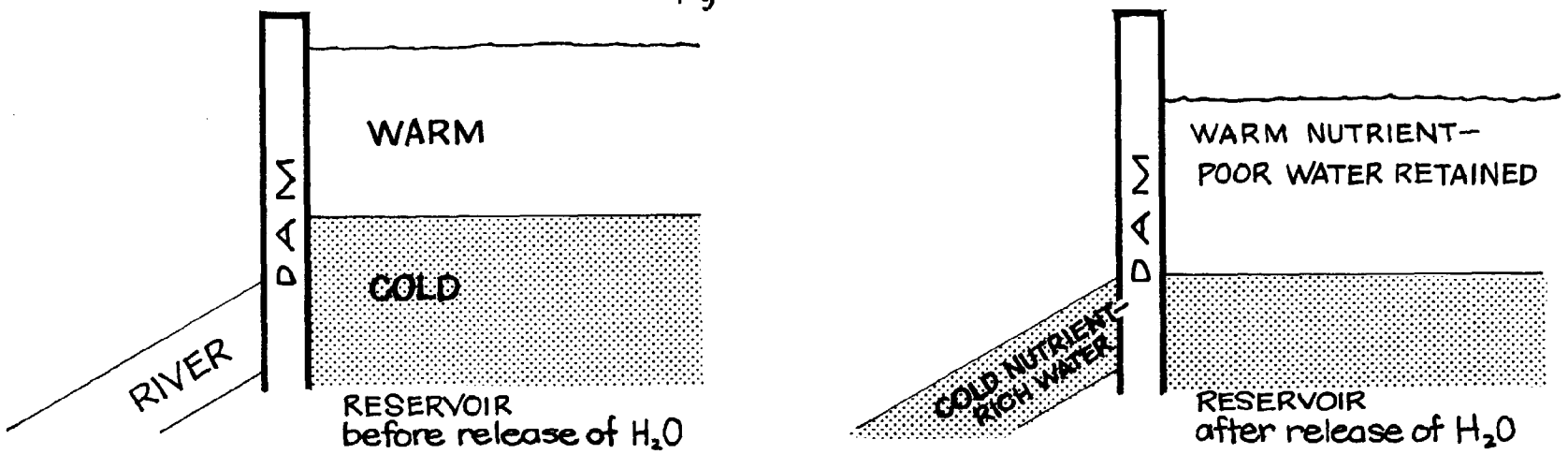
indirect effects on the circulation and loss of nutrients and the distribution of organisms within a reservoir. Increased depths of reservoirs are accompanied by decreases in the amount of bottom fauna a reservoir will have.

Reservoirs having extreme seasonal fluctuations in water levels can have such devastating effects on wildlife as flooding bird nests and dens of mammals.

Water fluctuations in reservoirs are usually so great that typical lake margin vegetation does not develop. The area covered and exposed by the seasonal water fluctuations is sparsely vegetated by short-lived annual flora. In those reservoirs having a relatively constant water level, typical littoral (nearshore) zone vegetation may be present, including spatterdock, fragrant water lily, pondweeds, and waterweed. A more complete discussion of littoral zone vegetation is found in the Lake and Pond Narrative (No. 52).

THERMAL STRATIFICATION

figure 53-2



Thermal stratification occurs in reservoirs and lakes and can reduce productivity. Thermal stratification and its ecological implications are discussed in the Lakes and Ponds Narrative (No. 52).

Fluctuations of water levels and thermal stratification work together in reservoirs to produce conditions of high turbidity. Lowered water levels expose mud and silt previously deposited on the bottom and wave action resuspends the material. Due to poor water circulation caused by thermal stratification, the silt laden waters upon entering the reservoir, spread out along the surface of the hypolimnion (lower water). This results in reduced levels of dissolved oxygen in the hypolimnion beneath the silted water level (see Figure 53-1).

Reservoir ecology is highly dependent on how the water is discharged from reservoirs. When water is released from the bottom as for hydroelectric power generation, the reservoir becomes a low productivity system. Cold, nutrient rich, and oxygen poor water is exported downstream and warm surface waters are retained (Figure 53-2). The conditions are opposite those of natural lakes which discharge surface waters, exporting heated water and retaining nutrients that enhance productivity.

Succession

Reservoirs, when first created by flooding areas, go through a highly productive initial stage. The system, using all the stored nutrients of the flooded watershed, is characterized by rapid decomposition, high microbial activity, abundant nutrients, and low dissolved oxygen concentrations in bottom waters. Rapid growth of fish may occur despite low oxygen levels. When stored nutrients have been totally diminished, the reservoir stabilizes at a lower rate of production having higher levels of benthic oxygen, but lower fish yields. If a watershed is protected with natural vegetation and erosion and runoff is controlled, reservoirs stabilize at this stage of low productivity. In areas where there is erosion and man-accelerated nutrient inputs, the reservoir goes through varying transitional states of productivity until it is filled.

Productivity

Reservoir productivity, as that of lakes, is strongly dependent on nutrient availability. Fluctuations of total net phytoplankton are closely correlated with concentrations of dissolved oxygen, carbon dioxide, and hydrogen ions (pH). Increases in phytoplankton abundance are accompanied by increases in dissolved oxygen and hydrogen ions and a decrease in the amount of free carbon dioxide present.

The optimal rate of net photosynthesis varies inversely with phytoplankton concentrations. Net euphotic zone photosynthesis is maximal at intermediate densities and is less above or below this intermediate range.

Zooplankton abundance is also dependent on reservoir nutrient concentrations. For example, Cladocera (freshwater crustaceans, also called water fleas) densities are correlated with concentrations of oxygen, bicarbonate and carbonate ions present. Cladocera densities are primarily determined by food supply, but are also significantly correlated with chemical and physical factors that are not related to food supply.

Reservoirs are used by fish, furbearers, and waterfowl. Waterfowl use reservoirs for resting areas; some birds feed along their edges and some may nest near by. The creation of reservoirs result in drastic changes in species composition of a given area. There can be large increases in the numbers of Mallards using an area, because of the adaptability of Mallards to a wide varity of environmental conditions. However, Wood Ducks, Hooded Mergansers, and other wildlife suffer habitat loss when shallow drainages are flooded by deep reservoirs.

The creation of reservoirs in pond and swamp areas destroys breeding habitat and reduces populations of American Coots, Redwinged Blackbirds, and some of our most uncommon nesting species such as Wood Ducks, Hooded Mergansers, Buffleheads, and Pileated Woodpeckers. Other birds which suffer population reductions due to loss of breeding habitat include Virginia Rail, Sora, Pied-billed Grebe, and Green-winged Teal. Other wildlife which would be affected by reservoirs and fluctuating water levels are black-tailed deer, beaver, river otters, and stream dwelling fish. The net result of the ecological changes resulting from creation of large reservoirs is a decrease in the variety of native flora and fauna. Concurrently, populations of a few very adaptable species increase in the area.

Interrelationships with Other Habitats

Reservoirs can drastically alter other habitats through their creation and through their effects on natural systems after being built. Reservoirs can alter downstream waters and estuaries by restricting river flow. As water is restricted, estuaries can become more saline which results in drastic alterations of plant and animal compositions.

River flow is one of the principal sources of dissolved nutrients and particulate organic matter (detritus) in estuaries. Thus, restrictions of freshwater into the estuary reduce estuarine productivity. Unrestricted river flow is also necessary to

maintain open migration passage ways for invertebrates and fish. Migrating juvenile and adult salmon are notable examples of fish affected by reservoir construction.

Reservoirs which have water released from lower levels also have effects on downstream waters. Deep water, when released, has a higher salinity than surface water and, containing many nutrients, promotes eutrophy downstream. Such discharge lowers downstream water quality and can result in fish kills.

Commercial/Recreational/Esthetical Benefits

Reservoirs are important as water storage areas and as part of power generating systems. Properly managed, reservoirs can provide areas for recreation such as boating, fishing, swimming and wildlife watching. Reservoirs can diversify terrestrial landscapes and provide habitat for some waterfowl.

Reservoirs have altered the Northwestern landscape drastically during this century. Because of the vast areas reservoirs can alter and/or destory, any proposed benefits of reservoirs must be carefully weighed against what we will lose in wildlife habitat and diversity, and scenic grandeur.

Suggested References

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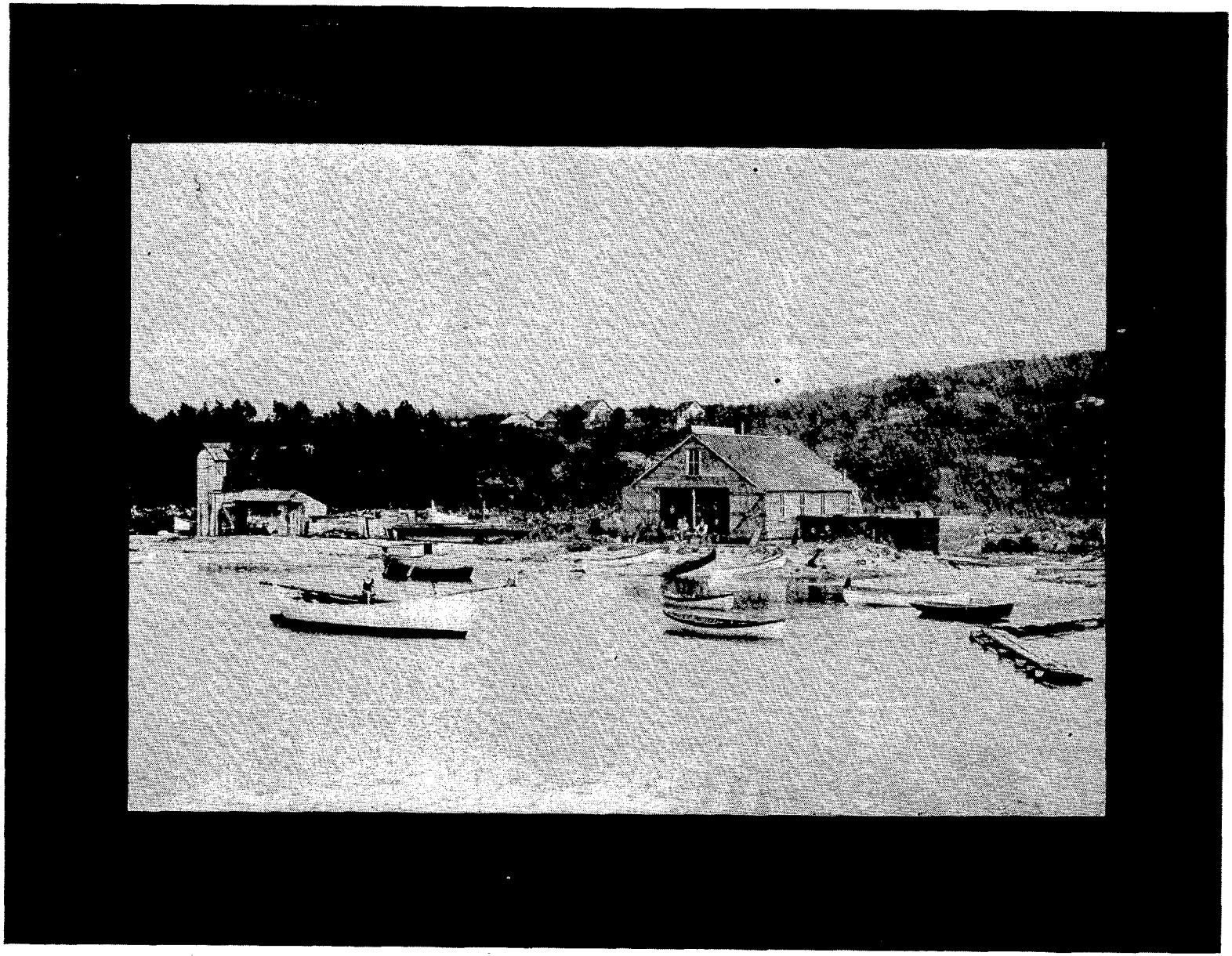


BAYS AND ESTUARIES (No. 54)

I. INTRODUCTION

Estuaries are one of the most highly productive and complex ecosystems in the Pacific Northwest. These moderately protected embayments are strongly influenced by marine waters from the open sea and by fresh water drainage. Non-estuarine bays receive little freshwater influence and salinities are comparable to adjacent open marine waters. Flora and fauna are adapted to marine conditions and benefit from protected waters within the shelter of the bay.

Salinities, flora, and fauna vary greatly in estuarine zones of fresh and salt water mixing. This zone of variable salinities creates stressful conditions for species adapted to strictly fresh or strictly marine environments. However, this mixing zone also produces conditions in which tremendous quantities of sediments, nutrients, and organic matter are exchanged between terrestrial, freshwater, and marine communities. Many organisms benefit from this effect and are dependent on these rich estuarine ecosystems which are composed of many interrelated parts. Refer to Table 54-1 for narratives discussing land cover types and interrelated habitats.

Estuaries are intimately associated with several terrestrial and aquatic communities as illustrated in Figure 54-1. These associated landforms, physical processes, plant and animal communities and the estuary as a whole can be viewed from several different perspectives. Thus there is a wide range of definitions of estuaries and some confusion in related terminology, processes, and management goals. All of Puget Sound may be considered an estuary, but only on a very broad scale. Several rivers and streams enter the Sound and dilute saline oceanic waters. The Sound is also isolated from the open ocean along its many inlets, coves, harbors, and bays. These smaller, more isolated and/or freshwater influenced units are defined as bays and estuaries in the Coastal Zone Atlas land use maps and in these narratives. Examples of estuaries within each coastal county are listed in Table 54-2. Each has several features in common, however, all vary considerably and should be managed according to basic estuarine principles and local variations in associated habitats, drainages, marine influences, and resource needs.

Table 54-1 NARRATIVES RELATED TO ESTUARIES AND BAYS

(Refer to these sections for more detailed information on these integral parts of estuarine systems)

NARRATIVES	MAJOR INTERRELATIONSHIP(S)
Riparian; River and Streams	Freshwater influence; nutrient, sediment, and effluent import; migration route for estuarine organisms. Watersheds draining into estuaries are the major terrestrial influence on estuaries. Detritus from terrestrial sources is a major contribution to estuarine productivity.
Bluffs	Bluffs supply sediment to spits which enclose several estuaries and lagoons.
Reservoirs; Impoundments	Alter freshwater influence, movement of organisms, and temperatures.
Lagoons	Lagoons are a type of estuary.
Slough	Sloughs extend the aquatic area of estuaries into marshes, generally on river deltas.
Open Water	Adjacent marine waters influence estuarine salinity, organisms, and morphology.
Wetlands	Marshes, seagrass, algae, and kelp beds all contribute primary productivity within the estuary or bay. Marshes are the major zone of overlap between terrestrial and aquatic systems within the estuary. More saline bays depend on seagrass, algae, and kelps for productivity base.
Beach Substrates	Communities associated with beach substrates are the principle feature of nearshore and benthic ecology of bays and estuaries.
Rock Outcroppings	Often form the protective "shoulders" of more saline bays, especially in the San Juan Islands.
Sand Islands; Dunes; Bars	Sand and other fine substrates are shifted by wind and wave action within bays and estuaries and along barrier spits. Sediments and formations they create are related to stream flow, tidal action, wind, waves, and human activities such as dredging.
Spit	Spits are often the major land form enclosing an estuary. Major spits in Washington include Ediz Hook, Dungeness Spit, and the Long Beach Penninsula.

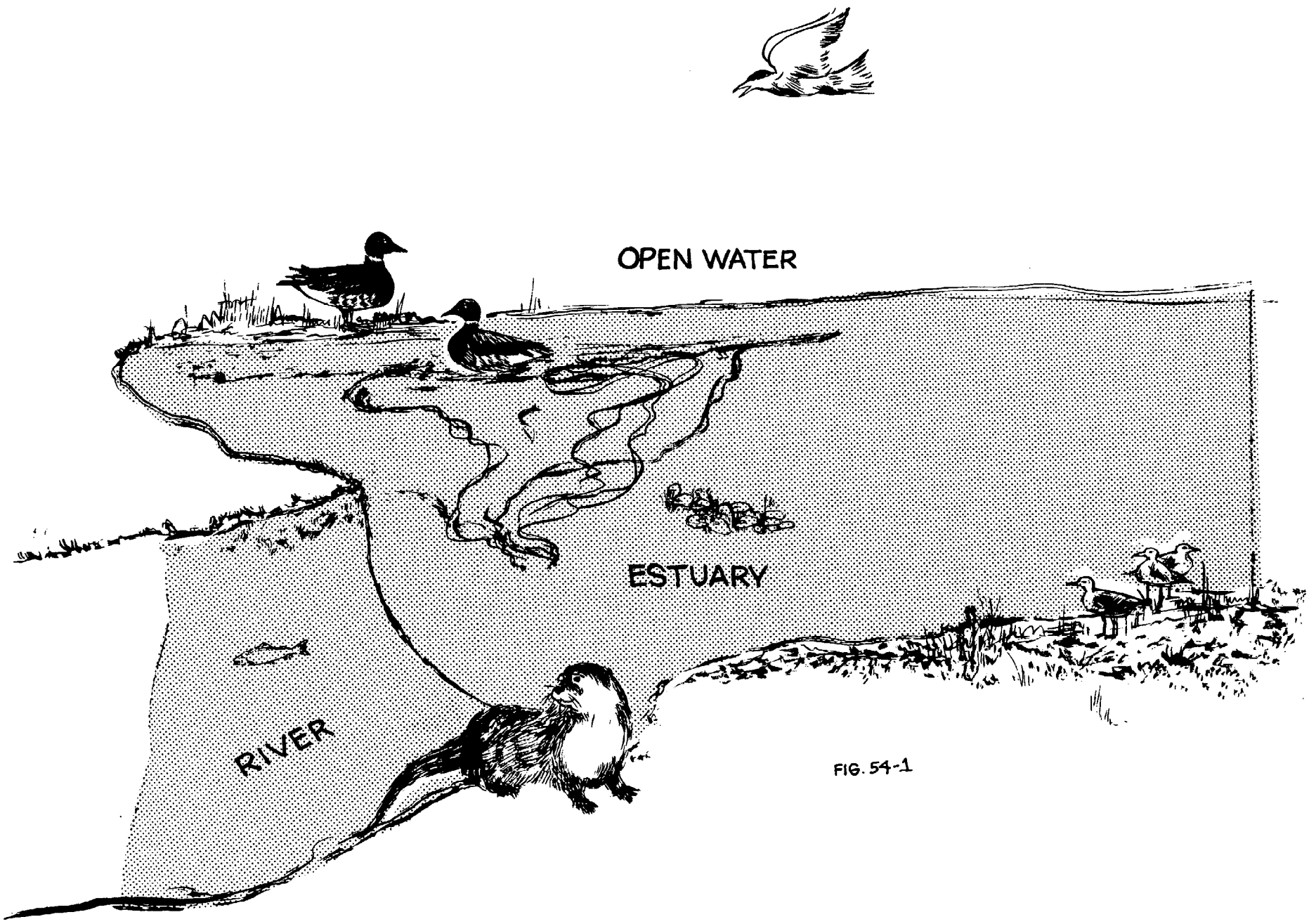


FIG. 54-1

All estuaries of Washington have been modified to some degree by human activities; some have been severely altered. Estuaries provided most of the level ground along the coast and were logical locations for early development in western Washington. The proximity to the sea, rich fishing grounds, potential farmland, and the protection they afforded from harsh oceanic conditions provided incentives to establish coastal cities, trade, and cargo centers. River mouths and adjacent marine waters also provided a convenient though ill-advised means of disposing urban and industrial wastes.

Development along bays and on estuarine areas occurs throughout the world and has led to widespread destruction of these valuable coastal systems. Seven of the largest cities in the world are located adjacent to estuaries and in the United States, one-third of our population lives and works close to them. Estuarine areas of Washington are centers for coastal populations, business, trade, and recreation and many of our largest estuaries are sites for major cities such as Seattle and Tacoma. The estuarine zone of the Duwamish River and its associated marsh and mudflats were all but destroyed as Seattle expanded. Only the small, but very important Kellogg Island remains to support marsh wildlife within the Duwamish estuary. Tacoma has also engulfed the majority of adjacent wetlands at the mouth of the Puyallup River. Other major Washington cities in estuarine locations include Everett (Snohomish River Estuary) and Aberdeen/Hoquiam (Chehalis River Estuary).

Although many of our estuaries have been severely altered, others remain as relatively undisturbed features of the coastal zone. Willapa Bay as a whole

"With salmon gone and industry moved in, birds don't bite the water. Once this river brought a cascade color to the sea. Now the clouds are cod, crossing on the prowl beneath the dredge that heaps a hundred tons of crud on barges for the dumping ground."

from: Duwamish Head
by Richard F. Hugo

and its many river mouths are perhaps the most pristine example. The entire bay and upland drainages encompass about 900 square miles of Pacific County. The bay is measurably diluted by freshwater from the Palix, Willapa, Naselle, Bear, Nemah, and North Rivers and by Smith Creek and other small drainages. The Longbeach Peninsula is a barrier spit formed by Columbia River sediments which isolated the bay from full oceanic exposure. Each river mouth forms an estuarine zone somewhat distinct from the rest of the bay, but all of Willapa Bay (like Puget Sound) can be regarded as an estuary. Extensive marsh and eelgrass beds throughout the bay are highly productive systems which support major fish, shellfish, waterfowl, and other wildlife populations. Oyster harvest alone surpasses any other area in the state with an estimated potential annual production of 50-60 million pounds. Conflicting land use activities pose various threats to Willapa Bay and other estuaries and must be carefully evaluated to ensure continued productivity of these valuable, but vulnerable systems.

