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AN ABSTRACT OF THE THESIS OF Larry D. McCallum for the
Master of Science in Geography presented September 27, 1977.

Title: Netarts Bay, Oregon: An Assessment of Human Impact
on an Estuarine System

APPROVED BY MEMBERS OF THE THESIS COMMITTEE:

John O. Dart, Chairman

James G. Ashbaugh

Larry W. Price

Problems associated with planning the future use of
estuarine areas stem from:

- a) A lack of knowledge on the critical
aspects of the system.
- b) Inability to predict the future changes
which will occur within the system in
order to effectively manage the resource
base.

These difficulties lie in the fact that changes within the
system occur because of both "natural" and "cultural"
conditions. The thesis hypothesis and subsequent research is
to describe the physical changes that have occurred within
the Netarts system, primarily due to man's impact.

Types of data gathered for the analysis includes that on historical and current land use activities, current research findings on system characteristics, and independent research on shoreline changes and vegetation composition. Much of the historical data were taken from early manuscripts and publications. Current research data were obtained from several engineering studies of the bay, as well as a baseline study of Netarts funded by a grant from the National Science Foundation and Oregon State University. This study included an inventory of man's utilization of the resource base. Methods utilized in data analysis included aerial photo-interpretation, planimetric measurement of shoreline and vegetative alterations, and on-site inventory of current shoreline and vegetation changes.

Results of the research have shown that it is possible to measure and describe changes within the Netarts Bay system. Specific findings include:

- a) A decrease in sandspit volume of nine percent between 1942 and 1974 due to construction of a boat basin and fill.
- b) Occurrence of marsh progradation in all marsh areas with sedge and low sand type showing the greatest increases between 1939-62.
- c) A decrease in rate of marsh progradation from 1962-1974.
- d) A total decrease in tidal prism of the bay between 1957-1969 as measured by cross sectional areas. The

rate of decrease is occurring at a faster rate south of the mouth of Whiskey Creek.

- e) Destruction of Chum salmon fisheries and native oyster populations due to over-harvesting and siltation.
- f) Destruction of Gaper clam beds along the eastern shore of the bay and increased erosion of the shore, due to road fill and road construction.

The results of the research and subsequent findings show that it is possible to describe an estuary as a "system" that has applicability for future development of a land and water use model for an estuary.

NETARTS BAY, OREGON: AN ASSESSMENT OF HUMAN IMPACT
ON AN ESTUARINE SYSTEM

by
Larry D. McCallum

A thesis submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE
in
GEOGRAPHY

Portland State University
1977

TO THE OFFICE OF GRADUATE STUDIES AND RESEARCH:

The members of the Committee approve the thesis of
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I would like to thank several people who, during the course of research helped make the task easier, first, Dick Smith, former Planning Director of Tillamook County, whose interest and love of the Netarts area inspired the author to undertake the study. Appreciation is also given to John Dart for assistance throughout the project period. Paul Gage, Cartographer, provided drafting and technical assistance on the figures. Sonia Morrison typed the final manuscript and was helpful in editing. Last, but not least, I would like to thank my wife Lynn, who provided moral support throughout the thesis project, even though the hours away from home were extensive.

...Man has too long forgotten that the earth was given to him for usufruct alone, not for consumption, still less for profligate waste. It is certain that man has done much to mould the form of the earth's surface, though we cannot always distinguish between the results of his action and the affects of purely natural causes...

George Perkins Marsh
1801-1882

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CHAPTER I

INTRODUCTION

The term "estuary" has been defined by biologists, physical geographers, and oceanographers on the basis of basin shape and structure as well as tidal mixing characteristics. Both Pritchard (1967) and Odum (1971) have defined the estuary in terms of the measurable quantity of fresh water dilution of sea water. Clark (1974) uses a modified definition of Pritchard which suitably places the lagoons with little fresh water inflow as estuarine in character. An estuary is a "semi-enclosed coastal body of water which has a free connection to the sea and strongly affected by tidal action and within it sea water is mixed (and usually measurably diluted) with fresh water from land drainage". Estuaries are considered a very valuable component of the life cycle of numerous vertebrates and invertebrates, especially the economically important fisheries of the coasts. The important functions of the estuary are partially-known at best. The uniqueness of an estuarine system is created by the variations in its physical and biotic elements such as basin shape, circulation, characteristics of the watershed, tidal circulation, water quality, and bottom sediment composition. These factors, as well as others, are instrumental in creating a wide diversity and number of inter-dependent habitats. Netarts Bay is one of the seventeen estuaries within the state, ranging in size from 41.3

hectares for the Chetco to 37,954 hectares of Columbia River Estuary. Excluding Alaska, the Pacific Coast states of California, Oregon, and Washington have approximately 2.83 million hectares of estuarine land compared to the national total of approximately 10.7 million hectares. Of the 2.83 million hectares about 56,000 or two percent are located in Oregon. Netarts Bay with 941 hectares ranks sixth in relative size to other Oregon estuaries. It has a relatively high water quality and a rich diversity of habitat. According to the Oregon Fish Commission, this richness is exemplified by the fact that almost every life form present in other Oregon estuaries are found in Netarts Bay.

The uplands, as with all other estuaries in Oregon, have been extensively logged and residential and commercial development has occurred on the marine terraces. But the densities have not, at this time, altered the pristine character of the Netarts landscape and the estuary has great value for scientific study.

During the summer of 1975, research was conducted on Netarts Bay by Oregon State University and Portland State University. A study proposal was drafted for a grant from the National Science Foundation and was funded through Grant Number EPP75-08901. The research proposal was to conduct an integrated, interdisciplinary study of the bay and its environs. The purpose of the study anticipated going beyond the traditional single-purpose engineering

and biological studies on estuaries and ultimately to develop an integrated framework to plan for the future use of an estuary. The original goals of the research were only partially attained because of the following reasons:

- (1) the scope of the project was too ambitious;
an entire summer was devoted to baseline inventories.
- (2) the citizen involvement process essential in establishing the framework required months of preparation and the politics are "heavy" when future land uses for an estuary are suggested.

A valuable result of the research was the establishment of a comprehensive inventory of existing flora, fauna, and human activity within the system. This physical and cultural inventory is a prerequisite for establishing land and water-use policies for the estuary.

The problem with planning the future use of estuaries stems from a lack of knowledge about the existing critical elements of the system and the historical changes which are occurring. This is further complicated by the fact that the character of an estuary is a dynamic one with changes occurring within the system by both natural and cultural causes. It is difficult to distinguish between changes that are "man-caused" and those which occur "naturally". This thesis utilizes an historical approach, coupled with an analysis of the current level of scientific data on

Netarts Bay to describe the system, determine, where possible, the critical environmental factors inherent in the system, and, finally to assess the impact of man's activities. The results of this research shall be useful in developing a land and water use model of an estuary for predicting future use within an estuarine system.

CHAPTER II

SETTING AND CHARACTERISTICS OF STUDY AREA

Netarts Bay, Oregon is located in Tillamook County approximately seven miles west of the City of Tillamook. It is one of several estuaries in the County; others including Nestucca Bay to the south and Tillamook and Nehalem Bay to the north (Fig. 1). The bays were formed by differential sub-aerial erosion and subsequent drowning by the rising sea level during the latter part of the Pleistocene Epoch (Baldwin 1964).

Netarts Bay, with its unique configuration is essentially the result of erosion of the soft, sedimentary Astoria Formation between two basaltic headlands, Cape Meares to the north and Cape Lookout to the south. The erosion created a small synclinal valley in the coastline during the Tertiary Period approximately twenty-five million years ago. Baldwin (1964) and others have described the sedimentary strata, the Astoria Formation, along the bayshore east and north of the bay. Mangum (1967) describes the geology of Cape Lookout as somewhat different than the rest of the watershed. Columbia River Basalt of Miocene Age occurs in sub-aerial and sub-aqueous flows visible as columnar and pillow formations on the sides and at the base of the Cape.

Figure 1. Vicinity map of Netarts Bay.

About one-million years ago to Recent times (Pleistocene to Recent Epochs) fluctuations in sea level occurred and an extensive marine terrace and dune system developed in the Netarts area. Cooper (1958) believes the bay was originally a fresh water lake with no permanent outlet. After the area was uplifted (after the last period of glaciation), the dunes were eroded away; the existing spit being the remnant of the two elongated dunes that formerly trended north-northeasterly. Schlicker (1972) describes the formation and topographic characteristics of the watershed as consisting of two thick sections of arkosic sandstone separated by several hundred meters of thin bedded siltstone. Massive landslide topography attest to earlier mass movement in the area north and east of Cape Lookout. The marine terrace, rising in elevation from 3 to 24 meters currently shows signs of instability with small scale slides and soil movement. The sandspit consists of both consolidated and unconsolidated dunes of Recent origin (Fig. 2).

The present study area consists of the watershed, the bay, and sandspit. The areal extent includes the headwaters of twelve small creeks and their watershed, the 941 hectares of tidelands and channels, the headland Cape Lookout, rising 91 meters above the bay, and the sandspit 8.05 kilometers in length. The watershed is small, 25.7 square kilometers in size. The bay is oriented with its longitudinal axis.

Figure 2. Geology of Netarts Bay
(after Wells and Peck, 1961).

trending northeast to southwesterly. Its physiography can be shown as distinct sub-units (Fig. 3).

DESCRIPTION

Soils and Sediment Characteristics

Soils of the study area are variable, depending on the elevation plant cover, and degree of human disturbance. Soils of the Hembre Association have been formed from dense basalt and have thin horizons weathered to a yellow, silty clay in a breccia matrix (Fig. 4). The differential soil movement and mass wasting in the uplands can be attributed to the large amounts of precipitation which has also caused increased rates of sedimentation in the floodplains and estuaries. Approximately seventy percent of all precipitation falls between November and April. Temperatures are mild, averaging 8.6 degrees centigrade at the Tillamook Station (Table 1).

Sediments within the bay proper have been described by Hunger (1966), Glanzman, et al (1971), and Shabica (1976). Sediment structure consists of four sedimentary facies characteristic of the bay with very well-sorted sands occurring in the main channel caused by a variable energy environment and indicative of rather constant current velocities. The facies are composed of very fine sands and silts at the head of the bay and along the eastern margin, fine sands on the central tide flats in the channel and

Figure 3. Physical sub-units of the Netarts Bay study area.

Figure 4. Soil associations, Netarts Bay (data from the Soil Conservation Service, 1957).

TABLE I
TEMPERATURE AND PRECIPITATION AT TILLAMOOK
STATION, TILLAMOOK COUNTY, OREGON

Month	Temperature M C			Precipitation in Millimeters	
	Average	Maximum	Minimum	Average	Av. Snowfall
January	5.9	22.4	-17.4	342.4	73.7
February	6.9	25.8	-15.1	294.4	20.3
March	7.7	28.6	-7.3	272.8	20.3
April	9.2	30.2	-3.4	161.5	2.5
May	11.2	35.3	-4.5	131.3	0.0
June	13.3	38.6	0.6	80.3	0.0
July	15.0	37.0	0.6	33.8	0.0
August	15.1	34.7	1.1	37.6	0.0
September	13.7	37.0	-1.2	106.2	0.0
October	11.7	33.6	-4.5	184.9	0.0
November	8.9	27.4	-9.0	343.1	2.5
December	6.7	25.2	-17.9	386.6	12.7
Year	10.4	37.6	-17.9	2374.9	132.0

Source: Soil Conservation Service, Soil Survey,
Tillamook Area, Oregon, 1957, p. 70.

along the southwestern margin, and medium sands at the mouth. Basaltic sands, clays, and silts were found to originate from the watershed and silica sands from offshore processes and wind and tide erosion of the spit (Fig. 5). Carbon measurements in the summer of 1975 showed an inverse relationship of sediment size to total carbon content with lowest mean weight percentage values occurring in the southern channel. The organic carbon content reflects the proximity of source areas as well as the energy of the environment. High organic carbon measurements along the eastern shore and at the head of the bay is thought to be caused by restriction of current flow and velocity causing the head of the bay to act as a "sink" for particulate organic matter. Eelgrass also acts as a sediment trap (Fig. 6).

All research on sediments within the bay was conducted during the summer months. Both Glanzman and Shabica agree that one would expect coarser sediments during the winter season because of increased fresh water inflow and subsequent flushing action. This also causes seasonal change in the organic carbon environment of the bay.

Vegetation

The flora of the study area contains distinct plant communities influenced by variations in salinity, slope, and soils. The study area has dune and marsh communities unique in themselves (see Appendix A for Plant Species List).

Figure 5. Physical sediment grain size and environments, Netarts Bay. (After Shabica, 1976).

The terrace and upland area plant communities have been modified by man and contain the greatest amount of introduced plant species replacing much of the original vegetation. Besides the cultural flora, dense stands of *Alnus rubra* (red alder) occur along the small streams that bisect the terrace and near the bayshore area. Main vegetation zones are the *Picea sitchensis* (Sitka spruce) and *Tsuga heterophylla* (Western hemlock). Plant communities have been described by Stout, Kornet, Munson, and the author. Transects along Whiskey Creek logging road into the old growth stand was found to be typical of the watershed area. Clear cut areas encompass nearly all of the watershed and dominant conifers observed include Sitka spruce, Western hemlock, and *Pseudotsuga menziesii* (Douglas fir). The densest stands of spruce and hemlock are approximately four meters in height and occur as isolated clumps. Surrounding brush communities consist of *Rubus parviflorus* (Thimbleberry), *Gaultheria shallon* (Salal), and *Rubus spectabilis* (Salmonberry). Riparian sites included a mixed community of *Alnus rubra* (Red alder), *Rhamnus purshiana* (Cascara buckthorn), Salmonberry, and *Sambucus cerulea* (Blue elderberry).

Mature forest selectively logged characteristically contain Sitka spruce and Western hemlock up to four hundred years old. Areas of brush have become established within the clearings. Understory herbs include *Polystichum*

munitum (Sword fern), *Oxalis oregana* (Oregon oxalis), *Maianthemum bifolium* (False lily-of-the-valley), and *Tiarella trifoliata* (Three-leaved cool wort). Cape Lookout has vegetation characteristic of the climax Sitka spruce zone which formerly was present in a narrow band along the entire coastline in Tillamook County. Sitka spruce is the dominant tree species with scattered shrubs and Sword fern as the dominant understory species. The herbaceous layer is predominantly Oregon oxalis (Table II).

