1977

Netarts Bay, Oregon: an assessment of human impact on an estuarine system

Larry D. McCallum

Portland State University

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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 S. 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 Larry D. McCallum presented September 27, 1977

John O. Dart, Chairman

James G. Ashbaugh

Larry W. Price

APPROVED:

Richard Lycan, Head, Department of Geography

Stanley E. Rauch, Dean of Graduate Studies and Research
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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
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>ACKNOWLEDGMENTS</th>
<th>iii</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIST OF TABLES</td>
<td>vi</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>viii</td>
</tr>
<tr>
<td><strong>CHAPTER</strong></td>
<td></td>
</tr>
<tr>
<td>I INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>Statement of Problem and Thesis</td>
<td>3</td>
</tr>
<tr>
<td>Purpose</td>
<td></td>
</tr>
<tr>
<td>II SETTING AND CHARACTERISTICS OF STUDY AREA</td>
<td>5</td>
</tr>
<tr>
<td>Description</td>
<td>9</td>
</tr>
<tr>
<td>III THE NETARTS BAY SYSTEM</td>
<td>32</td>
</tr>
<tr>
<td>Physical Systems and Their Influence on Netarts Bay</td>
<td>33</td>
</tr>
<tr>
<td>Biotic Systems of Netarts Bay</td>
<td>45</td>
</tr>
<tr>
<td>IV CRITICAL ENVIRONMENTAL FACTORS WITHIN THE SYSTEM</td>
<td>50</td>
</tr>
<tr>
<td>V HUMAN IMPACT ON THE SYSTEM</td>
<td>55</td>
</tr>
<tr>
<td>Methods</td>
<td>55</td>
</tr>
<tr>
<td>Indian Settlement and Resource Use</td>
<td>57</td>
</tr>
<tr>
<td>Early European Settlement and Resource Use</td>
<td>61</td>
</tr>
<tr>
<td>Post 1950 Settlement and Impacts on the Netarts System</td>
<td>71</td>
</tr>
<tr>
<td>VI CONCLUSIONS AND RECOMMENDATIONS</td>
<td>86</td>
</tr>
<tr>
<td>Conclusions</td>
<td>86</td>
</tr>
<tr>
<td>Recommendations</td>
<td>88</td>
</tr>
<tr>
<td>BIBLIOGRAPHY</td>
<td>PAGE</td>
</tr>
<tr>
<td>--------------</td>
<td>------</td>
</tr>
<tr>
<td></td>
<td>92</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>APPENDIX</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>A-1</td>
</tr>
<tr>
<td>B</td>
<td>B-1</td>
</tr>
<tr>
<td>C</td>
<td>C-1</td>
</tr>
</tbody>
</table>
# LIST OF TABLES

<table>
<thead>
<tr>
<th>TABLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>12</td>
</tr>
<tr>
<td>II</td>
<td>18</td>
</tr>
<tr>
<td>III</td>
<td>20</td>
</tr>
<tr>
<td>IV</td>
<td>22</td>
</tr>
<tr>
<td>V</td>
<td>25</td>
</tr>
<tr>
<td>VI</td>
<td>31</td>
</tr>
<tr>
<td>VII</td>
<td>41</td>
</tr>
<tr>
<td>VIII</td>
<td>42</td>
</tr>
<tr>
<td>IX</td>
<td>44</td>
</tr>
<tr>
<td>X</td>
<td>58</td>
</tr>
<tr>
<td>XI</td>
<td>60</td>
</tr>
</tbody>
</table>

- **TABLE I**: Temperature and Precipitation at Tillamook Station, Tillamook, County, Oregon
- **TABLE II**: Plant Species of the Upland and Watershed Area
- **TABLE III**: Salt Marsh Community Types, Netarts Bay
- **TABLE IV**: Partial List of Diatoms in Netarts Bay, Oregon
- **TABLE V**: Predominant Plant Species on the Netarts Spit
- **TABLE VI**: Most Abundant Ichthyofaunal Species within Channel (Percent of Total Number of Species Caught Under All Environmental Conditions)
- **TABLE VII**: Approximate Normal Runoff, Netarts Bay
- **TABLE VIII**: Seasonal Temperature, Salinity and Water Quality Measurements, Netarts Bay
- **TABLE IX**: Sediment Quantity from Comparative Estuarine Watersheds
- **TABLE X**: Floral Species Identified as Food Sources on Netarts Sandspit
- **TABLE XI**: Identification of Faunal Remains from Excavations on the Netarts Spit
<table>
<thead>
<tr>
<th>TABLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>XII</td>
<td>Names of Early Settlers and Acreages of Original Land Claims Along Netarts Shoreline.</td>
</tr>
<tr>
<td>XIII</td>
<td>Chronology of Logging in Netarts Watershed; Total Area Logged and Current Dominant Vegetation Type.</td>
</tr>
<tr>
<td>XIV</td>
<td>Marsh Type and Acreage, Netarts Bay, Oregon, 1939, 1962, and 1974.</td>
</tr>
<tr>
<td>XV</td>
<td>Differences in Water Volume for Four Cross Sectional Areas in Netarts Bay at High Slack Tide, 1957 and 1969.</td>
</tr>
</tbody>
</table>
**LIST OF FIGURES**