II. SIGNIFICANT ECOLOGICAL FEATURES

Bay and Estuary Formation

As mentioned earlier, there are many conflicting definitions of estuaries. Various classifications have been devised to define different types and among these are the following which are based on physical formation:

River Delta Estuary: Form at the mouths of rivers and streams. Freshwater influence is extended when they form in protected bays such as on the Skagit River Delta or is quite abbreviated along more exposed shorelines such as at the mouth of the Elwha River. A river delta or some abbreviated formation at stream or river mouths occurs in all areas defined as an estuary. When these freshwater influences are lacking, the protected area is often called a bay, cove, or harbor. Not all bays are estuaries, nor is the reverse necessarily true. Semi-enclosed bays, sloughs, and marshes typically form on shifting delta silt deposits. Spits may partially enclose one or more river delta estuaries, especially where river flow is weaker than influences of tides and winds from offshore. Estuaries formed behind spits are considered lagoons as discussed below.

Table 54-2 EXAMPLES OF ESTUARIES BY COUNTY

Location	Major Drainage(s) Entering Estuaries	Whatcom	Skagit	Snohomish	Island	San Juan	King	Pierce	Thurston	Kitsap	Mason	Jefferson	Clallam	Grays Harbor	Pacific	Wahkiakum
Drayton Harbor	California Creek	■														
Bellingham Bay	Nooksack River	■														
Nooksack Delta																
Skagit Bay	Skagit River		■		■											
Skagit Delta																
	Stillaguamish River			■												
Deer Harbor	Unnamed					■										
Elliot Bay	Duwamish River						■									
Nisqually Delta	Nisqually River							■	■							
Burley Lagoon	Burley Creek							■		■						
Head of Budd Inlet	Deschutes River								■							
Stavis Bay	Stavis Creek									■						
Head of Sinclair Inlet	Gorst Creek									■						
Oyster Bay	Kennedy Creek										■					
Lynch Cove	Union River										■					
Thorndyke Bay	Thorndyke Creek											■				
Duckabush Delta	Duckabush River											■				
Quilcene Bay	Big and Litter Quilcene Rivers											■				
Dungeness Bay	Dungeness River												■			
	Pysht River												■			
North Bay	Humptulips River													■		
South Bay	Elk River													■		
Willapa Bay	Willapa, Nemah, and Naselle Rivers														■	
Grays Bay	Grays River														■	■

- Spit Formation: Lagoons form behind spits which are created when sediments from eroding shorelines are deposited across bay mounths. Riverborne sediments may also contribute significantly to spit formation.

  The Long Beach Peninsula (spit) is a dramatic example of how the Columbia River sediments have been transported and deposited to the north, enclosing the Willapa Bay estuarine system. Several river delta estuaries exist within this large "lagoon." A single drainage is more common within other Washington lagoons. Examples include the lagoon at the mouth of Thorndyke Creek in Jefferson County. Other examples and related features are discuessed in the Lagoon Narrative, No. 56.

- Fjord-type Estuaries: Fjords are formed by glacial activity and are typically deep, u-shaped coastal indentures. Hood Canal and Puget Sound both have glacial origins, and the morphology of Hood Canal could classify it as a fjord. As stated earlier, we have limited our estuary and bay mapping to smaller, more isolated and/or freshwater influenced bodies of water. The discussions that follow are relevant to all of Hood Canal and Puget Sound, but are more appropriately or practically applied to these smaller units.

- Bays and Estuaries Produced by Other Geological Forces: A variety of shoreforms such as rock outcroppings often create protected pockets along the coast. These indentations are formed by a variety of geological processes. They are appropriately called estuaries when freshwater influence occurs. Those with freshwater influence are probably more common in Washington and are referred to as bays as well as coves and harbors. Larger coastal indentations which are generally more exposed than bays are often referred to as inlets. These bodies of water may be thought of as being progressively nestled or protected inland extensions of the ocean, "passages," "straits," and larger "inlets" connecting them to the Pacific. Dumas Bay in King County and Shoal Bay in San Juan County are examples of nonestuarine bays. Buck Bay on Orcas Island is an example of an estuarine bay.

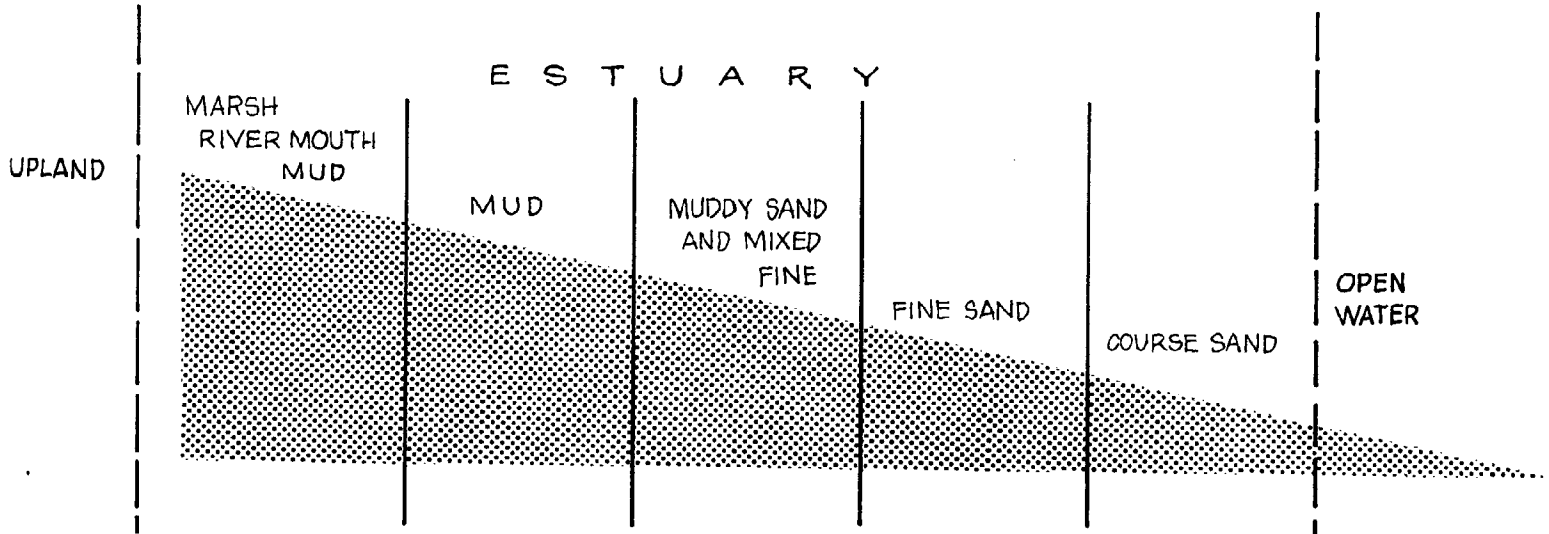
Sedimentation

All estuaries occur at the mouth of freshwater drainages and the majority of Washington estuaries form as part of river and stream deltas. Terminal flood plains and the delta are a direct result of silting and filling actions of river flood waters and tidal currents. The lower Skagit Valley and Skagit flats are examples of a major delta formation. Less extensive deltas occur at the mouths of small streams or in highly exposed coastal locations.

Rivers are the principal source of sediments in estuaries which are deposited near the river's mouth. Bottom currents may then carry sediments farther into the estuary. Estuarine sediments may also be derived from marine sources or from other river systems. Shoreline erosion and longshore drift may deposit these sediments within the estuary or contribute to spit formation.

Sediments are continually deposited and reformed within the estuary but follow a general structural pattern. In general, a gradient exists with fine sediments at the head and along the margins of the estuary. Extensive mudflats typically form in these areas. Coarser sediments appear toward the mouth of the estuary progressing from muddy sand and mixed fine to fine sand to coarse sand.

Patterns of sedimentation deposition vary significantly within estuaries. Inhabitants of bottom sediments also vary and are discussed in appropriate beach substrate narratives (No. 63).



ESTUARY SEDIMENT CROSS SECTION - VERY GENERALIZED VIEW

Salinity and Stratification

Estuaries are composed of three general zones of varying salinities which in fact are all part of an ever changing salinity continuum. The salinity gradients within an estuary change with tide cycles, river flow, and weather. They change many times within a day and also undergo seasonal changes. The general salinity classes are marine waters, fresh waters, and an extensive intermediate zone. In general, there is a salinity gradient within an estuary which has freshwater at the head and becomes more saline toward the mouth of the estuary. The intermediate zone undergoes the greatest and most rapid changes in salinities and is thus the most stressful of estuarine areas for many organisms.

An estuary such as the Columbia River often becomes stratified by salinity concentrations and temperature (Figure 54-2). Fresh and warm waters are less dense than cooler marine waters and form the upper levels of stratified waters. The maximum salinity intrusion on the Columbia River occurs during high tide and low river flow and extends as much as 20 nautical miles upstream. The minimum salinity intrusion, extending five miles upstream, occurs during low tides and high riverflow. It is during the latter occurrence that the Columbia River estuary becomes stratified. During periods of high river flow, freshwater animals penetrate far downstream in the fresh surface water. At the same time and same location, marine species are found in the denser saltwedge (saline bottom waters). The stratified distribution is unstable due to the energy for mixing the water layers provided by high tides. Thus, the two layered system is only maintained for portions of the tidal cycle.

The Duwamish estuary also shows mixing of freshwater and the salt wedge extending upstream. Mixing is highly time dependent and is most intense at maximum tidal velocities. In estuaries where there are large inputs of fresh water and little tidal influence, stratification may be stable.

The Columbia River Estuary is also seasonally stratified by temperature. Seasonal temperature extremes are greater in river water entering the estuary than sea water temperatures. Surface river water is warmer than the salt wedge during summer and cooler in winter.

The dissolved oxygen of the estuary varies inversely with salinity and temperature. Dissolved oxygen is at or near saturation level in unpolluted freshwater entering an estuary. Dissolved oxygen concentrations are lowest in the saltwedge in summer and fall.

Turbidity varies directly with the amount of river flow and inversely with salinity. Turbidity is the result of the presence of fine sediments, particulate organic matter, and plankton. Turbidity is highest during high river runoff.

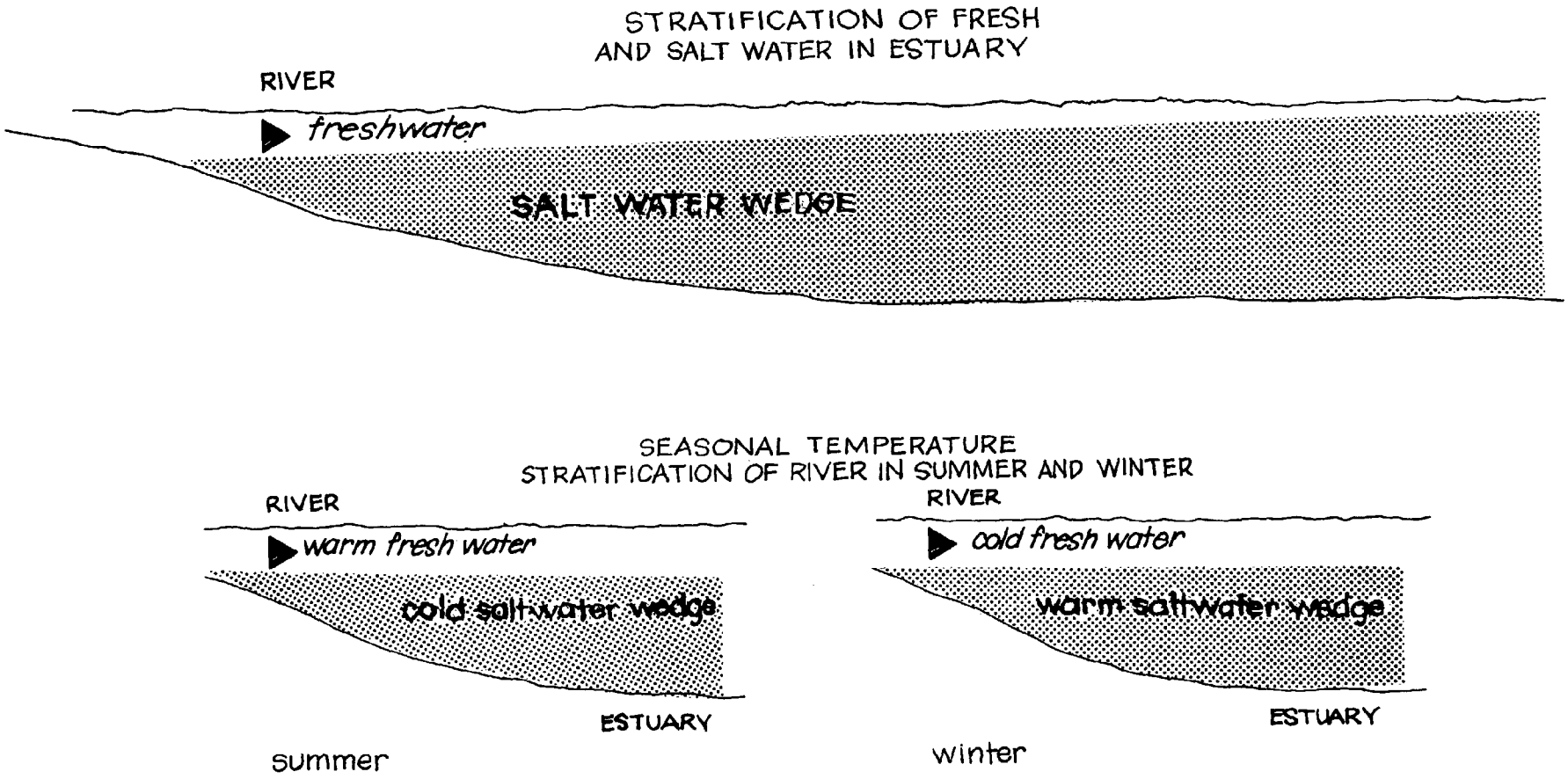

STRATIFICATION OF FRESH
AND SALT WATER IN ESTUARY
RIVER
freshwater
SALT WATER WEDGE
SEASONAL TEMPERATURE
STRATIFICATION OF RIVER IN SUMMER AND WINTER
RIVER
warm fresh water
cold salt-water wedge
ESTUARY
summer
RIVER
cold fresh water
warm saltwater wedge
ESTUARY
winter

Figure 54-2

Systems of Subsystems

Estuaries are composed of several interrelated habitat types or subsystems linked together by the movements of water resulting from tides and river flow. Marine and freshwater inflow provide energy input for the entire estuary. These aquatic links to the estuary also provide pathways for transport of nutrients and organisms outside the system.

Major interrelated habitats are listed in Table 54-1 and are reviewed below in terms of estuarine subsystems:

- Shallow Water Zone: These are highly productive areas within the estuary. The rate of primary production exceeds the rate of community respiration, resulting in a net surplus and export of energy and nutrients to deeper water both inside and outside the estuary. Major communities within the shallow water zone include salt marshes, eelgrass beds, and algal communities. Beach substrates vary considerably in these zones and provide attachment sites for aquatic vegetation.
- Deep Water Zones: In deep water zones within the estuary, respiration exceeds production. Detritus and dissolved organic matter produced in shallow water zones are consumed in these areas.
- Overlapping Water Column: This subsystem is composed of plankton and nekton in the water column which move freely between shallow and deep water zones. Plankton and nekton produce, convert, and transport nutrients and energy. These organisms react quickly to local fluctuations of available resources because of their mobility and/or high reproductive rates.

Productivity

Estuaries are probably the most productive ecosystem in the state of Washington. Estuarine waters and associated aquatic vegetation are extremely fertile and economically valuable food producing zones. Ninety percent of the American fishing industry is based on the continental shelf and two-thirds of harvested species depend directly or indirectly on estuaries for their existence. Fish, shellfish, and other commercially or recreationally important organisms are also produced within the estuary. For example, the annual production within Willapa Bay yields significant quantities of coastal food resources. Oyster production in the bay is estimated to yield a potential 50-60 million pounds per year, and hardshell clams would add another 10-15,000 pounds per year. Dungeness crab, salmon, herring, smelt, sturgeon, flounder and other food fish also occur within the estuary in large numbers.

Estuaries have such high production levels because they serve as nutrient traps. Stratification of salt and fresh water can hold nutrients in the estuary where they remain until used by estuarine organisms. Marsh and benthic flora and fauna also store nutrients which are trapped within sediments among plants and/or are used by these nearshore organisms. The nutrients are retained and are rapidly recycled within the estuary, creating a self-enriching system. It is important to note that pollutants

get trapped in the same manner in which nutrients are retained and recycled in the estuarine system. Pollutants are then transferred through food webs based on estuarine production. Toxins are often concentrated at higher trophic levels at which human consumption occurs.

Estuarine primary production is based on a variety of plant communities within which, photosynthesis is occurring throughout the year. Estuarine producers include macrophytic vascular plants and algae (marsh vegetation, seagrasses, seaweed), benthic microphytic algae, and phytoplankton. Marshes, eelgrass beds and seaweeds are the major producers in Washington bays and estuaries. These aquatic primary producers support food webs based on dirct grazing and detrital pathways as discussed in more detail in the various marine plant and marsh narratives.

The development of phytoplankton populations is influenced by turbidity and by the extent waters are confined and remain stable or are exchanged rapidly. Peak phytoplankton activity occurs during periods when retention and stability of estuary waters are at a maximum. Phytoplankton contributes a very small amount to estuarine primary production. However, high levels of phytoplankton production contribute to the dissolved oxygen concentrations in upper waters. The occurrence of persistently low concentrations of dissolved oxygen in bottom waters following phytoplankton blooms indicates their sinking and dying cells contribute to oxygen demand in that area.

Tidal action also enhances estuarine productivity. Tides remove wastes and transport nutrients and organisms within the estuary. Sessile organisms, such as oysters, are especially dependent on nutrients carried to them by tidal currents.

Much of the nutrients and organic detritus produced within estuaries is exported to more open waters and to the ocean. There is no net loss of energy within the estuary as a result of this export because so much more is produced than is consumed. Higher productivity is most often associated with protected estuaries (e.g., within lagoons). Coastal oceanic (or more open waters of Puget Sound and the Strait of Juan de Fuca) waters near such fertile estuaries are often more productive than other open water areas. This results from the export of plankton and detritus from estuaries which enhances secondary production of fish and invertebrates in the offshore environment.

The Estuary as a Stressful Environment

The physical properties of estuaries vary depending on the volume and contents of river water released, structural components of the estuary bed, tides, and microclimate. They are extremely stressful environments for many aquatic animals and plants due to daily and seasonal changes in salinity, dissolved oxygen concentrations and tidal action. The rhythmic nature of estuary salinity changes allows certain animals to exist permanently in an environment which temporarily confronts them with salinity conditions which would otherwise be fatal.

Estuarine organisms have developed several ways to reduce the effect of changing salinities. Some animals escape higher salinities by moving across salinity gradients within the estuary. The estuary bottom has higher, more stable saline conditions than the free water above. Accordingly, the distribution of bottom-dwelling residents often reaches farther up or downstream than that of their nektonic (free-swimming) counterparts possessing equal salt tolerances.

Many estuarine animals cope with their environment by reducing contact with adverse salinities. Annelids, molluscs, and fish produce slime or mucus to protect themselves. Polychaetes and crabs plug up their burrows during periods of high or low salt conditions. Hydroids, annelids and molluscs contract their muscles to reduce their surface volume and clams and barnacles close their shells. Other animals go into highly resistant resting stages during severe conditions, and bacteria form spores or cysts.

All estuarine animals have some ability to regulate the amount of salt in their body fluids. Flounders can control the amount of salt coming into their bodies better than many other fish. The most efficient regulators are migrant species moving from and to sea water and fresh water. Migrating salmon undergo dramatic exchanges in salt concentrations in their blood and the amount of urine flow as they go from salt to fresh water.

Estuarine Wildlife

Estuaries are nursery grounds for many species. These areas are also zones of reduced competition and thus are refuges for organisms that can withstand the stressful environment. Commercially harvested wildlife that use estuaries as nursery grounds include crabs, English sole, and starry flounder.

Estuaries are composed of many intergrading habitat types, including open water, mudflat, marsh, sand, and fresh, marine and brackish waters. These related areas provide rich habitat for a multitude of wildlife species. Birds, mammals, and fish use several of the estuarine areas for breeding, feeding, resting, and cover. Characteristic species of estuaries are discussed in appropriate narratives (e.g., salt marsh and beach substrates). Examples of estuarine organisms and their economic values are found in Table 54-3.

Migratory birds use bays and estuaries in Washington as stopover areas along the Pacific Flyway (migratory pathway). Some migrants nest as far north as Alaska and winter in Mexico. Other migrant birds, such as Dunlin, wigeon, and several other shorebirds and waterfowl, winter in Washington's protected waters. Many birds and mammals of open water also use the calmer waters of bays and estuaries during periods of rough weather.

Estuarine bird use is often divided by foraging strategies of individual species. Cormorants and waterfowl, such as Canvasbacks, grebes, scoters, and mergansers, use open water areas for resting and feeding. Marshes offer waterfowl and shorebirds cover for breeding, resting, and feeding. Shorebirds are affected by tides flooding prime intertidal feeding areas twice a day. Willets, rare migrants in Washington, cope with the changing estuarine environment by varying diet and feeding habits, using intertidal flats, saltmarsh, and ocean beaches. Least Sandpipers have very short bills and feed back from the water's edge. Greater Yellowlegs, having longer bills and legs, feed up to their bellies in water and may immerse their whole heads while foraging. Small sandpipers, in general, are more restricted to intertidal flats although many also use salt marshes.

Mammals, such as raccoons, skunk, deer, elk, and river otters, use salt marsh areas and tidal flats. Harbor seals and Pacific harbor porpoise feed in the open waters of estuaries.

