Exxon Valdez Oil Spill
Restoration Project Final Report

Clam Restoration Project

Restoration Project 99131
Final Report

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Study History: This project was initiated under Restoration Project 95131, a five-year pilot project entitled Nanwalek/Port Graham/Tatitlek Subsistence Clam Restoration. It was developed at the request of the villages impacted by the *Exxon Valdez* oil spill. The project title was changed to Clam Restoration Project in 1996. The project initially included work with littleneck clams, razor clams and the basket cockle. It included seedstock development at the Qutekcak Shellfish Hatchery in Seward and at shellfish nurseries at Tatitlek and Chenega Bay, growout trials at the villages, and expanding the project to additional villages. Expanding the project to additional villages was dropped after FY96 to reduce costs and give the project better focus. Work with cockles and razor calms was dropped after FY97 for the same reason. The project did encompass the five-year time period as initially planned. Annual reports were produced for FY95, FY96, FY97 and FY98 and were used in the production of this report.

Abstract: Procedures for establishing safe, easily accessible subsistence clam populations near Native villages in the oil spill region, which would be relatively inexpensive to set up and maintain, were developed and tested on beaches near the Native villages of Nanwalek, Tatitlek and Port Graham. Beaches with different energy levels and substrates were included to determine the most suitable beach types. All growout testing was done with littleneck clam (*Protothaca staminea*) seed supplied by the Qutekcak Shellfish Hatchery, which developed the techniques for culturing this seed. Studies using a tidal floating upwelling system (FLUPSY) to nursery hatchery seed to a size suitable for planting in a growout area were conducted. Seed development work with the basket or Nuttall's cockle (*Clinocardium nuttallii*) was also initiated under this project, but was dropped to focus on littleneck clams. Razor clam (*Siliqua patula*) studies near the Native village of Eyak were dropped after two years of work. The growout work with littleneck clams demonstrates the potential for subsistence littleneck clam enhancement and identifies beach types that are most suitable.

Key Words: Basket cockles (*Clinocardium nuttallii*), clam restoration, *Exxon Valdez* oil spill, FLUPSY, littleneck clam (*Protothaca staminea*), Nanwalek, Port Graham, Qutekcak Shellfish Hatchery, razor clams (*Protothaca staminea*), seedstock development, shellfish nursery, subsistence, Tatitlek.

Project Data: *Description of data* – screened data for littleneck clam growth and survival in growout, razor clam beaches substrate analyses, razor clam length and age of collected specimens, nursery seed growth and survival data, littleneck clam growth and survival at various stages in the Qutekcak shellfish hatchery. *Format* – Littleneck clam growout growth and survival data is entered on Excel spreadsheets; razor clam data is presented in the razor clam reports in the appendix; nursery data is on hand written spreadsheets; hatchery data is in the Qutekcak hatchery logbooks. *Custodian* – Littleneck clam growout data: contact Diana Rhodes, CRRC, 4201 Tudor Centre Drive, Anchorage, AK 99508, phone (907) 562-6647, e-mail phone (907) 288-3667, e-mail jjh@seward.net; Hatchery data: contact Jon Agosti, Qutekcak Shellfish Hatchery, P.O. Box 369, Seward, AK 99664, phone (907) 224-5181, e-mail qshatch@arctic.net. *Availability* – Littleneck clam growout data is available on floppy disk; Nursery data: not all data is available, available data can be faxed; Hatchery data: hatchery logs can be viewed at the hatchery. Small amounts of data can be e-mailed or faxed.

Citation:

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Exxon Valdez Oil Spill Restoration Project # 99131, Clam Restoration Project
Final Report

Table of Contents

List of Tables *page*

List of Figures

Appendices

Executive Summary
Clams were once a major subsistence resource in most of the Native communities in the *Exxon Valdez* oil spill region. Clam populations near most of these villages have been decreasing in recent years and their contribution to the subsistence harvest has been greatly reduced. There are likely several reasons for this including changes in currents and beach patterns, increasingly heavy sea otter predation and the *Exxon Valdez* oil spill. The oil spill impacted the wild clam populations and their importance as a subsistence food in two ways. First, some clam beds suffered from direct oiling. Second, even though the oil did not directly impact many clams, they have a tendency to accumulate, concentrate and store the toxic contaminants from non-lethal amounts of oil. This has badly eroded the confidence of the villagers in the healthfulness of the remaining wild clam populations as a subsistence food.

The project was developed as a five-year study beginning in FY 95. Its goal was to demonstrate the feasibility of providing Native villages in the oil spill region with safe, reliable, and easily accessible sources of clams for subsistence use. The study initially included working with littleneck clams (*Protothaca staminea*), cockles (*Clinocardium nuttallii*) and razor clams (*Siliqua patula*). The Qutekcak Shellfish Hatchery in Seward, Alaska was given the task of developing the culture techniques and providing littleneck clam and cockle seed for the project, and a study was designed to test the feasibility of using a tidally driven floating upwelling nursery system (FLUPSY) as a relatively efficient and inexpensive method of growing hatchery seed (about 3 mm to 5 mm in size) to a size (> 9 mm) suitable for planting in a growout area. Growout study areas were located near the villages of Nanwalek, Port Graham, Tatitlek and Eyak. The following is a description of the various activities that took place under this project.

<u>Hatchery</u>: The Qutekcak Shellfish Hatchery, located on the Institute of Marine Science grounds in Seward, Alaska has been in operation since October 1993. From its startup through December 1997 the hatchery was located in a small pilot facility. In January 1998 all Qutekcak hatchery operations were moved into the hatchery portion of the State of Alaska's newly constructed Mariculture Technical Center/Hatchery Complex and the pilot facility was shut down.

The project objective for the hatchery was to develop the culture techniques for littleneck clams and cockles and produce the seed for nursery and growout activities. It was successful with littleneck clams, but not with cockles.

In the summer of 1994 a small batch of about 7,000 littleneck clams were produced in the hatchery. As far as is known this was the first successful production of this species in a hatchery. This success lead to littleneck clams being designated the primary clam species for use in this project. Hatchery certification of littleneck clam broodstock from Kachemak Bay and Prince William Sound for use in the project was completed in late spring 1995. Brood clams were then brought into the hatchery to produce seed for the project.

Littleneck clam seed production in the pilot hatchery was very erratic. This appeared to be the result of lack of space and poor water quality. From FY 96 through FY 97 only around 20,000 seed were produced. Good spawning success in late FY 97 and moving hatchery operations to the new state mariculture complex in January 1998 greatly improved seed production. Around 10 million seed were produced in the new hatchery in FY 98. Since this number greatly exceeded the needs of the project no additional project seed was produced.

Because of the problems the pilot facility was having with littleneck clam, the decision was made not to attempt to work with cockles. Instead Aquatic Environmental Sciences of Port Townsend, Washington was contracted to develop the hatchery protocols for culturing cockles. This would allow the project to

quickly get into cockle production once the hatchery moved into the new facility. Unfortunately, Aquatic Environmental Sciences was not successful in its attempts to spawn cockles. Because of the problems encountered it was decided to drop cockles from the project.

Tidal FLUPSY: A tidal floating upwelling system (tidal FLUPSY) was designed and constructed to test its potential as a remote nursery system for the EVOS clam project. Nursery systems are used to grow hatchery seed, which is about 3 mm in size, to > 9 mm, which is a suitable size for planting in a growout area. Remote nursery systems offer several advantages over nursery culture at the hatchery. One is that it frees up hatchery space and personnel that can be better used in hatchery production. Another is that several remote nursery systems offer a redundancy of supply in case one of the systems fails. A third is that remote nursery systems can be located near the growout areas thus reducing transport costs. The big disadvantage is the cost of pumping water at a remote location in Alaska.

A tidal FLUPSY is designed as a low maintenance non-mechanical method to nursery shellfish. The unit, when anchored, directs tidal and current flow into a flume that forces large quantities of water (and plankton) to flow through upwelling bins with enough pressure to fluidize the seed inside.

An aluminum tidal FLUPSY identical in size to the system described in Baldwin, et al. "Construction and Operation of a Tidal-Powered Upweller Nursery System" 1995, South Carolina Sea Grant, was built in 1996 and located at Tatitlek. A satisfactory test of growth and survival would be for the hatchery seed to attain an average length of > 9 mm in a single growing season. Survival would need to be better than 70%.