<table>
<thead>
<tr>
<th>FIGURE</th>
<th>DESCRIPTION</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Vicinity Map of Netarts Bay</td>
<td>6</td>
</tr>
<tr>
<td>2</td>
<td>Geology of Netarts Bay</td>
<td>8</td>
</tr>
<tr>
<td>3</td>
<td>Physical Sub-units of the Netarts Bay Study Area</td>
<td>10</td>
</tr>
<tr>
<td>4</td>
<td>Soil Associations, Netarts Bay</td>
<td>11</td>
</tr>
<tr>
<td>5</td>
<td>Physical Sediment Grain Size and Environments, Netarts Bay</td>
<td>14</td>
</tr>
<tr>
<td>6</td>
<td>Distribution of Organic Carbon, Netarts Bay</td>
<td>15</td>
</tr>
<tr>
<td>7</td>
<td>Distribution of Eelgrass and Salt Marsh, Netarts Bay</td>
<td>21</td>
</tr>
<tr>
<td>8</td>
<td>Main Vegetational Habitat Types, Netarts Bay</td>
<td>26</td>
</tr>
<tr>
<td>9</td>
<td>Circulation in a Type D Estuary</td>
<td>35</td>
</tr>
<tr>
<td>10</td>
<td>Salinity Regime for a Well-mixed Estuary</td>
<td>35</td>
</tr>
<tr>
<td>11</td>
<td>Circulation within Netarts Bay During Ebb and Food Tides</td>
<td>39</td>
</tr>
<tr>
<td>12</td>
<td>Sediment Food Web, Netarts Bay</td>
<td>49</td>
</tr>
<tr>
<td>13</td>
<td>Netarts Bay System, 1977</td>
<td>54</td>
</tr>
<tr>
<td>14</td>
<td>Settlements and Overland Routes in the Netarts Area</td>
<td>63</td>
</tr>
<tr>
<td>15</td>
<td>Stakes Delimiting Early Oyster Plats</td>
<td>66</td>
</tr>
<tr>
<td>16</td>
<td>Historical Utilization of Tidal Areas, 1880-1940</td>
<td>67</td>
</tr>
<tr>
<td>FIGURE</td>
<td>Description</td>
<td>PAGE</td>
</tr>
<tr>
<td>--------</td>
<td>----------------------------------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>17</td>
<td>Remnant of Tidal Gate on Marsh on East Side of Whiskey Creek Road</td>
<td>69</td>
</tr>
<tr>
<td>18</td>
<td>Chronology of Logging andExisting Vegetation in Netarts Watershed</td>
<td>73</td>
</tr>
<tr>
<td>19</td>
<td>Change in Sandspit Morphology, 1882-1962, Netarts Bay</td>
<td>82</td>
</tr>
<tr>
<td>20</td>
<td>Whiskey Creek Subdivision and Fill, Netarts Bay</td>
<td>84</td>
</tr>
</tbody>
</table>
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

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</table>

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).
Figure 6. Distribution of organic carbon, 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 mensiesii (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 Polystichium
munitum (Sword fern), Oxalis oregana (Oregon oxalis), Maianthemum bicornu (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**

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

**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)

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

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)

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

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). Arctostaphylos 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

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

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 lotar (Raccoon), Mustela ermina (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 Peromysan 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 colubianus (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, specie 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 (Charodicus alexandrius), the long-billed
marsh wren (Telmatheres 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 usteulata), 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 Saddleback gunnel (Pholis ornata) were most abundant in the eelgrass beds associated with the channels (Table VI). Three species, Three spine stickleback, Bay pipefish, and Parophyrs vetulus (English sole) made up sixty-four percent of the total catch and encompassed a total of forty-nine species.
### TABLE VI

**MOST ABUNDANT ICHTHYOFANAL SPECIES ASSOCIATED WITH CHANNEL CONDITIONS**

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


*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 \(0.86 \times 1.71 = 1.47\) meters.