Table 54-3 EXAMPLES OF ESTUARINE ORGANISMS AND THEIR ECONOMIC VALUES

Organism	Economic Value	Comment
Plant		
Algae	PC	Support many commercial and recreational species.
Invertebrates		
Oyster	C, R	
Soft shell clams	PC, R	
Hard shell clams	C, R	
Amphipods	indirectly valuable	Support many commercial and recreational species.
Isopods	indirectly valuable	
Shrimp	C, R	
Crab	C, R	
Fish		
Flounder	C, R	
Sculpin	indirectly valuable	Support commercial, recreational species.
Sturgeon	C, R	
Stickleback	indirectly valuable	Support commercial, recreational species.
Herring	C, R	
Smelt	C, R	
Salmon	C, R	These are our most important sport fish.
Trout	C, R	
Birds		
Canvasback	R	These and many other estuarine birds are enjoyed by thousands for their esthetic values.
White-winged Scoter	R	
Dunlin	R	
Bufflehead	R	
Mammals		
Harbor seal	R	Esthetic values of these four mammals are extremely high.
Pacific harbor porpoise	R	
River otter	C, R	
Raccoon	C, R	

C = Commercially harvested
R = Recreationally valuable
PC = Potential commercial harvest

Local fish and aquatic invertebrate species composition changes with seasonal variations in salinity. Estuarine fish and invertebrates can be divided into three major groups; those occurring in fresh, brackish, and salt intrusion waters, as indicated by the following examples noted in the Columbia River Estuary. Fresh waters (0.1 percent salinity or less) are dominated by the copepod (Cyclops vernalis), cladocerans (Daphnia longispina and Bosmina spp.), juvenile amphipods, and rotifers. Zooplankton populations in fresh water of the Columbia River have reached a maximum of 2,700 per cubic meter.

Slightly brackish water in the Columbia River is dominated (90 to 100%) by a copepod (Eurytemora hirundoides). This zone of mixing fresh and salt waters supports few species of invertebrates because of the stresses of varying salinity. Reduced competition between species permits extremely high population densities of the few species present. The usual population density of zooplankton in the Columbia River Estuary's brackish waters is greater than 2,500 per cubic meter; the highest population recorded was 38,755 per cubic meter.

Zooplankton occurring in the salt intrusion area may be dominated by copepods, such as Cartia clausi, Acartia longiremus, and Pseudocalanus minutus.

Benthic invertebrates occurring in the fresh waters of estuaries include snails, clams, polychaetes, oligochaetes, crayfish, isopods, amphipods, and immature insects, especially Chironomid larvae and newly hatched sand shrimp.

Brackish water benthic invertebrates include isopods, immature sand shrimp, amphipods, copepods, and hydroids. Adult and immature sand shrimp, Dungeness crab, amphipods, isopods, and clams occur in waters nearer the ocean.

Fish occurring in estuaries include starry flounder, prickly sculpin (a freshwater fish), Pacific staghorn sculpin, longfin smelt, Pacific tomcod, Pacific snakeblenny, anchovies, steelhead, cutthroat trout, and chum, king, chinook, sockeye, and pink salmon. Plankton feeders which eat large quantities of copepods include snake blennies, longfin smelt, and juvenile starry flounder. Bottom feeders, fish eating amphipods and polychaetes, include larger juvenile starry flounder, prickly sculpin, and sturgeon. Consumers of fish include Pacific staghorn sculpin and sand sole. Fish with a wide range of food habits include younger Pacific staghorn sculpin, young lemon sole, and tomcod.

Estuaries serve as corridors for species entering and leaving fresh and salt water. Juvenile salmon use estuaries as feeding areas before entering the sea and the adults use estuaries before entering fresh water to spawn. Mortalities for juvenile salmon in the estuarine life phase are extremely high and vary from year to year. Thus, estuarine survival may be a highly critical point in their life cycle. Starry flounder also use fresh water areas in the upper estuarine river zone as juveniles and move through the estuary toward marine waters as adults.

Commercial/Recreational/Esthetical Benefits

Estuaries are one of the greatest producers of available protein in the world and are one of Washington's most important environmental resources. Many important commercial and sport fishes and invertebrates use these waters during some stage of their life cycle. Almost 60 percent of the United States fisheries are based on species requiring estuarine habitat. Chinook, coho, pink, chum, and sockeye salmon, steelhead, cutthroat trout, sole, flounder, smelt, and crabs all use estuaries for some portion of their lives. Oysters are primarily cultured in estuarine waters.

Many people use estuaries for recreation. Sailing and other water activities can be done in open water areas of the estuary. Estuarine areas provide incredibly rich habitat for wildlife and wildlife watchers can observe a great diversity of species. Open and nearshore waters, tideflats, eelgrass beds, and marshes support large numbers of esthetically valuable wildlife.

III. IMPACTS

Historical Changes and Trends

Estuaries have been important to mankind throughout history as centers for trade, fishing fleets and population centers. The rich food sources estuaries provide and the convenience of protected marine access made these areas extremely attractive to Indians, pioneers, and modern man.

During the last 200 years, West coast estuaries have been destroyed or impaired by pollution, dredging and filling and other development associated activities. During the 1950's, the discharge of raw sewage from Aberdeen, Hoquiam, and Cosmopolis so adversely affected the water quality of Grays Harbor that it interfered with use for recreation, fisheries, and shellfish culture.

The fish and shellfish resources have often been abused due to lack of knowledge of resource conservation. During the 1850's, Willapa Bay had a thriving industry based on the native oyster (Ostrea lurida) that occurred in extensive beds throughout Washington. Native oysters were harvested and shipped to California whose growing population had high food demands due to the Gold Rush. Washington's native

oyster population was soon depleted and the industry drastically suffered. In the 1920's, the Pacific oyster was introduced from Japan and Washington's oyster industry opened to a nationwide market. Unfortunately, many other species were also introduced with the Pacific oyster. Some of these introduced species, such as the Japanese oyster drill, have impacted the oyster industry in Washington.

Specific Impacts

1. Reduced River Flow

River flow and tidal action produce a delicate balance of currents and salinity gradients in estuaries. Reduced river flow from drought or the building of dams and reservoirs can have extreme long-term effects on estuarine species composition. Increased salinities force fresh water species farther upstream and out of the estuary. Brackish water species also move to less saline areas. Mobile invertebrates follow the changing salinity gradients as they are able; sessile organisms may die.

The current system can be so altered with decreased river flow that shoaling and scouring can set up completely different physical conditions. The estuarine substrate is important habitat to many invertebrates and severe changes in it can be detrimental to them.

Decreased river flow from dammed rivers or occasional droughts results in a decrease of dissolved nutrients into estuaries. Rivers are a major source of organic materials that are used by estuarine organisms.

2. Development and Pollution

One of the reasons industry uses estuaries is water availability for transportation, processing, and waste disposal. Unfortunately, many of these uses degrade the estuarine environment by increasing sedimentation, turbidity, and nutrients that lead to eutrophication, lowering dissolved oxygen levels, and introducing pollutants into the food web. Marshes and tidal flats, which produce vast amounts of food, have been destroyed with development.

Estuaries are vulnerable to pollution because of their nutrient trap mechanism. The tidal cycles that maintain a rich nutrient filled environment also collect and maintain pollutants introduced into the system. Human and industrial waste waters introduce heavy metals which can be assimilated into the food web and eventually reach toxic levels. Pollutants may be species selective in their effect; crustaceans may be highly sensitive to pesticides while molluscs may be tolerant of them. Some organisms, such as clams and oysters, tend to concentrate toxins to a great extent, facilitating the build-up of toxic levels in their predators (including man). A list of pollutants and their toxicities to estuarine species, adapted from the book, The Coastline, edited by R. S. K. Barnes, page 139, is found in Table 54-4.

Table 54-4

Toxicity of major pollutants to aquatic animals. An increasing number of symbols indicates increasing toxicity: +++++ represents an LC_{50}(24h) of less than 0.3 ppm, + indicates a median lethal concentration of over 1,000 ppm.

Pollutant	Plankton and invertebrate larvae	Lower invertebrates	Crustaceans	Molluscs	Fish
Heavy metals (salts)					
Copper	++++		++++	++++	++++
Lead			++		++++
Zinc	++		+++	+++	+++
Mercury	+++++		++++	++++	++++
Cadmium					+++++
Chlorine		+++	++++	+++	++++
CNCI					+++++
Cyanide			++++	+++	+++++
Fluoride					+++
Sulphide					++++
Mercaptan					++++
Phenol	++++		+++	++	+++
Cresol			+++	+++	+++
Formaldehyde			++		++
Herbicides					
Paraquat, simazine			+++		++++
Pentachlorophenate		++++	++++	++++	++++
2,4-D					++
Pesticides					
Rotenone				+++++	+++++
Chlorinated HC, PCB			+++++		++++
Organophosphorus			+++++		+++++
Typical crude and fuel oils	+++	+	+	+	++
Low aromatic hydrocarbons			+++		++++
Light oil products	++				++
Oil-spill cleaners					
Early (e.g. BP1002)			++++	+++	++++
Modern (e.g. BP1100)			++	+	+
Surfactants (anionic and nonion[illegible]	++++	++++	+++	+++	++++

The introduction of high concentrations of nitrogen and phosphorous has more immediate detrimental effects. Large quantities of these elements, usually limited in a natural environment, can allow massive blooms of blue-green algae and other phytoplankton. Such blooms eventually contribute to decreased levels of dissolved oxygen. Persistence of low levels of oxygen near the mouths of rivers where pollution often starts can prevent animals from moving upstream to fresh water.

Pulp effluents from paper industries have toxic effects on fish and invertebrates. The sulfite waste liquors inhibit oyster spawning and cause abnormal shell development. Such pollution can reduce an organism's ability to cope with environmental stresses.

3. Red Tides

Toxic red tides are caused by high population levels of the red pigmented dinoflagellate (Gonyaulax catenella). These dinoflagellates produce one of the strongest neurotoxins known which can cause mass mortality of fish, shellfish, and humans that eat the poisoned animals. Gonyaulax catenella populations bloom regularly during warm months along the outer coast and irregularly in north and central Puget Sound. Red tides are reportedly increasing on a world-wide basis. This may be due to agricultural activities which increase amounts of runoff and nutrients entering marine water which then trigger dinoflagellate production.

Summary

Estuaries are valuable and delicate ecosystems. Washington depends on estuaries for its fisheries industry, recreation, and support of its wildlife. If we are to continue to benefit from one of the richest environments in the world, we must protect these systems from pollution and destruction.

The value of an estuary must be measured against the value of restricting river water upstream. It may be that the economic benefits of fisheries, shellfish, and bird and mammal production exceed the benefits incurred from damming a river.

Polluted estuaries should be managed for dissolved oxygen enhancement, eutrophication reversal and reduction in potentially toxic materials including heavy metals. Waste waters should be treated to control nutrient inputs of nitrogen and phosphorous. Up to 82 to 96 percent of phosphorous can be controlled by removal at waste water treatment facilities.

Estuarine water quality management must consider the different yet interconnected areas within an estuary. Fresh, brackish, and salt environments may react differently to various stresses and should be treated separately. Management must also take into account that these waters do mix.

Further development on estuarine areas should be discouraged. The few undeveloped estuaries Washington has left are too valuable to become marinas, housing developments, or industrial sites. An estuary can be a multiple use environment only if we remember that modifying one point in the estuary can affect distant points upstream, throughout the protected waters, and the adjacent ocean.

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IMPOUNDMENTS (No. 55)

The word impoundment describes many man-made water areas including reservoirs, lakes, duck ponds, and other artificially constructed wetland types. We have used the impoundment classification to describe those portions of both marine and freshwater areas isolated from other bodies of water by manmade obstructions. Impoundments are created purposely and also as a result of highway, railroad, or dike construction.

The value of an impoundment to wildlife is dependent on the degree to which it is isolated from adjacent wetlands. Exchange of nutrients and organisms is often limited or blocked and stagnant pools may result. Even when tidal and impoundment waters are exchanged, providing a richer habitat, surrounding development often discourages impoundment use by wildlife.

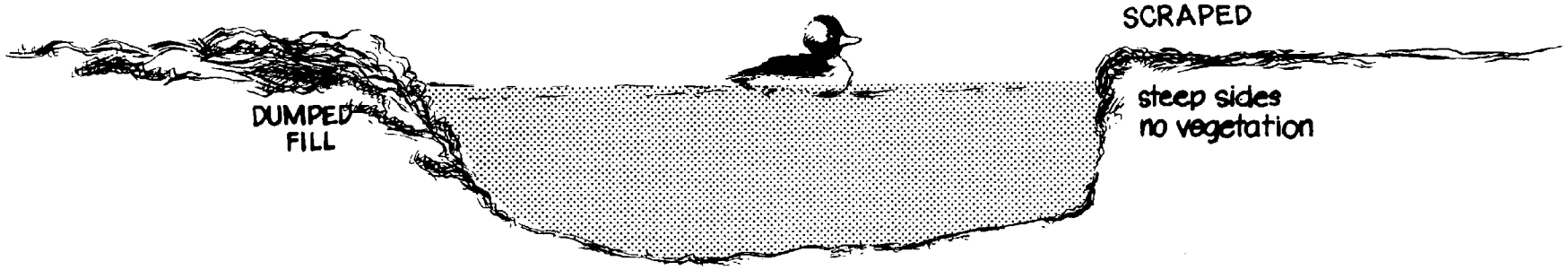
Impoundments generally have higher water temperatures than adjacent wetland systems. Salmon and trout prefer cool waters and avoid these warm water areas. Spiny ray fish prefer warm water and are known to spawn in freshwater impoundments and sloughs along the Columbia River.

Completely isolated freshwater impoundments are similar to ponds. Plant species occurring on gently sloped impoundments may be the same as those occurring in pond and lake littoral (nearshore) zones. Cattails and hardstem bulrush are characteristic plants found along less disturbed freshwater impoundments.

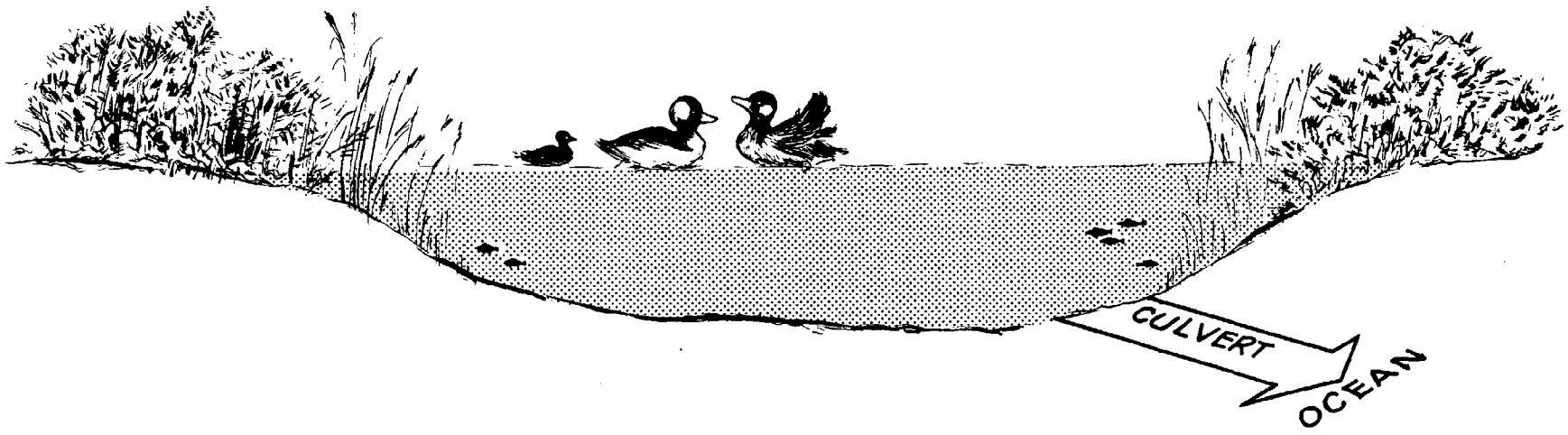
Isolated marine impoundments can eventually become freshwater ponds. This can also occur when tidegates or culverts are present. Some marine impoundments have culverts to maintain tidal flow. These impoundments usually occur in intertidal areas and are typically protected mud areas. Invertebrate use of marine impoundments is similar to that of lagoons and mud shrimp, ghost shrimp, and soft shell clams are characteristically found in them. Fish use of marine impoundments is generally restricted to sculpins (family Cottidae), and three-spine sticklebacks. Observations of impoundments during our studies suggest that bird use is minimal, even when tidal exchange occurs. Coots, Bufflehead, and Killdeer were among fewer than one dozen species observed at an impoundment in Jefferson County. Adjacent intertidal areas with comparable beach substrates were frequented by the same birds plus approximately forty additional species.

Impoundments joined to adjacent wetlands via culverts can be more productive areas than when isolated. Exchange of nutrients and organisms with other areas and the flushing of wastes increase the productivity of impoundments. Planting buffer vegetation around impoundments also encourages wildlife to use these areas by providing cover, nesting and feeding sites.

HIGHLY DISTURBED IMPOUNDMENT



A MORE PRODUCTIVE IMPOUNDMENT
connected with adjacent water
and surrounded with a buffer zone
of vegetation



LAGOON (No. 56)
includes: enclosed lagoon 561
open lagoon 562

I. INTRODUCTION

Lagoons are highly productive and biologically fascinating areas. They are formed when waterborne sediments are deposited by alongshore currents. These sediments gradually build up a spit, which partially or completely encloses an embayment. Streams typically flow into the lagoon and create estuarine conditions as discussed in the Estuary Narrative (No. 54).

Completely enclosed lagoons form when freshwater inflow is too week to maintain a channel through the spit. Open water areas within the lagoon are mapped as Enclosed Lagoons, No. 561. The open water is most often surrounded by salt marsh vegetation which typically increases its coverage of the lagoon over time. Eventually, marsh fills in the entire lagoon and succession to upland conditions proceeds. Examples of enclosed lagoons are Crockett Lake in Island County, and Kah Tai Lagoon in Jefferson County. Smaller enclosed lagoons and coastal ponds are very similar and uncertain origins have led to some confusion in distinguishing the two types. Therefore, some enclosed lagoons may have been mapped as ponds and readers are advised to consult the Lake and Pond Narrative (No. 52) because of similarities between these cover types.

Open lagoons (No. 562) are much more common and occur when freshwater inflow and tidal flushing action has maintained a stream channel through the spit. Marsh and tidal flats cover much of the lagoon which is usually drained and filled twice a day with tidal waters. Examples of estuarine lagoons which flush almost completely as tides fall occur at Thorndyke Bay in Jefferson County, Burley Lagoon in Kitsap and Pierce Counties, and Triangle Cove on Camano Island in Snohomish County. Some lagoons which have an open connection through the spit do not drain completely at low tide. The basin is deeper than the drainage channel through the spit and permanent standing water fills much of these lagoons. These lagoons are quite uncommon along our coast and include a small unnamed lagoon just north of Stavis Bay in Kitsap County. Eelgrass and other marine plants are generally more abundant than in lagoons which drain completely.

II. SIGNIFICANT BIOLOGICAL FEATURES

Creation and Succession

Spit formation is an integral part of the development of lagoons and is discussed in more detail in the Spit Narrative (No. 74) and in the Drift Sectors discussions in the Coastal Zone Atlas. The spit creates a protected environment within lagoons where silt and clay settle out of the water column. As the elevation of tide flats increases, low saltmarsh species such as pickleweed, arrow grass, and Lyngby's sedge colonize. This process is accelerated by the presence of marsh plants, algae, and eelgrass which trap sediments within the lagoon. Marshes are eventually succeeded by a terrestrial plant community after going through several vegetated, wetland stages. This marsh succession is a very slow, dynamic process and has led to complete coverage of some enclosed lagoons by marsh vegetation. A rim of marsh vegetation encircles most other lagoons and is the most characteristic lagoon edge community.

Interrelated Habitats

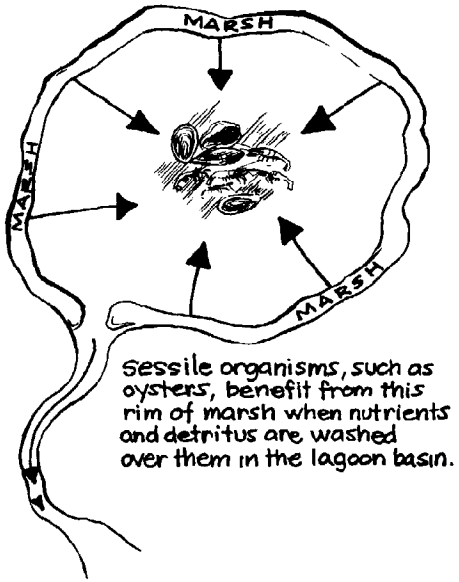
Spits and salt marshes are primary examples of land cover types which are integral parts of lagoon ecology. Several other closely related cover types occur within lagoons, each largely dependent on the other. Major cover types listed in the reference section at the end of this narrative are likely to occur in lagoons, several of which are shown in Figure 56-1. The lagoon at the head of Thorndyke Bay is depicted in this illustration in which major cover types are identified as they appear in the Coastal Zone Atlas (Fig. 56-1a). An enlarged view of the lagoon vicinity (Fig. 56-1b) depicts more detail within the complex of lagoon, tideflat, creek, and marsh. It can be seen that most of the lagoon drains at low tide to expose "bare" tideflats. However, creek channels and small pockets maintain permanent still and running water within the lagoon. These areas serve as refuges for aquatic organisms such as salmonids (salmon and trout) and waterfowl at low tide.

Representative wildlife of the lagoon and the various habitats used at high and low tide are shown in Figure 56-1c. Marsh, intertidal, and upland habitats are all very close together within the lagoon and each may be used by a given species in a short period of time. Hawks, otters, and waterfowl all make use of several areas in the lagoon system and benefit from the matrix of interrelated habitats. Note especially the movements of wildlife between different habitats as tides rise and fall. (For example, the shorebirds which move onto the flats as tides fall, then back to the marsh at high tide.)

Productivity

Primary productivity within the lagoon is usually quite high. Salt marsh vegetation often occurs around much of the lagoon edge, and eelgrass and algae in deeper portions. Trees and shrubs overhanging the upland edge also contribute nutrients to the lagoon, much like riparian vegetation which enriches streams.

Nutrients and detritus produced within the lagoon or washed into these estuaries create a very rich community. Much is exported from the lagoon, but significant consumption occurs within the lagoon and secondary production is usually high. Lagoon productivity forms the basis of a variety of food chains, particularly those based on detritus as discussed in Salt Marsh, Algae, and Seagrass Narratives.