The FLUPSY was seeded with 50,000 oyster seed in late May 1997 because no clam seed was available. They were removed in mid September. During that 14-week period the oyster seed doubled in size and had an 83% survival rate.

Around 10,000 littleneck clam seed were placed in the FLUPSY in late October 1997 to test the feasibility of over-wintering clams in a FLUPSY. It was hoped that the FLUPSY would prove a viable alternative to over wintering seed at the hatchery. Unfortunately the seed loss was very high with only 15% surviving the winter. Seed being washed out of the FLUPSY during winter storms caused most of the loss.

In early April 1998 the FLUPSY was seeded with 45,000 littleneck clams. The clams ranged in length from 3 mm to 6 mm with a mean of 4.4 mm. The clam seed was sampled every other month during the growing season with the last sampling occurring on October 23, 1998 when 27,000 (60%) clams remained averaging 11.9 mm in length with a range of 7 mm to 18 mm.

The 60% survival rate was less than expected. About 45% of the loss occurred prior to the first sampling in June. It is possible that a large portion of this loss resulted from the seed being in poor condition upon arrival.

Clam growth in the FLUPSY was good with the average size nearly tripling. This suggests that hatchery clam seed can be reared in the FLUPSY to a good planting size in a single growing season.

Approximately 10,000 clams from the 1998 FLUPSY test were left in the FLUPSY to over-winter. The unit was moved to a more protected area to see if that would improve survival. The survival rate for was slightly better than 80%, which was very encouraging.

The FLUPSY was again tested in 1999 with 100,000 three to five millimeter littleneck clam seed being placed in the unit in early June. Growth through September averaged 8 mm with a range of 6 mm to 11 mm. The survival rate was 76%. A rough comparison of the two nursery tests indicate that the seed grew at about the same rate for both years. Extrapolating survival for 1999 indicates that the survival rate to 9 mm would have been about 73%.

Fifty thousand clams were held in the FLUPSY over the 1999-2000 winter. The survival rate through March 2000 was 66% with about 30% of this attributed to winter storm damage.

The study indicates that a properly managed tidal FLUPSY would work well as a remote nursery system, but it would be a poor over wintering devise for shellfish seed. The project demonstrated that clam seed does fine over winter in a concentrated mass, if protected from physical damage. An inexpensive solution for over wintering shellfish seed might be to suspend them in mesh containers from a pier or float.

Razor Clam Studies: A study was initiated in 1996 under this project to provide baseline information for future efforts to restore and enhance razor clam populations. The study took place on the tide flats near Eyak, which is next to Cordova. A literature search, discussions with the Department of Fish & Game and the University of Alaska and interviews with tribal members were conducted to determine the best approach.

Initially, it was believed that there was some number of sub-legal (too small for legal harvest) clams on nearby beaches that would grow to harvestable size if predation could be reduced. The study design involved covering test plots of razor clams with Carcover™, a plastic cloth with a 12 mm mesh size commonly used in clam culture. The growth and survival of these clams would be compared against adjacent plots of uncovered clams. Unfortunately, after several surveys of intertidal beaches near Eyak, very few razor clams of any size were discovered.

In 1997 the study design was changed from locating a population of sub-legal razor clams and applying predator control measures to capturing as many razor clams as possible, with an emphasis on sub-legal clams, and transporting them to a selected growout area to conduct growth and mortality studies and evaluate predator control measures. A total of 82 clams was collected in June and July of 1997. They were mostly three and four year olds (legal harvest size is achieved at around age seven). These clams were marked and buried at the study site at 6-inch intervals with anti predator Carcover™ netting placed over them.

The clams were last sampled in March 1998. Fourteen clams were recovered at that time. Average growth on the clams was around 10%. This was less than what was expected from the literature.

It became apparent during the during the beach surveys that there are very few razor clams, adult or sub-legal, in the Cordova area. This is an area that once had the largest razor clam population in the state. This study was predicated on the assumption that there were significant numbers of sub legal razor clams whose survival could be enhanced with predator control techniques. Since this turned out not to be the case it was decided to curtail further work with razor clams under this project.

Littleneck Clam Growout Studies: During the summer of 1995 a series of baseline surveys was conducted in the vicinity of Tatitlek, Port Graham and Nanwalek to select a cross-section of beaches that might be suitable for growout. One beach per village was designated as a project beach for this study. The Nanwalek beach is representative of high energy beaches, the Tatitlek beach is representative of moderate energy gravel beaches, and the Port Graham beach is representative of protected areas.

In 1996 baseline surveys of tidelands near the villages of Chenega Bay and Ouzinkie were conducted. The intent was to survey tidelands near two oil spill region villages each year of the project to develop a database for identifying beaches suitable for enhancement. This would enable the villages to quickly benefit from the results of the project. This effort was curtailed after 1996 due to lack of funding.

From June 29 through July 5, 1996 each of the project beaches was seeded with 8,100 littleneck clam seed per village beach. The seed averaged 12.8 mm in length. The seeding regimen involved placing 100 measured clams in each of nine Norplex ™ clam bags. Three bags each were nestled into the substrate to a minimum depth of 4 inches at the -1.5 MLLW tide level, the "zero" tide level (mean lower low water) and the +1.5 MLLW tide level. These clams were used for detailed growth and mortality studies. The remaining clams were divided into 12 sub-samples of about 600 clams each. Six of the sub-samples were seeded at the +1.5 MLLW tide level, three under netted Carcover™ and three uncovered. The remaining six sub-samples were seeded at the -1.5 MLLW tide level in a similar arrangement.

Around 2 million littleneck clams were planted on the project beaches during the course of the study - all of them under Carcover™ netting in the -1.5 to +1.5 tidal range. However, only the clams planted in 1996 were used in the growth and mortality study.

The initial sampling design called for quarterly sampling of each site. However, sampling during the winter quarter proved impractical, mostly because of weather and darkness, and the summer sampling, which seemed unnecessary, was curtailed to reduce costs. The Port Graham and Tatitlek beaches were sampled in the fall of 1996, the spring, summer and fall of 1997 and the spring and fall of 1998 and 1999. Accessing the high energy Nanwalek beach proved difficult and was only sampled in the spring and summer of 1997, the spring of 1998 and the fall of 1999.

The survival rate at the Port Graham beach for the 1,162 day study period – encompassing the time between the clams being planted and the last sample date – for clams in both the bags and under Carcover™ ranged from 42% at the +1.5 tide level to 51% at the –1.5 tide level. Survival for clams planted with no anti predator protection had a survival rate of less than 3%. During the same time period the bagged clams doubled in size while the clams under Carcover™ increased 2½ times in size, nearly attaining an average length of 38 mm, the minimum harvest size.

Survival and growth at the Tatitlek site was compromised to an unknown degree from recruitment into the study area of wild littleneck clam seedstock. This tended to increase the apparent survival rate and reduce the apparent growth rate. The survival rate for clams at the Tatitlek beach for the 1,168 day study period was estimated at 46% for clams under Carcover™ and in bags at all tide levels. The survival rate for unprotected clams was estimated at 20%. Clams seeded into the bags nearly doubled in size while clams under the Carcover™ did slightly better than doubling in size. Clams planted at the high energy Nanwalek site did not do well because of beach movement during storms.

This project indicates that a subsistence enhancement effort using littleneck clams is quite feasible. The cost, assuming free labor, would be lees than $0.85 for each pound of harvestable clams produced. Although the five to six year time frame between spawning the clams and harvesting them is long, it would not be an impediment as long as survival rates remain as high as they have been during this study. Protected intertidal areas appear to provide the best habitat although moderate energy beaches also do well if the substrate is stable. High-energy areas are not suitable for littleneck clam enhancement. Achieving a good survival rate requires that the seed be protected, either in bags or under Carcover™. Sea Otter predation was not observed during the study, but, if it occurs, it may make subsistence clam enhancement infeasible.

Introduction

Clams were once an important subsistence food in the Native villages in the oil spill region. Clam populations in areas that are reasonably accessible to the villages have decreased to very low levels in recent years. Consequently, the role of clams in the subsistence diet in these villages has been greatly reduced from historical levels.

There are probably a number of reasons why local clam populations are currently at low levels. Since clams are basically an unmanaged resource in the oil spill area, there are no quantifiable data available that could point to the actual circumstances that lead to the sharp reduction in these clam populations. However, there are events that likely played a major role. These include changes in beach configurations and currents resulting from the 1964 earthquake, increasingly heavy sea otter predation, human over-harvest and the *Exxon Valdez* oil spill.

