SQUAXIN ISLAND SHORELINE STUDY

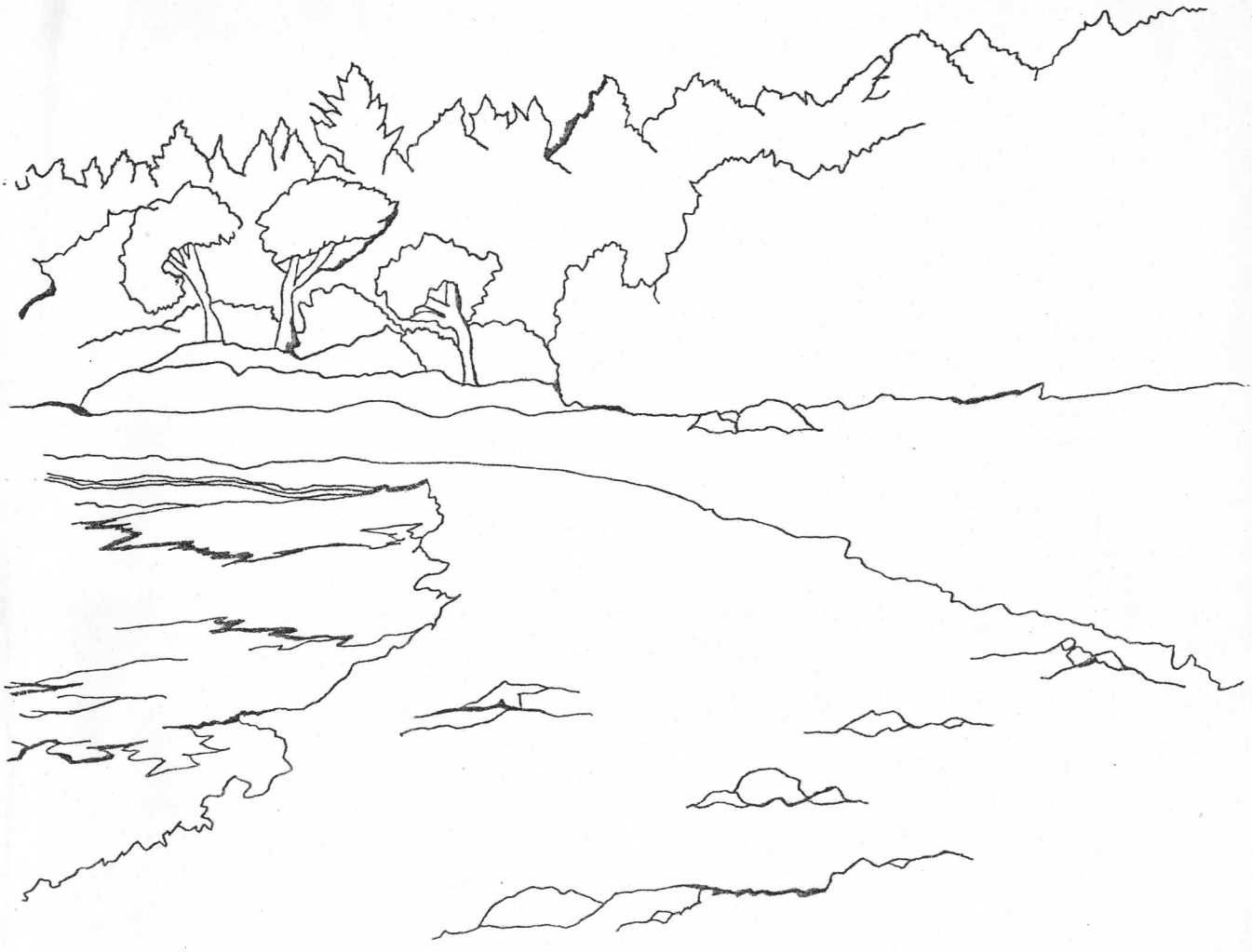

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

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Our special thanks to a few people without whom this project would not have been as successful.

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INTRODUCTION

The purpose of this project has been to survey the basic biological, chemical, and geological components of the western shoreline of Squaxin Island, in order to establish the present biological productivity of the shoreline. Within this study, special emphasis was given to the clam productivity of the area, in order to give the Squaxin Tribe an indication of the present clam populations existing in the seeded area of their beaches.

The study group, composed of four first year students from the Political Ecology program at The Evergreen State College, worked in cooperation with: the Squaxin Indian Tribe, Kaye V. Ladd, Robert Sluss, and other faculty members at The Evergreen State College in order to complete this study. Persons desiring more information about this project should contact Kaye V. Ladd through The Evergreen State College.

PROJECT BACKGROUND

Squaxin Island is located in the western portion of the Toten estuary, in Mason County, Washington, (see Figure 2). The island became the possesion of the Squaxin Indian Tribe with the signing of the Medicine Creek Treaty in 1854. The shoreline of the island is presently uninhabited and is utilized as a recreational area for members of the tribe. Although a small portion of land is leased from the Indians by the State of Washington for use as a public park, the remainder of the island is concidered Tribal Land and is not accessable to the general public.

Within the past six years, the Squaxin Tribe has been experimenting in small scale aquaculture as a method of supplimenting the fish, clam, mussel, and oyster production of the area for the purpose of increasing a tribal member's sport fishing catch. Although this project has been designed primarily for recreational purposes, the tribe is hoping to extend the development of the program to a point where the aquaculture project will sustain commercial harvesting by members of the tribe.

During the Spring months of 1980, biologists working with the tribe established an experimental clam farming operation located on the western shoreline of the island. Clam beds were established in several locations on the shoreline and were seeded with larval clams. The seeded beds were covered with a plastic meshing in order to prevent the larvi from being carried away by tidal currents.

In order to determine the success of this experiment, a monitoring scheme for the seeded shoreline was established. This base study of the bed area serves as the first step of the monitoring scheme. By compiling information about water quality, substrate composition, and invertebrate populations of the beach, it will be possible to estimate the populations of the clam beds.

In addition, the data collected in this report can be used in

the event of a change in the water quality of the area, (due to oil spillage or other sources of chemical contamination), to determine the extent of environmental change occuring to the beach.

WATER QUALITY

SECTION 1

AN OVERVIEW OF WATER QUALITY

The water quality tests for this baseline were conducted on three days: April 16, April 23, and May 7. The offshore water collection was made with the use of the Boston Whaler, a boat owned by the college. Three different sites were randomly selected for the collection. The samples were obtained from a depth of 0.5, 1.5, and 2.0 meters. The samples were transported back to the lab at The Evergreen State College and analyzed within six hours. All samples were analyzed by the students of the Political Ecology program, under the direction of K.V.Ladd. The methodologies for the tests conducted can be found in Appendix 1.