Within the lagoon, exchange of nutrients and organisms is facilitated because marsh, tideflat, and aquatic habitats are close together. Water is shallow and connects these habitats and associated organisms, therefore, not much energy is lost in transfer of nutrients and organisms. For example, kingfishers often fly short distances and capture schooling fish in the lagoon as they feed on amphipods. The amphipods may be grazing on detritus settling on the tideflat after having been washed from the marsh as the tide recedes. Likewise, young salmon which retreat to the creek channel at low tide move out over the rest of the lagoon and into the marsh to feed on insects and other invertebrates produced in the creek, marsh, eelgrass beds, or algal mats.

The almost continuous band of salt marsh which rims many lagoons also facilitates exchange of nutrients and organisms. There is an extended marsh/mudflat and marsh/water edge created by the rim of marsh. This increases surface area over which exchange can take place and increases the value of the salt marsh for fish, birds, and mammals. Nutrients, detritus, and small organisms are washed into the lagoon at this marsh edge and larger animals feed all along the lagoon's shoreline. Fish and waterfowl can swim to marsh plants at high tide, while shorebirds move out to the marsh/mudflat interface as tides recede and from there to the more open tideflats. Sessile organisms, such as oysters, benefit from this rim of marsh when nutrients and detritus are washed over them in the lagoon basin. Organisms outside the lagoon receive products of lagoon primary and secondary production as tides drain the lagoon at low tide through the creek channel. Many of these creek and offshore organisms also migrate into the lagoon to feed.

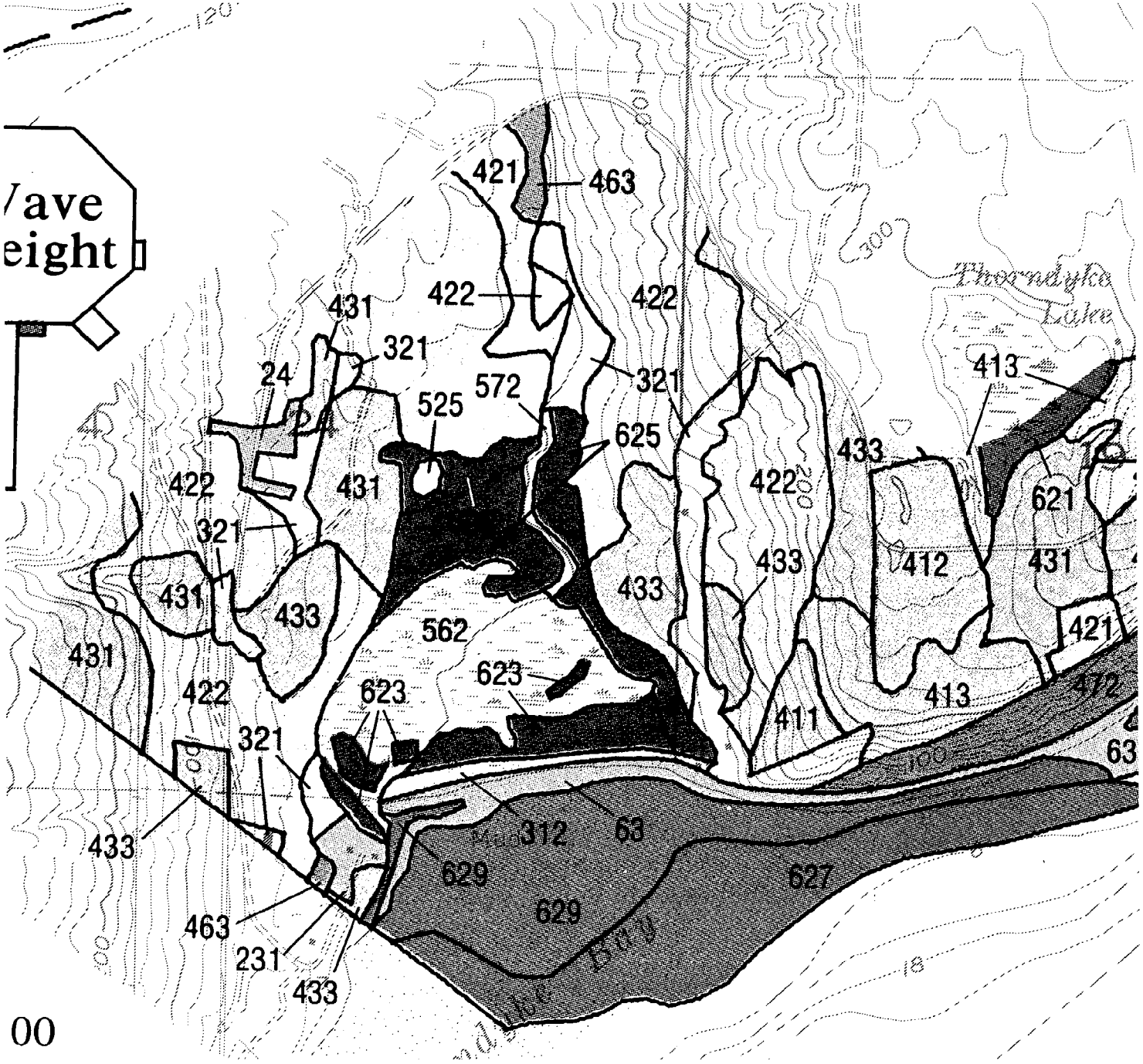
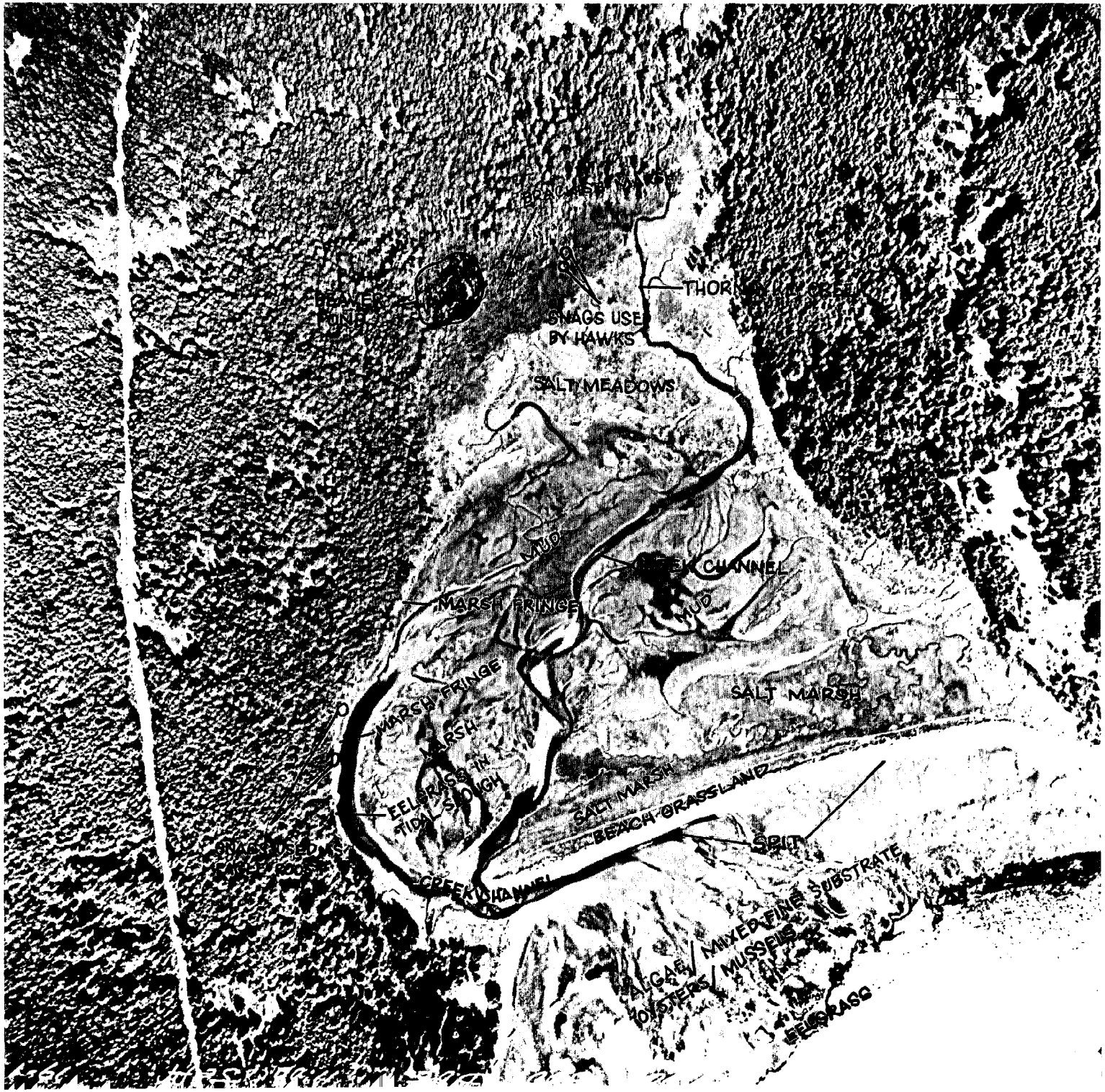


Fig.56-1a

Classes:

24	Abandoned Agriculture
312	Beach Grassland
321	Successional Shrub
331	Riparian Shrub
411	Conifer - Regeneration
413	Conifer - 2nd Growth
421	Broadleaf - Young
422	Broadleaf - Mature
431	Mixed Forest - Immature
433	Mixed - 2nd Growth
462	Riparian - Broadleaf
463	Riparian - Mixed Forest
525	Beaver Pond
562	Open Lagoon
623	Salt Marsh
625	Salt Meadow
627	Eelgrass
629	Other Algal Community
63	Beach Substrate


SNAGS USED BY HAWKS
SALT MEADOWS
MUD
MARSH FRINGE
MUD
MARSH FRINGE
SALT MARSH
SALT MARSH
BEACH-GRASSLAND
SPIT
EELGRASS IN TIDAL SLOUGH
CREEK CHANNEL
ALGAE
OYSTERS
MUSSELS
MIXED FINE SUBSTRATE
EELGRASS

Characteristic Plants and Animals

Lagoons are quiet refuges for a variety of wildlife, and the many associated cover types provide an abundance of food and other habitat requirements. Characteristic species will be representative of those cover types and are discussed in separate narratives. The following are additional examples of use of lagoons by wildlife:

Plants

Lagoon vegetation varies considerably as suggested in discussions of creation and succession. Intertidal vegetation may include a variety of algae, predominately greens such as sea lettuce and enteromorpha. Eelgrass occurs in creek channels, sloughs, and may be extensive in areas which do not drain completely at low tide. Marsh plants range from those tolerant of salt water inundation to those more representative of freshwater marshes or streambanks. This transition occurs from adjacent upland vegetation to the water's edge and along stream drainages entering the lagoon.

Fish and Invertebrates

Fish and invertebrates inhabiting lagoons and other estuarine areas include some of our most valuable marine species. Oysters occur in several lagoons and are harvested commercially where water quality permits. Clams, crabs, and a variety of amphipods, polychaete worms and other invertebrates also occur. Sediments, salinity, and tidal activity strongly influence species present.

Fish are primarily transient inhabitants of the lagoon and include several marine species which move into shallow waters to feed or spawn. Migrating salmon and other anadromous fish also occur in the lagoon as they more to or from freshwater. A study of the transient fish at Big Beef Lagoon on Hood Canal revealed that in general, numbers and species present were highest when temperatures and salinities were at or near their seasonal high. Highest numbers for the year occurred during the summer months. The most abundant species where shiner perch, surf smelt and pile perch. Table 56-1 lists species noted to occur in the Big Beef Lagoon in approximate order of abundance in decreasing order.

Birds and Mammals

Both aquatic and terrestrial species occur, and many are transient. Waterfowl are especially abundant and lagoons throughout the coastal zone are critical links in the migration route of many ducks as they pass through Washington. Some waterfowl also overwinter in lagoons and breeding, primarily by Mallards, also takes place in the sheltered lagoon environment. Table 56-2 lists birds and mammals which have been observed at the Thorndyke Bay Lagoon depicted in Figure 56-1. Many will occur at other open and enclosed lagoons with extensive marsh and open water. Shorebirds are especially more abundant where tideflats become available for feeding at

TABLE 56-1

FISH OF BIG BEEF LAGOON, HOOD CANAL (Kitsap County)

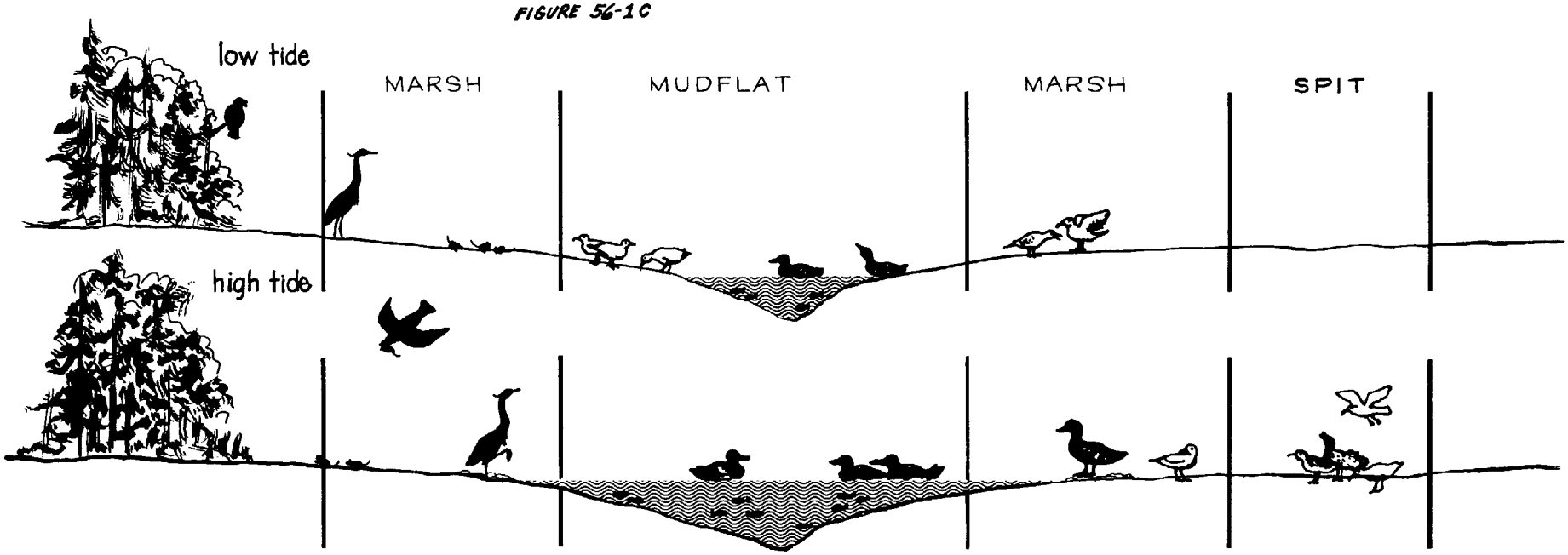
Common Name	Scientific Name	Spawn in Big Beef Creek
Shiner perch	Cymatogaster aggregata	
Surf perch	Hypomesus pretiosus	
Pile perch	Rhacochilus vacca	
Plainfin midshipman	Porichthys notatus	
Chum salmon	Oncorhynchus keta	■
Coho salmon	O. kisutch	■
Chinook salmon	O. tshawytscha	■
Steelhead (Rainbow trout)	Salmo clarki	■
Staghorn sculpin	Leptocottus armatus	■
Pacific lamprey	Entosphenus tridentatus	
Three-spine stickleback	Gasterosteus aculeatus	
Starry flounder	Platichthys stellatus	
Pacific herring	Clupea harengus	
Striped seaperch	Embiotoca lateralis	
Saddleback gunnel	Pholis ornata	
Pacific cod	Gadus macrocephalus	
Northern anchovy	Engraulis mordax	
Pacific tomcod	Microgadus proximus	
English sole	Parophrys vetulus	
Spiny dogfish	Squalus acanthias	
Bay pipefish	Syngnathus griseolineatus	

Table 56-2

BIRDS AND MAMMALS OF THORNDYKE BAY LAGOON,
HOOD CANAL (Jefferson County)

Species	Lagoon Habitat
Birds	
Common Loon	Creek channel at outlet
Horned Grebe	Creek channel at outlet
Canada Goose	Creek, marsh, sloughs, open water
Brant	Spit
Snow Goose	Marsh, open water
Mallard	Throughout
Pintail	Throughout
American Wigeon	Throughout
Green-winged Teal	Throughout
Wood Duck	Upper creek channel
Common Goldeneye	Creek channel and open water
Bufflehead	Creek channel and open water
Hooded Merganser	Creek channel and open water
Marsh Hawk	Marsh
Red-tailed Hawk	Marsh
Bald Eagle	Throughout, roosts on spit and nests in adjacent woodland
Osprey	Over open water
Merlin	Over marsh and tideflats
Great Blue Heron	Throughout
Killdeer	Tideflats, marsh, spit
Spotted Sandpiper	Creek channel and marsh edge
Greater Yellowlegs	Tideflats, marsh
Dunlin	Tideflats, marsh
Dowitcher sp.	Tideflats, marsh
Western Sandpiper	Tideflats, marsh
Common Snipe	Marsh
Glaucous-winged Gull	Tideflats, spit, open water
California Gull	Tideflats, spit, open water
Mew Gull	Tideflats, spit, open water
Bonaparte's Gull	Tideflats, spit, open water
Common Tern	Tideflats, spit, open water
Kingfisher	Spit, creek channel, open water
Barn Swallow	Over marsh, tideflats, open water
Violet-green Swallow	Over marsh, tideflats, open water
Tree Swallow	Over marsh, tideflats, open water
Common Crow	Throughout
Western Bluebird	Marsh
Long-billed Marsh Wren	Marsh
Red-winged Blackbird	Marsh
Savannah Sparrow	Marsh
Song Sparrow	Marsh
Mammals	
Townsend's vole (*Microtus townsendii*)	Marsh
Muskrat (*Ondatra zibethica*)	Marsh, creek channel
Mink (*Mustela vison*)	Creek channel, marsh edge
River otter (*Lutra canadensis*)	Spit, open water, creek channel
Raccoon (*Procyon lotor*)	Spit, tideflat, marsh
Blacktail deer (*Odocoileus hemionus*)	Marsh, tideflats

FIGURE 56-1C



low tide and occurrence varies considerably between open and enclosed lagoons. Suitable rest sites and nesting or escape areas adjacent to the lagoon will also affect species occurrence.

Commercial and Recreational Values

Lagoons are used by a signficant number of migratory waterfowl, shorebirds, and other species which have considerable recreational value. Many lagoons have been preserved by private hunting clubs, which also preserves the lagoon for other recreational uses throughout the year.

Salmonids and, to some extent, commercially and recreationally valuable flounders also occur in lagoons. Young salmon and cutthroat trout may feed in the estuarine waters of the lagoon for extended periods, while spawning adults typically pass through quickly. However, chum salmon spawning may occur very near the mouth of the stream entering the lagoon. Carcasses of spawned adults then drift into the lagoon where Bald Eagles and other birds enjoyed by wildlife watchers consume the fish.

Some lagoons, particularly in southern Puget Sound, are used for oyster culture and those with gravel in substrates have harvestable littleneck and butter clam populations. The edible, and potentially commercially harvestable sea lettuce and enteromorpha also may be present. Muddy lagoons often have soft shell clams and ghost shrimp, both of which are potential commercial and recreational species.

III. IMPACTS

Some lagoons reflect planning which has maintained water quality for oysters, salmon, and clam production and other natural features. Marshes, streams, and adjacent woodlands have been preserved as valuable and integral parts of the lagoon system in which waterfowl, hunting, eagles, bird watching, oysters, and oyster culture have persisted in these lagoons.

Other areas reflect biological and economic losses which occur when lagoons are altered. Marinas and housing developments are primarily responsible for impacts within lagoons and associated cover types. Dredging for marina construction reduces or eliminates tideflat, eelgrass, and marsh habitat used by waterfowl, shorebirds, and fish. Marina and housing wastes such as oil products and sewage intensify water quality problems which are especially sensitive in naturally warm waters of the protected lagoon. Large amounts of decaying organic matter occur in undisturbed lagoons and additions of sewage may reduce dissolved oxygen levels and increase coliform bacteria levels. Some lagoons are presently so polluted that oysters and other

shellfish from them cannot be sold commerically because of the danger of hepatitis. Refer to Impacts section in the Mud Narrative (No. 638) for more information related to disturbances within lagoon intertidal communities.

Housing or other developments adjacent to lagoons or on spits disturb wildlife using the area. People and domestic animals displace birds in the lagoon, and mammals such as deer which might also frequent the area. If vegetation is cut to the edge of lagoons or fill is deposited, nutrients contributed by the plants are lost. Habitat is also lost for edge species which are dependent on the land-water interface such as Bald Eagles, Belted Kingfishers, raccoons and Great Blue Herons.

Development along streams entering lagoons can also impact oysters, fish, and other organisms within the lagoon. Removal of riparian vegetation may increase sediment rates and smother oysters. Sewage and other pollutants entering the stream are also transported downstream and can severely alter the lagoon environment as noted by oyster producers in southern Puget Sound who have expressed concern over upstream sewage discharge.

Salmon culture occurs at the head of some lagoons where water quality is important in the hatchery and for survival for juvenile salmon entering saltwater via the lagoon. Natural spawning salmonids and outstream migrants pass through lagoons throughout the coastal zone. Stream and lagoon water quality and the presence of unaltered marsh and other lagoon is essential for those fish and many other wildlife.

References

Colombo, G. 1977. Lagoons. In: The Coastline (R.S.K. Barnes, ed.). John Wiley and Sons: 63-81.