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

\(^1\)The 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**

<table>
<thead>
<tr>
<th>Month</th>
<th>Inflow to Water Surface</th>
<th>Normal Runoff from land</th>
<th>Fresh Water Inflow to Netarts Bay</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>0.82 m/sec</td>
<td>4.84 m/sec</td>
<td>5.66 m/sec</td>
</tr>
<tr>
<td>February</td>
<td>0.74 m/sec</td>
<td>4.19 m/sec</td>
<td>4.92 m/sec</td>
</tr>
<tr>
<td>March</td>
<td>0.57 m/sec</td>
<td>3.59 m/sec</td>
<td>4.16 m/sec</td>
</tr>
<tr>
<td>April</td>
<td>0.31 m/sec</td>
<td>2.29 m/sec</td>
<td>2.58 m/sec</td>
</tr>
<tr>
<td>May</td>
<td>0.15 m/sec</td>
<td>1.27 m/sec</td>
<td>1.41 m/sec</td>
</tr>
<tr>
<td>June</td>
<td>0.04 m/sec</td>
<td>0.68 m/sec</td>
<td>0.71 m/sec</td>
</tr>
<tr>
<td>July</td>
<td>-0.12 m/sec</td>
<td>0.34 m/sec</td>
<td>0.23 m/sec</td>
</tr>
<tr>
<td>August</td>
<td>-0.08 m/sec</td>
<td>0.23 m/sec</td>
<td>0.14 m/sec</td>
</tr>
<tr>
<td>September</td>
<td>0.09 m/sec</td>
<td>0.28 m/sec</td>
<td>0.37 m/sec</td>
</tr>
<tr>
<td>October</td>
<td>0.38 m/sec</td>
<td>1.27 m/sec</td>
<td>1.67 m/sec</td>
</tr>
<tr>
<td>November</td>
<td>0.82 m/sec</td>
<td>3.48 m/sec</td>
<td>4.30 m/sec</td>
</tr>
<tr>
<td>December</td>
<td>0.88 m/sec</td>
<td>5.60 m/sec</td>
<td>6.48 m/sec</td>
</tr>
<tr>
<td>Annual</td>
<td>0.38 m/sec</td>
<td>2.55 m/sec</td>
<td>2.94 m/sec</td>
</tr>
</tbody>
</table>

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

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

<table>
<thead>
<tr>
<th>Time of Year</th>
<th>Measured Depth</th>
<th>Water Temp.</th>
<th>Salinity</th>
<th>DO</th>
<th>BOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early spring</td>
<td>1.83 meters</td>
<td>10.0 °C</td>
<td>30.4 ppm</td>
<td>9.7</td>
<td>0.6</td>
</tr>
<tr>
<td>Late spring</td>
<td>1.22 meters</td>
<td>15.0 °C</td>
<td>31.6 ppm</td>
<td>9.6</td>
<td>0.4</td>
</tr>
<tr>
<td>Mid summer</td>
<td>3.05 meters</td>
<td>16.0 °C</td>
<td>26.5 ppm</td>
<td>not given</td>
<td>not given</td>
</tr>
<tr>
<td>Late summer</td>
<td>3.05 meters</td>
<td>15.4 °C</td>
<td>30.3 ppm</td>
<td>8.7</td>
<td>1.0</td>
</tr>
<tr>
<td>Early fall</td>
<td>2.74 meters</td>
<td>9.4 °C</td>
<td>32.9 ppm</td>
<td>8.8</td>
<td>0.6</td>
</tr>
</tbody>
</table>


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

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. Specie numbers are relatively low at the mouth of the bay, but peaks and declines 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 as 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

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


### TABLE X Continued

<table>
<thead>
<tr>
<th>Area of Spit and Species Name</th>
<th>Part Utilized</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lupinus littoralis</strong> (dune lupine)</td>
<td>roots</td>
</tr>
<tr>
<td><strong>Poa confinis</strong> (dune blue grass)</td>
<td>seeds</td>
</tr>
<tr>
<td><strong>Solidago spathulata</strong> (goldenrod)</td>
<td>seeds</td>
</tr>
</tbody>
</table>