WATER QUALITY OF WESTERN SQUAXIN ISLAND

INTRODUCTION

When studying the populations of inter-tidal organisms it is important to be aware of all the environmental factors that effect those populations. Since most inter-tidal organisms come into direct contact with the water, the water can be said to be an environmental factor, or a part of a given species niche. The more chemically balanced the water is in terms of nutrient composition, the greater the chance that the inter-tidal organisms are living and reproducing at a "normal" rate. However, if the water is not in a balanced state, it will, more than likely, have some effect on the inter-tidal specie's population. There are many types of pollutants that can effect the balance of an aquatic system. In this study we will be confined to the testing of water as it relates to the productivity of phytoplankton and the abundance of total coliform bacteria in the area.

It is very important to know the ability of a given body of water to produce phytoplankton because the avalibility of phytoplankton has a direct effect on the populations of other marine species. Phytoplankton (the micro-scopic plants that float in the world's oceans) are at the bottom of the marine food chain, the first trophic level, and are refered to as "primary producers". The phytoplankton are fed upon by micro-scopic animals know as zooplankton. The zooplankton are refered to as "primary consumers". The zooplankton are in turn fed upon by the filter-feeders (bivalves and barnicles), limpits, and periwinkles, which constitute the third trophic level. These organisms are in turn

fed upon by the "top carnivors"; starfish, snails, ocean fish, crabs, and birds (in actuality the marine inter-tidal food web is much more complex, but for the purpose of discussion this one is adaquate). In this way all organisms are linked together by the food chain, with the phytoplankton at the bottom. Therefor; if the population of phytoplankton are adversly effected by the condition of the water, the populations of most inter-tidal organisms will be adversly effected as well.

It is also very important to know the amount of total coliform bacteria that are present in a given body of water, because their presence indicates that the water is unsuitable for human consumption. In most cases if the water is found to contain coliform bacteria so too will the inter-tidal organisms.

TEMPERATURE, pH, SALINITY, and ALKALINITY

The temperature and the pH are important to know because as they change, so too will the ability of phytoplankton to live in the water. pH is a measure of the acidity or basicity of the water. Salinity is a measure of the salt content of the water, and is used, along with the temperature, to calculate the saturation level of dissolved oxygen. Alkalinity is a measure of the ability of the system to withstand the addition of acid, or a lowering of the pH level. Refer to the table below to see results.

Temperature, pH, Salinity, and Alkalinity levels of Western Squaxin Island

Sample site	Temp.	Salinity	pH	Alkalinity
Date: April 16, 1980				
A	10°C.	28.0 ppt	8.05	56.16 $CaCO_3$/1.
B	10°C.	28.0 ppt	7.99	58.08 $CaCO_3$/1.
Date: April 23, 1980				
Sample site				
A	11°C.	27.0 ppt	----	----------
B	11°C.	27.0 ppt	----	----------
C	11°C.	27.0 ppt	----	----------
Date: May 7, 1980				
Sample site				
A	12°C.	28.0 ppt	8.02	66.96 $CaCO_3$/1.
B	12°C.	28.0 ppt	8.30	68.64 $CaCO_3$/1.
C	12°C.	28.0 ppt	8.01	68.52 $CaCO_3$/1.

TABLE 1

As can be seen from table 1, the temperature of the water increased over the three sampling periods due to the increase in sunlight, and the warming trends of spring. The amount of salt contained in the water indicates that the system is an estuary. Since sea water usually has a pH of 8 (refer to the Washington State Water Quality Standards in the last section of water quality), the pH level of the water is at normal level.

Nutrients

The water quality measurements made in this baseline are measurements of the nutrient concentration. Nutrients are the needed inorganic chemicals that are utilized by the phytoplankton to produce plant tissue. The phytoplankton utilize the sun's energy through photosynthesis to metabolize; nitrogen,

oxygen, carbon, and phosphorous. These chemicals are the needed nutrients to sustain the life of the phytoplankton. As the availability of these nutrients increase and decrease, so too, does the amount of phytoplankton produced.

Oxygen and Chlorophyll

Oxygen is produced either by photosynthetic organisms, or by direct exchange with the atmosphere. It is consumed by the respiration processes of plants and animals, and by the decomposition of organic matter.

The temperature and salinity of the water are used to calculate the saturation level of dissolved oxygen. The saturation level is the amount of oxygen dissolved in the water solely by physical exchange.

In order to know the net oxygen productivity, and biological activities in the water, a measure of the Biological Oxygen Demand (BOD) and Net Oxygen Production (NOP) were calculated. Since the BOD is the amount of oxygen consumed in a given period of time, and the NOP is the amount of oxygen produced in a given period of time, the difference between them will yeild the productivity of oxygen in the system.

Chlorophyll is the measure of the amount of phytoplankton in the water. Since phytoplankton contain chlorophyll, the more phytoplankton in the water the higher the chlorophyll level. Chlorophyll levels will usually varry with the amount of oxygen produced in the water. Refer to the table on the next page for results.

Dissloved Oxygen and Chlorophyll levels in the water of Western Squaxin Island

Date: April 16, 1980 Site	Dissolved Oxygen ppm	Saturation level mg./1.	D.O. light ppm	D.O. Dark ppm	NOP mg./1.	BOD mg./1.	Productivity in mg./1/day	Chlorophyll umol/1.
A	$12.90 \pm .04$	9.000	$18.18 \pm .02$	$6.10 \pm .10$	.220	-.283	.503	1.14
B	$12.86 \pm .02$	9.000	$18.61 \pm .09$	$14.34 \pm .01$	.239	-.061	.298	1.11
Date: April 23, 1980								
Site								
A	$12.67 \pm .04$	9.100	$16.03 \pm .03$	$10.43 \pm .03$	.140	.093	.047	1.20
B	$12.63 \pm .01$	9.100	$14.96 \pm .08$	$12.47 \pm .08$	.097	.006	.091	.80
C	$12.44 \pm .04$	9.100	$15.93 \pm .04$	$11.05 \pm .07$	.145	.057	.088	1.15
Date: May 7, 1980								
Site								
A	$11.29 \pm .05$	8.800	$11.29 \pm .05$	$10.66 \pm .05$	.000	.026	-.026	.52
B	$11.80 \pm .07$	8.800	$13.65 \pm .07$	$11.38 \pm .08$	.077	.017	.060	.32
CC	$10.46 \pm .02$	8.800	$12.41 \pm .03$	$11.13 \pm .01$	.081	-.027	.108	.74

TABLE 2

D.O. in this chart refers to the dissolved oxygen content of the given sample.

NOP in this chart refers to the Net Oxygen Production in the sample.

BOD in this chart refers to the Biological Oxygen Demand in the sample.

Since the dissolved oxygen in the water is greater than the saturation level determined by the temperature and salinity, the water is considered "super-saturated". This can be caused by wind and wave action, or by photosynthesis of phytoplankton within the water.