The shoreline and tidal flat area include marshes, dune communities, and the ubiquitous beds of *Zostera marina* (eelgrass) within the tidal flat and channel. Shallow water eelgrass and *Sargassum muticum* (Sargassum) grow in sheltered lower intertidal areas. Eelgrass beds occupy fifty-five percent of the tidelands (Stout 1976). Although species poor, macro-algae exists throughout the bay, particularly around the boat harbor where rip-rap fills provide attachments. Many of the tide flats were found matted with *Chaetomorpha* and *Cladophora*. Kunert (1972) found seventy-eight species of marine algae, of which forty-five belonged to the division Rhodophyta. He found *Rhizoclonium* on the south end and *Fucus* along the shoreline. Sandy areas were heavily populated with *Porphyra*, *Ulva*, *Enteromorpha*, and *Blidingia*. Jefferson (1975), Eilers (1973), and Stout (1976) have described five general types of salt marsh which contain thirteen specific plant communities, each of which are

TABLE II
PLANT SPECIES OF THE UPLAND AND WATERSHED AREA

Plant Species and Area	Frequency and Dominance	Environmental Site Characteristics
I. Clearcut		
<i>Picea sitchensis</i> (Sitka spruce)	Co-dominant	Wet
<i>Tsuga heterophylla</i> (Western hemlock)	Co-dominant	Drier
<i>Pseudotsuga menziesii</i> (Douglas' fir)	Co-dominant	Drier
<i>Thuja plicata</i> (Western red cedar)	Scattered	Wet, riparian
II. Disturbed Mature Forest		
<i>Alnus rubra</i> (Red alder)	Dominant along streams	Wet, riparian, disturbed
<i>Rubus parviflorus</i> (Thimbleberry)	Dominant understory	Wet, riparian, disturbed
<i>Rubus spectabilis</i> (Salmonberry)	Dominant understory	Wet, riparian, disturbed
<i>Gaultheria shallow</i> (Salal)	Dominant understory	Drier, undisturbed
<i>Rhamnus purshiana</i> (Cascara buckthorn)	Scattered	Drier, undisturbed
<i>Sambucus cerulea</i> (Blue elderberry)	Scattered	
III. Disturbed Mature Forest		
<i>Picea sitchensis</i> (Sitka spruce)	Co-dominant	Undisturbed
<i>Tsuga heterophylla</i> (Western hemlock)	Dominant	Drier sites
<i>Rubus spectabilis</i> (Salmonberry)	Understory herbaceous	Wet, riparian
<i>Polystichum munitum</i> (Sword fern)	Understory herbaceous	Undisturbed, mature
<i>Oxalis oregana</i> (Oregon oxalis)	Herbaceous dominant	Undisturbed, mature
<i>Maianthemum bifolium</i> (False lily-of-the-valley)	Herbaceous Co-dominant	Undisturbed, mature
IV. Mature Forest		
<i>Picea sitchensis</i> (Sitka spruce)	Dominant	Undisturbed
<i>Tsuga heterophylla</i> (Western hemlock)	Co-dominant	Drier sites
<i>Vaccinium parvifolium</i> (Red huckleberry)	Understory	Undisturbed, mature
<i>Tiarella trifoliata</i> (Three-leaved cool wort)	Herbaceous	Undisturbed, mature
<i>Maianthemum bifolium</i> (False lily-of-the-valley)	Herbaceous	Undisturbed, mature

Source: Data from Vegetational Transects in the Netarts Watershed, Summer 1975.

located in a particular part of the shoreline because of unique environmental conditions. A relationship was found between areas inundated by high tide, sediment characteristics, and the type of marsh community in existence (Table III).

The channels and lands covered by water at mean low tide contain diatoms, macro-algae, and eelgrass beds. Stout describes high reproduction and luxuriant growth of eelgrass in and around the channels during her investigations of the extensive beds in Netarts Bay. The deeper water standing stock showed a higher percentage of biomass in the leaves as compared to roots and rhizomes, depicting higher rates of reproduction. It was not established in channel areas where high water current velocities caused scouring (Fig. 7).

Diatoms are a prominent contributor to the flora of Netarts Bay. Research has identified one hundred species of diatoms. The more ubiquitous of these species found during sampling are listed in Table IV. Diatoms are very important in the energy cycle of natural waters and among the foremost of the photosynthetic producers (Reid 1961).

The dune system of the Netarts sandspit represents an outstanding example of plant associations typical of the Oregon dunes. Observations of vegetational patterns show a variety of dune vegetation associations which bear direct relationships to exposure to wind, storm, xeric site conditions, and the influence of man.

TABLE III
SALT MARSH AND COMMUNITY TYPES FOR NETARTS BAY
(AFTER JEFFERSON, 1975)

Salt Marsh and Community Type	Location within Bay	Site Conditions
I. Low sand marsh Distichlis-Cladophora- Salicornia Salicornia-Distichlis Scirpus americanus	Margin of east side of sandspit	Gentle, sandy slope from the tideflat and inundated by all high tides
II. Low salt marsh Cladophora gracilis Salicornia-Triglochin Salicornia-Cotual-Scirpus	South end of bay on west- ern shore	Low, silty tideflats fresh water; lower salinity
III. Sedge Marsh Carex lyngbyei	East side of bay	Fresh water influence
IV. Immature and mature high marsh Salicornia Distichlis Plantago Scirpus americanus Deschampsia	Southern end of bay	Excessive siltation

Source: Stout, H. ed: The Natural Resources and Human Utilization of Netarts Bay, Oregon (1976, p. 35).

Figure 7. Distribution of eelgrass and salt marsh, Netarts Bay. (After Stout, 1976).

TABLE IV

PARTIAL LIST OF DIATOMS IN NETARTS
BAY, OREGON, (McINTIRE AND MOORE UNPUBLISHED)

Achnanthes hauckiana Grun.
Achnanthes parvula Kutz.
Amphipleura rutilans (Trent.) Cl.
Cocconeis placentula var. euglypta (Ehr.) Cl.
Cocconeis scutellum var. parva (Grun.) Cl.
Fragilaria pinata (Ehr.)
Fragilaria striatula var. californica Grun.
Melosira moniliformis (Mull.) Agardh.
Melosira nummuloides (Dillw.) Agardh.
Melosira sulcata
Navicula complanatula Hust.
Navicula diserta Hust.
Navicula gregaria Donk.
Navicula pelliculosa Breb.
Nitzschia closterium
Nitzschia frustulum var. perpusilla (Rabh.) Grun.
Nitzschia oregana Sovereign.
Synedra fasciculata (Ag.) Kutz.

Source: Stout, H. ed. The Natural Resources
and Human Utilization of Netarts Bay,
Oregon (1976, p. 35).

The predominant features of the Netarts sandspit consists of a well-established primary dune, or foredune, dune trough, a relatively low back dune, and the bay shore. Approximately, 1.1 kilometers of the southern part of the spit contains foredune communities of *Ammophila arenaria* (European beach grass), *Cysticus scoparius* (Scotch broom), and *Pinus contorta* (Lodgepole pine). These species were planted in the 1940's by the Soil Conservation Service to help stabilize the foredune. The central portion of the spit is more complex in terms of diversity of plants. Plant communities typical of sand dunes, dune trough, and marsh areas were observed during vegetative investigations during the summer of 1975. Pioneer species identified on the foredune included European beach grass on the windward side and crest grading to dense shrub communities of Salal on the leeward side to the trough. Plant communities of the trough show gradation from xeric to hydrophilic species based on the elevation, exposure, and moisture characteristics within the trough. Those observed were *Lupus littoralis* (Shore Lupine), *Fragaria chiloensis* (Beach strawberry), *Abronia latifolia* (Yellow abronia), and *Convolvulus soldanella* (Coast morning glory).

Various species of *Agrostis* (Bentgrass) occur as thick ground cover on the wetter portions of the trough. An area of Sitka spruce of 46.5 hectares is located in the

central portion of the spit and is approximately fifty years old. Plant species in areas of trough between the forest consist of dense shrub communities of *Vaccinium ovatum* (Evergreen huckleberry), *Salix hookeriana* (Coast willow), and *Myrica californica* (Wax myrtle). *Acrctostaphylos uva-ursi* (Kinnikinnick) and *Ledum gladulosum* (Pacific labrador tea) were observed as rare contributions to the flora. The Huckleberry and Salal were found as sparse understory vegetation within the stand of spruce. The Coast willow and Wax myrtle were observed on low-lying depressions on the edge and between the dense, almost pure stands of Sitka spruce (Table V).

Fauna

Faunal and avifaunal species for the Netarts study area have been observed and recorded by Kornet and Munson (1976) (see Appendix A for reference to faunal lists). Eight habitat types have been described based on predominant plant communities (Fig. 8). The mature coniferous habitat, associated with the upland and watershed was found to have the greatest number of species, due to the high and varied plant community layers, the abundant food, and the moist, rich earth. A pronounced difference in bird densities was found between mature forest and disturbed mature forest due to the lack of vertical stratification of vegetation within the undisturbed habitat. Clearcut habitat bird densities were very high, due to dense brush communities and subsequent

TABLE V
 PREDOMINANT PLANT SPECIES ON THE NETARTS SPIT

SPECIES	AREA OF SPIT
I. Shrubs and Trees	
<i>Picea sitchensis</i> (Sitka spruce)	Leeward side of secondary dune as well as on the primary dune on the southern portion of the spit. Also within forest.
<i>Pinus contorta</i> (Lodgepole pine)	
<i>Gaultheria shallon</i> (Salal)	
<i>Cystiscus scoparius</i> (Scotch broom)	
<i>Vaccinium ovatum</i> (Huckleberry)	
<i>Ledum glandulosum</i> (Labrador tea)	
<i>Arctostaphylos uva-ursi</i> (Manzanita)	
<i>Salix</i> , Genus (Coast willow)	
<i>Myrticus californicum</i> (California myrtle)	
II. Grasses and Herbs	
<i>Ammophila arenaria</i> (European beach grass)	Deflation plain and sheltered leeward side of primary and secondary dunes.
<i>Poa macrantha</i> (Seashore bluegrass)	
<i>Fragaria chiloensis</i> (Coast strawberry)	
<i>Pteridium aquifolium</i> (Bracken fern)	
<i>Orthocarpus castillejoideus</i> (Paintbrush)	
<i>Convolvulus soldanella</i> (Beach Morning glory)	
<i>Lupinus littoralis</i> (Seashore lupine)	
<i>Abronia latifolia</i> (Yellow abronia)	
<i>Potentilla pacifica</i> (Pacific Silver weed)	

Source: Field survey Netarts Bay, 1975.

Figure 8. Main vegetational habitat types, Netarts Bay.
(After Kornet, 1976).

phased food supply during the breeding and reproductive season. The residential habitat area is included here to indicate avifaunal habitat. It was found that the variety of vegetation, the mix of open and shrub areas, and man-made structures increases the density of breeding birds.

A wide variety of habitat type was found in the shoreline and tidal flat area. Terrestrial habitats were identified by Kornet (1976) during the summer of 1975. Habitat types identified during that study include salt marsh, riparian alder sites, sandspit/beach grass, sandspit/spruce, and the intertidal areas (areas between mean low and mean high tide). The salt marsh habitat was found to be scarce in terms of the numbers and types of reptiles, amphibians, and mammals. There was only one species of animal, *Sorex vagrans* (Vagrant shrew) trapped during the ten-week observation period. The riparian alder habitat type found within the shoreline and tidal flat area is confined to those small streams which flow into marshes and in some areas west of the county road for short stretches before entering the bay. Three species of Evening bats, *Taricha granulosa* (Rough-skinned newt), two species of frogs, and *Bufo boreas* (Western toad) were found to utilize the quiet ponds for cover, food, and reproduction. *Neotoma cednera* (Bushy-tailed woodrat), *Procyon lotor* (Raccoon), *Mustela erminea* (Ermine) and *Mephitis mephitis* (Striped

skunk) were observed. The riparian alder habitat contained the greatest number of species of reptiles, mammals, and amphibians. High populations of *Peromyscus maniculatus* (Deer mice) and Vagrant shrews were observed in the sandspit/beachgrass and sandspit/spruce habitat. *Ursus americanus* (Black bear) were observed along with a resident population of *Odocoileus hemionus columbianus* (Black-tailed deer). Raccoon sign was also present.

Mammal species observed within the intertidal habitat type include the Black-tailed deer, the Raccoon, and *Phoca vitulina* (Pacific harbor seal) which inhabit the deeper waters of the bay mouth, but utilize the intertidal sand bars as "haul out" sites. The tidal flats (intertidal areas) lack cover and are utilized for food foraging and corridors by the Black-tailed deer (see Appendix B for a complete listing).

Avifaunal species have been studied at Netarts during the turn of the century by William L. Finley and H. T. Bohlman. A detailed survey of bird counts, species types, and habitat conditions was taken during the summer by Munson (1975) (see Appendix B). Bird densities were obtained by dividing the total number of individuals observed by the total area of the bay. Densities were not calculated for the spit; but its importance cannot be over-emphasized as a resting area for birds and its unique habitat for the Snowy plover (*Charadrius alexandrinus*), the long-billed

marsh wren (*Telmatodytes palustris*), Western meadowlark (*Sternella neglecta*). Purple martin (*Progne subis*), and the Savannah sparrow (*Passerculus sandwichensis*). Important habitat types on the spit are the Spruce forest and brush communities which serve as Great Blue heron (*Ardea herodias*) roosting areas and nesting and foraging habitat for numerous song birds, such as Swainson thrush (*Hylocichla ustulata*), Snowy plover, and Marsh hawk (*Circus cyaneus*).

During the summer sampling program of 1975, a total of eighty-seven invertebrate species were recorded for the channel and tidal flat area. Sixty-two were infaunal species taken from benthic core samples and the remainder from nets during the fish sampling. Data have been published on the frequency of occurrence of the sixty-two species examined during the survey for each transect area (see Appendix C). A relationship was found between variation associated with habitat and sediment conditions and diversity of infaunal and epifaunal invertebrate species within the sampled areas (Wilson, et al, 1975, p. 58). Dominant influences of strong tidal currents and coarse sediments were noted on the lower number of species associated with the main channel. Published data on the spatial occurrence of many of these species, as well as the statistical analysis of the discrete communities can be found in the Netarts Bay Interdisciplinary Study, The Natural Resources and Human Utilization of Netarts Bay, Oregon, 1976; H. Stout, editor.

The Oregon Department of Fisheries and Wildlife has sampled and published data on the importance and abundance of recreationally important bivalves in Netarts Bay. Other faunal species include those of the Class Osteichthyes. Forty-nine species representing nineteen families were collected during the period June to September, 1975 by the fisheries team. Greatest species diversity was found to occur over the rocky sand substrate within the channel and least over silt and rocky shell. Salinity concentrations were important environmental factors; the higher the salinity, the greater the species diversity. Although ichthyofaunal species were found to be common throughout the bay, the total numbers associated with the eelgrass beds were most numerous for four species. This reinforced other findings that collection sites within the channel had the greatest species diversity. Nine species were found in habitats similar to these conditions and comprised over fifty percent of all species collected. *Gasterosteus aculeatus* (Three spine stickleback), *Syngnathus griseolineatus* Bay pipefish), *Cymatogaster aggregata* (Shiner perch), and the Saddle back gunnel (*Pholis ornata*) were most abundant in the eelgrass beds associated with the channels (Table VI). Three species, Three spine stickleback, Bay pipefish, and *Parophrys vetulus* (English sole) made up sixty-four percent of the total catch and encompassed a total of forty-nine species.