The oil spill impacted the wild clam populations and their importance as a subsistence food in two ways. First, many clam beds suffered from direct oiling. The impact of the oil on the clam beds in Windy Bay, for instance, destroyed one of the more important clam beds in the lower Kenai Peninsula. With the current timber harvesting operations soon to provide road access from Port Graham and Nanwalek to the Windy Bay area, the loss of the clam resource there had a major impact on these villages. Second, even though many clams weren't killed from the oil, they have a tendency to accumulate and concentrate the toxic contaminants from non-lethal amounts of oil. This has badly eroded the confidence of the villagers in the healthfulness of the remaining wild clam populations as a subsistence food.

The Chugach Regional Resources Commission (CRRC) initiated this project in 1995 as a five-year study to demonstrate the technological and economic feasibility of providing Native villages in the oil spill region with reliable and easily accessible sources of clams for subsistence use. The project would be successful if it could determine what beach types are suitable for enhancement and describe inexpensive and easy to apply procedures for increasing the clam supply.

The study initially included working with razor clams (*Siliqua patula*), littleneck clams (*Protothaca staminea*) and cockles (*Clinocardium nuttallii*). Razor clams were chosen because they were a major subsistence species in the eastern Prince William Sound area where they were once found in great abundance. Littleneck clams were chosen because they are found throughout the oil spill region, are a popular subsistence shellfish species, and the Qutekcak Shellfish Hatchery in Seward had recently demonstrated the ability to produce littleneck clam seed. Cockles were chosen because surveys conducted in the villages showed that they were the most popular subsistence clam species.

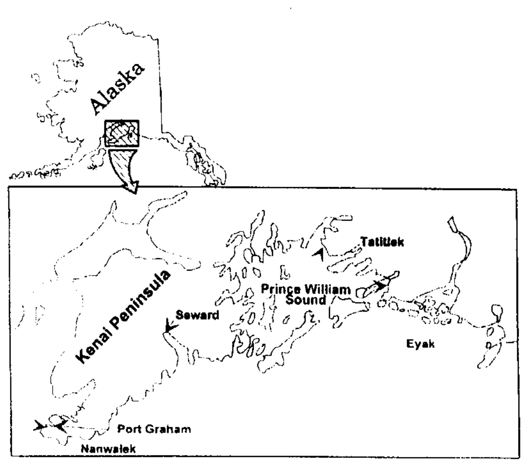


Figure 1. Map of project area

The razor clam work was designed to test the potential of enhancing the survival rate of wild seed with the use of standard predator control methods. A survey of the residents of Eyak village indicated there were significant numbers of sub-harvestable razor clams, but very few of harvestable size. No information on razor clam abundance in eastern Prince William Sound was available from either the Department of Fish & Game or the University of Alaska.

The initial study design involved covering test plots of razor clams with Carcover™, a plastic cloth with a 12 mm mesh size commonly used in clam culture. The growth and survival of these clams would be compared against adjacent plots of uncovered clams. Unfortunately, after several surveys of intertidal beaches near Eyak, very few razor clams of any size were discovered and the study was abandoned.

The following year the study design was changed from locating a population of sub-legal razor clams and applying predator control measures to capturing as many razor clams as possible, with an emphasis on sub-legal clams, and transporting them to a selected growout area to conduct growth and mortality studies and evaluate predator control measures. The study team was again unable to find sufficient numbers of clams. The clams that were found were placed in the study area, but the results were inconclusive.

The razor clam study was predicated on the assumption that there were significant numbers of sub legal razor clams whose survival could be enhanced with predator control techniques. Since this turned out not to be the case it was decided to cancel further razor clam work. Reports on the study are included in the appendix (appendices A & B).

The littleneck clam and cockle work involved applying shellfish hatchery and nursery techniques to provide seed for growout tests on selected intertidal beaches near the villages of Nanwalek and Port Graham, both located on the southwest Kenai Peninsula, and Tatitlek in northeastern Prince William Sound (see figure 1.). As part of the effort to identify growout areas near the villages a literature search was conducted through the University of Alaska to identify all previous research on littleneck clam and cockle life histories and population surveys. Time was spent with Alaska Department of Fish & Game (ADF&G) shellfish biologists from lower Cook Inlet and Prince William Sound to review and discuss clam surveys and management plans, and residents of the villages of Port Graham, Nanwalek and Tatitlek were interviewed to identify nearby areas that either now or once had significant populations of littleneck clams and/or cockles. Beach surveys were then conducted near each village.

One beach was selected from each project village in a combination that made them representative of the beach types commonly found in the oil spill region. The Port Graham site was a protected low energy beach. The Tatitlek site was a moderate energy cobble beach with good tidal flow, and the Nanwalek site was an exposed high-energy beach. In addition to identifying the project beaches a program was initiated to survey and map beaches near two villages each year of the project. This was in response to the large amount of interest in this project by villages in the oil spill region. The intent was to reduce the time between the completion of this project and getting enhancement projects established region wide by having the preliminary fieldwork out of the way. These surveys were canceled after the first year due to lack of funding.

The Qutekcak Shellfish Hatchery, operated by the Qutekcak Native Tribe and located on the Institute of Marine Science grounds in Seward, has been in operation since October 1993. From its startup through December 1997 the hatchery was located in a small pilot facility. In January 1998 all Qutekcak hatchery operations were moved into the hatchery portion of the State of Alaska's newly constructed Mariculture Technical Center/Hatchery Complex and the pilot facility was shut down.

The project objective for the hatchery was to develop the culture techniques for littleneck clams and cockles and produce the seed for nursery and growout activities. It was successful with littleneck clams, but not with cockles.

Littleneck clam seed production in the pilot hatchery was very erratic. This appeared to be the result of lack of space and poor water quality. From FY 96 through FY 97 only around 20,000 seed were produced. Good spawning success in late FY 97 and moving hatchery operations to the new state mariculture complex in January 1998 greatly improved seed production. Around 10 million seed were produced in the new hatchery in FY 98. Since this number greatly exceeded the needs of the project no additional project seed was produced.

Because of the problems the pilot facility was having with littleneck clams, the decision was made not to attempt to work with cockles. Instead Aquatic Environmental Sciences of Port Townsend, Washington was contracted to develop the hatchery protocols for culturing cockles. This would allow the project to quickly get into cockle production once the hatchery moved into the new facility. Unfortunately, Aquatic Environmental Sciences was not successful in its attempts to spawn cockles. It was then decided to drop cockles from the project. A report on the Aquatic Environmental Sciences work is provided in appendix C.

A seed nursery system is a step in the process of providing hatchery-produced seed for growout. It involves taking the three to five millimeter seed produced by the hatchery, placing them in an environment that offers protection from predators, and relying on naturally produced food to grow this seed to a size where it is better able to avoid predators – usually nine to twelve millimeters – before planting in a growout area. Nursery systems are preferred over using a hatchery for this step because it would be very expensive for a hatchery to both house large numbers of large sized seed and to produce the food needed to grow seed to a size suitable for planting. The floating upwelling system (FLUPSY) is the most common nursery system currently utilized in Alaska. A FLUPSY is essentially a floating collar supporting a series of mesh-bottomed bins containing shellfish seed through which seawater – and the accompanying plankton – is pumped in an upwelling fashion with enough force to cause the seed in the bins to become fluidized (suspended in the water). The FLUPSY has proven to be a very efficient nursery system. The only problems are the capital expense and the need for a power supply.

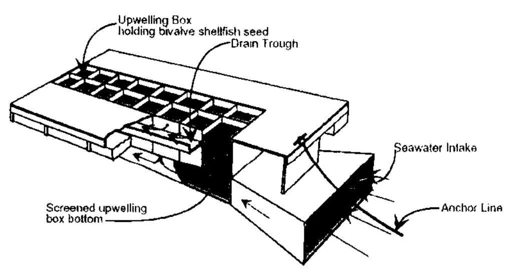


Figure 2. Tidal FLUPSY. Tidal current forces seawater entering the intake to move through the screened bottoms of the upwelling boxes, out the upwelling box drain holes and into the drain trough. The level of the drain trough is slightly above sea level. Not to Scale.