Also refer to the following narratives for associated covertypes:

Riparian No. 33
Bays and Estuaries No. 54
Salt Marsh No. 623
Seagrass No. 627
Other Algal Community No. 629
Beach Substrates No. 63
Spit No. 74

SLOUGH (No. 57)

I. INTRODUCTION

Sloughs occurring throughout the coastal zone enhance wetland habitat. This classification includes blind channels along streams and narrow marine inlets. These channels often result from abandoned stream channels which unlike oxbow lakes and coastal ponds, have not been isolated from adjacent water masses.

Freshwater Sloughs (No. 571) and Marine Sloughs (No. 572) are both discussed in this narrative because of their similarities. The two classes of sloughs differ in terms of salinity, but are structurally alike.

II. SIGNIFICANT BIOLOGICAL FEATURES

Freshwater Sloughs (No. 571)

Freshwater sloughs are stream inlets which receive backup water from the main channel. They are similar to standing water habitats, but maintain a more open connection with the parent stream. Additional information about slough associated habitats is found in the Riparian (No. 33) and River and Stream (No. 51) Narratives.

Marginal vegetation of freshwater sloughs is similar to that occurring at pond and creek margins. Marginal plant species include willows, red alder, black cottonwood, red-osier dogwood, and currants (Ribes divaricatum and Ribes bracteosum). Emergent vegetation occurring in freshwater sloughs include cattails, slough sedge, small-hermit bulrush, and touch-me-not.

Sloughs offer a quiet water refuge for stream animals and furbearers and, therefore, are frequented by wildlife species preferring still waters. They offer an advantage over ponds to some wildlife species because of the open connection with moving streams. Fish such as coho salmon which use sloughs for feeding, use nearby streams for spawning and as refuges while young.

Marine Sloughs (No. 572)

Marine sloughs are narrow inlets typically forming on river deltas, which receive tidal back-up water and some fresh water runoff. Marine sloughs are often interrelated with salt marsh habitat and are characterized by brackish and salt water organisms. Additional information about the relationship of salt marsh and marine slough ecology is discussed in the Salt Marsh Narrative (No. 623).

Plants and animals which require salt or brackish water conditions and mud substrates, but cannot withstand heavy tidal action, survive in these still water areas. Lyngby's sedge commonly forms a band along slough margins. Other species occurring along margins include seacoast bulrush, pickleweed, and arrow grass. Characteristic vegetation occurring in brackish areas is wigeon grass. In shallow, brackish areas, plants include lilaeopsis, low clubrush, shore buttercup, and hardstem bulrush.

Characteristic invertebrates occurring in marine sloughs include hairy shore crabs, the amphipod Corophium salmonis, Harpacticoid copepods and insect adults, larvae and pupae. Fish species which use marine sloughs are starry flounder, threespine stickleback, Pacific staghorn sculpins, juvenile chum, chinook, and coho salmon. Shiner perch use deep marine sloughs.

Many furbearers, such as raccoons, river otter, and mink, use sloughs as feeding areas; raccoons forage along the shore for hairy shore crabs. Shorebirds feed in these areas and use marginal vegetation for cover and nest sites.

Slough Productivity

Sloughs contribute to the productivity of an area by diversifying available habitat and providing stable systems for plants and animals to inhabit. Sloughs have a high shoreline to volume ratio and thus are greatly affected by detritus and nutrients derived from terrestrial systems. Freshwater sloughs are especially important in the production of waterfowl, furbearers, and salmon that move into marshes to feed at high tide.

Marine sloughs, when occurring at salt marshes, are part of a highly productive ecosystem. Detritus and nutrients from salt marsh vegetation contribute to the existence of many aquatic and terrestrial plants and animals associated with marine sloughs.

Commercial Benefits

Marine sloughs are important feeding areas for commercial fish species. Fish using Skagit Bay sloughs include juvenile chum, chinook, and pink salmon and juvenile starry flounder.

III. IMPACTS

Sloughs have been used for centuries as areas for trapping furbearers. Many beaver, otter, muskrat, and mink are still trapped along Washington's sloughs each year. Sloughs have been, as have much of our wetlands, adversely effected by encroaching development. Perhaps because of small size or nondramatic landscapes, modern man has paid little notice to sloughs as they have been filled in or destroyed by sedimentation, diking, and removal of bank vegetation. Small sloughs with limited water movement are particularly sensitive to pollution. Impacts on sloughs are very similar to those on rivers and streams. For detailed information on these impacts, refer to the River and Stream Narrative (No. 51).

Sedimentation

Construction, agriculture, logging, and urban activities can contribute to sedimentation of sloughs. Sedimentation can affect sloughs in the same manner it affects small streams (see the River and Stream Narrative). Sedimentation affects water quality by increasing turbidity, decreasing dissolved oxygen levels and can block connections of slough and stream, preventing fish passage.

Tidegates

Many marine sloughs have been altered by tidegates which prohibit exchange of waters with the marine environment. Salt marsh flora and fauna occurring in sloughs and along their margins are affected by tidegates. Tidegates may reduce the feeding value of sloughs for several species and they may block passage into productive feeding areas. More mobile organisms are not affected by them; ducks can fly over them and otters can go around the barriers.

The use of tidegates has created many freshwater sloughs, particularly on agricultural land, where historically, the entire area was salt marsh and the sloughs were marine.

Removal of Cover

Sloughs typically have limited water movement and, as such, are vulnerable to intense warming by increased solar radiation. Bank vegetation is important in the maintenance of proper water temperatures for fish and aquatic invertebrates. Removal of bank vegetation can result in water temperatures which can reduce wildlife productivity and survival and increase susceptibility of wildlife to disease. Vegetation removal may also decrease dissolved oxygen concentrations of the water. Refer to the Riparian (No. 33) and River and Stream (No. 51) Narratives for more information on the value of cover to aquatic habitats.

Logging and Agriculture

Logging and agricultural activities of massive land clearing can result in increased water runoff from the land. Increased runoff can flood usually stable slough environments and disrupt associated flora and fauna.

Fertilizers, herbicides, and insecticides can affect sloughs in direct line of their runoff. The typically still waters of sloughs have a tendency to become eutrophic and additional nutrients from fertilizers could have stong impacts. Herbicides and insecticides may remain in the still waters due to a lack of exchange between slough and stream and could have locally lethal effects to plants and animals.

Freshwater and marine sloughs are important parts of coastal wetlands. They are integral parts of riparian and often salt marsh habitats and are valuable to many wildlife species. Sedimentation and filling-in of sloughs should be prevented as should removal of cover vegetation. Buffer zones of vegetation around these areas would greatly reduce sedimentation and the filling in of sloughs, and the lethal temperature and oxygen effects vegetation removal has upon the system.

CANAL AND CHANNELS (No. 58)

Canals and channels include those waterways created and maintained by dredging. Examples of these waters include the Swinomish Channel in Skagit County and navigation channels near Everett in Snohomish County. These areas are used primarily for boating activities.

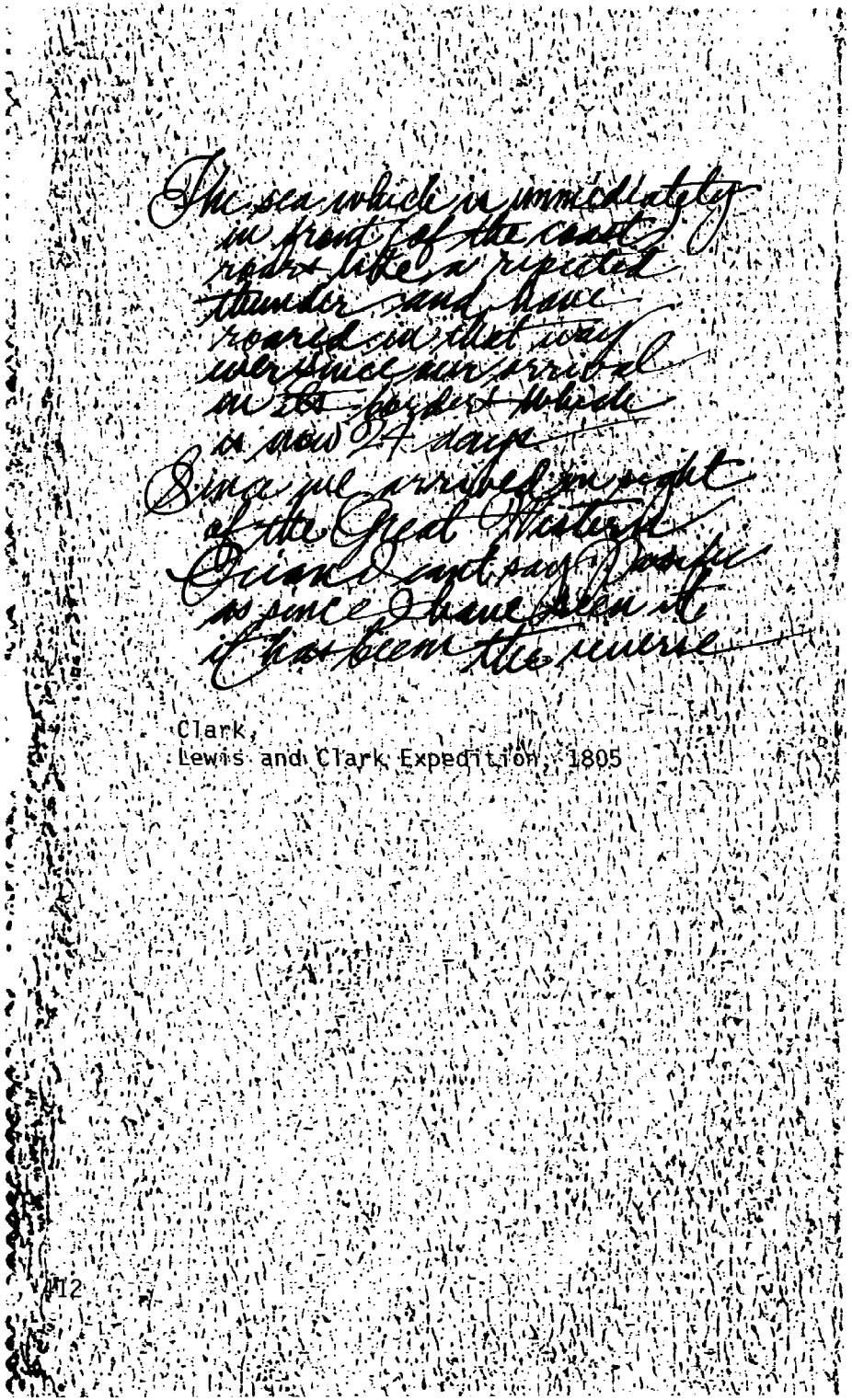
Undisturbed portions of canals and channels resemble sloughs and similar wildlife use them. However, channels provide more open water for resting waterfowl than do sloughs. The Swinomish Channel is similar to a marine slough and its flora includes Lyngby's sedge and seaside bulrush. Eelgrass and algae are found in the Swinomish Channel in shallow areas where dredging does not occur and are important in supporting crabs, fish, and birds.

Edges of channels are valuable salmon feeding areas. Flounder, sole, and Dungeness crabs also use channels and canals.

Canal and channel invertebrates and aquatic flora are frequently disrupted by recurrent maintenance dredging of the waterways. Dredged channels have fewer invertebrates than non-dredged channels. Dredging destroys vegetation directly by mechanical removal and indirectly by increasing turbidity which affects plant productivity. Dredging also produces unstable sediment conditions which reduces the ability of vegetation to become established.

Boating activities have an adverse effect on channel ecology. Boats can disrupt resting waterfowl and can tear rooted vegetation. Propwash, especially of larger boats, can be a significant disrupting factor for vegetation and benthic invertebrates. Pollution in channel water is concentrated due to limited water circulation within these areas. Oil and gas from boats and sewage are collected in channels and do not readily disperse.

Portions of channels can be enhanced for wildlife use. These areas can be managed for wildlife by restricting boat use in shallow isolated areas. Cessation of dredging in areas not used by boats will also encourage the development of more stable invertebrate and plant populations, thus encouraging channel use by other wildlife.



Clark,
Lewis and Clark Expedition, 1805

OPEN WATER (No. 59)

I. INTRODUCTION

All marine waters not classified as protected bay and estuary or lagoon are considered open water. Land areas near open water are subject to greater marine influence than when adjacent to protected embayments. Larger unprotected portions of Puget Sound and the Strait of Juan de Fuca are examples of these coastal waters. Open waters of the exposed outer coast extend into the Pacific beyond the continental shelf, while inland open waters are relatively protected and contained within many straits, inlets, and passages. The open ocean is a unique environment, inhabited by several species which rarely or never enter the coastal zone east of Cape Flattery. Many outer coast species do occur throughout the coastal zone, however, they are primarily those which feed nearer to shore.

Open waters are used as commercial and sports fishing grounds and are routes used by industry for shipping. Ferries and pleasure boats also use these areas regularly. Open water is also the major route for movements of large marine mammals occurring in Washington waters. Gray, humpback, and minke whales are among these mammals which share our coastal open waters. Porpoises, seabirds, sea lions, and an abundance of fish also inhabit this region.

II. SIGNIFICANT BIOLOGICAL FEATURES

A. Community Structure

1. Physical Structure

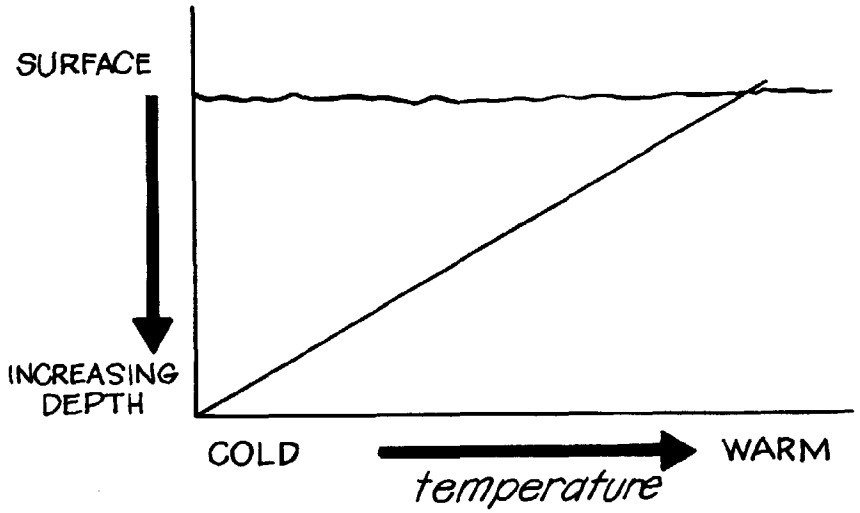
Depth and geomorphology have great influence on marine community structure. Puget Sound having large areas of open water is also characterized by channels and inlets. It occupies 767 square nautical miles within a basin which covers 11,000 square nautical miles. The center section of the sound is 600 to 700 feet deep and has a flat bottom of soft mud and sand. The slopes of the Sound are composed of poorly graded, heterogeneous glacial till of mud, sand, gravel and hard compacted clay.

Temperature, salinity, and depth are chief barriers to free movement of marine organisms. Open water organisms are usually stenohaline (having a narrow range of salinity tolerances) while inshore brackish water organisms are euryhaline (having a wide range of salinity tolerances). Ocean waters and Puget Sound are similar in salinity and share many similar species.

The average salinity of ocean sea water is 35 parts per thousand while that of Puget Sound, which shows little variation with time and depth, is 30 parts per thousand. In open water communities, organisms associate with water masses displaying certain hydrographic conditions rather than particular localities. Movement of water masses can carry a given community of organisms or parts of it great distances.

2. Tides and Currents

Circulation of open waters brings dissolved oxygen to deeper waters and the dissolved nutrients of deep waters up to the euphotic zone (area of photosynthesis). Tides, currents, and upwellings all contribute to the mixing of waters and the distribution of oxygen and nutrients. Considerable exchange of nutrients and organisms also takes place between nearshore environments and open water. Circulation processes are responsible for much of this exchange.



MARINE WATER THERMOCLINE

figure 59-1

Marine waters exhibit thermoclines although not as steep as in large bodies of freshwater (Fig. 59-1). At our temperate latitudes, marine surface layers are warmed during summer and are mixed by winds and small convection currents set up by evaporation and cooling. Thus, surface waters are fairly homogeneous (evenly mixed). In winter cooled surface waters are limited in depth by permanently colder deeper waters which remain on the bottom. Thus marine waters do not have a complete spring and autumn turnover of water and nutrients except in very shallow areas, such as in bays and portions of Puget Sound, where there is no permanent deep cold water layer.

Sources of vertical circulation include offshore winds, ocean currents and Langmuir circulation. Offshore winds which blow surface waters away from the shore cause upwelling of subsurface waters near shore. Major ocean currents sweeping over edges of continental shelves which parallel the general curve of the shore, create upwellings along their shoreline side and cause eddies and general turbulence over the shelf.

Langmuir circulation is caused by winds blowing steadily over the water surface which set up parallel zones of alternating divergence and convergence of water. Dissolved and particulate organic matter and planktonic organisms which concentrate in these mixing areas are eaten by small animals which attract concentrations of fish and marine birds and mammals. Langmuir circulation also concentrates dissolved organic substances onto larger particles making some dissolved organic matter available to detritus and filter feeders.

Tidal action varies considerably within the coastal zone. For example, Puget Sound tides show a progressive increase in range from Admiralty Inlet to the inner regions. Seattle has mean and diurnal tidal ranges of 8.2 feet (2.5 meters) and 11.5 feet (3.5 meters), respectively. Admiralty Inlet, Tacoma Narrows, and Deception Pass have high tidal currents up to five knots and exhibit strong turbulence. Tidal currents of open water on the Sound are usually less than one knot.

freshwater influence on circulation patterns

River discharge contributes to the circulation patterns of Puget Sound. The circulation pattern caused by runoff results in net seaward outflow of brackish surface water and net inflow of denser, more saline water at greater depths. The greatest freshwater input to the Sound is from the rivers along its northeast shore. In spring and summer, this freshwater runoff is derived mostly from melting snow, not rainfall. The principal basins of Puget Sound exhibit some stratification which is primarily due to the salinity differences of the brackish surface water and the deep saline oceanic water.

3. Photic Zones

Open water communities can be divided into zones based on light penetration (photic zones), (see Figure 59-2). The euphotic zone (or epipelagic zone) extends from the shoreline and consists of approximately the upper 330 feet (100 meters) of water that receive enough sunlight for effective photosynthesis.

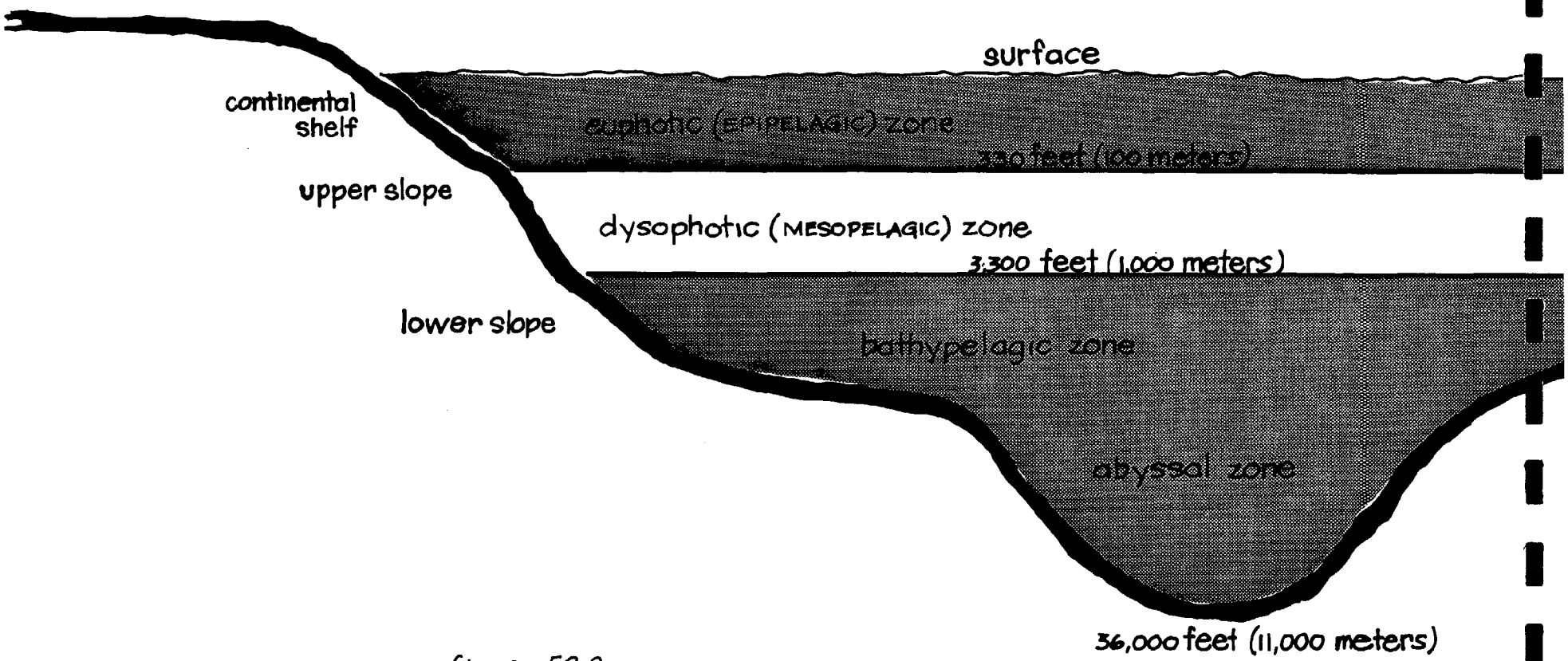

surface
continental shelf
euphotic (EPIPELAGIC) zone
330 feet (100 meters)
upper slope
dysophotic (MESOPELAGIC) zone
3,300 feet (1,000 meters)
lower slope
bathypelagic zone
abyssal zone
36,000 feet (11,000 meters)

figure 59-2

In turbid coastal waters this area may be as shallow as 16 feet (five meters). This upper zone contains all of the primary marine producers, most of the consumers, and a large part of the decomposer population. The depth and community composition of the euphotic zone varies tidally, daily, seasonally, and regionally. Differences result from the amount of sunlight available, temperature, and turbidity.