To distinguish between the oxygen created by the wind and wave action, and the oxygen created by photosynthesis, the amount of oxygen produced in the light (NOP) and consumed in the dark (BOD) were determined. Looking at table 2 it can be seen that in most cases there was oxygen produced that was higher than the initial concentration. This coupled with the fact that in most cases productivity was positive, indicates that the state of supersaturation was probably due to photosynthesis. This is reinforced by the chlorophyll data which indicates that there were large numbers of phytoplankton in the area.

It can also be seen from table 2 that the amount of tissue produced declined (for the most part) in respect to the previous sample day. This indicates that the phytoplankton were probably experiancing a fluxtuation in their population. It is the nature of plankton populations to grow at tremendous rates and then die off, only to grow again. The cycle usually takes about three weeks.

Over view of Phosphate and Nitrate

Usually the two nutrients that are most likely to create an abundance or decline in the phytoplankton population are nitrogen and phosphorous. In an estuarien system, such as the Puget Sound, the limiting factor is usually nitrogen. This means that if the system is to produce more or less phytoplankton it will

depend upon the amount of nitrogen in the system. This is the case because there is always enough phosphorous, as phosphate, in salt water. In a fresh water system phosphorous becomes the limiting factor, as there is always an abundance of nitrogen.

In a marine system that is functioning normally the nitrogen is aquired through the process of decomposition (there are also some algea that can "fix" nitrogen directly from the water and need not worry about decomposition). As the organic matter in the water dies, bacteria break it down and release all the nutrients that are present in the tissue. These nutrients are then used by the phytoplankton to produce more tissue. Thus the cycle continues.

However, in the case of excessive nutrient concentration, the system can be thrown out of balance. In the case of a salt water system if an excessive amount of nitrogen is dumped into the water there will be a rapid algea bloom. The algea keep growing until the tissue on the lower layer starts to decompose, due to the thickness of the growth and lack of light. The bacteria that break the tissue down oxidize it, consequently, if a lot of algea is being decomposed a lot of oxygen is going to be used up. This can lead to a reduction in the amount of oxygen in the system. Which, in turn, suffocates all aquatic life that needs oxygen to survive. As these creatures die, they too are decomposed, and more oxygen is lost from the system. Eventually the system can no longer sustain aerobic life. The main contributors to excessive nitrogen in the water are: mismanaged sewage treatment plants, open sewage run-off, and excessive amounts of animal wastes from feed lots. These sources are also the

main contributors of coliform bacteria to the water.

Phosphate

Phosphate is a chemical that is essential for photosynthesis, as well as other biological processes. There can be found in the marine environment two types of phosphates: Total Phosphate, which is the total amount of phosphate atoms (organic or inorganic) that are available in the water; and Ortho Phosphate, which is the amount of phosphate that can be directly metabolized by the phytoplankton. Organic phosphates that are found in a system usually derive from the decomposed tissue of living matter, while the inorganic phosphates usually originate from detergents, and chemicals that drain from fields and forests into the sea. Refering to table 3, the results of the phosphate test can be seen.

The Amount of Total and Ortho Phosphate in the Water of Western Squaxin Island

Site	Amount of Total Phosphate per liter in umoles	Amount of Ortho Phosphate per liter in umoles
Date: April 23, 1980		
A	$.24 \pm .36$	$.42 \pm .22$
B	$.39 \pm .24$	$.91 \pm .10$
C	$.98 \pm .11$	$.80 \pm .11$
Date: May 7, 1980		
Site		
A	$1.53 \pm .78$	$1.30 \pm .87$
B	$1.70 \pm .73$	$1.06 \pm .99$
C	$1.59 \pm .76$	$1.12 \pm .95$

TABLE 3

Looking at table 3 it can be seen that the phosphate levels are very low. The concentration of phosphate was rarely much greater than one. Since the total and ortho results were roughly the same it can be determined that the phosphate available is able to be metabolized.

Nitrate and Nitrite

In the water nitrate is utilized by the plankton to produce tissue. Nitrite, on the other hand, has to be oxydized by certain bacteria into nitrate before it can be utilized. Nitrate and nitrite tend to be the limiting factors in sea water. Refer to the table below for the results of the nitrate and nitrite testing.

Nitrate and Nitrite levels in the water of Western Squaxin Island

Date: April 16, 1980

Site	Amount of Total Nitrate in umoles per liter	Amount of Total Nitrite in umoles per liter
A	4.73 ± 2.58	$1.0 \pm .23$
B	4.09 ± 2.80	$.83 \pm .26$

Date: April 23, 1980

Site		
A	$1.40 \pm .16$	$1.21 \pm .16$
B	$1.40 \pm .16$	$1.37 \pm .14$
C	$1.83 \pm .13$	$1.54 \pm .13$

Date: May 7, 1980

Site		
A	$1.81 \pm .25$	$1.05 \pm .15$
B	$1.66 \pm .27$	$1.46 \pm .11$
C	$2.39 \pm .31$	$1.46 \pm .11$

TABLE 4

In an aquatic system that is operating "normally" on the high seas the ratio of phosphate to nitrate is 16:1*. In the case of the Squaxin Island water the ratio is 1:1. This indicates that the system is extremely nitrate limited.

Coliform Bacteria

Coliform bacteria are commonly found in the intestines of humans and other warm-blooded animals. They usually make their way into the water by means of sewage treatment plants, and other run-off that has been contaminated with excrement. Coliform bacteria themselves pose no threat to human health, however the presence of coliform in the water indicates the possible contamination of many types of pathogenic bacteria and viruses that are transmitted by humans.

In this test we measured the amount of coliform bacteria that survived twenty-four hours of incubation at 32°C. This test did not test for fecal coliforms, as the test is much more specific in temperature requirements.

The amount of Coliform Bacteria in the water of Western Squaxin Island

Date: April 16, 1980

Site	Coliform Colonies in 100 mls. of sample
A	3
B	1

Date: April 23, 1980

Site	
A	4
B	4
C	1

Date: May 7, 1980

Site	Coliform Colonies in 100 mls. of sample
A	6
B	1
C	2

TABLE 5

The coliform levels in the water off of the Western shore of Squaxin Island are extremely low. This indicates that the levels of pathogenic bacteria are also very low, consequently, the inter-tidal organisms in the area are fit for human consumption.

Comperison of Squaxin Island water to Washington State Water Quality Standards

According to our findings the water off of the Western shore of Squaxin Island falls into the catagorie of Class AA (Extraordinary) as defined by the WAC 173-201-045 standards. The temperature, pH, dissolved oxygen, and coliform levels as established by the state for Class AA water are as follows: -water temperature shall not exceed 13°C. The pH level shall be within a range of 7.0 to 8.5. The dissolved oxygen level shall be greater than 7.0 mg./l. The coliform level shall not exceed 14 organisms per 100 mls. of sample. As can be seen from the results of this water quality testing, the water of Western Squaxin Island falls within these limits. Not only is the water fit for human activities, but it is fit, as well, for the developement of a clam farm.