Recent work conducted under the South Carolina Sea Grant program lead to the development of a tidally driven FLUPSY (see Figure 2) that relies on tidal currents to pump seawater through the bins. This system has the advantages of being much cheaper to construct than a regular FLUPSY, plus it doesn't need a power supply. The disadvantages are that a tidal FLUPSY needs to be located in more exposed areas than a regular FLUPSY, plus it is difficult to control the flow of seawater through the unit.

From the perspective of developing an inexpensive clam rehabilitation/enhancement program, the apparent advantages of a tidal FLUPSY seemed to outweigh the disadvantages. A study was initiated to determine how well a tidal FLUPSY would work under Alaska conditions.

An aluminum tidal FLUPSY identical in size to the system described in Baldwin, et al. "Construction and Operation of a Tidal-Powered Upweller Nursery System" 1995, South Carolina Sea Grant, was built in 1996 and located at Tatitlek. The study was designed to test both the growth and survival of seed clams during the March through October growing season, and the potential for using the unit for storing seed clams over winter. A logistical problem currently facing the shellfish hatchery is the need to hold seed overwinter for distribution in the early spring. A solution would be to find inexpensive methods for over-wintering seed in the field.

A satisfactory test of growth and survival would be for the hatchery seed to attain an average length of > 9 mm – suitable for planting in a growout area - in a single growing season. Survival would need to be better than 70%. Growout tests were conducted in the tidal FLUPSY from 1997 through 1999. Oyster seed was used in 1997 because no clam seed was available. Littleneck clam seed was used in 1998 and 1999.

Seed was loaded into the FLUPSY bins at around 3 per square centimeter, which is the density used to load FLUPSYs with pumped water. Experience over the three seasons indicates that the desired growth can be achieved in a single growing season. The seed survival rate averaged 73% with a range of 60% to 83%. About half the loss in the batch with the 60% survival rate appears to be due to the seed being in poor condition upon arrival.

The survival rate for seed kept over winter at the hatchery is around 85%. Taking into account the savings that would be realized at the hatchery by over wintering seed elsewhere, it was felt that a minimum over winter survival rate of 75% in the tidal FLUPSY would justify its use as an over winter storage device. Over winter wintering tests were conducted in 1997 through 1999 using littleneck clam seed.

The FLUPSY proved itself to be very susceptible to winter storms; even when it was secured in a relatively protected area. In 1998, when winter storms were not a problem, the survival rate was 81%. Survival during 1997 and 1999 failed to meet the minimum level. In those years at least half the loss was attributable to storm damage.

It could be inferred from the 1998 survival rate that over wintering densely packed seed clams in protected, low energy areas is feasible, but a devise other than a tidal FLUPSY will need to be employed for this purpose.

The littleneck clam growout study on the selected beaches near the Nanwalek, Port Graham and Tatitlek villages was designed to determine growth and survival characteristics. It would answer the question on whether or not the survival rate between planting and the time the clams reach the minimum harvest size of 38 mm would be high enough to justify an enhancement effort. It would also determine if standard anti-predator techniques used in beach culture would significantly enhance clam growth and survival. A synopsis of the littleneck clam life history, clam culture techniques and the littleneck clam management in southcentral Alaska is provided in appendix D.

During the summer of 1995 baseline surveys were conducted at each of the selected beaches. In the early summer of 1996 each of these beaches was seeded with 8,100 littleneck clam seed. The seed averaged 12.8 mm in length. The seeding regimen involved placing 100 measured clams in each of nine Norplex™ clam bags. Three bags each were nestled into the substrate to a minimum depth of 4 inches at the -1.5 MLLW tide level, the "zero" tide level (mean lower low water) and the +1.5 MLLW tide level. These clams were used for detailed growth and mortality studies. The remaining clams were divided into 12 sub-samples of about 600 clams each. Six of the sub-samples were seeded at the +1.5 MLLW tide level, three under netted Carcover™ and three uncovered. The remaining six sub-samples were seeded at the -1.5 MLLW tide level in a similar arrangement.

Around 2 million littleneck clams were planted on the project beaches during the course of the study - all of them under Carcover™ netting in the -1.5 to +1.5 tidal range. However, only the clams planted in 1996 were used in the growth and mortality study.

The initial sampling design called for sampling each site each quarter. However, sampling during the winter quarter proved impractical, because of weather and darkness, and the summer sampling was curtailed to reduce costs. The Port Graham and Tatitlek beaches were sampled in the fall of 1996, the spring, summer and fall of 1997 and the spring and fall of 1998 and 1999. Accessing the high energy Nanwalek beach proved difficult and was only sampled in the spring and summer of 1997, the spring of 1998 and the fall of 1999.

The survival rate at the Port Graham beach for both bagged clams and those under Carcover™, for the 1,162 day study period, which extended from the time the clam seed was planted through the last sampling date, ranged from 42% at the +1.5 tide level to 51% at the –1.5 tide level. Survival for clams planted with no anti predator protection had a survival rate of less than 3%. During the same time period the bagged clams doubled in size while the clams under Carcover™ increased 2½ times in size, nearly attaining the 38 mm minimum harvest size.

The survival rate for clams at the Tatitlek beach for the 1,168-day study period was estimated at 70% for the bagged clams and 46% for clams under Carcover™ at all tide levels. The survival rate for unprotected clams was 20%. Clams seeded into the bags nearly doubled in size while clams under the Carcover™ did slightly better than doubling in size. Survival and growth at the Tatitlek site was compromised to an unknown degree from recruitment into the study area of wild littleneck clam seedstock. This would tend to increase the apparent survival rate and reduce the apparent growth rate.

Clams planted at the high energy Nanwalek site did not do well because of beach movement during storms. For the 1,161 day study period the clams in bags, which offered the best protection against beach movement, had about a 28% survival rate. Clams under Carcover™ had a 7% survival rate. None of the unprotected clams were recovered. The clams that managed to survive grew marginally well with a 70% increase in size.

This project has established that a subsistence clam enhancement effort using littleneck clams is feasible. A cost analysis indicates that a pound of harvestable clams from an enhancement program would cost less than $0.85 per pound, assuming free labor. Although the five to six year time frame between spawning the clams and harvesting them is long, it would not be an impediment to enhancement as long as survival rates remain as high as they have been during this study. Protected intertidal areas appear to provide the best habitat although moderate energy beaches also do well if the substrate is stable. High-energy areas are not suitable for littleneck clam enhancement. Affording the seeded clams protection, either in bags or under Carcover™ appears necessary to assure good survival rates. No sea otter predation was observed on the project beaches during the study period. Experience in the state's aquatic farming industry indicates that it takes sea otters take awhile to "discover" a protected food source. If this occurs with a clam enhancement project it may prove to be too expensive to enclose or cover the clams with a strong enough material to keep the sea otters out.

For the sake of continuity the Methods, Results and Discussion sections are presented for each study – hatchery, remote nursery and growout – conducted under this project. The Objectives section, which follows, covers the entire project, as does the Conclusions section.

Objectives

Objective 1. Develop hatchery culture techniques for the littleneck clam (*Protothaca staminea*). Produce a 3 mm to 5 mm seed in the hatchery within 19 week after spawning.

Objective 2. Develop an inexpensive, reliable and easy to operate remote nursery system that will produce 9+ mm seed from 3 mm to 5 mm hatchery seed within 20 weeks. Determine the potential for over wintering hatchery seed in the remote nursery system.

Objective 3. Describe the growth and survival of cultured clam seed on intertidal test sites near the villages of Port Graham, Nanwalek and Tatitlek. The test sites should be representative of intertidal areas commonly found within the oil spill region.

The objectives at the beginning of the project included working with the basket cockle (*Clinocardium nuttallii*) as well as the littleneck clam. The growth and survival objective also originally included testing predator control measures on wild razor clam (*Siliqua patula*) beds.

The basket cockle was dropped from the project because of the failure to develop successful hatchery culture techniques for the species. The razor clam predator control study was dropped because the study team was unable to collect enough razor clams to support the study.

Hatchery Culture of the Littleneck Clam

Methods

Methods for the hatchery culture of littleneck clam evolved over a two year period from FY 1995 through FY 1996. The process began with the implementation of standard bivalve culture techniques. These techniques were then altered through trial and error to adjust to the requirements of clams that have evolved in the colder Alaskan water temperatures and to accommodate specific differences in the hatchery environment. By FY 97 the temperature regimes, the diet and the feeding regimen had been worked out for littleneck clams at the different stages of development. When hatchery operations were moved to the new facility in January 1998 the additional space permitted the use of larger holding containers. This allowed a reduction in densities at the various development stages. Space and equipment in the new facility also allowed the hatchery staff to induce spawning outside the natural cycle. The following descriptions are a synopsis of the current procedures for the production of littleneck clam spat (juveniles) that were developed at the Qutekcak shellfish hatchery during the project period.