TABLE VI

MOST ABUNDANT ICHTHYOFAUNAL SPECIES ASSOCIATED
WITH CHANNEL CONDITIONS

Species	Substrate Type			Elgrass*
	Sand	Sandy	Silt	
Gastrosteus aculeatus (Three spine stickleback)	1	18	77	x
Leptocattus armatus (Pacific staghorn sculpin)	58	16	8	
Paraphrys vetulus (English sole)	59	--	--	
Cymatogaster aggregata (Shiner perch)	--	33	48	x
Hypomesus pretiosus (Surf smelt)	95	--	--	
Ammodytes hexapterus (Pacific sand lance)	92	--	--	
Pholis ornata (Saddle back gunnel)	7	15	59	x
Syngnathus griseolineatus (Bay pipefish)	1	5	93	x
Platichthys stellatus (Starry flounder)	19	23	23	
Total Species	8	6	6	4

Source: Stout, H. ed. The Natural Resources and Human Utilization of Netarts Bay, Oregon, (1976, p. 35)

*Greater than fifty percent of specimens caught in eelgrass

CHAPTER III

THE NETARTS BAY SYSTEMS

The previous discussion dealt with the various physical sub-units within the Netarts study area based principally on geological and topographical characteristics as well as the flora and fauna. It is the purpose of this section to describe the study area as a system and identify the functions that this system performs. This is done principally to establish a measure of system condition upon which the human utilization of resources can be compared. Eugene P. Odum (1961) has been a pioneer in estuarine ecology and has described many functions of estuaries in general. Cronin (1971), Clark (1974), Hedgepeth (1957), Teal (1962), and H. T. Odum (1969) are a few who have contributed to changing the image of these important ecosystems either by pure research or considering complex resource management problems. Estuaries can be regarded as "transition zones" or ecotones between fresh water and marine habitats. Although many important physical and biological attributes are "transitional", many are also unique. Odum (1971) characterized estuaries as belonging to that class of "fluctuating water-level ecosystems" that are important because of frequent nutrient input and maintenance of a youthful stage in regard to productivity. This high level of productivity sustains important commercial and sports fisheries. It also provides food and energy from three types of producers essential in

the food chain. Zonation of production units were found by H. T. Odum (1967) and Wood and Zieman (1969). Their research shows eelgrass (*Zostera*) as the major producer of cold water estuaries; the microbially-enriched grass detritus feeding the consumers in the channels and bay. Major functions of estuary systems in general are:

- (1) vital habitats for birds, fishes, and mammals
- (2) areas of primary productivity for creation
marine food chains
- (3) provides recreational and scientific resources
to the public

A discussion of an estuarine system entails some analysis of those physical factors which control the amount of physical and biological inputs to the system. Characterization of the shape of the Netarts basin and tides are essential for describing the estuary as a system.

PHYSICAL SYSTEMS AND THEIR INFLUENCE ON NETARTS BAY

Those involved in estuarine research have generally used two methods in classifying estuaries; one primarily analyzing the water stratification and circulation patterns and the other the impact of the energy environment on the biota and how the biota reacts to this impact.

Physically, Netarts Bay is principally influenced by variations in runoff, density differences between water

masses, tidal movements, and the morphology of the bay. Pritchard (1955) and Burt and McAlister (1959) have classified Netarts Bay as a Type D estuary; well mixed and vertically homogenous in terms of salinity. This classification based on water circulation and salinity recognized that the Netarts estuary can evolve into a partially-stratified estuary during certain times of the year when fresh water flows are optimum. Zimmerman (1971) found, after a hard rainfall, a large salinity difference from surface to bottom at a station one kilometer north of Whiskey Creek.

Hydrography

Hydrography, as used in this discussion, pertains to tidal elevations, flushing and circulation characteristics, the bottom configuration, and the natural and man-made features of the adjacent shorelines and bay proper. According to Burt and McAlister (1959), Netarts Bay is a type D estuary with essentially a well-mixed condition all year and exhibits a fairly predictable salinity regime based primarily on the ratio of fresh water discharge to the tidal prism and the physiographic character of the bay (Figs. 9 and 10). Two hydrographic surveys have been made of Netarts Bay by the U.S. Coast and Geodetic Survey in 1957 and the Oregon State University Engineering Experiment Station in conjunction with Glanzman's work in 1970. Comparison of these surveys, as well as analysis of aerial photos flown in 1939 shows evidence of change in the meander patterns of the

Figure 9. Circulation in a Type D estuary.
(After Pritchard, D.W. 1955).

Figure 10. Salinity regime for a well-mixed estuary.
(After Burt and McAlister, 1959).

the sandspit, and a decrease in the total tidal prism area.

Tidal Circulation and Flushing Characteristics

Tidal elevations, currents, and flushing characteristics are important features of biological productivity, energy regimes, and habitat conditions favorable for a range of diverse flora and faunal species. Tidal elevations currently serve as important planning landmarks in defining the legal boundary of state authority for regulating the use of Netarts shorelines, as well as for other Oregon estuaries. Glanzman et al (1971) perfected a means of predicting tidal heights at the Schooner Restaurant at the mouth of Netarts, based on the known heights at the Newport tide recorder. Within Netarts, he measured tidal ranges and times at both the Schooner and Whiskey Creek over a fourteen-day period. A choking coefficient of 0.86^1 was found for the tidal ranges between the Schooner and Whiskey Creek. Thus, if a mean tide range of 1.71 meters was measured at the Schooner, a corresponding mean tide range at Whiskey Creek would be $.86 \times 1.71 = 1.47$ meters.

Tidal currents and flushing of estuarine waters perform many functions. In general, these forces transport nutrients, propel plankton, and spread planktonic larva

¹The tide range at Whiskey Creek divided by the tide range at the Schooner.

of fish and shell-fish. They also act as flushing agents for animal and plant wastes and cleanse the system of pollutants. Current velocities and direction also control salinity and sedimentation. Tidal amplitude as well as the size and shape of the Netarts basin are the major factors responsible for estuarine circulation. Circulation forces tend to be greater and flushing rates better where tidal amplitudes are high (Clark 1974, p. 13). This is the case for Netarts Bay. During Glanzman's study (1971), currents with a strong, horizontal velocity gradient were observed. Most of the water was found to be transported in the deeper channels and flows directed onto and off the tidal flats perpendicular to main channel flow. Boley and Slotta (1974) used released Woodhead-type bottom drifters inside the bay at high and slack tides as well as outside the mouth during flood tides during the summer of 1971. After a series of tidal cycles, approximately 70 percent of the drifters were found either on the northern edge of the spit or at Cape Lookout State Park beach. Evidence shows a mean seaward bottom flow of water current occurs out of Netarts Bay with little vacillation of current force during the summer. Velocities were found to average between 30.5 cm/sec and 63.5 cm/sec. Bottom velocities are expected to be higher, based on the predominant larger flow (volume) near the bottom (the tide range at Whiskey Creek divided by the tide range at the Schooner). It was also found, that due to

well-mixed conditions, the bay is not subject to gradients in current velocity due to stratification (Glanzman et al 1971) (Fig 11).

Tidal flushing characteristics include total bay water capacity and residual volume during a complete tidal cycle. It is basically a quantitative measurement of the total amount and velocity of water entering and leaving the bay. The amount of water contained in the bay between high water and mean low water, the tidal prism, was calculated by Glanzman by first doing a cross section analysis of area from hydrographic survey maps in three sections of the bay, and then calculating the maximum and minimum volumes during the tidal cycle. The tidal exchange ratio was found to be approximately 0.746 or 74.6 percent of the water would be renewed during each tidal cycle. This shows a twenty-five percent residual of water left in the bay at mean low tide.

Hydrology, Salinity, and Water Quality

Hydrologic factors considered here are precipitation and runoff. These factors control the salinity values, sedimentation rates, water density, and temperature, as well as other water quality characteristics. Precipitation amounts are highest during the winter for Netarts Bay. A dominant influence during the winter is runoff and the impact of fresh water inflow to the system. This relationship between precipitation and stream water level has the

Figure 11. Circulation within Netarts Bay during ebb and flood tides. (Data from Glanzman, 1971).

effect of causing a small flushing action within the bay (Zimmerman 1972). Glanzman (1971) and Percy (1974) have calculated monthly fresh water inflow to Netarts based on precipitation records and different watershed size (25.7 and 22.5 square kilometers respectively). Percy also based his calculations on an estimated average annual yield for the north coast basin of 1,214 hectare meters per kilometer. Normal runoff volumes were calculated for the Netarts Bay watershed (Table VII).

Conditions of tidal mix have a direct bearing on salinity characteristics of the system. Although coastal nearshore salinity was found to vary in the Netarts area, salinity values remain close to those in the open ocean throughout the year due to limited fresh water inflow and the well-mixed condition of the estuary. Ocean waters typically contain, in total, about 35 parts of salt per thousand parts of water (Clark 1974). Coastal species have evolved over the years in harmony with their salinity environment and, depending on the species can tolerate a wide or narrow range of salinities to live and reproduce successfully. Salinity measurements taken on Netarts Bay were found to be variable with respect to season, the highest occurring in early fall and lowest in early spring (Table VIII). There also seems to be a pronounced salinity gradient within the bay during the winter months, although the overall characteristics of the

TABLE VII
APPROXIMATE NORMAL RUNOFF

	Inflow to Water Surface	Normal Runoff from land	Fresh Water Inflow to Netarts Bay
January	$\begin{smallmatrix} 3 \\ .82 \text{ m/sec} \end{smallmatrix}$	$\begin{smallmatrix} 3 \\ 4.84 \text{ m/sec} \end{smallmatrix}$	$\begin{smallmatrix} 3 \\ 5.66 \text{ m/sec} \end{smallmatrix}$
February	$\begin{smallmatrix} 3 \\ .74 \text{ m/sec} \end{smallmatrix}$	$\begin{smallmatrix} 3 \\ 4.19 \text{ m/sec} \end{smallmatrix}$	$\begin{smallmatrix} 3 \\ 4.92 \text{ m/sec} \end{smallmatrix}$
March	$\begin{smallmatrix} 3 \\ .57 \text{ m/sec} \end{smallmatrix}$	$\begin{smallmatrix} 3 \\ 3.59 \text{ m/sec} \end{smallmatrix}$	$\begin{smallmatrix} 3 \\ 4.16 \text{ m/sec} \end{smallmatrix}$
April	$\begin{smallmatrix} 3 \\ .31 \text{ m/sec} \end{smallmatrix}$	$\begin{smallmatrix} 3 \\ 2.29 \text{ m/sec} \end{smallmatrix}$	$\begin{smallmatrix} 3 \\ 2.58 \text{ m/sec} \end{smallmatrix}$
May	$\begin{smallmatrix} 3 \\ .15 \text{ m/sec} \end{smallmatrix}$	$\begin{smallmatrix} 3 \\ 1.27 \text{ m/sec} \end{smallmatrix}$	$\begin{smallmatrix} 3 \\ 1.41 \text{ m/sec} \end{smallmatrix}$
June	$\begin{smallmatrix} 3 \\ .04 \text{ m/sec} \end{smallmatrix}$	$\begin{smallmatrix} 3 \\ 0.68 \text{ m/sec} \end{smallmatrix}$	$\begin{smallmatrix} 3 \\ 0.71 \text{ m/sec} \end{smallmatrix}$
July	$\begin{smallmatrix} 3 \\ -.12 \text{ m/sec} \end{smallmatrix}$	$\begin{smallmatrix} 3 \\ 0.34 \text{ m/sec} \end{smallmatrix}$	$\begin{smallmatrix} 3 \\ 0.23 \text{ m/sec} \end{smallmatrix}$
August	$\begin{smallmatrix} 3 \\ -.08 \text{ m/sec} \end{smallmatrix}$	$\begin{smallmatrix} 3 \\ 0.23 \text{ m/sec} \end{smallmatrix}$	$\begin{smallmatrix} 3 \\ 0.14 \text{ m/sec} \end{smallmatrix}$
September	$\begin{smallmatrix} 3 \\ .09 \text{ m/sec} \end{smallmatrix}$	$\begin{smallmatrix} 3 \\ 0.28 \text{ m/sec} \end{smallmatrix}$	$\begin{smallmatrix} 3 \\ 0.37 \text{ m/sec} \end{smallmatrix}$
October	$\begin{smallmatrix} 3 \\ .38 \text{ m/sec} \end{smallmatrix}$	$\begin{smallmatrix} 3 \\ 1.27 \text{ m/sec} \end{smallmatrix}$	$\begin{smallmatrix} 3 \\ 1.67 \text{ m/sec} \end{smallmatrix}$
November	$\begin{smallmatrix} 3 \\ .82 \text{ m/sec} \end{smallmatrix}$	$\begin{smallmatrix} 3 \\ 3.48 \text{ m/sec} \end{smallmatrix}$	$\begin{smallmatrix} 3 \\ 4.30 \text{ m/sec} \end{smallmatrix}$
December	$\begin{smallmatrix} 3 \\ .88 \text{ m/sec} \end{smallmatrix}$	$\begin{smallmatrix} 3 \\ 5.60 \text{ m/sec} \end{smallmatrix}$	$\begin{smallmatrix} 3 \\ 6.48 \text{ m/sec} \end{smallmatrix}$
Annual	$\begin{smallmatrix} 3 \\ .38 \text{ m/sec} \end{smallmatrix}$	$\begin{smallmatrix} 3 \\ 2.55 \text{ m/sec} \end{smallmatrix}$	$\begin{smallmatrix} 3 \\ 2.94 \text{ m/sec} \end{smallmatrix}$

Source: Glanzman, et al, Tidal Hydraulics Flushing Characteristics and Quality of Netarts Bay (1971, p. 39)

TABLE VIII

SEASONAL SALINITY, WATER TEMPERATURE, DISSOLVED OXYGEN
BIOLOGICAL OXYGEN DEMAND BY SEASON AVERAGE, NETARTS BAY, OREGON

Time of Year	Measured Depth	Water Temp.	Salinity	1	
				DO	BOD
Early spring	1.83 meters	10.0 c	30.4 ppm	9.7	0.6
Late spring	1.22 meters	15.0 c	31.6 ppm	9.6	0.4
Mid summer	3.05 meters	16.0 c	26.5 ppm	not given	not given
Late summer	3.05 meters	15.4 c	30.3 ppm	8.7	1.0
Early fall	2.74 meters	9.4 c	32.9 ppm	8.8	0.6

Source: Department of Environmental Quality. Data in: Glanzman, et al,
Tidal Hydraulics, Flushing Characteristics, and Water Quality
of Netarts Bay, 1971, pages 98-103.

1

Measured as milligrams per liter

2

Measured as milligrams per liter

bay are well-mixed. Variation in salinity was recorded within the bay with salinity values ranging from 13.9 ppt to 30.1 ppt. Salinity values were found to rise from 33.25 ppt at mid-tide to 33.45 ppt at high slack and then drop to 23.05 ppt at low tide.

Sedimentation is occurring within the Netarts system, as is the case in all other estuaries along the Oregon coast. Glanzman, et al (1971) found a ten percent decrease in bay volume during a twelve-year time span. These high settlement rates reflect reduction of current strength and the presence of dense stands of eelgrass and saltmarsh which act as sediment traps. Whether this rate of infill has accelerated, stabilized, or decreased within the last eight years cannot be determined until sampling and sediment analysis is done for a number of winter seasons.