*Stumm, Werner and Morgan, James, J. Aquatic Chemistry; Wiley-Interscience, 1970 page. 431

POPULATION SURVEY

SECTION 2

INTERTIDAL POPULATION SURVEY

Introduction:

A survey that collects data on the existing state of an ecosystem is called a "Baseline Survey". A baseline's function is to act as a point of reference which enables change in the system to be detected. It is desirable to measure changes occurring in an ecosystem for various reasons, the most important of which is to determine the types of changes occurring and the factors influencing these changes.

One way to establish a reference point is with a Population Baseline Survey. This is done by monitoring various environmental parameters and by obtaining population estimations. With data such as this, it is possible to determine key environmental influences on population size variations.

BEACH TYPES AND CHARACTERISTICS: AN OVERVIEW

Because of a limited amount of time, we limited our study areas to three sites which exemplify all the beach types present on the western shore of Squaxin Island. The first beach sampled, (Site A, see Figure 3 Appendix), had the steepest slope of the three sample sites, and also the largest rocks. At low tide many starfish (Pisaster spp.), were observed.

The second beach sampled, (see Figure 3), was directly north of a clam bed that had been seeded. North of the sample area was a small freshwater runoff. The slope of this beach was the flatest of the three. The surface of the beach had a fine sand and mud, with a few small pebbles. At low tide starfish and sand collars, (moon snails-Polinices spp.- egg cases), were observed.

The third beach sampled, (see Figure 3), was between two clam beds also previously seeded. The slope of this beach was less than that of Site A, and greater than that of Site B. The sand was mixed with gravel, and had a surface cover of medium and small sized pebbles. At low tide, starfish and sand collars were observed.

All the sites sampled were densely populated with intertidal life. The surface was populated with the small shore crab (Hemigrapsus spp.), periwinkles (Littorina spp), limpets (Collisella spp.), anemones (class; Cnidaria), hermit crabs (Pagurus spp.), flatworms (class; Platyhelminthes), and barnacles (Balanus glandula).

The subsurface was full of many worms, mainly ribbon worms (class; Nemertea), and segmented worms (class; Annelida), ghost shrimp (Callianassa spp.), and mussels (Mytilus edulis).

The clams recorded were: heart cockle (Clinocaradium nuttalli), soft-shell (May arenaria), butter (Saxidomus giganteus), manilla (Venerupis joponica), little neck (Protothaca staminea), bent nose (Macoma nasuta), and geoduck (Panope generosa).

DISCUSSION OF THE POPULATION DATA

Some conclusions may be drawn from these data. First, because of the large amount of variance in the data, it is evident that random sampling does not provide the data needed for estimating the population of clams on the western shore of Squaxin Island. This suggests that the clams are not distributed randomly on the beach. The clams inhabiting the beach may be distributed in clumps or pockets in certain areas. Hence, in order to obtain data which would yield narrower ranges of estimated density, it would be necessary to either stratify the beach and sample the strata seperately or to determine a transformation function which would randomize the raw counts.

Evident in the data, is the large number of juvenile sized clams as compared to the small number of adult and harvestable clams found on the beach. This suggests a heavy mortality occurring between the juvenile and adult/harvestable age categories. The cause of this is important, because whatever is affecting the present clam's mortality rate may also effect the newly seeded clams.

This apparent mortality may be the result of harvesting, and/or predation, and/or some physical or nutritional effects. We observed a large number of starfish (Pisaster spp.), in the area and little evidence of predacious snail activity. Therefor, the most likely predator which could have caused the reduced adult and harvestable numbers is the starfish.

Our water quality does not indicate and explaination of the apparent mortality. Hence, unless considerable harvesting is occurring, it may be desirable to investigate starfish predation and its effects on various clam densities.

TABLE 6: 95% CONFIDENCE INTERVAL FOR THE MEAN DENSITY IN CLAMS PER SQUARE METER

SITE A

5-2-80

Clam Species	JUVENILE (0-25mm)	ADULT (25-40mm)	HARVESTABLE (40mm-)	TOTAL
Clinocaradium nuttalli				2*
May arenaria	7.2 ∓ 12.7			7.2 ∓ 12.7
Saxidomus giganteus	4.9 ∓ 7.4			5.6 ∓ 8.7
Venerupis joponica	3.5 ∓ 5.98			3.7 ∓ 6.46
Protothaca staminea	1.8 ∓ 6.0			1.8 ∓ 6.0
Macoma nasuta				4*
Panope generosa				

SITE B

5-3-80

Clam Species				
Clinicardium nuttalli				3*
May arenaria	7.2 ∓ 10.1			9.1 ∓ 12.69
Saxidomus giganteus				1.6 ∓ 2.69
Venerupis joponica	4.6 ∓ 8.17	3.3 ∓ 4.3		7.9 ∓ 11.1
Protothaca staminea			2.1 ∓ 5.9	2.6 ∓ 6.8
Macoma nasuta				3*
Panope generosa				4*

*This number represents the actual number of individual clams collected in the transect area. The data collected was insufficient to process.

SITE C

5-16-80

Clam Species	JUVENILE(0-25mm)	ADULT(25-40mm)	HARVESTABLE(40mm-)	TOTAL
Clinocaradium nuttalli	1.5 $\bar{+}$ 2.5			2.9 $\bar{+}$ 5.1
May arenaria	6.1 $\bar{+}$ 8.7			6.2 $\bar{+}$ 8.5
Saxidomus giganteus	3.5 $\bar{+}$ 7.19			3.8 $\bar{+}$ 6.9
Venerupis joponica	4.6 $\bar{+}$ 5.34			5.0 $\bar{+}$ 4.1
Protothaca staminea	3.0 $\bar{+}$ 5.96			3.2 $\bar{+}$ 6.5
Macoma nasuata				8*
Panope generosa				

*This number represents the actual number of individual clams collected in the transect area. The data was insufficient to process.

POPULATION CHART ANALYSIS

To catagorize the clam populations, the clams were divided into categories according to size. They were measured by their greatest dimension. 0 to 25 mm. were recorded as juveniles, 25 to 40 mm. were recorded as adults, and 40 mm. and up were recorded as harvestable. (see Table 6)

The data was processed seperately, according to size and grid area. The equation used to find the 95% confidence interval for the mean density of clams per square meter is;

$$\bar{y} \pm 2 \times \sqrt{\text{var. of } \bar{y}}$$

The variance of $\bar{y}$ is;

$$\frac{\sum y^2 - \frac{(\sum y)^2}{n}}{n-1}$$

$\sum y$ = the total amount recorded of a particular species in the grid area.

$(\sum y)^2$ = " " "
" " squared.

$\bar{y}$ = y divided by 10 (because 10 figures were recorded), or the point estimate of density.

n = 10, or the number of figures recorded.

These equations were found in E. C. Pielou's Population and Community Ecology, Gordon and Breach, Science Publishers Inc., N.Y., 1974.