The dysphotic (or mesopelagic) zone extends from the lower border of the euphotic zone down to approximately 3,300 feet (1,000 meters). There are no functional producers in this deep water zone because there is too little and/or too brief light penetration for effective photosynthesis. Many animals occur within the dysphotic zone as residents or daily and/or seasonal visitors.

The bathypelagic and abyssal zones receive no light and grade into one another extending to the deep sea floor beyond the continental shelf. No plants live in this region due to lack of sunlight. The animals in these areas must cope with intensely cold waters, higher salinity and immense hydrostatic pressure. They are dependent on organic matter produced in nearshore marsh and marine plant communities and in the euphotic zone further offshore.

Shallower areas such as Puget Sound and water above the continental shelf are called neritic waters. These nearshore zones are more productive than those of the open sea. Shallower open waters have greater mixing due to wave action and upwelling and derive many nutrients from terrestrial systems which enter open waters via rivers and streams. Kelp beds and other algae communities are prominent primary producers in the neritic zone. Eelgrass and other primary producers of more protected waters also significantly contribute to primary production, especially in our inland waters.

4. Nutrient Cycling

It is difficult to separate the topic of nutrient cycling from discussion of primary productivity. Much related information on open water nutrient cycling is in the Tides and Currents and Productivity and Producers sections of this narrative.

Many nutrients are leached from terrestrial habitats and are washed into marine waters by rivers and streams. Other minerals and nutrients enter open waters by the action of tides which erode the shoreline.

In contrast to freshwater systems, nitrogen in the form of nitrates is rarely a limiting factor to primary productivity in open waters such as Puget Sound. The supply of nitrate is rarely and then only briefly, exhausted in the Sound. The estuarine water circulation pattern in Puget Sound causes an intensive upward transport of nitrates and other essential nutrients which are in high demand during phytoplankton blooms. The same circulation pattern resupplies the euphotic zone with algal seed stock as phytoplankton is swept into more open waters by winds.

In open waters, vertical circulation brings dissolved oxygen to greater depths and dissolved plant nutrients to the euphotic zone. Deeper waters are usually richer in dissolved plant nutrients than surface waters and below the euphotic zone there is no plant growth to use the nutrients. Nutrients accumulate on the bottom as plant and animal bodies, feces, and detritus sink below the euphotic zone into deeper water. Areas of extensive mixing of surface and deeper water results in high productivity in open waters when these accumulations are brought to the surface.

In very shallow areas of open waters where vegetation can be rooted into the substrate, the plants act as nutrient pumps. As discussed in the Bay/Estuary Narrative (No. 54), much of the stock of nutrients occurs within sediments. Seagrasses and other plants retrieve these nutrients with their roots and incorporate them, boosting primary productivity rates.

5. Trophic Levels

productivity and producers

Primary production in open water on a unit area basis is of the same order of magnitude or slightly less as that on land. Because the oceans cover more area, it is estimated that total productivity of oceans is more than two to three times as much as terrestrial productivity.

Open water producers include plankton and larger seaweeds. These planktonic primary producers are the most important producers in offshore waters, while benthic algae and other marine plants are major producers in nearshore open waters. Phytoplankton occurs in vast numbers throughout the upper 330 feet (100 meters) of all oceans except portions of the Arctic and Antarctic which are permanently covered with ice. These producers comprise a mass of plant life greater than all of that found on land.

Producing phytoplankton is restricted in depth by the lower level of the euphotic zone (the light compensation level) where photosynthesis and respiration rates balance one another. The precise depth of the light compensation level varies for each

species with turbidity, amount of incident light, and species specific factors.

In shallower, nearshore waters seaweeds occur as part of the marine producer community. Green algae (Phylum Chlorophyta), brown algae (Phaeophyta) and red algae (Rhodophyta) attach to rock or other beach substrates in shallow water. Refer to the Kelp (No. 628), Other Algal Communities (No. 629), and Beach Substrate (No. 63) Narratives for more detailed discussions of these primary producers.

consumers

Marine consumers fill many extremely diverse ecological niches. Life forms include zooplankton, benthic animals (living on or in bottom substrate), nekton (organisms swimming actively in water, such as fish and zooplankton), and neuston (organisms floating or swimming in surface water). The majority of consumers occur in the euphotic zone of open water, but many also are found in deeper water. Species composition of a given nearshore area can often be related to substrate type. Discussions of species associated with beach substrate types are found in the Beach Substrate Narrative (No. 63).

Pelagic fish have unique behavioral patterns. Some bottom fish, such as ling cod, lay eggs on the bottom and guard them, but most marine fish lay large numbers of eggs which receive no parental attention. Unattended eggs and juveniles are extremely vulnerable to predation; large numbers of eggs are produced partially in response to this predation.

Many marine fishes, such as herring, sand lance, anchovy, smelt, and candlefish, travel in schools, a behavioral adaption which tends to protect them in open water. Some fish migrate seasonally, such as flounders which move between shallow and deep water. In general, juveniles use nearshore waters as nursery areas (e.g., English sole) and deep waters are frequented by adults. Some species do, however, complete their entire life cycle in deep, offshore waters. Vertical movement usually occurs at night in response to upward movement of prey species.

Anadromous species, such as salmon, migrate from rivers and streams through estuaries to the ocean and return to freshwater at maturity. Other migrations occur when eggs and larvae drift in currents as zooplankton until the fish return to their adult

habitat. The kelp greenling is an example of a fish which undergoes age related migration. Juveniles occur offshore and eventually move nearshore where rocky shores and kelp beds are preferred adult habitat.

benthic organisms

Benthic organisms can be classified as epifauna and infauna. Epifauna are animals living on top of the bottom surface that are either attached or freely moving on it. This faunal group is maximumly developed in intertidal areas but extends throughout the ocean bottom.

Infaunal organisms dig into marine substrates or construct tubes or burrows. This group is more fully developed in subtidal zones. Infaunal animals have definite preferences for substrate grain size or texture. Filter feeders predominate on sand substrate while deposit feeders dominate silt or mud substrates.

The majority of benthic species occur in the upper, oxidized layers of sediments. Animals found in oxidized sediments include polychaetes, bivalves, harpacticoid copepods, turbellarian flatworms, and nematodes. The oxidized sediment layer is thin in muddy bottoms. If the water is oxygen depleted, the oxygen reduced zone extends to the substrate surface and into the bottom waters.

Sediments below the oxidized surface layer are oxygen reduced and have large concentrations of sulfide. Anaerobic bacteria, such as sulfate reducers and methane bacteria, anaerobic protozoa and nematodes occur in this zone. Clams often occur in the anaerobic zone although they receive oxygen and food from oxidized regions via burrows.

Detritivores subsist on the sinking organic detritus primarily from the eutrophic zone. Animals in the abyssal region of deep seas are especially dependent on the organic matter from more productive regions. Bacteria are important sediment community members. As detritus feeders, some bacteria obtain most of their energy from other bacteria associated with the ingested detritus.

6. Characteristic Wildlife

Fish and invertebrate species listed for open waters above specific substrate types are found in the Beach Substrate Narratives, Numbers 631 through 638. A few of the characteristic fish of open waters in Washington (most of which are discussed in other narratives) include coho, chum, chinook, pink, and sockeye salmon, steelhead, juvenile kelp greenling, Pacific cod, sablefish (black cod), dogfish, halibut, China rockfish, sand lance, Pacific herring, candlefish, smelt, and northern anchovy. More detailed accounts of several of these species are included in the following discussions.

invertebrates

Ocean Pink Shrimp ■

This Pandalid shrimp is an important coastal commercial species. Adult shrimp occur from up to 20 miles offshore, ranging from off the south end of Willapa Bay to Cape Johnson. They are also harvested in Hood Canal and in Puget Sound from Vashon Island south and around Possession Sound and Saratoga Passage. They are often marketed locally as Hood Canal Shrimp.

Ocean pink shrimp are an open water species, however, juveniles and adults occur on the bottom during the day on a variety of substrates from 25 to 200 fathoms deep. The larval stage, which lasts two to three months, is planktonic. Shrimp primarily eat euphausiids and copepods which also make daily vertical migrations within the water column. Food eaten while on the bottom includes detritus.

Geoduck ■

This clam is the largest in Washington waters, usually weighing six pounds; they have been reported to weigh as much as 20 pounds. They are abundant in Puget Sound, the Strait of Juan de Fuca, Whidbey Basin, Admiralty Inlet, and Hood Canal. Geoducks are commonly dug in subtidal areas. They apparently do not occur along the outer coast and coastal bays and are scarce in northern Puget Sound.

The geoduck lives in sandy mud of the lower intertidal and subtidally in protected open water and bays and estuaries. Other bottom types used include sand, pebble-gravel, mixed fine, silt, and mixed coarse. During its larval state, it is planktonic for approximately one month.

fish

Coho Salmon ■

Coho salmon are one of the most numerous salmon in Washington. They spawn in large rivers and small streams and the young usually remain in freshwater for a year before migrating to the sea. Coho are also reared in hatcheries at several locations in Washington. Coho salmon remain in salt water for approximately one and one-half years, from the spring of their second year to November of their third year of life. Outmigrating juveniles remain in estuaries for 30 to 120 days before migrating to open water several hundreds of miles from spawning streams. The salmon occurs over all substrate types.

Juvenile coho salmon eat herring larvae, sand lance, kelp greenling, rockfish, eulachon, insects, crustaceans, and the larvae of copepods, amphipods, barnacles and crab. Adult prey includes lantern fish, sauries, herring, sand lance, squid, and euphausiids.

Coho salmon are an important commercial and sport fish in Washington. They are caught commercially by trolling, purse seining, and gillnetting. Coho (or "Silvers") are also a favorite of recreational fishermen and compose 60 percent of the Northwest's salmon sport catch.

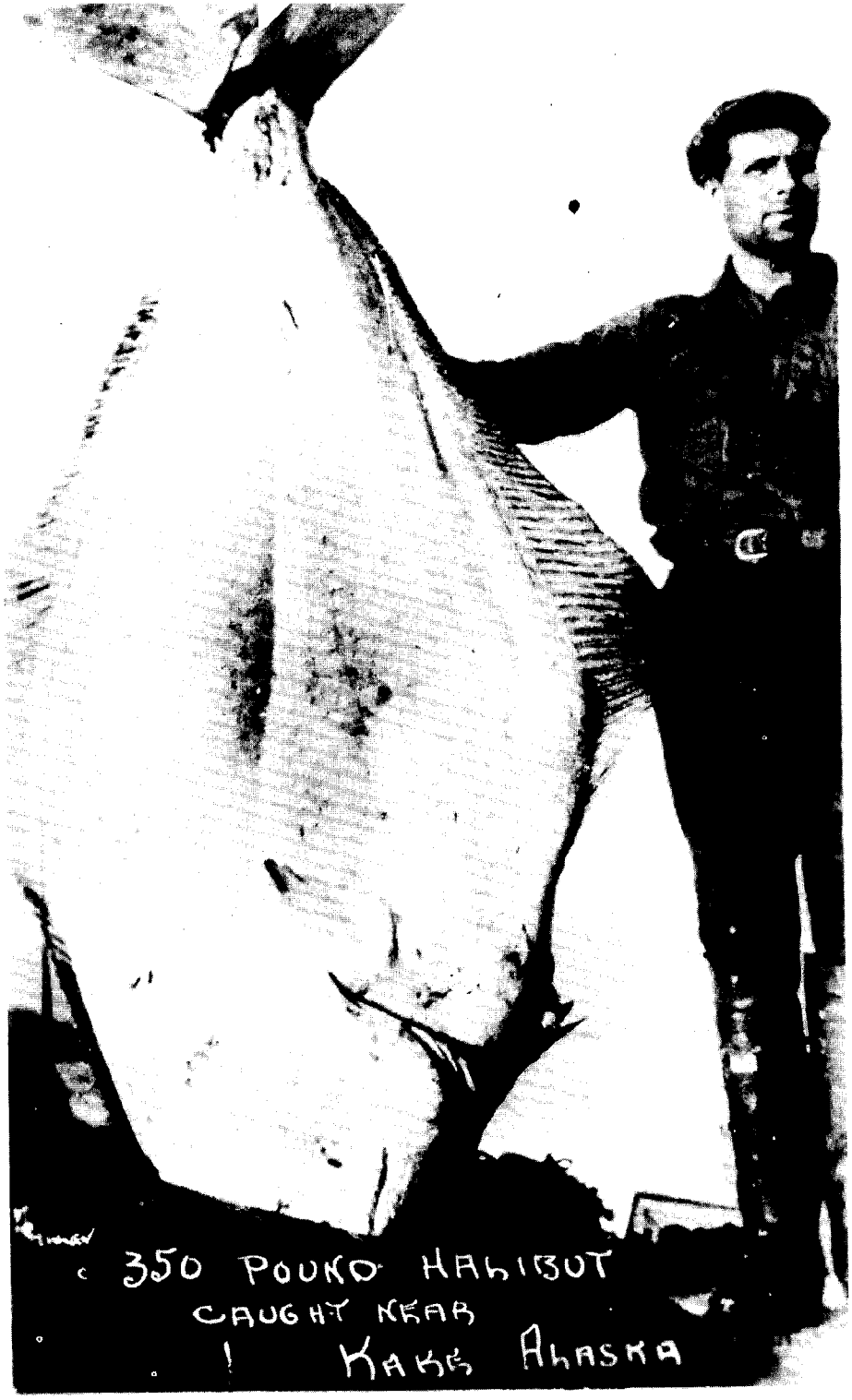
Pacific Halibut ■

This flatfish occurs primarily in open water; both juveniles and adults are bottom associated. Pacific halibut can live over 35 years and females which mature on the average at 12 years can produce two to three million eggs annually.

Halibut spawn at 150 to 225 fathoms of water in winter. The eggs and larvae are pelagic and concentrate between 55 and 109 fathoms. Young fish (three to five months) use shallower water (55 fathoms) and become established in sand and mixed fine bottom communities by six or seven months of age. They move to deeper water with age and after five or seven years are available for offshore commercial fisheries at depths of 10 to 150 fathoms. Their food consists of fish, crab, clams, squids, zooplankton, worms, and other invertebrates.

Halibut are reported in coastal bays, throughout the Strait of Juan de Fuca, and along the outer coast. They rarely come into Washington's inland waters farther than the eastern parts of the Strait of Juan de Fuca and Admiralty Inlet. Old timers do recall, however, having caught halibut in Hood Canal.

Pacific halibut have been an important food fish since the Pacific Northwest Indians first developed a special hook for catching the eight to nine foot long fish. Today, it is an extremely important commercial, and an uncommon, but highly prized, sports fish.

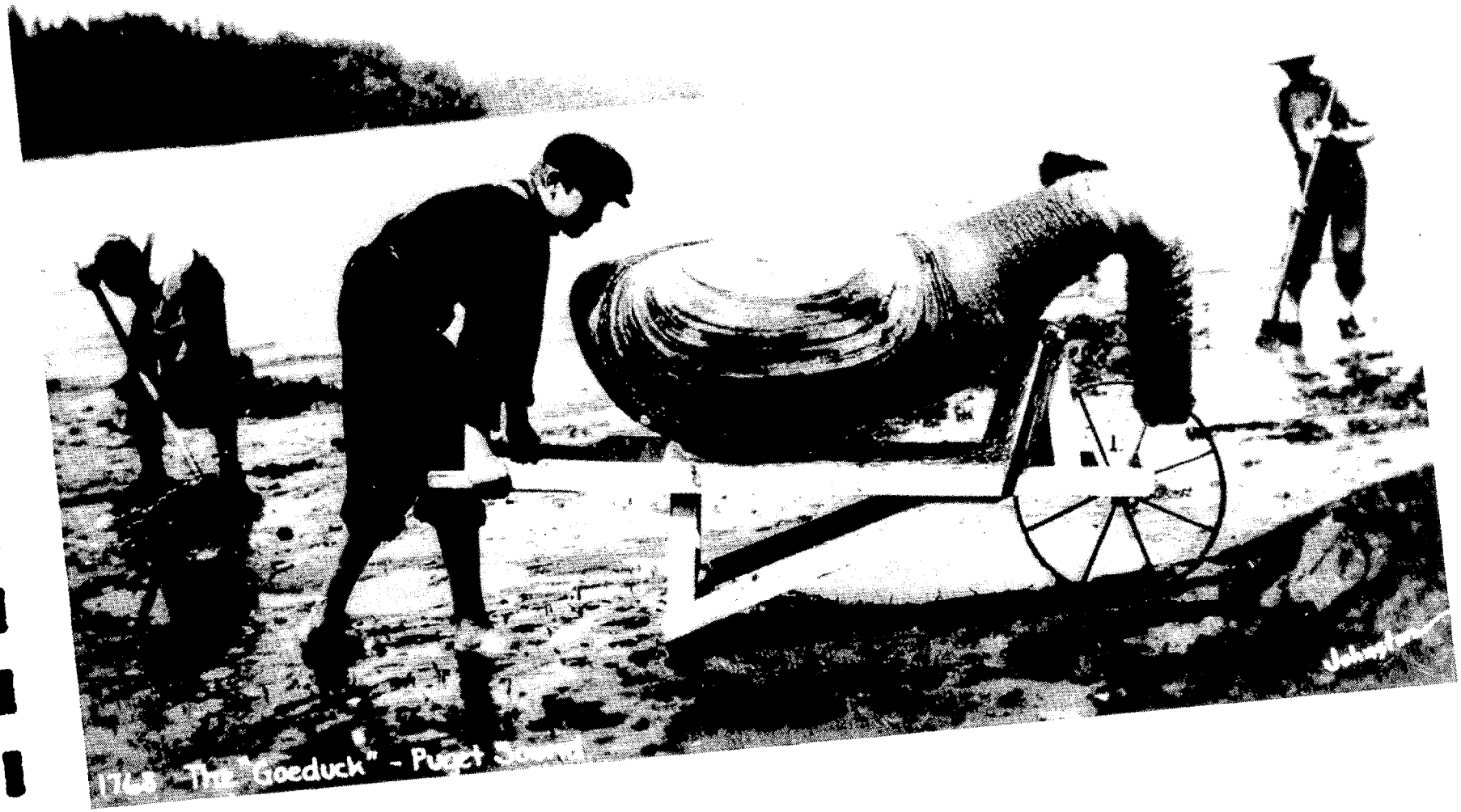

350 POUND HALIBUT
CAUGHT NEAR
KAKE ALASKA

July 16, 1938

Dear Dad,

Haven't seen one this big yet but they say there are lots of them around here, what would you do if you got that on your line? Vern was out again for a couple of days but is home again now, we have such close neighbors I'm not afraid at night so get along fine. Sister

Mr. Edward Drake
Route 2, Box 1094
Bremerton, Wash.


1768 - The "Goeduck" - Puget

Sablefish (Black Cod)

This deep water fish uses open water and is associated with clay, silt, or sand bottom most of its life. Sablefish can live at least 20 years and spawn at four or five years of age. They spawn during the winter months and eggs are pelagic, occurring throughout the water column. Fry are also pelagic, and are surface oriented. Adults, mostly bottom oriented, make vertical migrations to the surface at night where they eat saury, blue lanternfish, crustaceans, worms, and small fishes.

Sablefish occur in different marine areas seasonally and according to life stage. Young occur in shallower coastal waters and move into deep water with age. They are abundant in shallow waters in spring and summer and use deep water in winter. Shallow waters used include the Straits of Georgia and Juan de Fuca and Puget Sound. The main Washington fishing grounds in late summer and fall are located between Destruction Island and Barclay Sound, Vancouver Island. Sablefish are a highly valued commercial species in the United States and Canada where they are marketed as black cod.

birds

Marine birds have been discussed in many of the narratives. The species list in the Beach Substrate Narrative (No. 63) is relevant for many birds which occur in open waters. Open waters are used for foraging, resting, and as a place to escape from disturbances.

Characteristic birds of open waters include several species regarded as pelagic. They rarely come ashore other than to lay eggs and raise young and all feed on or near the water's surface. Among this group are the Northern Fulmar, Sooty Shearwater, Black-footed Albatross, Arctic Tern, and Pomarine Jaeger. These birds primarily occur offshore, out of sight of land and most are rare on inland waters. Other than a recent observation of a small colony of Arctic Terns, none of these species nest in Washington. Pelagic birds are attracted to the rich feeding grounds over the continental shelf during nonbreeding seasons, and many nest great distances from our coast. Millions of birds migrate hundreds or even thousands of miles over the open ocean. Shearwaters are especially numerous and are one of the more common of this group to be seen nearer to shore. Sooty Shearwaters are occasionally observed in flocks of several thousand birds along the outer coast and may be observed from the jetties at Westport and Ilwaco and occasionally from Point Roberts in Whatcom County and other inland locations.

Other marine birds which are regarded as pelagic include the Fork-tailed and Leach's Storm-petrel. Both these species feed offshore and breeding sites include islands off our outer coast. Inland waters are occasionally frequented.

Open water birds common in non-oceanic areas include those which regularly feed throughout the coast in nearshore zones within sight of land as well as further offshore in the Pacific. Some of these birds are surface feeders; others dive for fish, squid, and other nektonic prey. Some birds, gulls, for example, also feed and rest on shore. Several of these open water species nest in Washington and include Glaucous-winged Gulls, Western Gulls, California Gulls, Common Murres, Cassin's Auklets, Rhinoceros Auklets, and Tufted Puffins. Those which do not nest locally include Northern Phalaropes, Parasitic Jaegers, Herring Gulls, Common Terns, and Ancient Murrelets.

Nearshore open waters provide habitat for numerous birds which may frequent more protected bays and estuaries. Many of these species, especially those which feed primarily in the intertidal, are discussed in more detail in appropriate beach substrate narratives. A wide variety of feeding strategies are exhibited within this group which is represented by all but the strictly pelagic species of Washington's marine birds. Nearshore, bottom dwelling prey are captured by diving birds such as Surf Scoters, or those which can forage on or along the edge of the beach, such as Great Blue Herons.