1. Broodstock Conditioning and Development

   Beginning in mid August up to six hundred brood clams are entered into the conditioning (ripening) process by being placed in water at 9^{o}-10^{o} C. Four successive groups of up to three hundred additional brood clams begin conditioning every three weeks. Spawning can then commence in October and continue through January, as needed. Broodstock are maintained in 1000 liter or 3000 liter indoor conditioning tanks receiving slow continuous ambient seawater flow for dilution and temperature control. The tanks are drained and cleaned every other day. During this period the brood clams are fed a diet of six species of microalgae rich in essential lipids and sterols such as eicosopentanoic, docosohexanoic, and arachidonic acids to impart maximum reserves to the eggs. The six species are *Pavlova (ccmp459), Tetraselmis striata,* Tahitian *Isochrysis sp.(tIso), Thalassiosira pseudonana (3H),* and *Chaetoceros calcitrans (Ccal),* and a cold water diatom *Thalassiosira gravida,* isolated from the seawater pond. Phytoflagellates are fed at a 2:1 ratio to diatoms at a continuous cell density of about 100,000 cells per ml. This protocol has repeatedly yielded well-ripened adults that mass spawn three to five million eggs per female.

2. Spawning and Larval Rearing

The spawning method used is an induced, controlled spawn of 100 to 200 clams using a 600 liter spawning tank, individual containers, and carefully controlled fertilization. This method, although more labor intensive than the commonly practiced uncontrolled mass spawning of 100 brood clams in a 30,000 liter rearing tank, avoids stimulating initially high levels of pathogens during the first 48 hours of development to the D-veliger stage by eliminating the build-up and decomposition of excess sperm. Early development can also be reliably observed with this method to gauge overall health and viability by observing and measuring the condition of gametes and by monitoring the normal development rate during the first few cell divisions.

Raising the water temperature about 1° C induces spawning. After fertilization the clam embryos are transferred to 30,000 liter larval rearing tanks filled with 1µ filtered and UV-irradiated seawater at 16° C for the next 48 hours. One-micron filtration has proven necessary to remove the fine glacial flour seasonally present in the water at the head of Resurrection Bay. Initial embryo density is kept under ten per milliliter (ml).

Supplementation of essential metals such as strontium, magnesium, and calcium may be used during periods of surface water downwelling in Resurrection Bay (induced by sustained, strong southerly winds) combined with high flow rates from a nearby stream. University of Alaska Institute of Marine Science (IMS) research revealed nutrient depletion down to the 70 meter intake depth during periods of downwelling and an analysis of hatchery seawater found a depleted selenium concentration. Sustained downwelling weather conditions appear to occur very infrequently.

On day two the larvae tanks are gently drained onto an immersed 38 micron screen and the new D-veligers are washed repeatedly, measured and counted, and returned to another filled larval rearing tank at a density of one per ml. Littleneck clam larvae at the Qutekcak hatchery have proven sensitive to standard rearing densities and handling. Because of this on each successive water change, which is every three days rather than the standard two days, the density is gradually lowered until a concentration of about 0.25 larva per ml is reached between day eleven and fourteen. On day eight the larvae tanks are drained on a 54 micron screen. A 68 micron screen is used on day 14, and a 75 micron screen on day 20. Pediveligers are removed with a 120 micron screen. The littleneck clam larval cycle has consistently required around 30 days at 16° C after which the 200 µ pediveligers are screened off and placed in a setting system.

The following data are collected each day for each larvae tank: temperatures, observations of larval health, activity and feeding, alga cell density and specific ratios (measurements are taken several times to monitor clearance and maintain food cell density), and total *Vibrio* bacterial levels by TCBS plating. Initially the clam larvae are fed a 3:1 phytoflagellate to diatom ration of 50,000 cells/ml of *Pavlova*, *tIso*, *Ccal*, and *3H*. Each of these species is small enough to be ingested by the D veliger. The ration is maintained at 80,000 cells/ml after day 14 by which time the phytoflagellate to diatom ratio has been gradually decreased to 1:1. *Tetraselmis striata*, another particularly nutritious but larger species, is also incorporated into the diet at day 14.

3. Larval Metamorphosis (Setting) and Spat Rearing

Clam pediveligers are placed into gentle down-welling setting systems at one million pediveligers per 4 ft^3 screened tray with three trays per a 600 liter partially recirculating tank. Temperatures, diet and ration remain the same as during larval rearing. Systems are drained and cleaned every other day. Temperature, larval health and feeding, and percent metamorphosed are monitored daily. The larvae complete the complicated metamorphic process on the surface of the tray screen and retain their larval foot and their ability to secrete byssal threads.

Pediveligers are called spat after metamorphosis. Once the spat have grown to about 1 mm and are firmly byssing (attaching) themselves to the screen surface, the water flow is reversed to an upwelling flow through the trays to better monitor flow rate and to better assure even feeding and oxygenation of the mat of spat on the screen surface. When the spat approaches 2 mm in size the upweller water temperature is dropped in steps to 12° C to prepare the expanding volumes of spat for transfer to outdoor upwelling systems plumbed to the one million liter seawater pond. The spat are transferred to this outdoor pre-nursery at 2 mm in size where much greater quantities of natural food can be grown to support their exponentially increasing appetites, and where they can acclimate to more natural conditions. Pond seawater is up-welled through the trays of spat at about 10 to 15 gpm and at higher flow rates as the spat grow to 3 to 5 mm seed. The spat may be placed on a sand substrate in the upwellers depending on the loading density. The sand substrate appears to be less of an advantage at higher loading densities. At this point they are ready for transfer to a field nursery for the next stage of growth.

4. Microalgae Culture

Both batch and semi-continuous culture methods of microalgae culture are used. All microalgae cultures originate from axenic flask cultures of the seven species we use: *Pavlova sp.(ccmp459)*, *Tetraselmis striata*, Tahitian *Isochrysis sp.(tIso)*, *Thalassiosira pseudonana (3H)*, and *Chaetoceros calcitrans(Ccal)*, and two cold water strains of the diatoms *Thalassiosira gravida* and *Skeletonema costatum* isolated from the seawater pond. Stock cultures are regularly restarted using sterile technique in a transfer cabinet. Sterility for every transfer is verified by testing for bacterial growth in tubes of Guillard's sterility test medium. Four day old flasks are used to inoculate larger batch cultures such as carboys or 200 liter tubes which in turn are used to inoculate the much larger tank batch cultures. The seawater for flask and carboy scale culture is one micron filtered, UV irradiated, and percolated through activated carbon for 40 minutes. Flasks are autoclaved and carboys are chlorinated overnight at 8 ppm then de-chlorinated prior to use. Microalgae are also cultured in more efficient semi-continuous 600 liter bag cultures. Seawater is pasteurized and fertilized before flowing into the bag cultures. All aeration of the above-mentioned cultures is sterilized and filtered at 0.2 microns. Guillard's L1 nutrient medium (an enhanced F/2) is used to fertilize all cultures. The solutions are prepared from dry compounds in distilled freshwater and kept refrigerated.

Seawater for large tank batch cultures receives the same treatment described above for hatchery microalgae culture. The only differences are that the activated carbon treatment is omitted and the air is not sterile filtered. These larger open cultures are fed only to larger spat and brood clams. They are plated on TCBS medium for pathogen levels at less regular intervals than the carboys and bags.

Great care is now taken in choosing which cultures to feed to larvae. The additional precautions are necessary to avoid as much as possible the feeding of a pathogenically bacterized alga culture to larvae. Our routine procedure requires that the culture has been TCBS plated one or two days earlier with no colonies present, that the alga cultures do not exhibit any clumping, degradation, or contamination with other organisms when examined under the microscope, and that it smells "good". Odor can regularly reveal a pathogenically bacterized culture that TCBS medium and visual examination miss.

Results

Littleneck clam seed production in the pilot hatchery was very erratic. This appeared to be the result of lack of space and poor water quality. From FY 96 through FY 97 only around 20,000 seed were produced. Good spawning success in late FY 97 and moving hatchery operations to the new state mariculture complex in January 1998 greatly improved seed production. Around 10 million seed were produced in the new hatchery in FY 98. Since this number greatly exceeded the needs of the project no additional project seed was produced.