SEDIMENTATION ANALYSIS

SECTION 3

SEDIMENTATION ANALYSIS

As the water of Puget Sound moves back and forth with the pull of the tides, the chaneling of the water creates curents and a sweeping effect on the shoreline. The velocity of these curents can be altered by the land masses forming the water's path, such as in the redirection of the curent caused by a point, or the funneling effect of a narrows. Erosion and sedimentation caused by the direction and velocity of the curent influences the physical surface characteristics of the beach.

Erosion is caused when the curent is strong enough to transport particles of silt, sand, and gravel, stirred by the wave action on the beach. Sedimentation occurs when the curent is not strong enough to move or support the weight of these stirred particles, and they settle back to the bottom. Therefore, a beach will reflect the effect of the water's action. A beach with a rocky surface cover will generally have much of the smaller particles washed away by a strong curent, wheras the weaker curent at a muddy beach will allow small particles of silt and clay to settle out. Larval clams are also affected in a similar manner as they are swept along with the surface particles of the beach and are deposited with the diminishing curent.

Clams, being a stationery animal, usually dig themselves in the substrate of a beach, where in the larval stage they were transported by the water curents. By knowing the existing sedimentation of a beach it is possible to select sites for establishing clam beds, and perhaps alter the effect of the curent on the beach, making it more suitable for clam seeding. At the present test sites on the west shore of Squaxin Island, plastic netting is secured on the beach to buffer the curent, trapping the larger particles that are usually transported when subjected to the full force of the curent. Thus, where larval clams might have normally been swept away by the curent, there is now a chance for these seeded clams to establish themselves in a protected area.

DISCUSSION OF SEDIMENTATION ANALYSIS

The results of the 2.25 x 15cm. samples,(see Appendix Tables), does not give as accurate a picture of the sediment found on the beach, because of the large pebbles interferring with the sample taking, (see Methodology for Sedimentation in Appendix). Therefore, only the larger samplings will be used in this discussion.

The particle size of sediment on a beach is a determining factor in the success of a clam farm. Since clams must burrow down into the substrate to establish their niche, certain areas are more favorable because of the easier penetration by the clams. The clam has to draw it's shell after it's probing foot, and maintain a siphon hole to the surface for feeding. A high percentage of coarse gravel or clay can halt the digging efforts of the clams leaving them closer to the surface and reach of preditors.

In comparing the three large samplings, (see Figure 1 below), it became obvious that the three beaches were relatively similar when comparing the particle sizes from 0.125 through 1.981mm.,(fine sand to fine gravel). This range made up over 50% in each area. The clams surveyed in this study are usually found on a beach that has a high percentage of this sediment, and therefore their survival rate would be higher. The upper range, 4.0 through 16.0mm.,(fine to coarse gravel), made up a sizeable portion of the beach sedimentation. These grains, being larger, would make the burrowing more difficult. The lower range, from under 0.125mm.,(silt, clay, and very fine sand), make up a rather small portion of the beach sedimentation. These grains have very little influence on the burrowing of clams unless in a high percentage.

TABLE 7

GROUPING OF SEDIMENT SIZES

SIZE CLASS	SITE A	SITE B	SITE C
Silt, clay, and very fine sand.	0.75%	3.37%	2.01%
Fine sand to fine gravel	50.8%	59.03%	59.83%
Fine to coarse gravel	48.44%	37.6%	38.12%

FIGURE 1

LARGE SEDIMENT SAMPLING

CONSLUSIONS AND RECOMENDATIONS

It has been concluded from this baseline that further investigation is warrented before full scale clam aquaculture is established on the western shore of Squaxin Island. Three major areas of study were focused on during the research: Water Quality, Species Populations Survey, and Sedimentation.

From the Water Quality research done it was concluded that the water was Class AA (Extraordinary), as defined by the Washington State Code: WAC 173-201-045. This means the water is fit for human consumption and use. It was also concluded that the water contained enough nutrients to provide the phytoplankton an adaquate food source, thus insuring the inter-tidal species enough food to live and reproduce. Hence, the western shore of Squaxin Island, in terms of Water Quality is fit for the establishment of a clam farm.

The Species Population Survey has shown that the clams on the western shore of Squaxin Island were found to be distributed in pockets, rather than randomly. There also appeared to be a high mortality rate between the juvenile and the adult/harvestable clams.

It was concluded through the Sedimentation analysis that the beach was within the ranges normally associated with clam populations. The surface of the beach, though an indication of wave action, is not a determining factor of the substrate, but should be taken into account when seeding the larval clams.

Since the Water Quality and Sedimentation analyses found the beach to be within the normal ranges associated with clam production, but the Species Population Survey determined that there was a high mortality rate among maturing clams, it is recommended that in the future a more extensive study be conducted on the western shoreline of Squaxin Island. We feel this study should focus on the reasons for this high mortality rate of the clams. We also feel that a periodic monitoring system be extablished to keep track of the beaches' activity.

AUTHORS OF THE SQUAXIN ISLAND SHORELINE STUDY

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APPENDICES

APPENDIX 1

METHODOLOGIES

WATER QUALITY METHODOLOGY

The site for water collection was determined randomly. The only criteria being that one sample had to be located at the northern end of the beach and the other had to be located at the sothern end. The water collected was taken from a point 20 to 30 meters off shore.

A Van-Doren collection bottle was lowered into the water and "triggered" shut. It was then pulled to the surface and placed into the boat. Three biological oxygen demand (BOD) bottles were filled. One BOD bottle was then "fixed" by pipeting 2 mls. of manganese chloride ($MnCl_2$), and 2 mls. of iodide (I_2), into the bottle. All three of the bottles were then placed into a light tight box.

Two 1 liter plastic bottles were then filled up with the remaining water. Into one of them a thermometer was placed and the temperature noted. This process was repeared for each sample site.

METHODOLOGY FOR pH, ALKALINITY, AND SALINITY

To measure the salinity, we used a Bausch & Lomb temperature compensated salimometer.

To measure pH, we calibrated the Orion 407A Specific Ion Meter with hydrogen electrode using two buffer solutions: pH = 6+8. We measured the pHs of a* sample, and then to measure the Alkalinity of the samples we did the following. We added three drops of Bromcresol Green Indicator to the sample, as it was mixing on a magnetic stirrer. As the solution was being stirred, we titrated a solution of 0.12M HCL, using a Gilmont Micro-Buret, untill the color change occured. The stirring was continued for 5 minutes and further titration was completed. A recording of the ammount of HCL used became our results.

*50 ml. of sample water was used for each testing.

Dissolved Oxygen Methodology

Field Methods

Three BOD bottles were filled at each site. One was fixed (see below) immediately to determine the amount of dissolved oxygen in the field. This bottle along with the other two was placed in a light tight box and transported back to the lab. The two unfixed BOD bottles were placed in an incubator for 24 hours at $11^{o}C$. One of the bottles was left in the light, while the other was left in the dark.