Any amount of infill can change circulation patterns, water temperature and clarity, and oxygen characteristics of the water. Some initial calculations have been made to estimate the quantity of sediments transported from the watershed by using comparative figures from other small estuarine watersheds and hydrologic runoff data from Glanzman et al (1971). Although the sediment loads transported to the Netarts system are smaller than the comparative estuaries, the shallow depth of the bay could magnify the impact of the deposition (Table IX).

TABLE IX
COMPARATIVE SEDIMENTATION IN
THREE OREGON ESTUARIES

Name of Estuary	Estuary Size	Size of Watershed	Volume of Runoff	Volume of Sedimentation	Sediments/Hectare
Netarts Bay	940.9 ha	22.75 sq. km	16,997 ha/m	2.25 million Kg	2,391 kg/ha
Siletz Bay	480.4 ha	586 sq. km	21,701 ha/m	74 million kg	154,038 kg/ha
Alsea Bay	868.5 ha	763 sq. km	Data not available	249 million kg	2.87 million kg/ha

Data source for sediment quantities and physical measurement: Oregon Coastal Conservation and Development Commission, Coastal Wetlands of Oregon, August 1973.

Other parameters of water quality are very important to the function of the estuary and can affect habitat, nursery, and animal breeding grounds. Temperature, dissolved oxygen, and biochemical oxygen demand in the presence of other chemicals are the essential building blocks of the estuarine food chain. The amount of oxygen in the waters of the bay fluctuate with variations in temperature and other factors. Glanzman, et al (1971) found extremely low BOD values indicating the system is unpolluted from organic matter. Lowest bay water temperatures were found in late winter and the highest in mid to late summer (see Table VIII).

Hydrogen ion concentration measurement are important in estuarine waters because of the many vital chemical reactions which occur. Water will normally be acidic if Hydrogen Sulfide is produced in a situation of typical anaerobic conditions. The State Department of Environmental Quality data shows between 1970 and 1975 the pH of the waters in Netarts ranged from 7.8 to 8.4. Dissolved oxygen was found to average seven milliliters of oxygen to one liter of water. The state recognizes that Netarts Bay is not only unpolluted, but has an extremely high water quality.

BIOTIC SYSTEMS OF NETARTS BAY

Although some research has been done on the zooplankton of Netarts by Zimmerman (1972) and Hunger (1966), knowledge

concerning the critical biotic systems within the bay is fragmentary at this time. Productivity measurements were taken by Glanzman but the data were inconclusive.

In general, the importance of biotic productivity cannot be over emphasized for temperate zone estuaries such as Netarts. Characteristically, estuaries tend to be more productive than either the sea or their fresh water drainage system (Odum 1971). The following discussion will examine known biological functions of temperate estuaries in general, and point out salient aspects of the Netarts biota when available from previous research.

The life system of an estuary begins with plant life; in Netarts case, significant areas of eelgrass beds, phytoplankton, and mature marsh. The marshes of Netarts serve important functions to the biotic system of the bay. They trap rich sediments from the watershed, retain nutrients and chemicals for gradual release, supplies organic detritus, and provides productive habitat for a large number of fish, birds, and mammals. Milne and Milne (1951) have documented the importance of decayed plants from marshes as a vital nutrient element in the food chain of estuaries. Stout (1975) during her study of eelgrass in Netarts also noted this important function. The interdependence of benthic communities on available carbon from detritus and sediments has been shown for twenty species by Wilson (1975).

The importance of the eelgrass "lakes" is indicated by the presence of the dense aggregations of blue mud shrimp (Stout 1975).

Research on benthic invertebrate habitat in Netarts was done during the summer of 1975 by Wilson et al. The invertebrate assemblages found in Netarts range from relatively stable co-occurring species groups to short-lived and loosely-lived aggregations. They are not clearly-defined ecological units, but rather gradational in nature adapting to the heterogeneity of the physical environment. Factors found to be of importance in species assemblages within the bay include salinity, sediment size, organic content of the sediments, and tidal height. A close relationship was found between species diversity and sediment grain size, sediment heterogeneity, and currents within the Netarts system. Species numbers are relatively low at the mouth of the bay, but peak and decline slightly at the head of the estuary. Cronin and Mansueti (1970) have also described the abundance of benthos near the center of estuarine systems. Although some research on invertebrates have been done, several factors should be pointed out as "unknowns" in regard to the benthic communities of the Netarts system. These are:

- (a) The difficulty in quantifying biological interactions such as inter and intra specific competition for space and the spatial separation of

deposit and suspension feeders are very difficult to quantify.

- (b) The incomplete analysis of distribution patterns; those described in 1975 are only for the summer months of the sampling program. It is concluded that surface sediment characteristics would be altered and animal distributions changed during the winter months because of high fresh water run-off and different sediment conditions.

In summary, the biotic systems of Netarts are partially known at best, but exhibit unique and important characteristics which are useful in assessing human impacts. A rough food web can be illustrated which serves as a link between the physical and biotic components (Fig. 12). This relationship between the physical and biological environment is important. Bella (1973) proposes that the estuarine planner consider that biological features of the system be superimposed upon the the mix of physical-chemical features of that system. This is helpful since particular biologic systems will generally be found in relation to habitats or localized environments.

Figure 12. Sediment food web, Netarts Bay (after Glanzman, 1971).

CHAPTER IV

CRITICAL ENVIRONMENTAL FACTORS WITHIN THE SYSTEM

It is necessary at this point to identify the physical and biotic factors of the Netarts estuarine system which would, if altered or eliminated cause irreversible changes in the functions and stability of the system. The previous chapter has described "known" physical and biological properties and characteristics of the estuary. The factors, or environmental conditions which play a major role in either food production or influence habitat conditions within the system should be identified for two reasons:

- (a) it is necessary to recognize the basic features of the Netarts system which should be protected to prevent system degradation
- (b) an ultimate goal of the thesis is to show how man has altered these physical and biological features over time.

In general, habitat types and conditions have been shown to be critical environmental factors within the Netarts system. Conditions of the environment pose as limiting factors to critical habitats. For example, *Zostera* (eelgrass) beds occupy fifty-five percent of the tidal areas. Their productivity and function have been described as a part of the biotic system of the estuary. Their rate of productivity and total biomass depends on tidal elevation (which affects plant dessication), type of

substrate (silty sand), and current velocity (too much scouring limits plan propagation). Since the extent of and productive rate of eelgrass is considered a critical environmental factor to the system; critical environment factors as tidal elevation, type of substrate, and current velocities are also critical environmental factors since they influence the eelgrass habitat condition. The marshes, another source of primary productivity, are considered critical within the Netarts system. The specific plant associations and location depends on some of the same factors important in maintaining this critical habitat type, namely substrate characteristics, tidal level, and salinity. The limited amount of existing marsh within the system makes this habitat type a key factor.

The tidal flats, the habitat of the benthic invertebrates, provide niches for a large variety of species. Their abundance, distribution, and diversity were found to be dependent on several critical environmental and biological factors. Grothaus and Wilson (1975, pps. 58-103) tested sample data of benthic invertebrates with diversity and similarity measures as well as principal components analysis to determine if discrete species assemblages existed within the bay's marine benthic community and if the physical and biological variables correlated to the distributions. The results of the analysis identifies critical factors of tidal flat habitat and is summarized as follows:

- (a) primary environmental variables are substrate characteristics, salinity, and tidal level
- (b) substrate depth and sediment size are important to the size of individual species within the community and to the level of organic material available for consumption
- (c) eelgrass beds and their related substrated conditions show a high index of diversity and abundance of macro-benthic species.

Again, as in the other important habitat types, the benthic invertebrates require specific substrate conditions such as sediment size and organic content, as well as eelgrass beds for diverse habitat types and sediment traps. The critical environmental factors can be summarized as main habitat types and conditions. These are:

- (a) eelgrass beds
- (b) marshes
- (c) sediment size, distribution, and organic content
- (d) tidal level and current velocity
- (e) salinity range

It must be stressed that existing unidentified biological and physical processes can be of more importance than the "identifiable" factors. It is important to recognize this fact, especially when discussing estuaries. These identified

factors can be diagrammed and will receive further attention in this chapter as an examination is given to how man has altered some or all of these critical elements (Fig. 13).

Figure 13. Netarts Bay system, 1977.

CHAPTER V

HUMAN IMPACT ON THE NETARTS SYSTEM

METHODS

Human occupancy of the Netarts Bay area infers utilization of basic resources and, thus, a modification of the resource base and environmental conditions of the estuary. One cannot fully understand the sequence of events unless research is done on the historical as well as the active current forces. Man is as much a part of the Netarts system as the physical elements. In order to identify this historic role, early manuscript data were collected from the Oregon Historical Society collection, especially that relating to observed or actual utilization of natural resources in and around Netarts Bay. Land deed research from the files of the Pioneer National Title and Trust Company in Tillamook provided data for plotting land use settlement patterns for the pre-1800 era. Unfortunately, early U.S. Coast and Geodetic Survey maps were not available for Netarts, but Bureau of Land Management maps dating back to the mid-1800's showed cultural patterns and settlement routes. Personal interviews of Netarts pioneer citizens who lived at Netarts and in the Netarts area since the turn of the century were invaluable. These interviews were supplemented by field work and mapping of early resource use activity along the shoreline. Early photographs, when available, showed

land use activities and the early physical geography of Netarts.

It was necessary to stereoscopically examine aerial photos to compare the natural and cultural features of the shoreline and watershed. Flights for the Netarts area were available for the years, 1939, 1962, and 1974. After features were identified, areas of the shoreline were planimetered for aerial comparison. This was especially helpful for determining residential and recreational land use impacts and changes in the marshes and the sandspit. Field surveys of residential clearing and construction, as well as subdivision plat maps and building permit records provided ground truth confirmation of residential and related activity. The watershed was considered a primary link to the system and methods were developed to measure the extent of logging activity. The Crown Zellerbach Tillamook office provided vegetation and clear cut maps dating back to the early 1900's. The watershed areas were categorized by time periods and planimetered for total area cut. Dominant vegetation types were noted for the logged areas. In this manner, a chronology of logging activity was developed for the entire watershed.

Methods of analysis were strongly dependent on the current level of knowledge of the bay as a system. Defining the critical environmental factors within the system required synthesis of physical and biological studies of

Netarts Bay, as well as supplemental research on factors found to be critical in other estuarine systems.

INDIAN SETTLEMENT AND RESOURCE USE

Indians were migrating through the Netarts Bay area as early as 1400 A.D. and were present when the white settlers arrived in the mid-19th century. The name Netarts is of Indian origin from Ne'ta'at meaning "near the water" (Tillamook Memories, Tillamook County Pioneer Association, 1972). Indian encampments have been found both on the spit and along the western margin of the bay. Newman (1959) during his investigations of Indian sites and middens on the sandspit found evidence of flora and fauna utilized by the Indians. This documented evidence shows a variety of resources present in the Netarts area at a very early time (Tables X and XI). The Indians occupied two main areas along the bay; an extensive village within the trough of the main dune on the sandspit in a small spruce forest and along the east side of the bay at what is now called "Wilson Beach". Personal investigation of the extensive shell middens on the northern third of the spit uncovered large mammal bones, native oyster shells, and five, possibly six different species of clams. Predominant species utilized were cockrel and mud. Others include gaper, quahog, butter, and littleneck.

TABLE X

FLORAL SPECIES IDENTIFIED AS FOOD
SOURCES FOR THE INDIAN ON THE NETARTS
SANDSPIT

Area of Spit and Species Name	Part Utilized
A. Tide Flats	
<u>Agrostus alba</u> (bent grass)	seeds
<u>Bromus sp.</u> (brome grass)	seeds
<u>Carex obnupta</u> (sedge)	stems
<u>Potentilla anserina</u> (silverweed)	roots
<u>Scirpus americanus</u> (bulrush)	rootstocks
<u>Triglochin maritima</u> (arrowgrass)	seeds
<u>Tristum canescens</u> (oatgrass)	seeds
B. Dunes	
<u>Abronia latifolia</u> (sand verbenae)	roots
<u>Angelica hendersonii</u> (angelica)	roots/ young shoots
<u>Arctostaphylos ura-ursi</u> (kinnikinnick)	fruits
<u>Festuca rubra</u> (red fescue)	seeds
<u>Fragaria chiloensis</u> (dune strawberry)	fruits
<u>Lonicra involucrata</u> (twinberry)	fruits

TABLE X Continued

<u>Area of Spit and Species Name</u>	<u>Part Utilized</u>
<u>Lupinus littoralis</u> (dune lupine)	roots
<u>Poa confinis</u> (dune blue grass)	seeds
<u>Solidago spathulata</u> (goldenrod)	seeds
C. Forest (on old dunes)	
<u>Amelanchier florida</u> (service berry)	fruits/ berries
<u>Arctostaphylos columbiana</u> (manzanita)	fruits
<u>Gaultheria shallon</u> (salal)	fruits
<u>Pinus contorta</u> (beach pine)	cambium
<u>Pteridium aquilinum</u> (bracken fern)	rootstocks
<u>Pyrus diversifolia</u> (crab apple)	fruit
<u>Ribes sp.</u> (goosberry)	fruits
<u>Rubus parviflorus</u> (thimble berry)	fruits
<u>Vaccinium ovatum</u> (evergreen huckleberry)	fruits

Source: Newman, Thomas (1959), Tillamook Prehistory and its Relationship to the Northwest Coastal Area, PhD. Thesis, p. 75.

TABLE XI

IDENTIFICATION OF FAUNAL REMAINS FROM
EXCAVATIONS ON THE NETARTS SPIT

<u>Scientific Name</u>	<u>Common Name</u>
<u>Eumetopias</u>	Stellar sea lion
<u>Zalophus</u>	California sea lion
<u>Enhydra</u>	Sea otter
<u>Lutra</u>	Land otter
<u>Phoca</u>	Seal
<u>Delphinid</u>	Porpoise
<u>Castor canadensis</u>	Beaver
<u>Cervis</u>	Elk
<u>Odocoileus</u>	Deer
(bird and fish bone not specifically identified)	

Source: Newman (1959)

EARLY EUROPEAN SETTLEMENT AND RESOURCE USE: 1805-1950

Before settlers came to Netarts Bay in any significant numbers, the area was surveyed by the U.S. Government and traversed by explorers. The survey job was rugged, difficult, and sometimes thankless. Samuel D. Snowden surveyed the Tillamook area including Netarts Bay between 1857 and 1858. Warren Vaughn (1905, Book No. III) wrote about Snowden's difficulties:

...Mr. Snowden meandered nearly all the tide sloughs tidelands, but when the government sent their agent out to look after the survey, he would not accept Snowden's meanderings of the tide slough and some of the rivers and threw out a considerable amount of his surveys...and had to sell some of his donation land claim to pay the survey crew.