Development times and survival for littleneck clam seed greatly improved during the course of the project, especially after the transfer to the new facility. At the end of the project it was taking 8 to 12 weeks to condition the clams for spawning, around 17 days for the spawn to reach the pediveliger stage, about three weeks to complete metamorphosis from pediveliger to spat, around 8 weeks for the spat to reach 2 mm in size and around 12 weeks for the 2 mm seed to reach the 3 mm to 5 mm size required for transfer to a nursery system. Total time from spawn to 3 mm to 5 mm seed averages 25 weeks.

Survival during littleneck clam seed development is measured at three points. The first point is after the spawn has reached the pediveliger stage. The second point is after the pediveligers have gone through metamorphosis to spat and grown to 2 mm seed. No accurate accounting of survival is taken between pediveliger and 2 mm seed because the animals are too delicate to handle during this time. The third point is when the 3 mm to 5 mm seed is shipped from the hatchery.

During the project the survival rate from spawn to pediveliger averaged around 70%. Survival from pediveliger to 2 mm seed averaged 38% and survival from 2 mm seed to 3 mm to 5 mm seed averaged 95%. Overall survival from spawn to 3 mm to 5 mm seed was around 25%.

Discussion

The littleneck clam hatchery objective for the project was to produce 3 mm to 5 mm seed within 19 weeks after spawning. This objective was not met. The 19 week timeframe was based on the amount of time it takes Manila clam seed to go from spawn to 3 mm to 5 mm seed in the Pacific Northwest. Littleneck clams are apparently slower to develop than Manila clams since the hatchery has subsequently not been able to make much improvement in development time from what it was at the end of this project.

Spawning littleneck clams in October produces 3 mm to 5 mm seed starting in early April. This seed can then go into a nursery system and attain the 9 mm minimum growout size and be ready for planting in mid to late summer. This eliminates the need to hold seed over winter for planting in the spring.

The 25% average survival rate from spawn through 3 mm to 5 mm seed for littleneck clams at Qutekcak falls on the low end of the normal range for Manila clams in the Pacific Northwest hatcheries. It is hard to gauge the significance of that or to determine if the survival rate is more an artifact of the species or the current hatchery techniques. In any case it is likely that the survival rate will increase as the hatchery gains more experience working with this species.

Tidal FLUPSY Nursery System

Methods

An aluminum tidal FLUPSY (Figure 2) identical in size to the system described in Baldwin, et al. "Construction and Operation of a Tidal-Powered Upweller Nursery System" 1995, South Carolina Sea Grant was constructed and set up near Tatitlek in July 1996. The unit had 12 bins with each one measuring 457 mm long by 457 mm wide by 610 mm deep.

In late August 1996 the unit was seeded with 50,000 oyster seed (no clam seed was available) with an average length of 15 mm. Length is determined by randomly collecting a 100 seed sub-sample and measuring each seed's longest point with monastat vernier calipers. Seeding density was 12,500 seed per bin or 3.4/cm^2 of bin bottom. The seed was checked every three weeks and stirred but not sorted. All surviving seed were removed from the FLUPSY in mid November after a storm damaged the unit.

The unit was reseeded with 50,000 oyster seed in late May 1997. Again, no clam seed was available. Average length of the seed was 7 mm. Loading density was the same as the 1996 seeding. The seed were treated in the same manner as the 1996 lot. All surviving seed were removed from the FLUPSY in mid September 1997 and their growth and mortality determined.

Littleneck clam seed became available for use in the FLUPSY in late September 1997. In October 1997 10,000 littleneck clam seed were loaded into a single bin of the FLUPSY. The intent was to determine the potential of a tidal FLUPSY as an over wintering device. The Loading density was 2.4/cm^2 and the average length was 4.8 mm. The seed was left undisturbed in the FLUPSY until March 1998.

In April 1998 the FLUPSY was seeded with 45,000 littleneck clam seed with an average length of 4.4 mm. Loading density was 3/cm^2. There was a problem with the transport. Due to weather the seed missed its originally scheduled flight to Tatitlek and two days elapsed before they were placed on another flight. This meant that the seed was out of the water for four days. The seed was sampled every other month until October 23, 1998.

Around 10,000 seed from the 1998 growing season test were left undisturbed in the FLUPSY to over-winter. The unit was moved to a more protected area to see if that would improve survival.

Although this location was more protected from the weather the normal current was not enough to fluidize the seed in the bins. The trial was ended on March 25, 1999.

In early June 1999 100,000 littleneck clam seed with an average length of 4.2 mm was loaded into the FLUPSY at a density of $3.4/cm^2$. The seed was sampled on August 20, 1999 and for a final time on October 1, 1999.

Results

The November 1996 storm that terminated the first FLUPSY nursery trial of the 50,000 oyster seed that was loaded into the unit in mid August also washed out a lot of the oysters. This negated the possibility of obtaining a reliable growth and mortality profile so all data from this trial was discarded.

The second seeding of the FLUPSY with oyster seed, initiated in May 1997, had good results. During the 14 weeks the seed were in the unit they doubled in size on average and had an 83% survival rate.

The first seeding of littleneck clams into the FLUPSY occurred in October 1997 as a test to determine the over wintering potential. The seed in this test experienced negligible growth over the winter and high losses with only 15% of the seed remaining when the test was terminated the following March. Periodic inspections of the unit during the winter indicated that most of the loss was caused by seed being washed out during winter storms.

The second littleneck clam seed trail in the FLUPSY, which ran from early April through October 1998, resulted in a 60% survival rate and a 125% increase in the average seed size. Figures 3 & 4 present this information graphically.

Figure 3: Valve length growth of littleneck clam seed placed in tidal FLUPSY in Tatitlek from April 3, to October 23, 1998

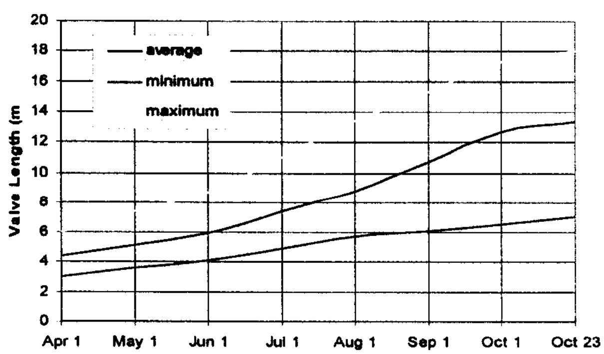
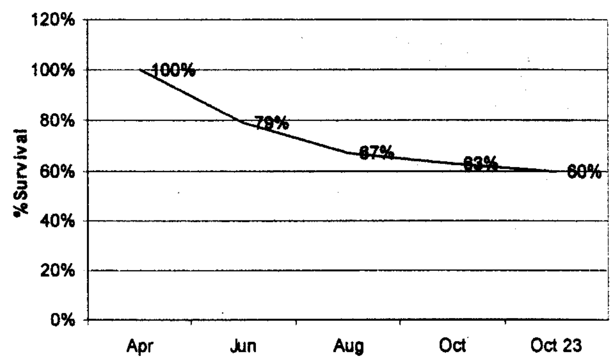


Figure 4: Percent survival of littleneck clam seed placed in tidal FLUPSY in Tatitlek from April 3, to October 23, 1998



The over wintering test of littleneck clam seed in the tidal FLUPSY that occurred during the winter of 1998/1999 resulted in negligible seed growth and an 80% survival rate. The winter was marked by an absence of serious storms.

The summer of 1999 nursery test of littleneck clam seed in the tidal FLUPSY resulted in a 76% survival rate and a 95% increase in the average seed size. This is graphically presented in Figures 5 and 6.