Fixing

To determine the dissolved oxygen content of a given sample the following chemicals were added to the BOD bottle with a calibrated Pasture pipet. 2 mls. of Manganese Chloride ($MnCl_2$)-2.1 M-, and 2 mls. of Iodide Hydroxide (KOH-KI)-12.5 M-.

Analysis

Each BOD bottle had one ml. of 18 M sulfuric acid added to it using a 1 ml. transfer pipet. Using a modified Winkler Method 20 mls. of sample was pipeted from the BOD bottle to a 50 ml. beaker. The beaker was placed on a magnetic stirrer and a stirring bar was added. Using a Gilmont 2.0 ml. Buret thiosulfate ($Na_2S_2O_3$)-0.025M- was added to the beaker until the color of the solution turned clear. Three drops of starch solution was added to the solution, turning the color blue. The titration was continued until the color was again clear. The volume of the thiosulfate used was recorded.

METHODOLOGY FOR THE DETERMINATION OF CHLOROPHYLL

For this experiment, 10 dram vials were filled with 10 ml. of 90% acetone, which acted as the solvent of the chlorophyll in the tissue suspended in the water sample.

A known volume of water was filtered through a 1u. glass fiber filter, (millipore), using an aspiration filtering technique. Each filter was rolled and placed into a vial, capped and shaken vigorously. All vials were then stored in a dark incubator, set at approximately 1° C for 24 hours.

The supernatent in each vial was pipeted into a centrifuge tube and centrifuged at medium speed for approximately one minute. The supernatent was then pipeted into an optical cubicle and tested for it's optical density, (Absorbance), at both 663nm., and 750 nm. A 90% acetone filled optical cubicle was used to zero the Bausch & Lomb Spectronic 88 in which the samples were tested.

The density of each sample was computed by using the equation below.

$$\frac{\text{mg. of Chlorophyll}}{\text{1000 ml. } H_2O} = \frac{\text{(Absorbance Value*) (volume Acetone)}}{\text{volume of sample in ml.}}$$

* 663 nm. or 750 nm. reading

METHODOLOGY FOR DETERMINATION OF ORTHO AND TOTAL PHOSPHATE

Treatment of Glassware:

All glassware was rinsed with 6M HCL, rinsed with deionized water, and dried in an oven. This method was used to clean all glassware used.

Conversion of Total Phosphate to Ortho Phosphate:

Fifty ml. of sample water was first measured into an Erlenmeyer flask. To each sample, 1 ml. of 20% H_2SO_4 and 1 ml. 1M Ammonium Per Sulfate solution was added. The flasks were then placed on a hot plate under a hood and heated to reduce the volume of the sample to less than 15 ml., but not to driness. The flasks were removed from the hot plate and allowed to cool, before adding two drops of 1%Phenolphtalin Indicator solution. To this, 6M NaOH was added dropwise until the first permenent pink color was observed. To complete this phase of the testing, 1M H_2SO_4 was added untill the pink color dissapeared. The sample was then transfered to a graduated cylinder, diluted to 50 ml. with deionized water, returned to the same flask, and analyzed for Ortho Phosphate as described below.

Analysis for Ortho Phosphate:

To a dry Erlenmeyer flask, 50 ml. of sample water was transfered. To this, 10 ml. of the Coloring Reagent, (see below), was pipeted. A reaction time of five minutes was allowed after mixing. The Absorbance of this solution was determined aganist deionized water at 885 nm., using a Bausch & Lomb Spectronic 88.

Preparation of Coloring Reagents:

Reagent A:

To 150 ml. Distilled Water add;

- 2.64 g. Ascorbic Acid
- 50 mg. Disodium EDTA
- 1 ml. Formic Acid
- 250 ml. 2.5M H_2SO_4

Reagent B:

0.274 g/ 100 ml. of Antimony Potassium Tartrate

Reagent C:

4 g/ 100 ml. Ammonium Molybdate

The coloring reagents were prepared just prior to usage. First, 240 ml. of Reagent A was transfered into a dry beaker. To this, 15.6 ml. of Reagent B, and 47.7 ml. of Reagent C were added. This was mixed by swirling.

Preparation of Calibration Solutions:

The Phosphate Stock Solution, (50 umol/L), was prepared by transfering 10 ml. of a prepared Phosphate solution, ($5x10^{-3}$umol/L), into a 1 liter volumetric flask and diluted to the mark with deionized qater. 50 ml. deionized water was transfered to an Erlenmeyer flask using a graduated clynder. Into a graduated clynder, 1 ml. of Phosphate Stock Solution was pipeted, diluted to the mark with deionized water, and transfered to another flask. This same method was repeated with 2 ml., 3ml., and 4 ml., to form the concentrations of: 0 umol/L, 1 umol/L, 2 umol/L, 3 umol/L, and 4 umol/L, forming our calibration curve solutions.

Analysis of Total Phosphate:

To a dry Erlenmeyer flask, 50 ml. of sample water was transfered. To this, 10 ml. of the Coloring Reagent, (see above), was pipeted. A reaction time of five minutes was allowed aftermixing. The Absorbance of this solution was determined aganist deionized water at 885 nm., using a Bausch & Lomb Spectronic 88.

Data Reduction:

The concentrations of Ortho and Total Phosphate as absorbance readings were plotted on the Calibration Curve Graph, and the best straight line was drawn to the point as determined by linear regression analysis method.

Methods for Nitrate and Nitrite

Preparation of Solutions

A 10^{-4} M nitrate stock solution was made from a 10^{-2} M nitrate solution in a solution in a one liter volumetric flask. A set of five calibration solutions were made up with concentrations of 0, 2.5, 5, 7.5, and 10 umole/l using 0, 5, 10, 15, and 20 mls. respectively of 10^{-4} M nitrate stock solution and diluting to 200 ml in a volumetric flask.

A 5×10^{-3} M nitrite stock solution was made from a 50 umole/l nitrite solution in a one liter volumetric flask. Another set of calibration solutions were made with concentrations of 0, 1, 2, 3, and 5 umole/l using stock solution and diluting to 50 ml. in a graduated cylinder.

Reduction of Nitrate to Nitrite

200 ml of sample water for the nitrate experiment and 50 ml of a sample water for the nitrite and calibration solutions were measured into a 250 ml erlenmeyer flask. One ml of 4M NH_4Cl was added to each flask. The solution was pumped through an amalgomated zinc column (a Jone's reductor) using a sage pump (Orion model 375A) set at 10 ml/min. The initial 50 ml of sample were discarded and the subsequent 50 ml were collected and analyzed as below for nitrite.