**C. Forest (on old dunes)**

<table>
<thead>
<tr>
<th>Species Name</th>
<th>Part Utilized</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Amelanchier florida</strong> (service berry)</td>
<td>fruits/berries</td>
</tr>
<tr>
<td><strong>Arctostaphylos columbiana</strong> (manzanita)</td>
<td>fruits</td>
</tr>
<tr>
<td><strong>Gaultheria shallon</strong> (salal)</td>
<td>fruits</td>
</tr>
<tr>
<td><strong>Pinus contorta</strong> (beach pine)</td>
<td>cambium</td>
</tr>
<tr>
<td><strong>Pteridium aquilinum</strong> (bracken fern)</td>
<td>rootstocks</td>
</tr>
<tr>
<td><strong>Pyrus diversifolia</strong> (crab apple)</td>
<td>fruit</td>
</tr>
<tr>
<td><strong>Ribes sp.</strong> (goosberry)</td>
<td>fruits</td>
</tr>
<tr>
<td><strong>Rubus parviflorus</strong> (thimble berry)</td>
<td>fruits</td>
</tr>
</tbody>
</table>
| **Vaccinium ovatum** (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**

<table>
<thead>
<tr>
<th>Scientific Name</th>
<th>Common Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eumetopias</td>
<td>Stellar sea lion</td>
</tr>
<tr>
<td>Zalophus</td>
<td>California sea lion</td>
</tr>
<tr>
<td>Enhydra</td>
<td>Sea otter</td>
</tr>
<tr>
<td>Lutra</td>
<td>Land otter</td>
</tr>
<tr>
<td>Phoca</td>
<td>Seal</td>
</tr>
<tr>
<td>Delphinid</td>
<td>Porpoise</td>
</tr>
<tr>
<td>Castor canidensis</td>
<td>Beaver</td>
</tr>
<tr>
<td>Cervis</td>
<td>Elk</td>
</tr>
<tr>
<td>Odocoileus</td>
<td>Deer</td>
</tr>
</tbody>
</table>

*(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
Figure 14. Settlement and overland routes in the Netarts area.
### TABLE XII

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

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

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 Willamette 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

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

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>
<thead>
<tr>
<th>Year</th>
<th>Low Sand Marsh</th>
<th>Sedge Marsh</th>
<th>Immature High Marsh</th>
<th>Mature High Marsh</th>
<th>Total Hectares</th>
<th>Increase 39-62</th>
<th>Increase 62-74</th>
</tr>
</thead>
<tbody>
<tr>
<td>1939</td>
<td>5.07</td>
<td>13.80</td>
<td>44.92</td>
<td>69.77</td>
<td>13.80</td>
<td>188%</td>
<td>113%</td>
</tr>
<tr>
<td>1962</td>
<td>14.58</td>
<td>21.73</td>
<td>54.63</td>
<td>103.60</td>
<td>21.73</td>
<td>258%</td>
<td>29%</td>
</tr>
<tr>
<td>1974</td>
<td>18.23</td>
<td>24.12</td>
<td>59.55</td>
<td>118.25</td>
<td>24.12</td>
<td>113%</td>
<td>11%</td>
</tr>
</tbody>
</table>

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

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

*a meters squared

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 sand spit 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 Sorensen'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 Sorensen'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.


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Elliot, T. C. John Meare's Approach to Oregon, 1778--extracted from: Voyages to the Northwest Coast of America by John Meares.


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## APPENDIX A

### INDEX TO SPECIES NAMES

#### Animals

**Amphibians**

<table>
<thead>
<tr>
<th>Species</th>
<th>Scientific Name</th>
<th>Common Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Western toad</td>
<td><em>Bufo boreas</em></td>
<td>Western toad</td>
</tr>
<tr>
<td>Pacific tree frog</td>
<td><em>Hyla regilla</em></td>
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</tr>
<tr>
<td>Red-legged frog</td>
<td><em>Rana aurora</em></td>
<td>Red-legged frog</td>
</tr>
<tr>
<td>Bullfrog</td>
<td><em>Rana catesbeiana</em></td>
<td>Bullfrog</td>
</tr>
<tr>
<td>Rough-skinned newt</td>
<td><em>Taricha granulosa</em></td>
<td>Rough-skinned newt</td>
</tr>
</tbody>
</table>

**Benthic Invertebrates**

**Hydrozoa**

<table>
<thead>
<tr>
<th>Species</th>
<th>Scientific Name</th>
<th>Common Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jelly fish</td>
<td><em>Cladonema californica</em></td>
<td>Jelly fish</td>
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</table>

**Nemertea**

<table>
<thead>
<tr>
<th>Species</th>
<th>Scientific Name</th>
<th>Common Name</th>
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</thead>
<tbody>
<tr>
<td>Ribbon worm</td>
<td><em>Cerebratulus californiensis</em></td>
<td>Ribbon worm</td>
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</table>