After the Netarts area was surveyed, a primary impetus for settlement was afforded by the Donation Land Law of 1850 and the Federal Homestead Act of 1862 which provided settlers with up to 320 acres of land. Settlement first occurred in Clatsop County, north of Tillamook and in the interior of Willamette Valley. Infertile soil and summer drought in the North Coast area encouraged settlers to move southward into the Tillamook and Netarts areas. Dickens (1971), reports that the settlers utilized Indian routes by canoe, horse, and back packing. Settlers from the Willamette Valley came across the Coast Range following Upper Yamhill River drainage basin, then the Nestucca River up through Netarts to Tillamook Bay. The Indians ferried the settlers across the mouth of Netarts Bay to the spit where

a trail took them south along the ocean and over Cape Lookout (Fig. 14). The present developed area of Netarts was passed over for the fertile, extensive flood plains of Tillamook Bay until the early 1860's. Three or four claims were recorded on Netarts in the fall of '63 (Vaughn, 1905, Book III). Tim Goodale built the first house in 1867 or 1868. A Mr. Jones lived at the head (south end) of the bay and harvested oysters.

Deed research on original Donation Land Claims for the Netarts area showed extensive settlement including tideland, shoreline, and upland areas. Prior to 1880, only five settlers had officially filed on Donation Land Claims. Approximately one-half of all settlement before 1910 occurred between 1868 and 1890. Mildred Edner (1972) during an interview referred to both the Grimes and Hardman places, the latter located within the spruce forest on the spit (Table XII). The density of settlement in the Netarts area did not substantially increase from 1910 to 1950, but there was substantial impact on the study area due to land use activity and alteration of both the shoreline resource quality and quantity.

Changes in the Resource Base

The shoreline and tidal flat area of the Netarts estuary was a focal point for many early human use activities. Interviews with the pioneer Netarts citizens, such as

Township No. 2 South Range No. 10 West Willamette Meridian, Oregon.

1374

- ▲ Indian Village Site
- Early Homesteads
- Trails
- = Wagon Road

SURVEYS DESIGNATED.	BY WHOM SURVEYED.	NO.	DATE OF CONTRACT.	AMOUNT OF SURVEY.		WHEN SURVEYED.	Total number of acres New Survey 12,652.25	
				Acres.	Sections.		MEAN DECLINATION.	
Thompson Line	Samuel D. Spaulden	67	July 2 1856	31	05	93	21° East	
Subdivisions	William J. Wright	144	May 16 1882	2	37	00		
Intersections	do do do	do	do do do					

The above map of the Willamette Meridian, of Township No. 2 South of Range No. 10 West of the Willamette Meridian, Oregon, is strictly conformable to the field notes of the survey thereof on file in this office, which have been examined and approved.

T. S. Surveyor-General's Office,
Portland, Oregon.

Witness my hand and seal, 1882, 12th March, 1882.

Figure 14. Settlement and overland routes in the Netarts area.

TABLE XII

NAMES OF EARLY SETTLERS AND ACREAGES
OF ORIGINAL LAND CLAIMS ALONG SHORELINE

Name	Section No.	Acreage	Date Claim Filed
Wiley	18 @ 19 (on spit)	69	1890
Grimes	18 (on spit)	unknown	1890
Hardman	17 (on spit)	157	1891
Frier	19 (spit) ¹	28	1862
Page	17 (on spit)	163 ²	1891
Hardman	8 (mainland)	104	1906
McKormach	8 (mainland)	137	1875
Thompson	17 (tidelands)	37	1883
Leland	17 (tidelands)	37	1869
Austin	20 @ 21	158	1903
Morgan	20	150	1898
West	19	138	1903
Palmer	30	152	1897
Jackson	30 (spit @ mainland)		

¹
possibly a grazing claim

²
includes tidelands

Source: Pioneer National Title and Trust Company
Historical Donation Land Claims, Tillamook,
Oregon, 1971.

Mildred Edner, presents a picture of a vast array of activities, most of which are associated with the settlers livelihood. Oystering was one of these early resource-use activities. Netarts Bay had an abundance of native oysters. The oysters were for the taking; as early as 1868 Claus Christiansen harvested native oysters in Netarts. It was reported that sloops would enter the bay to be loaded by the Indians when weather permitted for shipment to San Francisco. Alternate shipping was by 30-mule team pack trains to Tillamook. An early name for Netart's Bay was "Oyster Bay". A shanty town "Oysterville" sprang up at the head of the bay between 1880 and 1900 to house oyster shuckers (Tillamook Memories 1972). The demise of the native oyster was due to over-harvesting, mud strangulation from heavy runoff from the watershed, and introduction of the larger more commercially acceptable Japanese oyster. The Federal government restocked the native oyster beds and set a limit of two acres per person for commercial purposes. The Japanese oyster industry flourished between 1930 and 1957, due to ideal environmental conditions for growth. Square (1972) indicates that in 1957, the Japanese Oyster drill (*Ocenebra japonica*) was accidentally introduced in the bay. This species preyed on the oysters until the bay was too infested and oystering was not economically feasible. The oyster drill was also one of the reasons for the extinction of the native oyster (Figs. 15 and 16).

Figure 15. Stakes delimiting early oyster plats.

Figure 16. Historical utilization of tidal areas, 1880-1940.

Other human activities within the shoreline and tidal flat areas included shell fish processing, grazing of the marshes, recreational camps, and boat building. The Jackson family maintained a local razor clam industry at the mouth of Jackson Creek on the beach at the south end of the spit around 1900. Cattle were grazed on the spit and mature marshes in the late 1800's and early 1900's. Early recreational activity include an area which exists today, Happy Camp, just north of Netarts. Mrs. Edner (Tillamook Memories 1972) documents that the settlers on the sandspit were in the dairy and tourist business. Some families ran cabins at Happy Camp. Boat building activities were stimulated by wrecking salvage operations in Netarts. Vaughn (Book III, 1905, p. 188) reports that men engaged in building a 70-ton ship, The Brant of Tillamook around 1861. A two-masted boat, The Sea Lion was built around the turn of the century. Diking and alteration of creek meander patterns occurred as early as 1900. A hand built dike in 1903 provided access to the southeast shore of the bay, and restricted tidal flushing of the marshes located along this area. During an interview with Lauren McKinley on March 1, 1973, it was reported that dikes were extensively built, as well as water gates to divert creek waters so various portions of the marsh would be accessible for haying and grazing. Remnants of water gates, roads, and fence lines can still be observed on the mature marsh along the southeast shore and to the head of the bay (Fig. 17).

Figure 17. Remnant of tidal gate on marsh on east side of Whiskey Creek Road.

Early logging in the upland and watershed has changed the resource base of the Netarts area. Primary impacts are evidenced by the demise of the Chum salmon runs in Whiskey Creek as well as other smaller streams which feed into the bay. From 1900 to 1950, thirty-one percent of the total watershed area was logged. Trees were yarded out of the watershed by oxen and milled along the bayshore. In 1917, a water-powered mill on Whiskey Creek was used to manufacture timber for tourist cottages and milled spruce for airplanes during World War I (Tillamook Memories 1972).

Alteration of the physical and biological resources of the bay as of 1950, can be summarized as follows:

- (a) a change occurred in the vegetative composition of the watershed from spruce and hemlock to dense brush communities and Douglas fir stands because of forest fires
- (b) early logging activities destroyed the large Chum salmon runs in the small streams; especially in Whiskey Creek by spawn bed siltation and logging debris
- (c) diking of the marshes along the southeast shore and at the head of the bay, as well as creek diversion for grazing purpose altered the tidal flushing action within the marshes and may have accelerated marsh succession and maturation
- (d) over-harvesting, heavy siltation, and introduction of the oyster drill led to the extinction of once profitable native oyster industry.

POST 1950 SETTLEMENT AND IMPACTS ON THE NETARTS SYSTEM

Impacts of land use activities become more visible and quantifiable since 1950. They can be generally categorized into three groups; logging and road construction in the watershed, road construction along the east side of the bay with development of the county Boat Facility, Cape Lookout State Park, other recreational activities, and residential development in the uplands and marine terrace. Critical environmental factor of the Netarts system was identified earlier as main habitat types and conditions. Clark (1974) uses the terms "vital areas" and "transient vital areas" to describe components of an estuarine ecosystem of great importance to certain species or to the functioning of the entire ecosystem. The five critical environmental factors discussed earlier in the chapter can be considered both vital and transient-vital areas. For example, the location of the marshes and eelgrass beds are relatively fixed; whereas characteristics of sediment distribution and size fluctuate during the winter and summer seasons. The impact of these three groups of land use activities on these vital areas will now be discussed.

Logging and Related Road Construction in the Watershed

The Crown Zellerbach Corporation bought the extensive timber holdings in the watershed from Crown Willamete Lumber Company in 1923. Since that time, essentially all old growth timber has been clear cut and partially replanted.

It is assumed, as is the case in other Oregon estuaries, that this activity has accelerated the rate of sedimentation within the bay. Johannessen (1961) found the process of filling of Oregon estuaries accelerated after the coming of the Europeans. Studies by Jefferson (1974), Johannessen (1961), and Eilers (1973) show a strong relationship between types and quantity of sediment deposited and the rate of marsh progradation in a given estuary. It is believed that increased logging in the Netarts watershed has contributed to significant marsh progradation in some areas, as well as causing a decrease in the total bay water volume (reduction of the tidal prism). In order to explore this further, maps depicting vegetative clear cuts were measured with a polar planimeter and acreage recorded. The data shows that approximately seventy percent of the total watershed was clear cut between 1950 and 1975 (Fig. 18 and Table XIII). To further explore the possibility of high levels of bay sedimentation, marsh acreage was measured from aerial photos for two time periods; 1939-1962 and 1962-1974, 1939 being the earliest available aerial photo of the bay. Also, the tidal wetland type was subdivided into four different marsh communities based on species composition described earlier. All marsh areas were found to be prograding, but at different rates according to the type of marsh examined. The low sand marsh showed 18.8 percent increase from 1939 to 1962. This substantial increase is

Figure 18. Chronology of logging and existing vegetation in the Netarts watershed.

TABLE XIII

CHRONOLOGY OF LOGGING IN NETARTS WATERSHED, TOTAL
AREA LOGGED AND CURRENT DOMINANT VEGETATION TYPE

<u>Time Period</u>	<u>Dominant Vegetation</u>	<u>Total Acreage</u>	<u>% of Total Watershed</u>
1) Pre-1930	Sitka Spruce	1864.8	17
2) 1930-1950	Western Hemlock	1556.9	14
3) 1951-1960	Western Hemlock	1090.5	10
4) 1961-1965	Douglas Fir	2641.3	24
5) 1966-1971	Douglas Fir	2146.4	19
6) 1972-1975	Sitka Spruce	272.6	2
Unforested Uplands		<u>1533.2</u>	14
Total		11,106 acres	

Source: Crown Zellerbach Clear Cut Maps.

due to the breaching of the spit in 1939 and consequent sand deposition on silt sediments and not due to heavy siltation from the watershed since the marsh type is established on a sand substrate. Other marsh types show lesser amounts of progradation. A decrease in marsh type was not observed for the period 1939-1962 (Table XIV), Jefferson (1973) and Johannessen (1961) note that the presence of low silty marsh type can be seen from aerial photos as circular islands of plants and depict areas where marsh margin is advancing into the tidal flat. Netarts Bay tidal flats show a very small amount of this marsh type. Overall, the 1939-1962 time period experienced the greatest amount of marsh progradation, pointing to the fact that the relatively large amount of progradation in the sedge type marsh represents the succession of former low, silty marsh to sedge type during earlier times.

It was previously assumed the increase in logging activity in the watershed (over 70 percent of the total area was logged between 1950-1975) would correlate with an increase in sedimentation and, thus, marsh progradation for this time period. Data shows that, at least for the period 1962-1974 this was not the case. Either the sedimentation rate was slower or other environmental factors are responsible for a lack of marsh growth during this period. The increased

TABLE XIV

MARSH TYPE AND ACREAGE
NETARTS BAY, OREGON
1939, 1962, 1974

Marsh Type	Year and Hectares			% Increase	
	1939	1962	1974	1939-62	1962-74
I Low Sand Marsh	5.07	14.58	18.23	188%	25%
II Sedge Marsh	5.95	12.67	16.34	113%	29%
III Immature High Marsh	13.80	21.73	24.12	57%	11%
IV Mature High Marsh	44.92	54.63	59.55	22%	9%
Total Hectares	69.77	103.60	118.25	48%	14.14%

Source: Planimetric measurement of marsh types identified by
Jefferson (1973) for Netarts Bay.

rate of marsh progradation between 1939-1962; especially the sedge and immature marsh on the eastern edge of the bay could be due to the earlier impacts of burning in the watershed. It is possible as the brush communities established themselves, the sedimentation rate decreased. It is probable that burning played a more prominent role in bay sedimentation than logging.

Another factor examined was the impact that sedimentation has had on the total bay water volume. The best historical data available was collected by Glanzman, et al (1971) who found a ten percent decrease in total bay volume as measured from cross sectional areas between 1957 and 1969. Graphed data were compared to determine if there was a correlation between location within the bay and variation of bay volume. The volume was found to vary according to the location of the cross sectional area measured (Table XV). With the exception of the area at the mouth of the bay, there was a progressively larger decrease in water volume from north to south, the largest, a 10.9 percent decrease at the mouth of Whiskey Creek. The total volume of the bay has an important relationship to both tidal levels and flushing action which act as environmental limitations to eelgrass growth at +1.0 tidal level. Approximately one-half (48 percent) of the eelgrass beds in the bay grow in shallow water. Any further reduction in bay water volume could endanger the shallow water beds because of the

TABLE XV
DIFFERENCES IN WATER VOLUME FOR
FOUR CROSS SECTIONAL AREAS IN NETARTS BAY
AT HIGH SLACK TIDE, 1957 and 1969

Cross Section #	Description	Distance from Mouth	X-Sect. Area 1975	Area 1969	^a Percent Increase/ Decrease in Volume	
					Decrease in Volume	
I	320 m south of spit end	320 meters	3.66 m	4.42 m	25%	increase
II	305 m south of county small boat basin at Wilson Beach	1.58 km	5.79 m	5.24 m	8.7%	decrease
III	73 m south of Whiskey Creek Road junction	3.10 km	5.85 m	5.27 m	9.9%	decrease
IV	Across from Whiskey Creek	5.54 km	6.10 m	5.43 m	10.9%	decrease

^a
meters squared

Source: Glanzman, et al (1971), p. 14.

increased probability of plant dessication. This is especially true in the Whiskey Creek area.

Impacts related to logging and related road construction can be summarized as follows:

- (1) The data indicates the marshes are prograding, but at varying rates according to marsh type and time periods analyzed; rapid between 1939-1962 and much slower between 1962-1974.
- (2) Total bay water volume is decreasing at differing rates depending on location and could adversely effect eelgrass growth in the Whiskey Creek area.
- (3) Data is inconclusive, but the decrease in bay water volume may have increased tidal velocities and inhibited marsh growth in the bay from 1962-1974.

It must be noted that data on bay sedimentation are inconclusive at this time. Accurate sediment measurements are needed for a long time period covering all seasons in order to predict and give an accurate account of marsh growth within the bay.