Analysis for Nitrite

One ml of sulphanilemide (1% sulphanilemide 10% HCl) was added to 50 ml of the solution to be analyzed. After 2-8 minutes elapsed one ml of ethylene diamine (1% naphthyl ethylene diamine dihydrochloride) was added. After ten minutes, but less than two hours, each solution was analyzed spectrophotometrically using a Bausch and Lombe Spectronic 88 set at a wavelength of 540 nm. 1 cm. cuvettes were used to measure the sample.

METHODOLOGY FOR TOTAL COLIFORM ANALYSIS

The membrane filter technique was used for determining the total coliform count of the water samples. The analysis was conducted using sterile technique. The M F Endo Medium was made 24 hours in advance and had been stored in petri dishes in the dark. The medium ingredients for approximately 25 plates were as follows:

1) 4.8 DIFCO m Endo Broth
2) 2.69 Agar (Bacto)
3) 175 ml. deionized water
4) 3.5 ml. 95% Ethenol

The Millipore membrane filter apparatus was assembled with a Millipore membrane filter (pore size 0.45 microns) in place. The selected amount of the water sample (either 1 ml., 10 ml., or 100 ml.) was poured into the funnel of the apparatus. The aspirator was turned on creating a vacum which filtered the water through. After filtration the filter was removed and placed on the MF Endo medium in a petri dish. The dish was inverted and incubated for 26 hours.

During the 26 hour incubation, the coliform grew into distinct colonies. The colonies which were purplish with a metallic green sheen on the surface were considered members of the coliform group. The sheen may appear in a small central area or cover the entire colony. The colonies were counted and the following formula was used to convert the findings to colonies per 100 ml. of sample water.

$$\text{Coliform Colonies/100 ml.} = \frac{\text{Coliform colonies counted} \times 100}{\text{Sample filtered in ml.}}$$

METHODOLOGY FOR AN INTERTIDAL POPULATION SURVEY

Site Selection

The beach area designated for study was surveyed, and the different beach types noted. Starting at one end of the beach, a one meter square random digging was conducted, and repeated every 100 paces until the entire study area was sampled. From this data, specific study sites were selected.

Transect Line Establishment

An inmoveable object just above the study site was chosen and marked. The tidal height of the object was measured and recorded. The 5 foot tidal height was determined and marked with a stake. A transect line was then established by laying a 25 m. rope parallel to the water at the 5 foot tidal height marker. To establish the digging area, a 10 m. rope was laid perpindicular to the 25 m. rope, towards the water.

Random Sampling

The numbers 1-25 were placed into a hat. The hat was shaken and 10 numbers were chosen. The the same process was repeated but only with numbers 1-10. The chosen numbers were paired according to the order chosen and became the coordinates on the grid where sampling took place.

Sampling

The coordinates were found on the grid on the beach. A square meter was measured and drawn into the sand. The upper left hand cornor of the square was the intersection of the 2 chosen coordinates. The tidal height was then measured. The square was dug to 10 cm. in depth and sediments dug up were sifted through a 1/4 inch mesh screen. All indicator organisms present were recorded.

METHODOLOGY FOR SEDIMENTATION ANALYSIS

A 2.25cm. diameter core sampler was used to extract the sediment from an area free of surface rocks, to a 15cm. depth. The sampling site for sedimentation was visually chosen in the area immediately adjecent to the sampling grid site, randomly chosen. At times a complete 15cm. depth sample was not obtainable due to the many larger pebbles in the substrate. The sample was then deposited in a clean plastic sample jar and it's origin labeled. Three larger one pound coffee can samples were obtained from a site that was most similar to the surface characteristics evident within that transect area.

The samples were dried in an incubator set at 55° C, for a minimum of 36 hours, and all moisture had evaporated. Each sample was weighed,(see Appendix 2 Tables), and then sifted through a series of screens for 10 minutes on a Ro-Tap mechinical sifter. A weight was taken for each mesh size. The screens used were in close correspondence to the suggested sieve series recommended by the National Research Council, (see Table 1 below).

TABLE 8

SIEVE SERIES USED IN SEDIMENTATION ANALYSIS

U.S.STANDARD MESH NUMBER	OPENING IN MM.	SIZE CLASS NATIONAL RESEARCH COUNCIL
TRAY	0.00	Silt and Clay
230	0.063	Very fine sand
120	0.125	Fine sand
60	0.250	Medium sand
35	0.50	Coarse sand
18	0.991	Very coarse sand
10	1.981	Very fine gravel
5	4.0	Fine gravel
4	4.75	Fine gravel
3½*	5.6	Fine gravel
5/16*	8.0	Medium gravel
5/8*	16.0	Coarse gravel

* Used only in Large Sampling.

APPENDIX 2

SEDIMENTATION TABLES

TABLE 9

SQUAXIN ISLAND SEDIMENTATION ANALYSIS

LARGE SAMPLING

SITE	UNDER .063*	.063*	.125*	.250*	.500*	.991*	1.981*	4.0*	4.75*	5.6*	8.0*	16.0*	TOTAL	
TRANSECT A	4.66g	7.76g	54.46g	350.25g	186.64g	106.11g	139.2g	70.36g	101.6g	123.24g	198.81g	303.89g	1650.27g	-3.29
	0.28%	0.47%	3.31%	21.27%	11.33%	6.44%	8.45%	4.27%	6.17%	7.48%	12.07%	18.45%	99.9%	
TRANSECT B	17.63g	39.89g	143.12g	139.16g	236.3g	174.13g	215.01g	65.48g	60.02g	187.2g	323.11g	5.82g	1712.15g	-5.28
	1.03%	2.34%	8.38%	14.01%	13.84%	10.2%	12.6%	3.84%	3.52%	10.97%	18.93%	0.34%	100.0%	
TRANSECT C	14.38g	20.63g	124.42g	341.77g	165.86g	179.43g	206.76g	67.12g	54.61g	155.83g	323.79g	47.24g	1703.5g	-1.66
	0.9%	1.21%	7.31%	20.08%	9.75%	10.54%	12.15%	3.94%	3.21%	9.16%	19.03%	2.78%	99.97%	

*SIEVE SIZES IN MM

TABLE 10

SQUAXIN ISLAND SEDIMENTATION ANALYSIS

TRANSECT A

SITE	UNDER .063*	.063*	.125*	.250*	.500*	.991*	1.981*	4.0*	TOTAL
21-6	0.78g	0.79g	3.59g	9.25g	5.19g	9.25g	3.97g	5.94g	33.65g -.23
20-9	1.03g	1.0g	5.21g	11.51g	5.77g	4.66g	3.35g	4.65g	37.18g -.04
24-10	0.57g	0.94g	4.82g	10.83g	6.39g	6.04g	3.67g	2.02g	35.28g -.28
17-7	0.81g	1.29g	5.42g	8.06g	3.36g	3.38g	3.61g	3.17g	28.94g -.16
21-6	2.32%	2.35%	10.67%	27.49%	15.42%	12.3%	11.8%	17.65%	100.0%
20-9	2.77%	2.69%	14.01%	30.96%	15.52%	12.53%	9.01%	12.51%	100.0%
24-10	1.62%	2.66%	13.66%	30.7%	18.11%	17.12%	10.4%	5.73%	100.0%
17-7	2.78%	4.43%	18.62%	27.7%	11.55%	11.61%	12.41%	10.89%	100.0%