**Polychaeta**

<table>
<thead>
<tr>
<th>Species</th>
<th>Scientific Name</th>
<th>Common Name</th>
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<tbody>
<tr>
<td>Lug worm</td>
<td><em>Abarenicola pacifica</em></td>
<td>Lug worm</td>
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<tr>
<td>Thread worm</td>
<td><em>Mediomastus californiensis</em></td>
<td>Thread worm</td>
</tr>
<tr>
<td>Mud flat worm</td>
<td><em>Capitella capitata</em></td>
<td>Mud flat worm</td>
</tr>
<tr>
<td>&quot;</td>
<td><em>Glycera convoluta</em></td>
<td>&quot;</td>
</tr>
<tr>
<td>&quot;</td>
<td><em>Glycera tenuis</em></td>
<td>&quot;</td>
</tr>
<tr>
<td>&quot;</td>
<td><em>Glycinde armigera</em></td>
<td>&quot;</td>
</tr>
<tr>
<td>&quot;</td>
<td><em>Lumbrineris zonata</em></td>
<td>&quot;</td>
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<td>Sand worm</td>
<td><em>Nephtys californiensis</em></td>
<td>Sand worm</td>
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<tr>
<td>&quot;</td>
<td><em>Nephtys caecoides</em></td>
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<tr>
<td>&quot;</td>
<td><em>Nephtys caeca</em></td>
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<tr>
<td>Clam bed worm</td>
<td><em>Neanthes brandti</em></td>
<td>Clam bed worm</td>
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<tr>
<td>Mud flat worm</td>
<td><em>Neanthes succinea</em></td>
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<td>Blood worm</td>
<td><em>Ophelia assimilis</em></td>
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<tr>
<td>&quot;</td>
<td><em>Euzonous mucronata</em></td>
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<tr>
<td>&quot;</td>
<td><em>Euzonous williamsi</em></td>
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</tr>
<tr>
<td>&quot;</td>
<td><em>Armandis brevis</em></td>
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<tr>
<td>Mud flat worm</td>
<td><em>Orbinia johnsoni</em></td>
<td>Mud flat worm</td>
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<td>&quot;</td>
<td><em>Haploscoloplos elongatus</em></td>
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<td>&quot;</td>
<td><em>Owenia collaris</em></td>
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<tr>
<td>&quot;</td>
<td><em>Eteone californica</em></td>
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<td>&quot;</td>
<td><em>Eteone dilatae</em></td>
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<tr>
<td>&quot;</td>
<td><em>Halosydna brevisetosa</em></td>
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<tr>
<td>&quot;</td>
<td><em>Lepidasthenia interrupta</em></td>
<td>&quot;</td>
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</tbody>
</table>
Polychaeta, continued

- *Pygospio elegans* (Spionidae)
- *Pygospio californica*
- *Rhynchospiro arenicola*
- *Pseudopolydora paucibranchiata*
- *Pseudopolydora kempi*
- *Spiro filicornis*
- *Spirophanes bombyx*
- *Polydora socialis*
- *Eupolymina crescentis* (Terebellidae)
- *Pista pacifica*

Bivalvia

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

Gastropoda

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

Phoronida

- *Phoronis pallida*

Crustacea

- *Lepas pacifica* (Cirripedia)
- *Balanus glandula*
- *Leptocheilia dubia* (Tanaidacea)
- *Excirolina linguifrons* (Isopoda)
- *Idotea resecata*
- *Eohaustorius sp.* (Amphipoda)
- *Corophium brevis*
- *Amphithoe valida*
Crustacea, continued

- Paraphoxus milleri
- Paraphoxus spinosus
- Photis brevipes
- Hyale grandicornis californica
- Heptacarpus pictus (Decapoda)
- Heptacarpus paludicola
- Crangon nigricauda
- Pinnixa faba
- Pinnixa littoralis
- Pinnixa sp.
- Hemigrapsus oregonensis
- Rhithropanopeus harrissi*
- Pugettia richii
- Pugettia producta
- Petrolisthes cinctipes

Echinoidea

- Dendraster excentricus

Asteroidea

- Pycnopodia helianthoides (Forcipulatida)
- Pisaster brevispinus

Urochordata

- Botrylloides sp. (Stolidobranchia)

Hemichordata

- Saccoglossus sp.