Filling and Jetty Construction for Recreational and Residential Use

Other types of land use activities which have altered or influenced the Netarts Bay system can be directly associated with the attractiveness of the area as a location for

recreational and residential facilities and homesites. Recreational development significantly influencing the system includes the filling and construction of the county boat facility near the Schooner Cafe just south of the town, the road construction and paving of the bayshore road, and the clearing of land and residential development along the marine terrace. Prior to 1911, portions of the bayshore south of Whiskey Creek were diked and rip-rapped so the area would be accessible to cattle and farming. A dirt road was built in the late 30's along the southeast shore of the bay. In 1953, Cape Lookout State Park was established when the Cape and adjoining lands were deeded to the state from the Hill Family Foundation. This precipitated road construction along the east shore of the bay, as well as inland. It was also during this time the county boat facility and jetty system was constructed on the northeast side of the bay south of the town of Netarts. Both road construction and the opening of Cape Lookout State Park were primary incentives for residential development in the Netarts Bay area. As of 1975, the fill areas, including the boat basin totaled 12.23 hectares; much of this comprising the fill used for a parking lot. Undoubtedly, an economic asset to the community, the new roads and access points to the bay system have also put more pressure on the shell and fin fisheries, constricted tidal flow within the bay, and increased sedimentation within marsh inlet areas. The fill itself, especially the

the parking lot has covered and depleted Gaper clam habitat along the eastern shore.

The basin and jetty system for boating has caused a significant change in the morphology of the end of the sandspit. Comparison of 1939 and 1962 aerial photos shows a decrease in total hectares of the end of the spit from 90.9 hectares in 1939 to 84.9 hectares in 1962; a decrease of approximately nine percent. This alteration is primarily due to dredging of the basin and the placement of two small jetties which caused a realignment of the adjacent channel westward eroding the end of the spit (Fig. 19).

Residential development and associated filling has occurred along the bayshore and marine terrace area principally since 1900 when the town of Netarts was platted. Developed areas within the town of Netarts were measured by planimeter from early aerial photos. Copies of early subdivision plats, as well as building permit statistics were compiled from the Tillamook County Planning Office. The largest amount of growth in the Netarts area occurred between 1956-1975 (38.0 hectares). Another period of increased growth was during 1900-1942. Careful site planning is needed because of extremely unstable soil conditions along the east side of the bay.

Preservation of tidal marsh is also important. For example, a large subdivision established in the early 1960's altered Yeager Creek and a lake was formed. The

Figure 19. Change in sandspit morphology for the period 1882-1962, Netarts Bay (from U.S. Army aerial photos and topographic maps).

marsh was diked and thus, destroyed. It now serves the residents with a flooded area in winter and a semi-dry swamp in summer (Fig. 20).

As shown by the changes in the spit shoreline, residential land use and related developments can alter tidal currents and velocities. A change in sediment conditions can also be expected including sediment heterogeneity and organic content, factors which are considered critical or vital for benthic species diversity within the Netarts system. Personal communications with George Smith, Tillamook County Soil Conservation Service agent discloses increasing erosion along the county road which presently requires extensive maintenance with rip-rap. It is assumed this increase in shoreline erosion has caused an alteration of bottom sediment composition in the bay. The cause of this increased erosion is undoubtedly due to constriction of the original tidal surge plain area (the marsh inlets along the shore). Further filling could upset the existing sedimentation processes that give the species assemblages their variability. Natural phenomena have also altered the bottom sediment facies. In 1939, the spit was breached about three miles north of Cape Lookout Park. Sand was distributed over a large area on the east side of the spit. The spit was planted with European beach grass in the early 1950's and helped stabilize its southern extent.

Figure 20. Whiskey Creek subdivision and fill,
Netarts Bay.

Alterations of the Netarts system that can be related to residential and recreational land use can be summarized as follows:

- (1) Road fill and construction have destroyed Gaper clam beds along the eastern shore of the bay as well as causing increased erosion of the shoreline due to the constriction of marsh flood areas.
- (2) The development of the county boat basin and parking facility have caused an increase in erosion of the spit head and a change in the main channel, due to dredging and jetty construction. It also has destroyed clam beds.
- (3) Residential development has accelerated shoreline erosion and has destroyed marsh inlets in the Yeager Creek area.
- (4) All future development can ultimately alter existing sediment processes and threaten benthic species diversity.

Data are still incomplete, especially in regard to impacts from residential and recreational land use activity. The factor of erosion and to what extent shoreline erosion contributes to the sedimentation process is crucial in understanding the impact of land clearing. This information would be valuable in planning intensity of development within the system.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

The purpose of this study is to determine what are the critical environmental factors of the Netarts estuary and if one can determine what alterations and impacts have occurred on these factors by using an "historic-analytic" approach. Although physical and biologic data are incomplete, it is possible to tentatively identify those factors important to the system as a whole. This was possible only after an intensive physical and cultural baseline study on the Netarts area in the summer of 1975 and detailed engineering completed on the hydrology and flushing characteristics of Netarts Bay in 1969-1970. It is noteworthy that only after all of these data were compiled and synthesized was it possible to make reference to the critical environmental factors due to the highly coupled nature of the system. Netarts Bay is relatively pristine in comparison with other Oregon estuaries in terms of the natural versus the man-altered condition. It is concluded that more knowledge is needed on the complex systems of marsh growth and its relationship to sedimentation. Netarts Bay could serve as a marine sanctuary for study purposes if development could be restricted in the uplands and the terrace areas. It is difficult to assess the magnitude of impact on system conditions from man's

activities on an estuary such as Netarts Bay, especially from the historical record, although indications of these changes can be seen from comparative aerial photos and engineering studies. Discernible changes in the Netarts system have and are presently occurring in the marshes and spit areas of the shoreline. Inferences have been made concerning sedimentation processes and current velocities. Unfortunately, a sedimentation study spanning several years is needed before an analysis of land use impact could be undertaken. The Netarts system, with its variation in shoreline and watershed would be a valuable area for specific sedimentation studies which could be correlated with diverse land uses and ranges of intensity of shoreline use. More study is also needed on benthic species assemblages during the winter months, especially since these assemblages are strongly correlated with sediment heterogeneity and organic carbon content. It is concluded that it is necessary to isolate those naturally-occurring changes which are important to the system from those that are man-caused so one can adequately determine to what extent man has influenced natural conditions. Accelerated marsh progradation seems to indicate interference in Netarts, as well as accelerated erosion of the spit. The decrease in total bay water volume indicates an increase in sediment load transport from the spit, watershed, or shoreline. Variation in depositional characteristics is dependent on the bay configuration.

It is not known whether this decrease in volume is due to natural or cultural factors.

RECOMMENDATIONS

Although research on both historical and current events on estuarine areas are interesting for their own sake, it becomes valuable only when it can be used as a tool for making rational decisions related to land and water use. Since the McHarg era, resource and other land use planners have grappled with the problem of environmental data synthesis and the modeling of environmental systems. The hypothesis was that it was important to isolate those variables important to the system as a whole. A question still exists for resource managers; if we manage one resource what effect does this have on the food chain? There have been numerous methodologies proposed to assess impacts on various environmental conditions by man's activities in estuarine areas. The National Environmental Policy Act of 1969 mandates the assessment of these impacts and exploration of alternative development solutions to mitigate impacts. Certain states, such as Washington have an adopted State Environmental Policy Act ordinance which requires virtually all development to go through the process of determining environmental significance before construction is allowed. Coastal Zone authorities in California, Oregon, Washington, and other states are developing methods to retrieve useful planning

information on the biota and physical geography of estuaries. Sorensen (1971), recognizing this need, developed a matrix system capable of displaying many types of planning and resource use data. The original purpose of Sorenson's work was to develop a system capable of computerization which can predict the impact of any proposed use on the total system. The extended matrices in his work represent relationships among causes, conditions, and effects. Although it is not possible here to make an exhaustive treatise on Sorenson's work, it is considered the best and perhaps the most useful example of the matrix in the process of impact assessment.

Bella and Klingeman (March 1973) under a grant from the Pacific Northwest River Basin Commission drafted what is probably one of the most progressive documents for the planning of Oregon estuarine systems. The systems approach is emphasized throughout including an understanding of the processes along with information on properties and discrete elements of the estuary. Several ideas stand out as germane to the total document. These are:

- (1) Planning for estuaries must recognize that the maintenance of diversity is as important to the natural biological resources as is large-scale similarity to the economics of development.
- (2) The planner needs to incorporate "ignorance of the system" into his planning methodology.

- (3) It is necessary at the onset to recognize the "uniqueness" of the particular estuary system and to identify as many different and descriptive habitats as possible.
- (4) The planner should utilize an impact analysis procedure from the very start of the planning process.
- (5) There is a need to plan for preserving future options, especially in light of the dynamic character of estuarine systems.

This systems approach proposed by Bella and others is essential for making prediction and land use decisions in estuarine areas.

This thesis can be considered an attempt to establish a base for systems analysis for future planning purposes; one of the crucial steps in developing an estuarine land use model. In order to realistically model an estuary, one has to relate the physical as well as the human environment. This thesis is not a model of Netarts Bay but it does note the historical and current changes within the systems which is of value in developing the model. By using the "historical-analytic" approach in documenting changes in the landscape and resource base and supplementing this study with baseline data on the biophysical elements, one can tentatively identify critical environment factors within the system and, in the future, draft development guidelines that

are cognizant of these factors. This is important for preservation of future options within the system. Myron Blank (1974) has proposed both "attractiveness" and "impact" models to determine land use suitabilities for planning which may have applicability to estuaries. Netarts Bay would be a good candidate for development of a land and water use model if supplemental research on seasonal sedimentation and benthic fauna were undertaken.

SOURCES CONSULTED

- Baldwin, Ewart 1964. Geology of Oregon, Eugene, Oregon: University of Oregon Press.
- Bella, David A. and Peter C. Lingeman March 1973. General Planning Methodology for Oregon's Estuarine Natural Resources, prepared for the Pacific Northwest River Basins Commission, Corvallis, Oregon: University of Oregon Press.
- Blank, Myron A. 1974. Computers: Their Place in Land Use Analysis, MS Thesis, Utah State University, Logan, Utah.
- Boley, S. L. and L. S. Slotta 1974. Relevant Data Concerning Proposed Discharge of Domestic Wastes into Netarts Bay, Oregon, Bulletin No. 50, Engineering Experiment Station, Oregon State University.
- Burt, W. V. and W. B. McAlister 1959. "Research Studies in the Hydrography of Oregon Estuaries," Fish Commission Research Briefs, Vol. 7, No. 1, Fish Commission of Oregon.
- Clark, John 1974. Coastal Ecosystems; Ecological Considerations for Management of the Coastal Zone, Washington, D.C.: The Conservation Foundation.
- Cooper, W. S. 1958. Coast Sand Dunes of Oregon and Washington, Geological Society of America Memoir No. 72.
- Cronin, Eugene L. and Alice J. Mansueti March 1971. "The Biology of the Estuary," A Symposium on the Biological Significance of Estuaries, supported by the National Science Foundation Sea Grant No. H000070, Washington, D.C.: Sport Fishing Institute.
- Dicken, Samuel N. 1961. Some Recent Physical Changes of the Oregon Coast, Department of Geography, University of Oregon.
- Dicken, Samuel N. 1971. Pioneer Trails of the Oregon Coast, Portland, Oregon: Oregon Historical Society.
- Elliot, T. C. John Meare's Approach to Oregon, 1778-- extracted from: Voyages to the Northwest Coast of America by John Meares.
- Franklin, Jerry F. and C. T. Dyrness 1969. Vegetation of Oregon and Washington, U.S. Department of Agriculture, Forest Service Research Paper No. 80.

Gaumer, T. F., D. Darrel and L. Osis 1974. 1971 Netarts Bay Estuary Resource Use Study, Fish Commission of Oregon.

Glanzman, Charles F., Bard Glenne, and Fred J. Burgess January 1971. Tidal Hydraulics, Flushing Characteristics, and Water Quality of Netarts Bay, Oregon, Corvallis, Oregon: Oregon State University Engineering Experiment Station.

Hedgpeth, Joel W., ed. 1957. Treatise on Marine Ecology and Paleocology, Vol. 1, New York: The Geological Society of America.

Horner, J. B. 1919. Oregon History and Early Literature, Portland, Oregon: The J. K. Gill Company.

Hunger, A. A. 1966. Distribution of Foraminifera, Netarts Bay, Oregon, MS Thesis, Corvallis, Oregon: Oregon State University.

Jefferson, C. A. and G. J. Aikens 1973. Coastal Wetlands of Oregon, Salem, Oregon: Oregon Coastal Conservation and Development Commission.

Mangum, Doris 1967. "Geology of Cape Lookout State Park Near Tillamook, Oregon," Ore Bin, Vol. XXIX, No. 5, 85-109.

Milne, L. J. and M. J. Milne 1951. "The Eelgrass Catastrophe," Scientific American, Vol. 184 (1), 52-55.

Newman, Thomas 1959. Tillamook Prehistory and its Relationship to the Northwest Coastal Area, unpublished PhD thesis, University of Oregon, Eugene, Oregon.

Odum, Eugene P. 1971. Fundamentals of Ecology, Philadelphia, Pennsylvania: W. B. Saunders Co.

Odum, H. T. 1967. "Biological Circuits and the Marine Systems of Texas," Pollution and Marine Ecology (T. A. Olson and F. J. Burgess, eds.), New York: John Wiley and Sons, Inc.

Odum, H. T., B. J. Copeland and E. A. McMahon, eds. June 1974. Coastal Ecological Systems of the U.S., Vols. I, II, and III, Washington, D.C.: The Conservation Foundation.

Pritchard, D. W. 1955. "Estuarine Circulation Patterns," Proceedings for the American Society of Civil Engineers, Vol. 81.

- Pritchard, D. W. 1967. "What is an Estuary? A Physical Viewpoint," Estuaries (G. E. Lauff, ed.), American Association for the Advancement of Science, Publication No. 83: 3-5.
- Reid, George K. 1961. Ecology of Inland Waters and Estuaries, New York: Reinhold Publishing Corporation.
- Schlicker, Herbert G., Robert J. Deacon, John D. Beaulieu and Gordon W. Olcott 1972. Environmental Geology of the Coastal Region of Tillamook and Clatsop Counties, Oregon, Bulletin 74, prepared for Oregon District No. 1 Council of Governments, Clatsop-Tillamook Counties by the State of Oregon, Department of Geology and Mineral Industries.
- Sorenson, Jens C. December 1971. A Framework for Identification and Control of Resource Degradation and Conflict in the Multiple Use of the Coastal Zone, MS Thesis, Berkeley, California: University of California Press.
- Squire, Douglas R. June 1972. The Japanese Oyster Drill, *Ocenebra Japonica* in Netarts Bay, Oregon, MS Thesis, Oregon State University, Corvallis, Oregon.
- Stout, Heather, ed. 1976. The Natural Resources and Human Utilization of Netarts Bay, Oregon, an interdisciplinary study funded through the student-originated studies program of the National Science Foundation Grant No. EPP75-08901, Corvallis, Oregon: Oregon State University Press.
- Teal, John M. 1962. "Energy Flow in the Salt Marsh Ecosystem of Georgia," Ecology, Vol. 43, 614-624.
- Tillamook Pioneer Association 1972. Tillamook Memories, Tillamook, Oregon.
- U.S. Department of Agriculture 1957. Soil Survey, Tillamook Area, Oregon, Series 1957, No. 18, Washington, D.C.: U.S. Government Printing Office.
- Vaughn, Warren N. 1905. Journal, 1851-54, Books I-IV, the Oregon Historical Society Manuscript Collection No. 213.
- Wiedemann, Alfred M., L. Dennis and Frank H. Smith 1969. Plants of the Oregon Coastal Dunes, Corvallis, Oregon: Oregon State Bookstore, Inc.