*SIEVE SIZES IN MM

TABLE 10

SQUAXIN ISLAND SEDIMENTATION ANALYSIS

TRANSECT B

SITE	UNDER .063*	.063*	.125*	.250*	.500*	.991*	1.981*	4.00*	TOTAL
18-2	1.8g	1.99g	3.32g	9.57g	9.14g	6.43g	7.2g	20.12g	59.57g -.05
12-9	1.47g	2.0g	3.2g	7.25g	8.14g	6.28g	6.21g	19.99g	54.41g -.13
4-4	1.44g	1.99g	4.15g	7.46g	6.3g	5.06g	8.29g	23.92g	58.47g -.14
11-5	1.51g	1.67g	2.54g	5.41g	5.24g	3.31g	6.41g	26.07g	52.43g -.27
18-2	3.02%	3.34%	5.57%	16.07%	15.34%	10.79%	12.09%	33.78%	100.0%
12-9	2.7%	3.67%	5.87%	13.29%	14.92%	11.51%	11.39%	36.65%	100.0%
4-4	2.46%	3.4%	7.08%	12.73%	10.75%	8.63%	14.14%	40.81%	100.0%
11-5	2.89%	3.2%	4.87%	10.37%	10.05%	6.35%	12.29%	49.98%	100.0%

* SIEVE SIZES IN MM

TABLE 10

SQUAXIN ISLAND SEDIMENTATION ANALYSIS

TRANSECT C

SITE	UNDER .063*	.063*	.125*	.250*	.500*	.991*	1.981*	4.0*	TOTAL
4-4	0.61g	0.65g	4.41g	18.0g	5.85g	3.28g	3.31g	5.17	41.05g -.23
16-10	0.73g	0.84g	4.68g	17.69g	4.41g	2.84g	3.88g	6.1g	40.87g -.3
22-5	0.71g	0.82g	4.91g	16.45g	5.51g	3.66g	4.04g	4.37g	40.47g -.33
20-4	0.57g	0.67g	5.15g	19.34g	5.99g	3.27g	2.75g	3.19g	40.93g -.23
4-4	1.48%	1.57%	10.68%	43.6%	14.17%	7.94%	8.03%	12.52%	99.9%
16-10	1.77%	2.04%	11.37%	42.97%	10.71%	6.9%	9.42%	14.81%	99.9%
22-5	1.75%	2.03%	12.13%	40.65%	13.62%	9.04%	9.98%	10.8%	100.0%
20-4	1.39%	1.64%	12.58%	47.25%	14.63%	7.99%	6.72%	7.79%	99.9%

* SIEVE SIZES IN MM

APPENDIX 3

MAPS

FIGURE 2

LOCATION OF SQUAXIN ISLAND IN PUGET SOUND

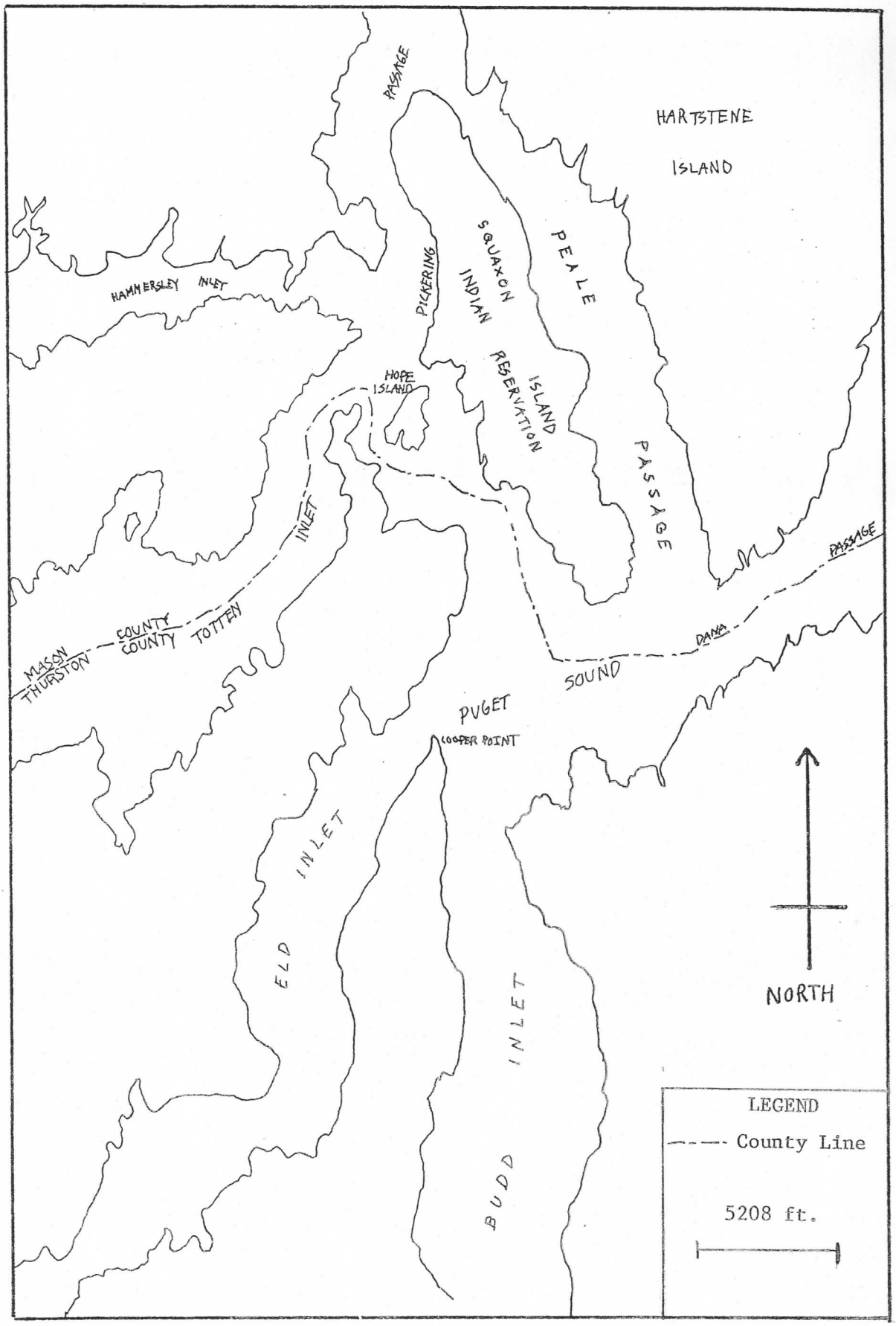

FIGURE 3

SQUAXIN ISLAND