Birds

- Melospiza melodia
- Chamaea fasciata
- Calydocetus purpureus
- Hylocichla ustulata
- Turdus migratorius
- Columba fasciata
- Larus occidentalis
- Larus glaucescens

* Denotes introduced species.
<table>
<thead>
<tr>
<th>Scientific Name</th>
<th>Common Name</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Larus delawarensis</em></td>
<td>Ring-billed gull</td>
</tr>
<tr>
<td><em>Larus californicus</em></td>
<td>California gull</td>
</tr>
<tr>
<td><em>Larus heermanni</em></td>
<td>Heerman's gull</td>
</tr>
<tr>
<td><em>Hydroprogne caspia</em></td>
<td>Caspian tern</td>
</tr>
<tr>
<td><em>Uria aalge</em></td>
<td>Common murre</td>
</tr>
<tr>
<td><em>Cephus columba</em></td>
<td>Pidgeon guillemot</td>
</tr>
<tr>
<td><em>Phalacrocorax auritus</em></td>
<td>Double-crested cormorant</td>
</tr>
<tr>
<td><em>Phalacrocorax pelagicus</em></td>
<td>Pelagic cormorant</td>
</tr>
<tr>
<td><em>Ardea herodias</em></td>
<td>Great blue heron</td>
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<tr>
<td><em>Corvus brachyrhynchas</em></td>
<td>Common crows</td>
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<tr>
<td><em>Anas platyrhynchos</em></td>
<td>Mallard duck</td>
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<tr>
<td><em>Mergus serrator</em></td>
<td>Red-breasted merganser</td>
</tr>
<tr>
<td><em>Erolia alpina</em></td>
<td>Dunlin</td>
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<tr>
<td><em>Anas acuta</em></td>
<td>Pintail</td>
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<tr>
<td><em>Gavia immer</em></td>
<td>Common loon</td>
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<tr>
<td><em>Buteo jamaicensis</em></td>
<td>Red-tailed hawk</td>
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<tr>
<td><em>Oreortyx pictus</em></td>
<td>Mountain quail</td>
</tr>
<tr>
<td><em>Zenardula macroura</em></td>
<td>Mourning dove</td>
</tr>
<tr>
<td><em>Bubo virginianus</em></td>
<td>Great horned owl</td>
</tr>
<tr>
<td><em>Chodéléles minor</em></td>
<td>Common nighthawk</td>
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<td><em>Chaetura vauxi</em></td>
<td>Vaux's swift</td>
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<tr>
<td><em>Selasphorus rufus</em></td>
<td>Rufous hummingbird</td>
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<tr>
<td><em>Megaceryle alcyon</em></td>
<td>Belted kingfish</td>
</tr>
<tr>
<td><em>Dryocopus pileatus</em></td>
<td>Pilated woodpecker</td>
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<tr>
<td><em>Dendrocopos villosus</em></td>
<td>Hairy woodpecker</td>
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<tr>
<td><em>Dendrocopos pubescens</em></td>
<td>Downy woodpecker</td>
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<tr>
<td><em>Empidonax difficilis</em></td>
<td>Western flycatcher</td>
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<tr>
<td><em>Trachycineta thalassina</em></td>
<td>Violet-green swallow</td>
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<tr>
<td><em>Tridopiocte bicolor</em></td>
<td>Tree swallow</td>
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<tr>
<td><em>Hirundo rustica</em></td>
<td>Barn swallow</td>
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<tr>
<td><em>Progne subis</em></td>
<td>Purple martin</td>
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<tr>
<td><em>Perisoreus canadensis</em></td>
<td>Gray jay</td>
</tr>
<tr>
<td><em>Cyanocitta stelleri</em></td>
<td>Steller jay</td>
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<tr>
<td><em>Corvus corax</em></td>
<td>Common raven</td>
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<tr>
<td><em>Parus atricapillus</em></td>
<td>Black-capped chickadee</td>
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<tr>
<td><em>Parus rufescens</em></td>
<td>Chestnut-backed chickadee</td>
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<tr>
<td><em>Psaltiparus minimus</em></td>
<td>Common bushtit</td>
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<td><em>Sitta canadensis</em></td>
<td>Red-breasted nuthatch</td>
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<td><em>Certhia familiaris</em></td>
<td>Brown creeper</td>
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<tr>
<td><em>Troglydotes aedon</em></td>
<td>House wren</td>
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<tr>
<td><em>Troglydotes troglodytes</em></td>
<td>Winter wren</td>
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<td><em>Thryomanes bewickii</em></td>
<td>Bewick's wren</td>
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<td><em>Ixoreus naevius</em></td>
<td>Varied thrush</td>
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<td><em>Regulus satrapa</em></td>
<td>Golden crowned kinglet</td>
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<td><em>Bombyrella cedrorum</em></td>
<td>Cedar waxwing</td>
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<td><em>Sturnus vulgaris</em></td>
<td>Starling</td>
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<td><em>Vermivora celata</em></td>
<td>Orange-crowned warbler</td>
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<td><em>Piranga ludoviciana</em></td>
<td>Western tanager</td>
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<td><em>Pheucticus melanocephalus</em></td>
<td>Black-headed grosbeak</td>
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<tr>
<td><em>Spinus pinus</em></td>
<td>Pine siskin</td>
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</tbody>
</table>
Birds, continued