Figure 5: Growth of littleneck clam seed placed in tidal FLUPSY in Tatitlek from June 3, to October 1, 1999

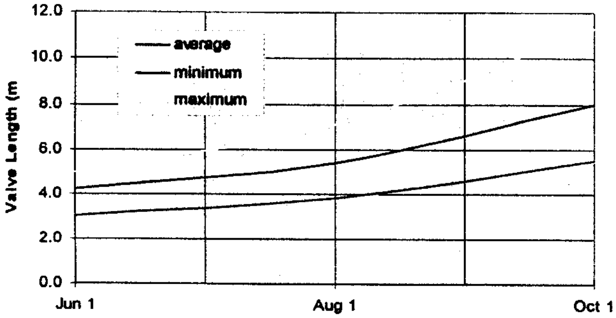
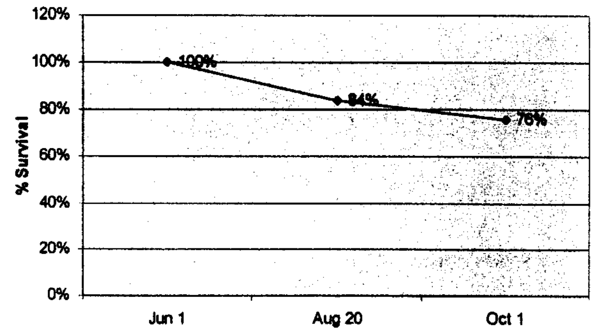


Figure 7: Percent survival of littleneck clam seed placed in tidal FLUPSY in Tatitlek from June 3, to October 1, 1999



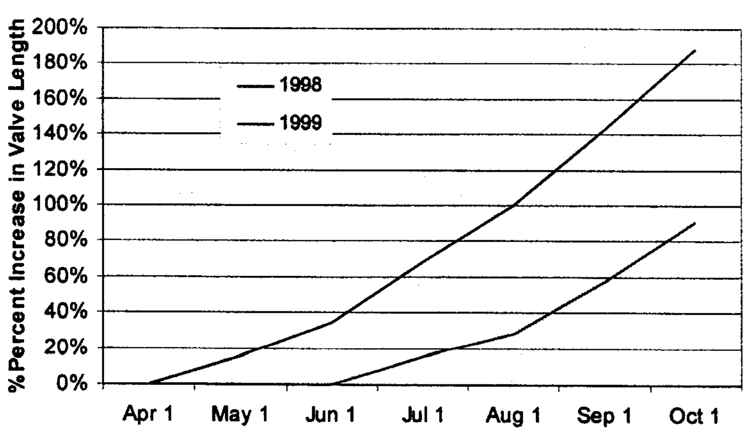
Discussion

This study established that a tidally driven FLUPSY can be an effective shellfish nursery system in Alaska. For a shellfish subsistence enhancement program it may be an essential piece of equipment. Although there is a substantial up-front cost to a tidal FLUPSY of between $4,000 to $9,000 thousand dollars, depending on the construction materials, it could pay for itself in as little as a single season through the cost difference – and availability - between three to five millimeter nursery seed and nine millimeter growout seed from the hatchery.

Unfortunately, littleneck clam seed did not become available for testing in the FLUPSY until August 1997. That left only two growing seasons for the clam seed nursery trials. That is not enough to establish a trend - especially when the two trails are not readily comparable. Nevertheless, the trials give some indications of how a tidal FLUPSY might function in a subsistence clam enhancement program.

The 1998 trial began on April 3 with 4.4 mm average sized seed and ran through October 23 when the remaining seed averaged 13.3 mm in length. The 1999 trial began on June 3 with 4.2 mm average sized seed and ran through October 1 when the average size of the remaining seed was 8.0 mm. To compare the two trials, the percent increases in growth for both trials were interpolated from the actual data points and plotted for the period April 1 to October 1. The results are presented in Figure (7).

Figure 7: Comparison of percent increases in average valve length of littleneck clam seed in a tidal FLUPSY near Tatitlek for the years 1998 and 1999.



Comparision of the monthly growth rates for both years shows them to be similar. For the first two months for both years the valve length increased at a compound rate of around 15%. This increased to a coumpound rate of around 22% for the remainder of the time the seed was in the FLUPSY.

Since the 1999 trial had only three actual data points this comparision is not very solid. However, it appears that the growth pattern for both years was somewhat similar and if the 1999 seed were placed in the FLUPSY in early spring, as they were in 1998, their average size would likely have exceeded the 9 mm minimum size for growout placement by late summer.

The project's minimum survival objective for the nursery of littleneck clams in the FLUPSY was 70%. It is apparent that the transport problem in 1998 caused an increase in seed mortality during their first two months in the FLUPSY. The mortality for April and May was about 21% compared to about 12% for the first two months in 1999. In 1998, the seed achieved an average size of 9 mm – the minimum size for growout placement - around August 10. At that time slightly more than 70% of the seed placed in the FLUPSY in April were still alive. By that measure the survival objective was met in 1998.

The nursery trail in 1999 lasted four months. Around 76% of the seed survived during that period, but only reached an average size of 8 mm. Extrapolating the growth beyond October 1, indicates that the seed would have achieved the 9 mm minimum growout placement size around mid October. Extrapolating the survival to mid October indicates that about 73% of the original seed placement would still be alive, which again would meet the minimum survival objective.

Experience in the state's mariculture industry indicates that the survival rate in a FLUPSY can be greatly increased if the seed is checked and stirred more frequently than was done on this project. FLUPSYs on aquatic farms are checked at least weekly. The survival rates commonly exceed 80%.

The seed over wintering trials have established that a tidal FLUPSY is not suited for this due to the adverse effects of winter storms on the unit. However, the 1998/1999 over winter test indicated that over wintering clam seed in an unfluidized state could be accomplished without suffering a major loss. The ability to over winter clam seed on site could be a great benefit to a clam enhancement program. It could be that placing the seed in a small mesh bag and suspending it in the water is all that would be needed to accomplish this. More work is needed to find an effective and inexpensive procedure for over wintering seed clams on site.

Based on the results of this project a good nursery program for a subsistence clam enhancement effort would involve placing 3 mm to 5 mm hatchery seed in a tidal FLUPSY no later than mid April. The unit would be checked weekly and the seed gently stirred to prevent suffocation. The seed would be kept in the FLUPSY until the average size was > 9 mm, which would likely occur in late summer. The seed would then be planted in the growout area.

Littleneck Clam Growout Studies

There are two segments to the growout studies. The first segment consisted of conducting the baseline surveys of the Nanwalek, Port Graham and Tatitlek growout test sites and on a beach site at both Chenega Bay and Ouzinke to determine clam enhancement potential. The second segment consisted of planting littleneck clam seed to determine growth and mortality characteristics. The Methods, Results and Discussion sections will be presented separately for each segment.

Baseline Surveys:

Methods

On each of the selected intertidal sites a series of test digs was undertaken to qualitatively evaluate substrate quality and existing or pre-existing shellfish resources by examining living clams and empty shells. The highest tide level at which clams were found was identified and the width of the area to be surveyed was determined and assessed for stratification by substrate type. This information formed the basis of a systematic random survey beginning at the highest elevation on the beach at which clams were found. This procedure was reversed at Passage Island because the crew arrived there at low tide. The number of transects and the number of samples per transect were determined based on the area of the beach, homogeneity of the substrate, and the time and human resources available for collecting samples during a single low tide.

The length and width of the productive area was measured using a 300' fiberglass tape. The length was divided by the number of transects plus one to obtain a transect interval. A random number between zero and the interval length was then selected and the first orthogonal transect placed at the random distance from the margin of the productive beach. Additional orthogonal transects were laid out at the specified intervals. Each transect was run at right angles (orthogonal) to the water line. The width of the beach was divided by the number of samples to be collected on each transect plus one to obtain a sample station interval. The first sample station was located at a random distance (between zero and the calculated sample interval) from the highest point on the beach at which clams were observed. Additional samples were taken at the specified interval. A single horizontal transect was also evaluated at Chenega, Ouzinke and Port Graham. These transects were evaluated at 0.0' MLLW where the orthogonal transects revealed the highest clam densities. For each sample station, red wire flags were labeled with the sample station designation and placed in the substrate at the appropriate point by the survey crew leader. These flags followed each sample until sieving and picking of clams was completed at an upland station.
Individual samples were collected with the aid of 3/32" thick aluminum plate quadrats that covered 0.1 m^2 (Figure 8). The quadrats were pushed down into the substrate during excavation. This prevented sloughing of the sides and provided a precise sample area. Each sample was dug to a depth at which no additional clams were obtained. The ¼" screen is removable allowing the fixture to be used for either sampling or sieving the contents. In the current studies, most sediments were sieved on a 1 mm stainless steel screen to evaluate recruitment.