Wood, E. J., Ferguson, W. E. Odum and J. C. Zieman 1967.
"Influence of Sea Grasses on the Productivity of
Coastal Lagoons," Lagunas Costeras Un Simposio,
Mexico, D.F.

Zimmerman, S. T. 1971. Seasonal Succession of Zooplankton
Populations in Two Dissimilar Marine Embayments in
Oregon, PhD Thesis, Oregon State University,
Corvallis, Oregon.

APPENDIX A

INDEX TO SPECIES NAMES

Animals

Amphibians

Bufo boreas
Hyla regilla
Rana aurora
Rana catesbeiana
Taricha granulosa

Western toad
 Pacific tree frog
 Red-legged frog
 Bullfrog
 Rough-skinned newt

Benthic Invertebrates

Hydrozoa

Cladonema californica

Jelly fish

Nemertea

Cerebratulus californiensis

Ribbon worm

Polychaeta

Abarenicola pacifica (Arenicolidae)
Mediomastus californiensis (Capitellidae)
Capitella capitata
Glycera convoluta (Glyceridae)
Glycera tenuis
Glycinde armigera (Goniadidae)
Lumbrineris zonata (Lumbrineridae)
Nephtys californiensis (Nephtyidae)
Nephtys caecoides
Nephtys caeca
Neanthes brandti (Nereidae)
Neanthes succinea
Ophelia assimilis (Opheliidae)
Euozonus mucronata
Euzonus williamsi
Armandis brevis
Orbinia johnsoni (Orbiniidae)
Haploscoloplos elongatus
Owenia collaris (Oweniidae)
Eteone californica (Phyllodocidae)
Eteone dilatata
Halosydna brevisetosa (Polynoidae)
Lepidasthenia interrupta

Lug worm
 Thread worm
 " " "
 Mud flat worm
 " " "
 " " "
 " " "
 Sand worm
 " " "
 " " "
 Clam bed worm
 Mud flat worm
 " " "
 Blood worm
 " " "
 Mud flat worm
 " " "
 " " "
 " " "
 " " "
 " " "
 Scale worm
 " " "

Polychaeta, continued

<u>Pygospio elegans</u> (Spionidae)	Sandy tube worm
<u>Pygospio californica</u>	" " "
<u>Rhynchospio arenicola</u>	" " "
<u>Pseudopolydora paucibranchiata</u>	" " "
<u>Pseudopolydora kemp</u>	" " "
<u>Spio filicornis</u>	" " "
<u>Spiophanes bombyx</u>	" " "
<u>Polydora socialis</u>	" " "
<u>Eupolytmia crescentis</u> (Terebellidae)	Parchment tube worm
<u>Pista pacifica</u>	" " "

Bivalvia

<u>Macoma balthica</u> (Tellinidae)	Nestling clam
<u>Macoma inquinata</u>	" "
<u>Macoma nasuta</u>	Bent-nosed clam
<u>Tellina bodegensis</u>	Sand flat clam
<u>Cryptomya californica</u> (Myidae)	Shrimp clam
<u>Mya arenaria</u> *	Soft-shelled clam
<u>Protothaca staminea</u> (Veneridae)	Littleneck clam
<u>Protothaca tenerrima</u>	" "
<u>Tapes japonica</u> *	" "
<u>Saxidomus giganteus</u>	Quahog clam
<u>Tresus capax</u> (Mactridae)	Blue clam
<u>Clinocardium nuttallii</u> (Cardiidae)	Cockel
<u>Lucinoma annulata</u> (Lucinidae)	Nestling clam
<u>Crassostrea gigas</u> (Ostreidae)*	Japanese oyster
<u>Zirfae pilsbryi</u> (Pholadidae)	Boring clam
<u>Mytilus edulis</u> (Mytilidae)	Bay mussel

Gastropoda

<u>Phyllaplysia taylori</u>	Sea slug
<u>Olivella biplicata</u> (Neogastropoda)	Purple olive snail
<u>Ceratostoma inornatum</u> *	Oyster drill snail

Phoronida

<u>Phoronis pallida</u>	Sand tube worm
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Crustacea

<u>Lepas pacifica</u> (Cirripedia)	Goose-neck barnacle
<u>Balanus glandula</u>	Acorn barnacle
<u>Leptochelia dubia</u> (Tanaidacea)	Sand tube crustacea
<u>Exciorolana linguifrons</u> (Isopoda)	Isopod
<u>Idotea resecata</u>	Isopod
<u>Eohaustorius</u> sp. (Amphipoda)	Amphipod
<u>Corophium brevis</u>	"
<u>Amphithoe valida</u>	"

Crustacea, continued

<u>Paraphoxus milleri</u>	Amphipod
<u>Paraphoxus spinosus</u>	"
<u>Photis brevipes</u>	"
<u>Hyale grandicornis californica</u>	"
<u>Heptacarpus pictus</u> (Decapoda)	Eelgrass shrimp
<u>Heptacarpus paludicola</u>	" "
<u>Crangon nigricauda</u>	" "
<u>Pinnixa faba</u>	Pea Crab
<u>Pinnixa littoralis</u>	" "
<u>Pinnixa sp.</u>	" "
<u>Hemigrapsus oregonensis</u>	Hairy shore crab
<u>Rhithropanopeus harrissi</u> *	Atlantic shore crab
<u>Pugettia richii</u>	Decorator crab
<u>Pugettia producta</u>	Kelp crab
<u>Petrolisthes cinctipes</u>	Porcelain crab

Echinoidea

<u>Dendraster excentricus</u>	Sand dollar
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Asteroidea

<u>Pycnopodia helianthoides</u> (Forcipulatida)	Sunflower starfish
<u>Pisaster brevispinus</u>	Seastar

Urochordata

<u>Botrylloides</u> sp. (Stolidobranchia)	Tunicate
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Hemichordata

<u>Saccoglossus</u> sp.	Acorn worm
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Birds

<u>Melospiza melodia</u>	Song sparrow
<u>Chamaea fasciata</u>	Wrentit
<u>Caysodacus purpureus</u>	Purple finch
<u>Hylocichla ustulata</u>	Swainson's thrush
<u>Turdus migratorius</u>	American robin
<u>Columba fasciata</u>	Band-tailed pigeons
<u>Larus ocridentalis</u>	Western gull
<u>Larus glaucescens</u>	Glaucous-winged

* Denotes introduced species.

Birds, continued

Larus delawarensis
Larus californicus
Larus heermanii
Hydroprogne caspia
Uria aalge
Cepphus columba
Phala-crocorax auritus
Phalacrocorax pelagicus
Ardea herodias
Corvus brachyrhynchos
Anas platyrhynchos
Mergus serator
Erolia alpina
Anas acuta
Gavia immer
Buteo jamaicensis
Oreortyx pictus
Zenaidura macroura
Bubo virginianus
Chordeiles minor
Chaetura vauxi
Selasphorus rufus
Megasceryle alcyon
Dryocopus pileatus
Dendrocopos villosus
Dendrocopos pubescens
Empidonax difficilis
Trachycineta thalassina
Tridopioche bicolor
Hirundo rustica
Progne subis
Perisoreus canadensis
Cyanocitta stelleri
Corvus corax
Parus atricapillus
Parus rufescens
Psalt riparius minimus
Sitta canadensis
Certhia familiaris
Troglodytes aedon
Troglodytes troglodytes
Thryomanes bewickii
Ixoreus naevius
Regulus satrapa
Bombyrella cedrorum
Sturnus vulgaris
Vermivora celata
Piranga ludoviciana
Pheucticus melanocephalus
Spinus pinus

Ring-billed
 California gull
 Heerman's gull
 Caspian tern
 Common murre
 Pidgeon guillemot
 Double-crested cormorant
 Pelagic cormorant
 Great blue heron
 Common crows
 Mallard duck
 Red-breasted merganser
 Dunlin
 Pintail
 Common loon
 Red-tailed hawk
 Mountain quail
 Mourning dove
 Great horned owl
 Common nighthawk
 Vaux's swift
 Rufous hummingbird
 Belted kingfisher
 Pileated woodpecker
 Hairy woodpecker
 Downy woodpecker
 Western flycatcher
 Violet-green swallow
 Tree swallow
 Barn swallow
 Purple martin
 Gray jay
 Steller jay
 Common raven
 Black capped chickadee
 Chestnut-backed chickadee
 Common bushtit
 Red-breasted nuthatch
 Brown creeper
 House wren
 Winter wren
 Bewick's wren
 Varied thrush
 Golden crowned kinglet
 Cedar waxwing
 Starling
 Orange-crowned warbler
 Western tanager
 Black-headed grosbeak
 Pine siskin

Birds, continued

<u>Spinus tristis</u>	American goldfinch
<u>Loxia curvirostra</u>	Red crossbill
<u>Pipilo erythrophthalmus</u>	Rufous-sided towhee
<u>Passerculus sandwichensis</u>	Savannah sparrow
<u>Zonotrichia leucophrys</u>	White-crowned sparrow
<u>Passerella iliaca</u>	Fox sparrow
<u>Sternella neglecta</u>	Western meadowlark
<u>Molothrus ater</u>	Brown-headed cowbird
<u>Agelaius phoeniceus</u>	Red-winged blackbird
<u>Melospiza melodia</u>	Song sparrow
<u>Pelicanus occidentalis</u>	Brown pelicans
<u>Circus cyaneus</u>	Marsh hawk
<u>Erolia melantos</u>	Pectoral sandpipers
<u>Erolia bairdii</u>	Baird's sandpipers
<u>Actitis macularia</u>	Spotted sandpiper
<u>Squatarola squatarola</u>	Black-bellied plovers
<u>Limosa fedoa</u>	Marbled godwits
<u>Charadrius alexandrinus</u>	Snowy plover
<u>Charadrius semipalmatus</u>	Semi-palmated plover
<u>Charadrius vociferus</u>	Killdeer
<u>Numenius phaeopus</u>	Whimbrel
<u>Totanus melanoleucus</u>	Greater yellowlegs
<u>Telmatodytes palustaris</u>	Long-billed marsh wren
<u>Branta bernicla</u>	Black brandt

Fishes

<u>Allosmerus elongatus</u>	Whitebait smelt
<u>Ammodytes hexapterus</u>	Pacific sand lance
<u>Anarrhichthys ocellatus</u>	Wolf-eel
<u>Anoplarchus purpureus</u>	High cockscomb
<u>Apodichthys flavidus</u>	Pen point gunnel
<u>Artedius fenestralis</u>	Padded sculpin
<u>Artedius harringtoni</u>	Scalyhead sculpin
<u>Atherinops affinis</u>	Top smelt
<u>Citharichthys sordidus</u>	Pacific sanddab
<u>Citharichthys stigmaeus</u>	Speckled sanddab
<u>Clinocottus acuticeps</u>	Sharpnose sculpin
<u>Clinocottus globiceps</u>	Mosshead sculpin
<u>Cottus aleuticus</u>	Prickly sculpin
<u>Cottus asper</u>	Coastrange sculpin
<u>Cottus gulosus</u>	Riffle sculpin
<u>Cymatogaster aggregata</u>	Shiner perch
<u>Embiotica lateralis</u>	Striped seaperch
<u>Engraulis mordax</u>	Northern anchovy
<u>Enophrys bison</u>	Buffalo sculpin
<u>Entosphenus tridentatus</u>	Pacific lamprey
<u>Gasterosteus aculeatus</u>	Three spine stickleback

Fishes, continued

Hemilepidotus hemilepidotus
Hemilepidotus spinosus
Hexagrammos decagrammus
Hexagrammos lagocephalus
Hexagrammos stelleri
Hyperprosopon argenteum
Hypomesus pretiosus
Lampetra richardsoni
Leptocottus armatus
Lumpenus sagitta
Microgadus prximus
Oligocottus maculosus
Oligocottus snyderi
Onchorhynchus tshawytscha
Ophidon elongatus
Pallasina barbata
Parophrys vetulus
Phanerodon furcatus
Pholis ornata
Plaichthys stellatus
Psettichthys melanostictus
Rhacochilus vacca
Salmo clarki
Scorpaenichthys marmoratus
Sebastes caurinus
Sebastes melanops
Stellerina xyosterna
Syngnathus griseolineatus

Red Irish lord
 Brown Irish lord
 Kelp greenling
 Rock greenling
 White spotted greenling
 Walleye surf perch
 Surf smelt
 Western brook lamprey
 Pacific staghorn sculpin
 Snake prickleback
 Pacific tom cod
 Tidepool sculpin
 Fluffy sculpin
 Chinook salmon
 Ling cod
 Tubenose poacher
 English sole
 White sea perch
 Saddle back gunnel
 Starry flounder
 Sand sole
 Pile perch
 Cutthroat trout
 Cabezon
 Copper rockfish
 Black rockfish
 Pricklebreast poacher
 Bay pipefish

Mammals

Canis latrans
Castor canadensis
Clethrionomys occidentalis
Eutamias townsendii
Felis rufus
Glaucomys sabrinus
Mephitis mephitis
Microtus oregoni
Microtus townsendii
Mustela ermina
Mustela vison
Myotis californicus
Myotis lucifugus
Myotis yumanensis
Neotoma cinerea
Odocoileus hemionus columbianus
Peromyscus maniculatus
Phoca vitulina
Procyon lotar

Coyote
 Beaver
 Western red-backed vole
 Townsend's chipmunk
 Bobcat
 Northern flying squirrel
 Striped skunk
 Creeping vole
 Townsend's vole
 Ermine
 Mink
 California myotis
 Little brown myotis
 Yuma myotis
 Bushy-tailed woodrat
 Black-tailed deer
 Deer mouse
 Harbor seal
 Raccoon

Mammals, continued

<u>Sorex trowbridgii</u>	Trowbridge's shrew
<u>Sorex vagrans</u>	Vagrant shrew
<u>Sylvilagus backmani</u>	Brush rabbit
<u>Tamiascivrus douglasii</u>	Douglas' squirrel
<u>Urocyon cinereoargenteus</u>	Gray fox
<u>Ursus americanus</u>	Black bear
<u>Zapus trinotatus</u>	Pacific jumping mouse

Reptiles

<u>Gerrhonotus coeruleus</u>	Alligator lizard
<u>Thamnophis sirtalis</u>	Common garter snake
<u>Thamnophis ordiroides</u>	Northwestern garter snake

PlantsAlgae

<u>Alaria marginata</u>
<u>Chaetomorpha tortuosa</u>
<u>Claophora gracilis</u>
<u>Desmarestia herbacea</u>
<u>Desmarestia munda</u>
<u>Enteromorpha intestinalis</u> var. <u>intestinalis</u>
<u>Enteromorpha linza</u>
<u>Fucus disticus</u>
<u>Gigartina exasperata</u>
<u>Gigartina spinosa</u>
<u>Laminaria saccharina</u>
<u>Monostroma zostericola</u>
<u>Polyneura latissima</u>
<u>Polysiphonia pacifica</u> var. <u>gracilis</u>
<u>Porphyra perforata</u> var. <u>perforata</u>
<u>Prionitis lyallii</u>
<u>Sargassum muticum</u>
<u>Smithora naiadum</u>
<u>Ulva expansa</u>
<u>Ulva lactuca</u>
<u>Urospora wormskioldii</u>