Spinus tristis
Loxia curvirostra
Pipilo erythrophthalmus
Passerculus sandwichensis
Zonotrichia leuconyctes
Passerella iliaca
Sternella neglecta
Molothrus ater
Agelaius phoeniceus
Melospiza melodia
Pellcanus occidentalis
Circus cyaneus
Erolia melanocephala
Erolia bairdii
Actitus macularia
Squatarola squatarola
Limosa fedoa
Charadrius alexandrinus
Charadrius semipalmatus
Charadrius vociferus
Numenius phaeopus
Totanus melanoceles
Telmatoctyes palustarlis
Branta bernicla

Fishes

Allosmerus elongatus
Ammodytes hexapterus
Anarrhichthys ocellatus
Anoplarchus purpurescens
Apodichthys flavidus
Arctedius fenestralis
Arctedius harringtoni
Atherinops affinis
Citharichthys sordidus
Citharichthys stigmaeus
Clinocottus acuticeps
Clinocottus globiceps
Cottus aleuticus
Cottus asper
Cottus gulosus
Cymatogaster aggregata
Embiotica lateralis
Engraulis mordax
Enophris bison
Entosphenus tridentatus
Gasterosteus aculeatus

American goldfinch
Red crossbill
Rufous-sided towhee
Savannah sparrow
White-crowned sparrow
Fox sparrow
Western meadowlark
Brown-headed cowbird
Red-winged blackbird
Song sparrow
Brown pelicans
Marsh hawk
Pectoral sandpipers
Baird's sandpipers
Spotted sandpiper
Black-bellied plovers
Marbled godwits
Snowy plover
Semi-palmated plover
Kildeer
Whimbrel
Greater yellowlegs
Long-billed marsh wren
Black brandt
Whitebait smelt
Pacific sand lance
Wolf-eel
High cockscomb
Pen point gunnel
Padded sculpin
Scalyhead sculpin
Top smelt
Pacific sanddab
Speckled sanddab
Sharpnose sculpin
Mosshead sculpin
Prickly sculpin
Coastrange sculpin
Riffle sculpin
Shiner perch
Striped seaperch
Northern anchovy
Buffalo sculpin
Pacific lamprey
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

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

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
Tuberose 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

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

Sorex trowbridgii
Sorex vagrans
Sylvilagus hudsonianus
Tamiasciurus douglasi
Urocyon cinereoargentus
Ursus americanus
Zapus trinotatus

Reptiles

Gerrhonotus coeruleus
Thamnophis sirtalis
Thamnophis ordoripodes

Algae

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

Diatoms

Achnanthes haukiana
Achnanthes parvula
Amphipleurus rutilans
Cocconeis placentula
Diatoms, continued

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

Vascular Plants

Abies grandis
Abronia latifolia
Agrostis alba
Alnus rubra
Amelanchier florida
Ammophila arenaria
Angelica hendersonii
Arctostaphylos columbiana
Arctostaphylos uva-ursi
Athyrium filix-femina
Bromus sp.
Carex obnupta
Carex lyngbyei
Cotula coronopifolia
Cytisus scoparius
Deschampsia caespitosa
Digitalis purpurea
Distichlis spicata
Epilobium angustifolium
Elymus mollis
Festuca rubra
Fragaria chiloensis
Franseria chamissonis
Gaultheria shallon
Glehnia leiocarpa
Juncus leseuri
Lonicera involucrata
Lupinus litoralis
Lysichitum americanum
Myrica californica
Petasites palmitus

Grand fir
Yellow abronia
Creeping bentgrass
Red alder
Service berry
European beach grass
Angelica
Manzanita
Kinnikinnick
Lady fern
Brome grass
Sedge
Sedge
Brass buttons
Scotch broom
Tufted hairgrass
Foxglove
Green seashore saltgrass
Fireweed
American dune grass
Red fescue
Strawberry
Silver beach weed
Salal
Beach silver-top
Salt rush
Twinberry
Seashore lupine
Skunk cabbage
Western wax myrtle
Western coltfoot
Vascular Plants, continued