Birds which feed on free-swimming prey or other organisms not restricted to the intertidal may occur in open waters at variable distances from the shoreline. This group of marine birds rarely forages in oceanic waters beyond sight of land. Several more pelagic species may intermingle with these birds, and a number of species discussed above, such as Rhinocerous Auklets and Common Terns, are included. As mentioned earlier, however, auklets and terns also forage further offshore. Species using free swimming prey typically feed in the deeper waters of bays and estuaries which overlap or are similar to open water habitats. This group includes Arctic Loons, Western Grebes, Pelagic Cormorants, Bonaparte's Gulls, and Marbled Murrelets.

Offshore open water areas, particularly inland waters, are used by many other birds which feed elsewhere and swim or fly out to rest. Flocks of waterfowl, gulls, and grebes may be encountered as resting birds. The variety of bird use of open water is illustrated in Figure 59-3 and representative species are discussed below.

Black-footed Albatross ■

This fantastic bird soars with a seven-foot wing span over the open waters of the Pacific Ocean. It has been fabled by mariners that if an albatross is killed, bad luck befalls the ship of the killer. The albatross occurs in the offshore zone beyond sight of land in areas of prey and nutrient rich upwellings that also attract

petrels, auklets, gulls, shearwaters, and whales. Albatrosses often follow fishing boats for scraps of fish thrown overboard. The Black-footed Albatross is the only albatross now found regularly off Washington's Pacific Coast. These birds breed in colonies on sandy areas of islands in the central and western Pacific, particularly in the northwest chain of the Hawaiian Islands. Other albatrosses which occur off our coast include the Laysan Albatross and the rare Short-tailed Albatross which is thought to be near extinction.

Bonaparte's Gull ■

This graceful , small gull occurs on fresh and salt waters in western Washington and is a common winter resident and migrant. It occurs on open water nearshore where it is often seen resting on kelp beds. They are also common offshore, typically in large flocks. They feed on herring and are often observed picking small prey items from the water's surface in open waters.

Parasitic Jaeger ■

This spring and fall migrant occurs along the outer coast and inland marine waters. It often relentlessly follows gulls and terns, forcing them to give up their food. Parasitic Jaegers are frequently seen in Grays Harbor, among the San Juan Islands, and in the Strait of Juan de Fuca.

Northern Phalarope ■

This phalarope is a spring and fall migrant along Washington's outer coast, the Strait of Juan de Fuca, and Puget Sound. They travel in large migrating flocks containing up to several thousand birds. Phalaropes are unusual in that they are shorebirds which prefer to swim rather than wade. They feed by spinning on the water surface to concentrate plankton and marine invertebrates which they pick out with their needlelike bills. Phalaropes also capture insects in flight. Unlike most birds, the female phalarope has colorful courtship plummage and leads courtship activities; the male has drab plummage and incubates the eggs and raises the young.

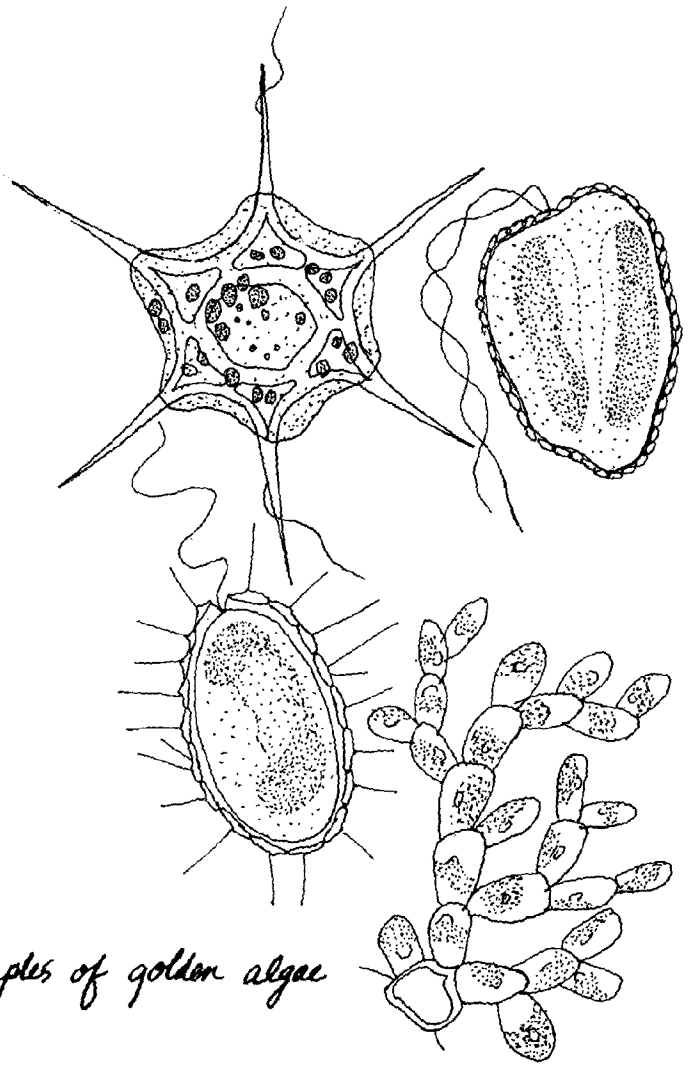
Habitat Partitioning of the Marine Environment

The marine environment is divided into many different habitats by seasonal and daily times of use, feeding strategies, food selection, area used, and by many other means. The distribution of many marine animals is also dependent on variable distribution of plankton.

Phytoplankton populations are characteristically dynamic and everchanging.
Amount of light, nutrients, and the
local aquatic environment work together to produce different seasonal vertical population distributions. In early spring when nutrients are abundant in surface water, some phytoplankton accumulate near the surface because of good nutrition and a low sinking rate. In summer, nutrients are depleted at the surface, the cellular sinking rate increases, and phytoplankton accumulates near the bottom of the euphotic zone. Better nutrition and darkness revives the cells and retards their sinking below the level of light compensation. The rate of chlorophyll synthesis increases at lower light intensities, deterring phytoplankton from sinking to deeper depths.

Phytoplankton have many other adaptations to prevent sinking into waters below the euphotic zone. Some plankton have flotation bristles or vacuoles containing less dense fluid or oil droplets. Other phytoplankton have expanded surface to volume ratios to maintain their depth positions. Dinoflagellates and other flagellates can swim to prevent sinking.

Neritic (shallow water) phytoplankton in temperate regions have a seasonal density cycle similar to phytoplankton occurring in eutrophic lakes. Marine phytoplankton blooms are dominated by a small number of species which are most favored by local



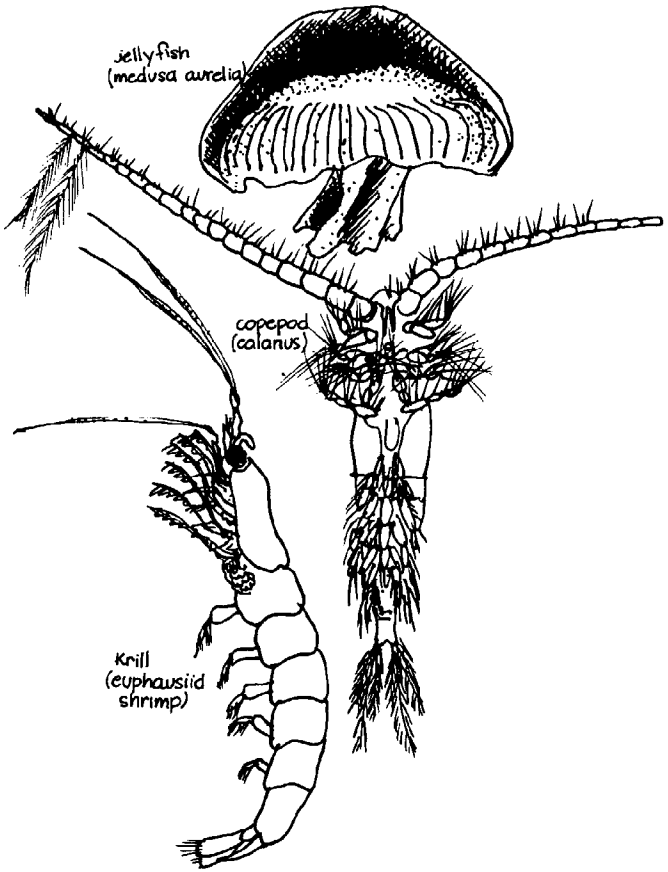
Examples of golden algae

conditions at the time. When the carrying capacity of a local open water area is approached, ecological succession begins and species diversity increases until a more stable equilibrium is reached.

The composition of zooplankton populations also changes seasonally. Holoplanktonic organisms are those completing their life cycle while drifting with the surrounding water. Other zooplankton which are larval stages of benthic and nektonic animals are called meroplankton. Meroplankton populations vary seasonally with the spawning habits of adults and specific life stage cycles of this type of zooplankton. Examples of zooplankton include copepods (including Calanus), larger crustaceans (including euphausiids), protozoa, molluscs, medusae stages of jellyfish, pelagic tunicates, free floating polychaete worms, and predaceous arrow worms.

Nekton and nueston consumers include large crustacea, fish, whales, seals, sea lions, porpoises, sea otters, and marine birds. The distribution of these active swimmers and surface dwellers is limited by barriers of temperature, salinity, nutrients, and bottom type.

Competition for food resources has often led to habitat partitioning. Many small marine fishes, such as herring, anchovies, sand lance, smelt, and candlefish, swim in large groups ("schools") partially as protection against predators. Larger fish, such as salmon, marine birds, and mammals feed on these schooling fishes and may even compete for these food resources. Salmon returning to fresh water via the Strait of Juan de Fuca in July and August feed on schools of herring and sand lance; during the same time period adult Rhinoceros Auklets eat herring and sand lance and feed them to their chicks. Because the size of salmon runs varies from year to year, the competition between fish and birds may also vary annually.



Marine birds divide what would appear a homogeneous open water environment into many habitats by a division of feeding zones, habits, and prey taken (Fig. 59-3). Rhinoceros Auklets and related seabirds catch their prey by swimming under water propelling themselves with their wings. Cormorants, loons, grebes, and diving ducks swim underwater using their feet.

Each species has a fairly restricted zone (according to depth and proximity to shore) in which it is best adapted and where they feed on prey populations. Some birds feed near shore where bottom organisms are primary prey while others in this group feed mostly in deep offshore waters. When food is especially abundant, all may join mixed foraging flocks in a feeding frenzy.

Terns hunt by plunging from the air using momentum gained to approach their prey at high speed. Albatrosses, gulls, fulmars, and phalaropes feed while settled on the water surface. Some birds which feed this way scavenge a variety of food items or seize prey swimming by. Fulmars strain zooplankton from water and also feed extensively on fish, fish offal, and carrion.

Other birds feed while flying and capture their prey at or near the water surface. Terns and small petrels feed by dipping into the water for small fish. Leach's and Fork-tailed Storm-Petrels feed by pattering along the surface using their feet and wings, permitting them to rapidly pick small prey items from the water. Gulls and terns skim along the surface while foraging. Their white colored ventral surface may be an adaptation for capturing fish near the surface. White objects contrast less with the sky than those which are darker, thus, they may be able to approach closer to prey than if they had dark undersides.

Some birds obtain food in flight by piracy or aerial pursuit. Parasitic Jaegers, Skuas, and many gulls force birds to disgorge or give up prey. Large gulls may pursue and capture small birds.

Birds also divide the marine habitat by time of day they feed. Adult Tufted Puffins feed themselves and their nestlings during the day and suffer gull piracy. Adult Rhinoceros Auklets also feed themselves during the day but avoid piracy on return trips to feed auklet nestlings by foraging for their young at night.

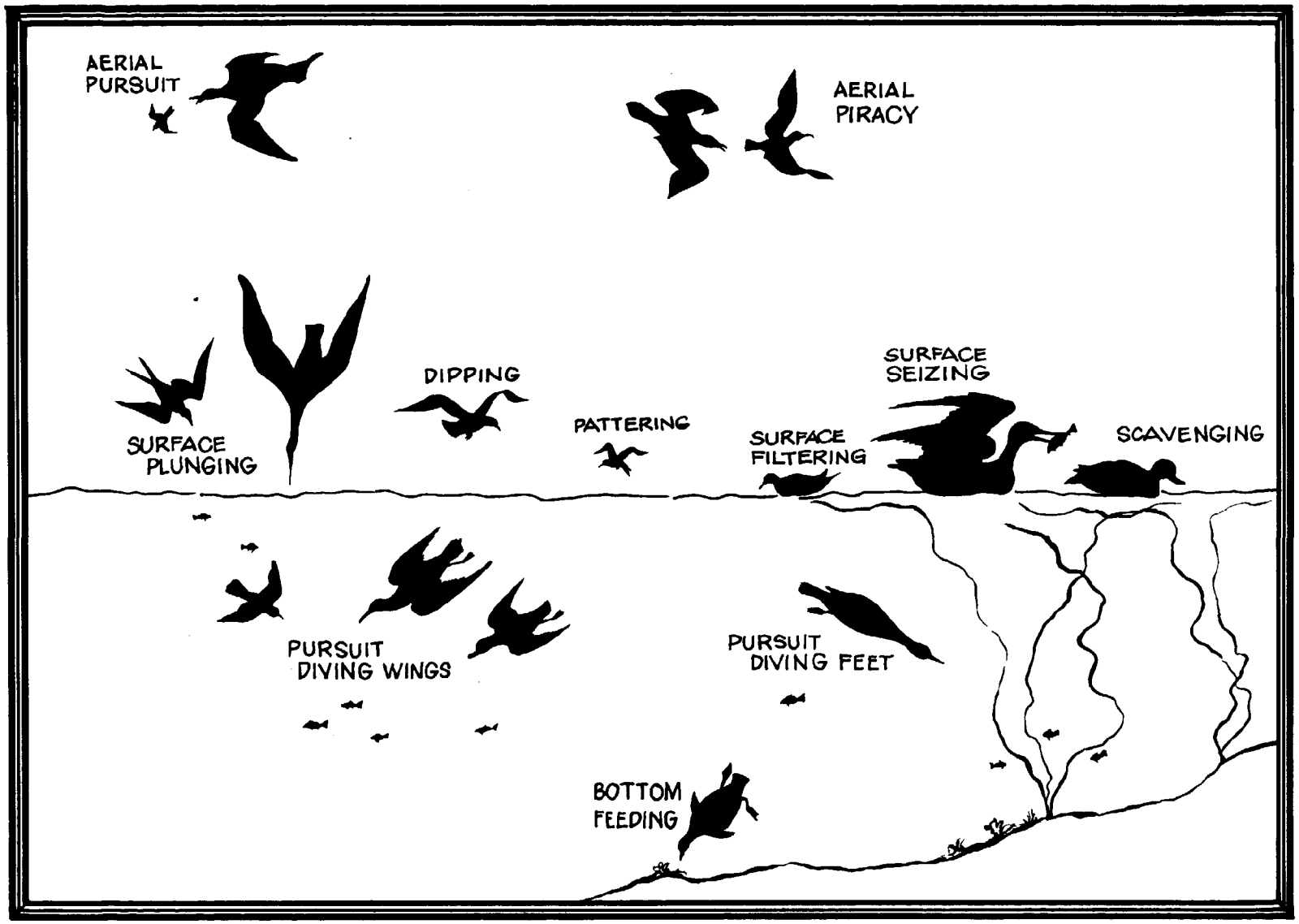

AERIAL
PURSUIT
AERIAL
PIRACY
SURFACE
PLUNGING
DIPPING
PATTERING
SURFACE
SEIZING
SURFACE
FILTERING
SCAVENGING
PURSUIT
DIVING WINGS
PURSUIT
DIVING FEET
BOTTOM
FEEDING

Figure 59-3

mammals

Mammals occurring in open waters of Washington include:

River otter (Lutra canadensis)
Sea otter (Enhydra lutris)
California sea lion (Zalophus californianus)
Northern sea lion (Eumetopias jubatus)
Northern fur seal (Callorhinus ursinus)
Harbor seal (Phoca vitulina)
Northern elephant seal (Mirounga angustirostris)
Gray whale (Eschrichtius robustus)
Minke whale (Balaenoptera acutorostrata)
Fin whale (Balaenoptera physalus)
Humpback whale (Megaptera novaeangliae)
Whitehead grampus (Grampus griseus)
Pacific white-side dolphin (Lagenorhynchus obliguidens)
Saddle back dolphin (Delphinus delphis)
False killer whale (Pseudorca crassidens)
Shortfin pilot whale (Globicephala macrorhynchus)
Killer whale (Orcinus orca)
Dall porpoise (Phocoenoides dalli)
Harbor porpoise (Phocoena phocoena)
Pygmy sperm whale (Kogia breviceps)
Goosebeak whale (Zipius cavirostris)
North Pacific giant bottlenose whale (Berardias bairdi)

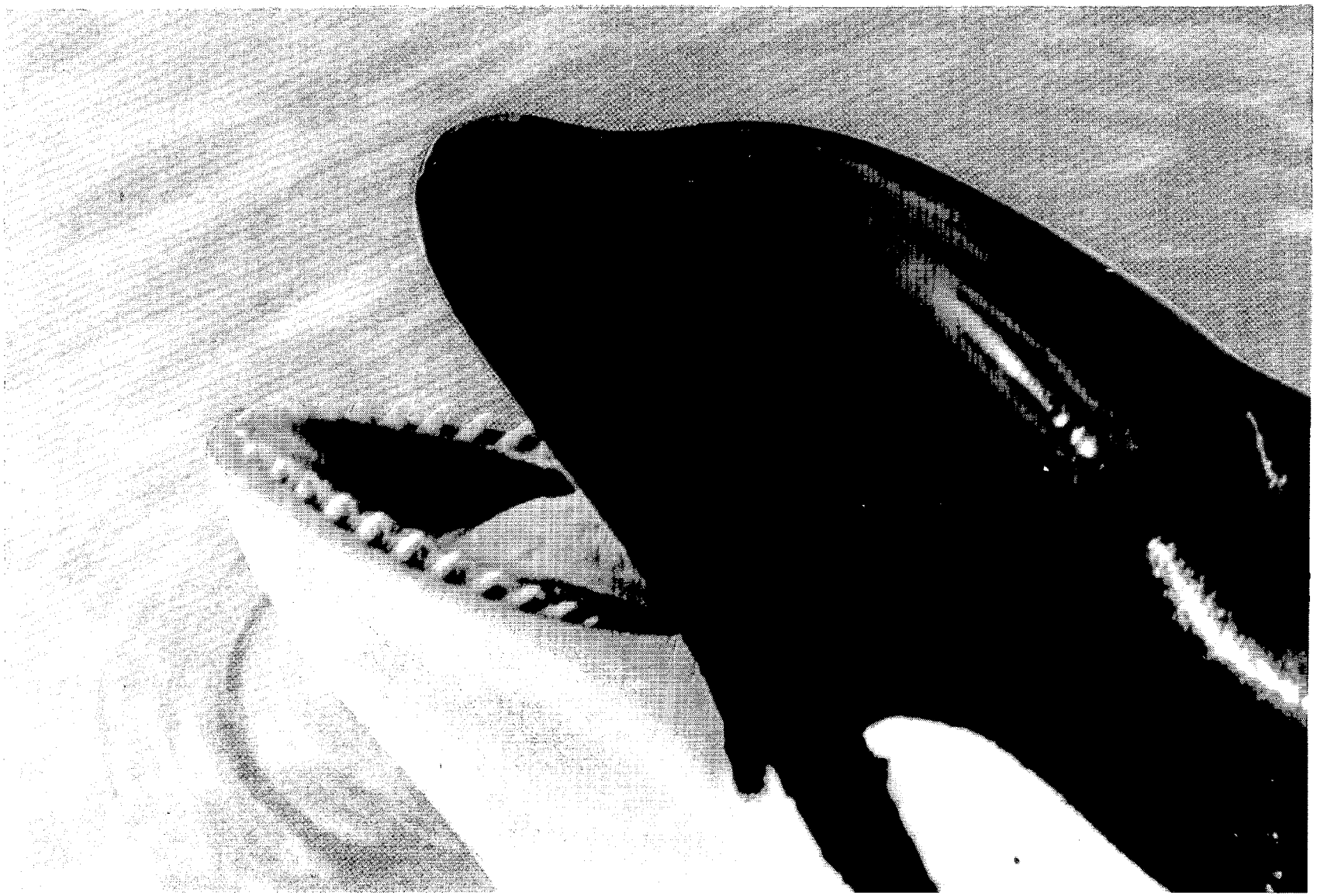
Many of the species have been discussed in the Kelp Narrative (No. 628) and the Beach Substrate Narrative (No. 63). Readers wanting more information are urged to consult the recent inventory of marine mammals published by the Marine Ecosystem Analysis Program (MESA) which is referred to at the end of this narrative. The report presents current information on Washington's marine mammals, including distribution, abundance, and ecological problems. The following are brief accounts of some of these species.

Northern (Steller) Sea Lion

Sea lions use open water for feeding and rock and mixed coarse habitats for breeding and hauling-out. They inhabit much of Washington's marine and estuarine waters, but primarily use those off the northern half of the outer coast and the Strait of Juan de Fuca. Rock and mixed coarse habitats are potential colony sites if they occur in isolated locations with some shelter, have free access to the sea and are free from human disturbance. Critical areas as defined in the Coastal Zone Atlas for the sea lion in Washington include:

Quillayute Needles rocky islets
Jagged Island
Split Rock
Spike Rock
Umatilla Reef
Rocks one mile off Ozette River mouth
Bodelteh Islands
Carroll Island
North side of Sucia Island
Tatoosh Island

Sea lions do not breed in Washington. They use our waters and islands for feeding and resting during the winter and some nonbreeding individuals remain during the summer. Adults may feed considerable distances from their hauling-out grounds. They often feed in pathways of major fish runs and can dive to depths of 60 to 100 fathoms. They eat many kinds of fish and cephalopods, but no commercially important fish have been shown to be a major food item.