Diatoms

<u>Achnanthes haukiana</u>
<u>Achnanthes parvula</u>
<u>Amphipleura rutilans</u>
<u>Cocconeis placentula</u>

Diatoms, continued

Cocconeis scutellum
Fragilaria pinnata
Fragilaria striatula var. californica
Melosira moniliformis
Melosira nummuloides
Melosira sulcata
Navicula complanata
Navicula diserta
Navicula gregaria
Navicula pelliculosa
Nitzschia closterium
Nitzschia frustulus var. perpusilla
Nitzschia oregana
Synedra fasciculata

Vascular Plants

<u>Abies grandis</u>	Grand fir
<u>Abronia latifolia</u>	Yellow abronia
<u>Agrostis alba</u>	Creeping bentgrass
<u>Alnus rubra</u>	Red alder
<u>Amelanchier florida</u>	Service berry
<u>Ammophila arenaria</u>	European beach grass
<u>Angelica hendersonii</u>	Angelica
<u>Arctostaphylos columbiana</u>	Manzanita
<u>Arctostaphylos uva-ursi</u>	Kinnikinnick
<u>Athyrium filix-femina</u>	Lady fern
<u>Bromus sp.</u>	Brome grass
<u>Carex obnupta</u>	Sedge
<u>Carex lyngbyei</u>	Sedge
<u>Cotula coronopifolia</u>	Brass buttons
<u>Cytisus scoparius</u>	Scotch broom
<u>Deschampsia caespitosa</u>	Tufted hairgrass
<u>Digitalis purpurea</u>	Foxglove
<u>Distichlis spicata</u>	Green seashore saltgrass
<u>Epilobium angustifolium</u>	Fireweed
<u>Elymus mollis</u>	American dune grass
<u>Festuca rubra</u>	Red fescue
<u>Fragaria chiloensis</u>	Strawberry
<u>Franseria chamissonis</u>	Silver beach weed
<u>Gaultheria shallon</u>	Salal
<u>Glehnia leiocarpa</u>	Beach silver-top
<u>Juncus leseurii</u>	Salt rush
<u>Lonicera involucrata</u>	Twinberry
<u>Lupinus littoralis</u>	Seashore lupine
<u>Lysichitum americanum</u>	Skunk cabbage
<u>Myrica californica</u>	Western wax myrtle
<u>Petasites palmatus</u>	Western coltfoot

Vascular Plants, continued

<u>Picea sitchensis</u>	Sitka spruce
<u>Pinus contorta</u>	Shore pine
<u>Poa confinis</u>	Dune bluegrass
<u>Polystichum munitum</u>	Western bracken fern
<u>Potentilla anserina</u>	Silverweed
<u>Potentilla pacifica</u>	Pacific silverweed
<u>Pseudotsuga menziesii</u>	Douglas fir
<u>Pteridium aquilinum</u>	Sword fern
<u>Pyrus diversifolia</u>	Crab-apple
<u>Ribes sp.</u>	Gooseberry
<u>Rubus parviflorus</u>	Thimbleberry
<u>Rubus spectabilis</u>	Salmonberry
<u>Rubus ursinus</u>	Blackberry
<u>Salix hookeriana</u>	Coast willow
<u>Salicornia virginica</u>	Woody glasswort
<u>Sambucus callicarpa</u>	Red elderberry
<u>Sambucus racemosa</u>	Elderberry
<u>Scirpus americanus</u>	Three square
<u>Scirpus validus</u>	American great bulrush
<u>Solidago spathulata</u>	Goldenrod
<u>Thuja plicata</u>	Western red cedar
<u>Trifolium wormskjoldii</u>	Springbank clover
<u>Triglochin maritima</u>	Seaside arrow-grass
<u>Trisetum canescen</u>	Oatgrass
<u>Tsuga heterophylla</u>	Western hemlock
<u>Vaccinium parvifolium</u>	Red huckleberry
<u>Zostera marina</u>	Eelgrass

APPENDIX B

THE OCCURRENCE OF AMPHIBIANS, REPTILES AND MAMMALS
IN IDENTIFIED HABITATS, JUNE-SEPTEMBER 1975

SPECIES	HABITAT							
	DMSH	CC	RA	AGR	SM	SSS	SSB	IZ
AMPHIBIANS								
Rough-skinned newt (<u>Taricha granulosa</u>)	+		+					
Western toad (<u>Bufo boreas</u>)			+					
Pacific tree frog (<u>Hyla regilla</u>)	+		+					
Red-legged frog (<u>Rana aurora</u>)	+		+					
Bullfrog (<u>Rana catesbeiana</u>)			+					
REPTILES								
Alligator lizard (<u>Gerrhonotus coeruleus</u>)				+				
Common garter snake (<u>Thamnophis sirtalis</u>)	+	+	+	+				
Northwestern garter snake (<u>Thamnophis ordinoides</u>)	+							
MAMMALS								
Vagrant shrew (<u>Sorex vagrans</u>)	+	+	+	+	+	+	+	
Trowbridge's shrew (<u>Sorex trowbridgii</u>)	+	+		+				
Little brown myotis (<u>Myotis lucifugus</u>)			+					
Yuma myotis (<u>Myotis yumanensis</u>)			+					
California myotis (<u>Myotis californicus</u>)			+					
Brush rabbit (<u>Sylvilagus bachmani</u>)	+	+	+					
Townsend's chipmunk (<u>Eutamias townsendii</u>)	+	+	+			+		
Douglas' squirrel (<u>Tamiasciurus douglasii</u>)	+	+	+					
Northern flying squirrel (<u>Glaucomys sabrinus</u>)	+							
Beaver (<u>Castor canadensis</u>)			+					
Deer mouse (<u>Peromyscus maniculatus</u>)	+	+	+	+		+	+	
Bushy-tailed woodrat (<u>Neotoma cinerea</u>)			+					
Western red-backed vole (<u>Clethrionomys occidentalis</u>)	+							
Townsend's vole (<u>Microtus townsendii</u>)			+	+			+	
Creeping vole (<u>Microtus oregoni</u>)		+		+				
Pacific jumping mouse (<u>Zapus trinotatus</u>)							+	

THE OCCURRENCE OF AMPHIBIANS, REPTILES AND MAMMALS
IN IDENTIFIED HABITATS, JUNE-SEPTEMBER 1975
CONTINUED

SPECIES	HABITAT							
	DMSH	CC	RA	AGR	SM	SSS	SSB	IZ
Coyote (<u>Canis latrans</u>)		+						
Gray fox (<u>Urocyon cinereoargenteus</u>)	+			+				
Black Bear (<u>Ursus americanus</u>)		+				+		
Raccoon (<u>Procyon lotor</u>)		+	+			+	+	+
Ermine (<u>Mustela ermina</u>)	+		+			+		
Mink (<u>Mustela vison</u>)	+							
Striped skunk (<u>Mephitis mephitis</u>)			+					
Bobcat (<u>Felis rufus</u>)		+						
Harbor seal (<u>Phoca vitulina</u>)		+						
Black-tailed deer (<u>Odocoileus hemionus columbianus</u>)	+	+	+	+		+	+	+

KEY:

DMSH = Disturbed Mature Spruce-Hemlock
CC = Clearcut
RA = Riparian Alder
AGR = Agricultural

SM = Salt Marsh
SSS = Sandspit/Spruce
SSB = Sandspit/Beachgrass
IZ = Intertidal Zone

AVIAN SPECIES OCCURRENCE ACCORDING TO HABITAT

SPECIES	Occurrence	Residential	Forest Type		
			Clearcut	Disturbed Mature	Mature
Red-tailed hawk	1/7		+		
	1/6			+	
Mountain quail	1/7		+		
Band-tailed pigeon	2/3	50			
	4/7		30		
	2/6			49	
Mourning dove	1/3	+			
Great horned owl	2/6			+	
Common nighthawk	1/8		2		
	2/6			1	
Vaux's swift	2/6			6	
Rufous hummingbird	2/3	40			
	5/7		61		
	3/6			38	
					+
Belted kingfisher	1/7		+		
Common flicker	3/3	31			
	5/7		48		
	6/6				
Pileated woodpecker	1/7		+(1)		
	1/6			+(1)	
					+(2)
Hairy woodpecker	2/3	35			
	1/7		22		
	4/6			72	
Downy woodpecker	2/3	17			
Western flycatcher	1/3	+			
	1/7		+		
	5/6			40	
					42
Olive-sided flycatcher	2/3	+			
	5/7		38		
	4/6			35	
					10
Violet-green swallow	1/3	+			
	1/7		+		
Tree swallow	1/3	+			
Barn swallow	3/3	159			
	2/7		39		
Purple martin	1/3	+			
Gray jay	2/6			4	
Stellar's jay	2/3	36			
	7/7		27		
	6/6			83	
					32
Common raven	2/7		+		
Common crow	3/3	321			
	2/7		6		
	1/6			+	
Black-capped chickadee	2/3	142			
Chestnut-backed chickadee	3/3	188			
	4/7		99		
	6/6			193	
					169

AVIAN SPECIES OCCURRENCE ACCORDING TO HABITAT
CONTINUED

SPECIES	Occurrence	Residential	Forest Type		
			Clearcut	Disturbed Mature	Mature
Common bushtit	3/6 1/6		81	+	
Red-breasted nuthatch	3/6			24	
Brown creeper	2/7 3/6		+	145	+
Wrentit	3/3 7/7 3/6	95	162	19	+
House wren	3/3 4/7 4/6	42	9	31	25
Winter wren	2/3 1/7 6/6	32	72	92	60
Bewick's wren	1/1 3/7	+	+		
American robin	3/3 7/7 6/6	161	195	154	46
Varied thrush	1/7 4/6		+	41	+
Swainson's thrush	3/3 7/7 6/6	86	56	70	35
Golden-crowned kinglet	3/3 1/7 6/6	260	+	208	298
Cedar waxwing	3/3 7/7	41	133		+
Starling	3/3	324			
Orange-crowned warbler	2/3 7/7 3/6	89	72	+	39
Wilson's warbler	3/3 7/7 6/6	61	178	156	39
Western tanager	3/7 1/6		6	+	
Black-headed grosbeak	4/7 1/6		5	+	
Purple finch	1/3 4/7 2/6	51	128	+	

AVIAN SPECIES OCCURRENCE ACCORDING TO HABITAT
CONTINUED

SPECIES	Occurrence	Residential	Forest Type		
			Clearcut	Disturbed Mature	Mature
Pine siskin	3/3 4/7	49	35	15	
American goldfinch	3/6 3/3 6/6	123	172		+
Lesser goldfinch					
Red crossbill	2/3 1/7 2/6	59	+	86	
Rufous-sided towhee	1/3 7/7	14	30		
Savannah sparrow	1/3	+			
Dark-eyed junco	5/7			147	
White-crowned sparrow	3/3 6/6	89	20		
Fox sparrow	1/7		+		
Song sparrow	3/3 7/7	96	200		
TOTAL SPECIES 54 Per Transect		34	39	32	17

SPECIES OCCURRENCE ACCORDING TO HABITAT

SPECIES	Occurrence	Residential	Forest Type		
			Clearcut	Disturbed Mature	Mature
Townsend's chipmunk	3/3 7/7 5/6	88	181	99	+
Douglas squirrel	2/7 5/6		+	56	+
Brush rabbit	6/7		107		
Bobcat	1/7		+		
Black bear	1/6			+	
Black-tailed deer	2/6			+	
People					1979
Dogs					250

Occurrence: 4/7 = species recorded 4 times out of total times the transect was walked (7).

+ = species recorded, but too few individuals were found to estimate density.

(2) = actual number of individuals recorded.

APPENDIX C

NETARTS BAY INVERTEBRATE SPECIES LIST

Hydrozoa

Cladonema californica

Nemertea

Cerebratulus californiensis

Polychaeta

Abarenicola pacifica (Arenicolidae)
Mediomastus californiensis (Capitellidae)
Capitella capitata
Glycera convoluta (Glyceridae)
Glycera tenuis
Glycinde armigera (Goniadidae)
Lumbrineris zonata (Lumbrineridae)
Lumbrineris latreilli
Nephtys californiensis (Nephtyidae)
Nephtys caecoides
Nephtys caeca
Neanthes brandti (Nereidae)
Neanthes succinea
Ophelia assimilis (Opheliidae)
Euzonus mucronata
Euzonus williamis
Armandia brevis
Orbinia johnsoni (Orbiniidae)
Haploscoloplos elongatus
Owenia collaris (Oweniidae)
Eteone californica (Phyllodocidae)
Eteone dilatata
Halosydna brevisetosa (Polynoidae)
Lepidasthenia interrupta
Pygospio elegans (Spionidae)
Pygospio californica
Rhynchospio arenicola
Pseudopolydora paucibranchiata
Pseudopolydora kemp
Spio filicornis
Spiohanes bombyx
Polydora socialis
Eupolymnia crescentris (Terebellidae)
Pista pacifica

NETARTS BAY INVERTEBRATE SPECIES LIST
CONTINUED

Bivalvia

Macoma balthica (Tellinidae)
Macoma inquinata
Macoma nasuta
Tellina bodegensis
Cryptomya californica (Myidae)
Mya arenaria*
Protothaca staminea (Veneridae)
Protothaca tenerrima
Tapes japonica*
Saxidomus gignateus
Tresus capax (Mactridae)
Clinocardium nuttallii (Cardiidae)
Lucinoma annulata (Lucinidae)
Crassostrea gigas (Ostreidae)*
Zirfaea pilsbryi (Pholadidae)
Mytilus edulis (Mytilidae)

Gastropoda

Phyllaplysia taylori (Anaspidea)
Olivella biplicata (Neogastropoda)
Ceratostoma inornatum*

Phoronida

Phoronis pallida

Crustacea

Lepas pacifica (Cirripedia)
Balanus glandula
Leptochelia dubia (Tanaidacea)
Excirrolana linguifrons (Isopoda)
Idotea resecata
Eohaustorius sp. (Amphipoda)
Corophium brevis
Amphithoe valida
Paraphoxus milleri
Paraphoxus spinosus
Photis brevipes
Hyale grandicornis californica
Heptacarpus pictus (Decapoda)
Heptacarpus paludicola
Crangon nigricauda

NETARTS BAY INVERTEBRATE SPECIES LIST
CONTINUED

Crustacea, continued

Pinnixa faba
Pinnixa littoralis
Pinnixa sp.
Hemigrapsus oregonensis
Rhithropanopeus harrisi*
Pugettia ricnii
Pugettia producta
Petrolisthes cinctipes
Cancer magister
Callinassa californiensis
Upogebia pugettensis

Echinoidea

Dendraster excentricus

Asteroidea

Pycnopodia helianthoides (Forcipulatida)
Piaster brevispinus

Urochordata

Botrylloides sp. (Stolidobranchia)

Hemichordata

Saccoglossus sp.

* Denotes introduced species.