Picea sitchensis
Pinus contorta
Poa confinis
Polystichum munitum
Potentilla anserina
Potentilla pacifica
Pseudotsuga menziesii
Pteridium aquilinum
Pyrus diversifolia
Ribes sp.
Rubus parviflorus
Rubus spectabilis
Rubus ursinus
Salix hookeriana
Salicornia virginica
Sambucus callicaupa
Sambucus racemosa
Scirpus americanus
Scirpus validus
Solidago spathulata
Thuja plicata
Trifolium wormskjoldii
Triglochin maritima
Trisetum canescens
Tsuga heterophylla
Vaccinium parvifolium
Zostera marina

Sitka spruce
Shore pine
Dune bluegrass
Western bracken fern
Silverweed
Pacific silverweed
Douglas fir
Sword fern
Crab-apple
Gooseberry
Thimbleberry
Salmonberry
Blackberry
Coast willow
Woody glasswort
Red elderberry
Elderberry
Three square
American great bulrush
Goldenrod
Western red cedar
Springbank clover
Seaside arrow-grass
Oatgrass
Western hemlock
Red huckleberry
Eelgrass
APPENDIX B

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

<table>
<thead>
<tr>
<th>SPECIES</th>
<th>HABITAT</th>
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<tbody>
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<td></td>
<td>DMSH</td>
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<tr>
<td>AMPHIBIANS</td>
<td></td>
</tr>
<tr>
<td>Rough-skinned newt</td>
<td></td>
</tr>
<tr>
<td>(Taricha granulosa)</td>
<td></td>
</tr>
<tr>
<td>Western toad</td>
<td></td>
</tr>
<tr>
<td>(Bufo boreas)</td>
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</tr>
<tr>
<td>Pacific tree frog</td>
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</tr>
<tr>
<td>(Hyla regilla)</td>
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</tr>
<tr>
<td>Red-legged frog</td>
<td></td>
</tr>
<tr>
<td>(Rana aurora)</td>
<td></td>
</tr>
<tr>
<td>Bullfrog</td>
<td></td>
</tr>
<tr>
<td>(Rana catesbeiana)</td>
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</tr>
<tr>
<td>REPTILES</td>
<td></td>
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<tr>
<td>Alligator lizard</td>
<td></td>
</tr>
<tr>
<td>(Gerrhonotus coeruleus)</td>
<td></td>
</tr>
<tr>
<td>Common garter snake</td>
<td></td>
</tr>
<tr>
<td>(Thamnophis sirtalis)</td>
<td></td>
</tr>
<tr>
<td>Northwestern garter snake</td>
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</tr>
<tr>
<td>(Thamnophis ordinoides)</td>
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</tr>
<tr>
<td>MAMMALS</td>
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<tr>
<td>Vagrant shrew</td>
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</tr>
<tr>
<td>(Sorex vagrans)</td>
<td></td>
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<tr>
<td>Trowbridge's shrew</td>
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THE OCCURRENCE OF AMPHIBIANS, REPTILES AND MAMMALS
IN IDENTIFIED HABITATS, JUNE-SEPTEMBER 1975
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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
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## AVIAN SPECIES OCCURRENCE ACCORDING TO HABITAT
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<th>Mature</th>
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</thead>
<tbody>
<tr>
<td>Townsend's chipmunk</td>
<td>3/3</td>
<td>88</td>
<td>181</td>
<td>99</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>7/7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5/6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Douglas squirrel</td>
<td>2/7</td>
<td></td>
<td>+</td>
<td>56</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>5/6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brush rabbit</td>
<td>6/7</td>
<td></td>
<td>107</td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>Bobcat</td>
<td>1/7</td>
<td></td>
<td>+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black bear</td>
<td>1/6</td>
<td></td>
<td>1979</td>
<td>250</td>
<td></td>
</tr>
<tr>
<td>Black-tailed deer</td>
<td>2/6</td>
<td></td>
<td>1979</td>
<td>250</td>
<td></td>
</tr>
<tr>
<td>People</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dogs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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
Glycine armigera (Coniadiidae)
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 dilatae
Halosydna brevisetosa (Polynoidae)
Lepidasthenia interrupta
Pygospio elegans (Spionidae)
Pygospio californica
Rynchospio arenicola
Pseudopolydora paucibranchiata
Pseudopolydora kempi
Spio filicornis
Spichanes bombyx
Polydora socialis
Eupolyxna 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 giganteus*
*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)
*Excirolana 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 richii
Pugettia producta
Petrolisthes cinctipes
Cancer magister
Callianassa californiensis
Upogebia pugetensis

Echinoidea

Dendraster excentricus

Asteroidea

Pycnopodia helianthoides (Forcipulatida)
Piaster brevispinus

Urochordata

Botrylloides sp. (Stolidobranchia)

Hemichordata

Saccoglossus sp.

* Denotes introduced species.