Killer Whale

The killer whale has become widely known in recent years. This is partly due to them being kept in captivity. Local knowledge of whales in their own environment, however, has been largely stimulated by a research effort by the Moclips Cetological Society which is currently based on San Juan Island. This group's research and encouragement of public reports of whale observations through the "whale hotline" (observers phone in sightings of killer whales and other cetaceans) has provided much information concerning Puget Sound whales. Current information on killer whale populations in Washington waters is summarized in NOAA's 1979 report on marine mammals cited at the end of this narrative. Readers are urged to consult this document for information concerning killer whales and other marine mammals of Washington. The following information from the NOAA report is a summary of seasonal distribution and relative occurrence of killer whales in open waters throughout the year:

LOCATION					SEASON
Strait of Juan de Fuca (West)	(East)	Haro Strait	Rosario Strait	Protected Waters	
+	+	+	+	0	spring
+	+	+	+	0	summer
+	+	+	+	+	fall
0	0	+	0	0	winter

+ = greatest abundance 0 = killer whales present

Several other whales occur in Washington's open waters and abundance for most species begins to increase in spring to maximum numbers in summer (refer to Table 59-1). Haro Strait and the eastern half of the Strait of Juan de Fuca were noted in the marine mammal report as being important to nearly all species. Rosario Strait was noted as having whales present the year round.

The time of greatest vulnerability of whales to oil and other impacts is in late spring and summer when the greatest variety of species can occur in open waters. Breeding behavior is at a peak at this time and is an important period for early survival of young. Note that the Marine Mammal Protection Act of 1972 provides complete protection for whales in U.S. waters. Those species having asterisks in Table 59-1 are regarded as being endangered with extinction.

Table 59-1 Whales of the State of Washington[1]

**Species with asterisks are regarded as being endangered with extinction.

ODONTOCETI (Toothed Whales)	Comment[2]
North Pacific giant bottlenose whale (Berardius bairdi)	(A)
North Pacific beaked whale (Mesoplodon stejnegeri)	One record of a stranded individual in Clallam County in 1942.
Moore's beaked whale (M. carlhubbsii)	One record of an individual stranded at Grays Harbor.
Goosebeak whale (Ziphius cavirostris)	(A)
** Sperm whale (Physeter catodon)	Occurs primarily offshore, strandings have been reported in Grays Harbor County.
Pygmy sperm whale (Kogia breviceps)	(A)
Striped porpoise (Stenella coeruleoalba)	Primarily offshore.
Saddleback dolphin (Delphinus delphis)	(A)
Northern right-whale dolphin (Lissodelphis borealis)	Strandings reported from Westport to Copalis.
Pacific white-sided dolphin (Lagenorhynchus obliquidensi)	(R)
Killer whale (Orcinus orca)	(C)
Whitehead grampus (Grampus griseus)	(A)
False killer whale (Pseudorca crassidens)	(A)
Shortfin pilot whale (Globicephala macrorhynchus)	(R)
Harbor porpoise (Phocoena phocoena)	(C)
Dall's porpoise (Phocoenoides dalli)	(C)

Table 59-1 (Continued)

MYSTICETI (Baleen, or Whalebone Whales)	Comment[2]
** Gray whale (Eschrichtius robustus)	(C)
** Fin whale (Balaenoptera physalus)	(A)
** Sei whale (B. borealis)	Occurs along outer coast, in Grays Harbor and Willapa Bay.
Minke whale (B. acutorostrata)	(C)
** Blue whale (B. musculus)	Occurs offshore along outer coast.
** Humpback whale (Megaptera novaeangliae)	(R)
** Right whale (Eubalaena glacialis)	Rare in Washington waters - occurs offshore.

[1]Adapted from a checklist of Marine Mammals by Murray Johnson and Steven Jeffries of Puget Sound Museum of Natural History, Tacoma.

[2](A) = Reported as accidental in northern Puget Sound and Strait of Juan de Fuca by Everitt, et al., 1979 (cited at end of this narrative).

(C) = Reported as common in same

(R) = Reported as rare in same

Additional information on these species can be obtained from Everitt's report. Little information is available on most other species in Washington waters; refer also to report of Eaton, et al., cited at the end of this narrative.

B. Interrelationships with Other Habitats

Marine open waters are intimately interconnected with bay and estuarine waters and with shoreline habitats. Unprotected shorelines are strongly influenced by the wave and tidal actions of open waters that erode and reshape the terrestrial boundaries. The composition of plant and animal communities of the intertidal and shallow subtidal zones are largely determined by the degree of their exposure to open water. Marine waters receive many nutrients and minerals eroded and leached from the shoreline areas by wave action. Nutrients are also derived from shore plant communities through mineral transport and the decay of vegetation. The protected areas of bays and estuaries exchange waters with open water. They depend on tidal action to bring new salt water into the embayments and to flush away biological wastes and stale waters. Nutrients produced in excess of estuarine demands enter open water via tidal action. Thus areas of open water immediately adjacent to protected waters often have high nutrient concentrations and are biologically more productive.

Many fish which occur in estuaries at some stage of their life cycles also use open waters; the Pacific herring, many salmon and English sole live in estuaries before moving into open waters.

Open waters are also connected with rivers and streams by fish use. Candlefish and coho, chinook, chum, pink, and sockeye salmon and anadromous trout leave freshwater and and pass through estuaries to enter marine water. Where there are no estuaries, salmon directly enter the unprotected coastal waters. Salmon and trout remain in open water for one to four years, depending on species, before returning to freshwater to spawn.

Even inland terrestrial areas have an influence on marine waters. Nutrients from inland habitats are collected by rivers and streams which empty into coastal waters. These added nutrients boost productivity of marine areas near river mouths but may also transport contaminants from uplands.

It is important to remember that any given area of open water is ultimately connected with marine waters throughout the world. Management decisions for one area of Washington's open waters could eventually affect other marine areas of Washington and perhaps Oregon, British Columbia, and beyond. The massive proportions of marine waters does not alleviate the need for precautionary management.

C. Commercial/Recreational/Esthetic Benefits

The majority of commercial fisheries are based on species occurring in open water, although many spend a portion of their life in more protected waters. In 1974, the value of Washington's sea products were as follows in Table 59-2.

Table 59-2 Dollar Value of Washington's Sea Products, 1974.

SPECIES	# OF POUNDS	CASH VALUE (1974)	PROCESSED VALUE (1974)
salmon	45,920,844	$ 34,032,215	$ 63,010,903
bottom fish	38,081,474	4,628,526	7,313,071
halibut	1,105,159	858,618	1,785,925
other food fish & livers	42,325,386	9,093,173	26,370,200
oysters	4,018,925	4,660,853	22,139,050
shellfish	18,072,755	5,605,520	12,276,090
TOTALS	149,524,543	$ 58,878,905	$ 132,895,239

A large proportion of sea products come from the open waters of Puget Sound. The fishery production of the Sound is demonstrated in Table 59-3.

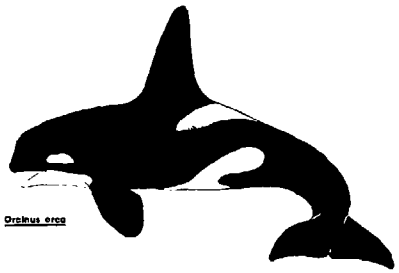
Table 59-3 Fishery Production of Puget Sound, 1974

SPECIES	# OF POUNDS	TOTAL VALUE TO FISHERMEN
salmon	32,493,222	$ 24,922,095
shellfish	5,474,398	3,006,107
cod	8,079,883	930,133
sole & flounder	7,502,024	1,036,946
rockfish & ocean perch	13,028,693	1,293,927
herring	12,139,035	1,569,741
albacore & tuna	3,037,573	1,072,970
halibut	1,101,407	856,408
miscellaneous	11,271,568	1,043,339
TOTAL	94,127,803	$ 35,731,666

Open waters provide many people with an extremely pleasant environment to view and to use. Many enjoy boating and fishing for esthetic as well as recreational reasons. Marine areas also offer wildlife watchers opportunities to view extremely unique marine mammals and birds. Gray whale migrations can be observed off the outer coast from several locations and killer whales have endeared themselves to many Washington residents. The sight and sound of whales is a thrill which is not likely to be forgotten and a very successful whale "hotline" keeps whale watchers and researchers in close contact. This public awareness and contribution has been a significant factor in improved knowledge of Washington marine mammal populations.

Marine birds of open waters are enjoyed from shore, but boaters often get a much closer look. Offshore trips from the outer coast yield views of albatrosses, shearwaters, and other pelagic species. Boating in more protected waters also provides exciting views of marine birds in open water and often allows close observation. Ferry routes cross Puget Sound, Hood Canal, Strait of Juan de Fuca, and thread through the San Juan Islands. These regularly scheduled boat trips provide excellent open water viewing and regular travelers will observe a seasonal change in bird populations. Whales, seals, and sea lions should also be looked for along the ferry route.

The Pacific Northwest is famous for its recreational fisheries. Sport fisheries contribute much money to the state economy by related activities and by attracting out-of-state visitors. Coho salmon are a favorite of open water sports fishermen. In 1974, an estimated 134,000 coho salmon were caught in inner Puget Sound and 227,839 cohos near Westport. The total coho salmon catch that year in Washington's salt water areas was approximately 756,000 fish.



Orcinus orca

ORCA SURVEY

THE ORCA SURVEY is an intensive study of KILLER WHALES in the Pacific Northwest waters. Biologists aboard the 'Saliena Pacifica' in conjunction with the National Marine Fisheries Service are photographing Orcas and following the movements of *recognizable individuals and/or groups.*

The study is purely scientific. Detailed examination of photographs will enable researchers to identify distinctive individuals. Information gathered will give *a clearer understanding of the natural* biology, social behavior, and population *dynamics of these animals.*

PUBLIC COOPERATION is vital to the success of the study. Researchers aboard the study vessel are prepared to respond instantly to sighting calls anywhere in Washington waters.

HAVE YOU SEEN ANY KILLER WHALES?
IF YOU SEE KILLER WHALES PLEASE CALL IN YOUR SIGHTING IMMEDIATELY.

WHALE HOTLINE

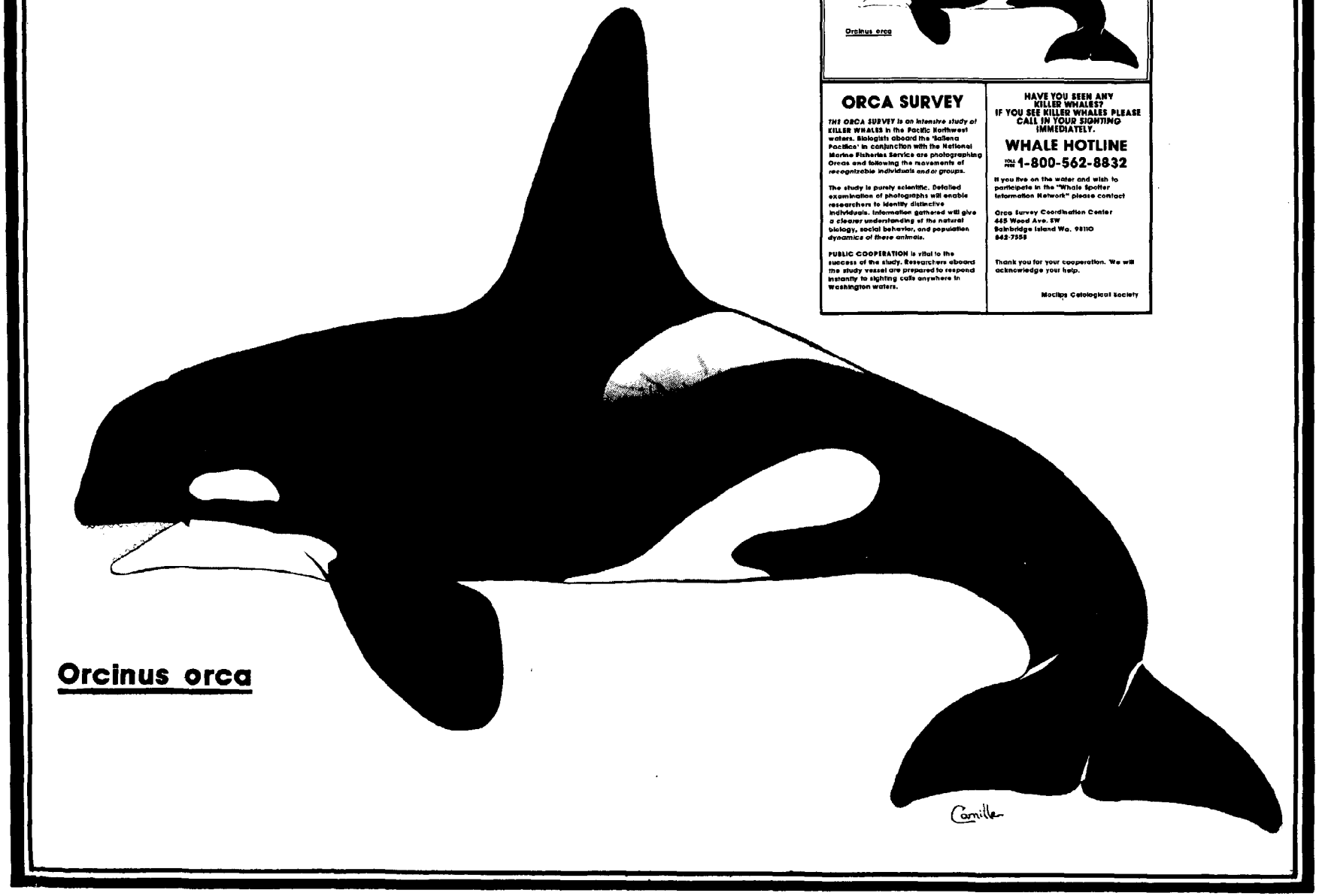
TOLL FREE **1-800-562-8832**

If you live on the water and wish to participate in the "Whale Spotter Information Network" please contact

Orca Survey Coordination Center
465 Wood Ave. SW
Bainbridge Island Wa. 98110
842-7558

Thank you for your cooperation. We will acknowledge your help.

Moclips Cetological Society



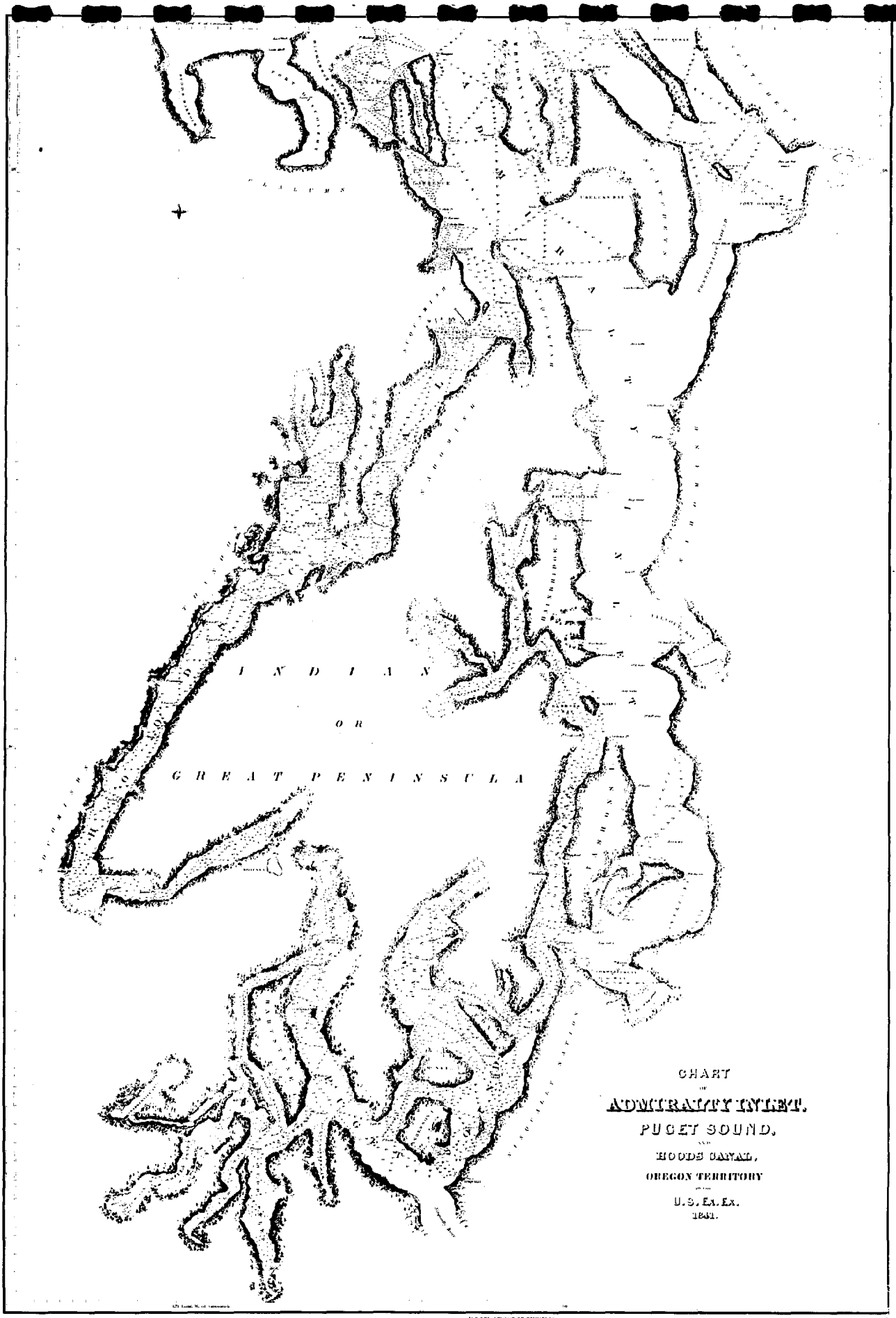


CHART
OF
ADMIRALTY INLET,
PUGET SOUND,
AND
HOODS CANAL,
OREGON TERRITORY
BY
U. S. Ex. Ex.
1841.

444

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL OCEAN SURVEY

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III. IMPACTS

History

"Thus by our joint efforts, we had completely explored every turning of this extensive inlet: and to commemorate Mr. Puget's exertions, the south extremity of it I named Puget's Sound."

Captain George Vancouver, 1792

Open waters have played a major role in the settlement of the Pacific Northwest. Long used for fishing and transportation by coastal Indians, marine waters brought European explorers and traders to Washington's coast. Captain Vancouver charted Northwestern waters for England's claims in the late 1700's.

Through the late 1700's and 1800's, Europeans and Russians hunted whales, sea otters, and other marine mammals in the Northwest's open waters. Whaling was historically a large but unmanaged industry and as such, severely depleted marine mammal populations. Humpback whales, one of the most commercially used species in Washington in the past, occurs only rarely in the State's waters today. The Humpback is considered an internationally rare and endangered species.

Europeans established trading posts for centers of bartering with the Indians for furs and food needed while travelling and eventually these posts became permanent settlements. In the late 1800's, many white settlers travelled cross-country by wagon train to reach the west coast, but the small cities to which they came were established mainly as marine based lumbering, fishing, and trade areas.

Modern Impacts

Marine water use has been expanded to encompass many activities this century. Man still uses ocean waters for discovery, but instead of new continents, we are exploring the sea itself. We are just beginning to understand how the marine ecosystem works and what additional riches it may hold. Marine waters are used for regular cargo shipping and ferry routes. Scientists are currently studying the possibilities and techniques for locally harvesting sea plants as food stuffs and harnessing wave and tidal energies for use by humans. A new perspective exists for new ways to use marine waters which represent a productive world for man to use and manage wisely.

Several impacts which affect open water also affect beach substrates, rock islands, sand, spits, and seagrass, kelp, and other algal communities and are discussed more fully in these narratives. The following are impacts which can negatively affect open waters.

1. Oil Spills

Oil spills, as discussed in the Rock Island Narrative, No. 713, are a major threat to marine life. Marine birds, such as auklets, murres, grebes, cormorants, and diving ducks, are highly susceptible to oil remaining on the water's surface. As they dive for food or even as they rest on the water, spilled oil collects on feathers, destroying their insulation. Such birds almost inevitably die from exposure of chilling air and water temperatures or from starvation due to their inability to fly with damaged feathers. Indirect bird mortalities from oil spills may occur from failure of foraging adults to return to awaiting young. Reproductive success may also be affected by adults accidentally rubbing traces of oil onto incubated eggs which destroys the eggs' ability to exchange air and waste gases.

Uncontained oil slicks can travel great distances before they disperse into globules. These globules eventually sink to the ocean bottom. It is of major importance that potentials for oil spills be prevented, especially near islands used by birds and marine mammals. Major shipping lanes and proposed oil terminals are currently near important marine bird nesting islands and thus are a threatening impact to these animals.

2. Boating

Pleasure boating is a valuable and enjoyable recreation for many people and is a valid use of open water when its disturbance to the ecosystem is minimal. Boating can have negative impacts when done on waters used by breeding marine birds and mammals. Waters surrounding nesting and breeding colonies are important feeding and nest areas for wildlife and should be avoided by water traffic. Harrassment by noise and physical displacement (chasing) must be prohibited. Boat propellers can also destroy vegetation by cutting or uprooting it. Oil, fuel spills, and waste disposal from boats also pose a threat to open waters. Travel in vegetated areas important to wildlife should be discouraged.

Washington's open waters are one of its most valuable natural resources. They are extremely important commercially and recreationally for fishing, boating, wildlife watching, and many other activities. Because we are just beginning to understand the marine ecosystem, we must be aware and cautious of any actions we take which may alter it. Perhaps one of the greatest assets of open water is its esthetic value where the tremendous power of rolling waves or that of a breeching whale are juxtaposed with the graceful diving of terns and Bonaparte's gulls while magnificent, prehistorically large albatrosses glide over the seas. The sea is perhaps one of the last of the world's ecosystems in which man, still truly a newcomer, can remain a dreamer.

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