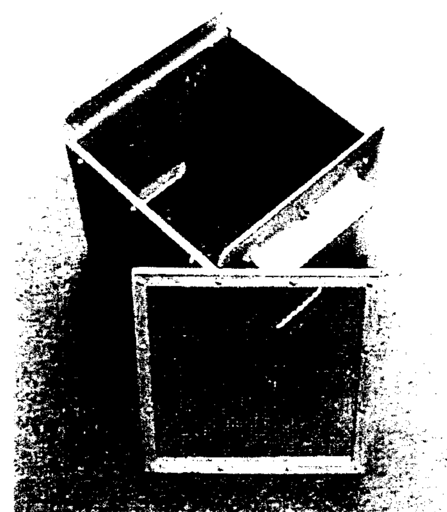


Figure 8. Aluminum sampling quadrat covering an area of 0.1 m^2 with a removable ¼" sieve

The beach slope was determined during each survey by placing a properly leveled Berger™ Model SAL-1 Automatic Level at the lowest point inundated at low tide. The elevation of each sample station was then determined relative to this reference point using an aluminum stadium. The height, above Mean Lower Low Water (MLLW), was calculated by assuming that the actual low tide equaled the predicted low tide. Small, but undetermined, errors in beach elevation might have been caused by differences between the actual and predicted low tide caused by winds and/or barometric pressure. In view of the benign weather experienced during these surveys, any errors were likely small.

A Write in the Rain™ label was placed in each sample bag with the substrate removed from the quadrat. The samples were then placed in boats for transport to a suitable upland sorting location. Sediment samples were sieved on 6.4 and 1.0 mm sieves and all clams and whole clamshells removed from each of these sieves and placed in pre-labeled, one gallon, ZIPLOCK™ bags. Where juvenile clams (< 6 mm valve length) were observed under a magnifying glass, the entire sample retained on the 1.0 mm sieve was retained for picking under a dissecting microscope. The free label placed in the bags during field sampling followed the sample into the ZIPLOCK™ bag. All samples were placed on blue ice in a cooler and shipped via overnight mail to the Aquatic Environmental Sciences laboratory in Port Townsend, Washington for processing.

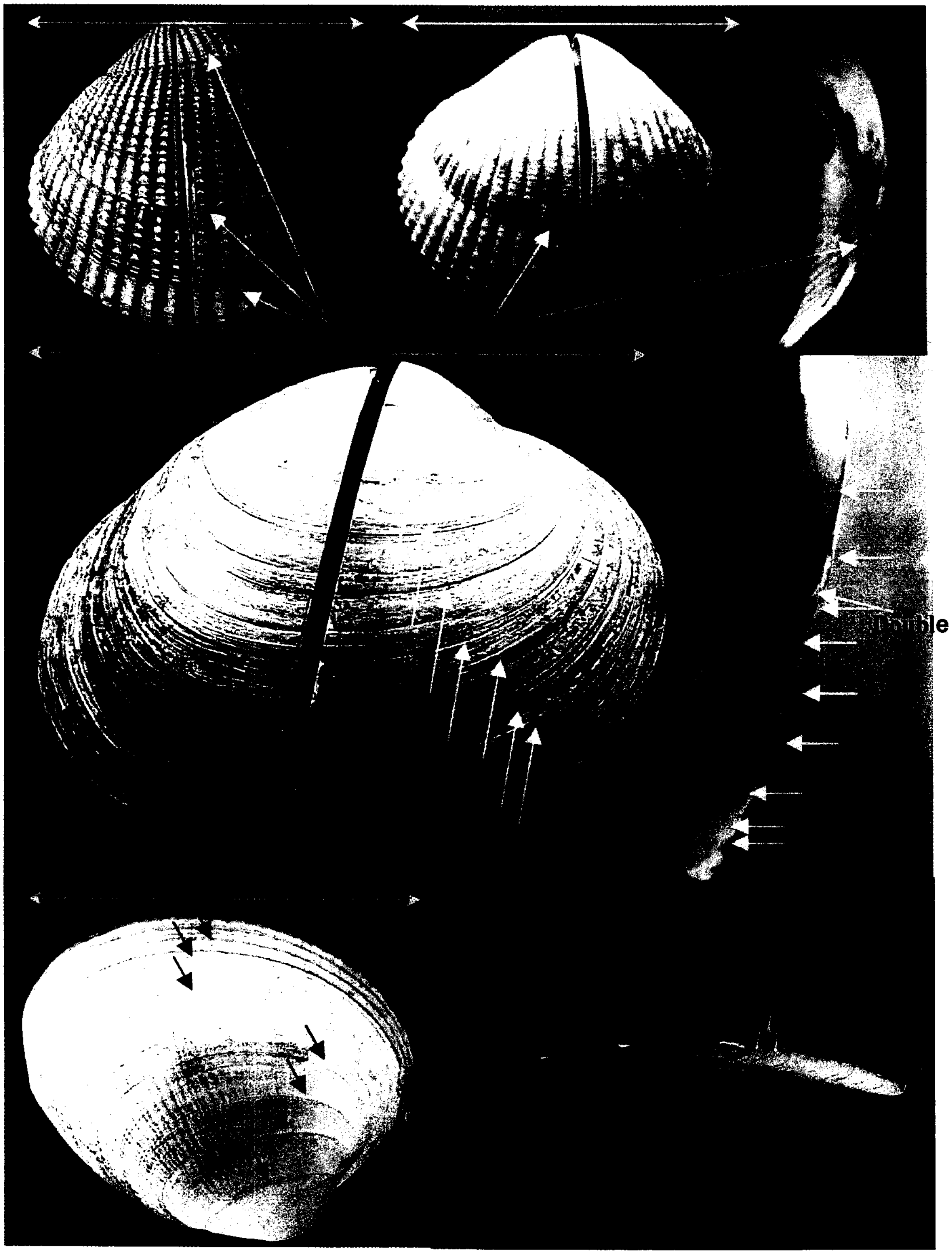
All clams in each sample were aged using the techniques described by Feder and Paul (1973) and Ham and Irving (1975), weighed, and their maximum valve length at each apparent annulus measured to the nearest 0.01 mm. Figure (9) provides photographs of the exterior shell surfaces and sections for a) basket cockle (*Clinocardium nuttallii*); b) butter clam (*Saxidomus giganteus*) and; c) littleneck clam (*Protothaca staminea*). Presumptive annuli are identified in each photograph. The presumed annuli or *checks* appeared as deep notches in the prismatic layer following a general thickening of the entire shell.

Note the apparent doubled or paired dark annuli in the sectioned butter clam valve. These closely spaced checks were also apparent at many presumptive annuli in the sectioned valves of native littleneck clams of known age in this study. They appear characteristic of some annuli produced in butter clams and native littleneck clams from Alaska. The dark lines demarking annuli in sectioned valves appear to be extensions of the inner nacreous shell layer, which is continuously laid down by the mantle on the interior of bivalves, through the prismatic layer to the exterior of the valve. In some sectioned specimens, the prismatic layer was worn away, exposing only the harder nacreous layer. In these cases, the first and perhaps second annuli were not apparent in sections.

Funding was not provided for the sectioning of valves in this study and therefore only a limited number of bivalves (27) were sectioned. The results were generally consistent with the findings of Trowbridge *et al.* (1996).

- A few individuals in all three species showed evidence of double checks at one or more presumptive annuli. In some instances, these checks became very complex and consisted of a series of closely spaced dark extensions of the underlying lamellar structure through the white prismatic shell layer. These were most apparent in cockles (Figure 5a).
- Cockles were the most difficult valves to read because of what were apparently false checks on the exterior of the valves. This will be discussed in Section 5 of this report.
- The first four or five annuli in native littleneck and butter clams were more closely associated with discontinuities in sectioned material and few false checks were apparent.

Figure 9. Typical valves of a) Nuttall's cockle (*Clinocardium nuttallii*), b) butter clams (*Saxidomus giganteus*) and c) native littleneck clams (*Protothaca staminea*).



- The valves of older native littleneck clams from Quzinke were badly eroded near the umboes. This made reading the first and second annulus very difficult because the exposed prismatic layer was nearly eroded away and it is in this layer that the annulus is observable in sectioned material. This is consistent with the findings of Trowbridge *et al.* (1996) who noted that the sectioning procedure tended to underestimate age when compared to counting presumptive annuli on the exterior of the valves.

- For purposes of this study, only data collected using the exterior valve checks was included in the database. Some specimens were discarded because their valves were either too worn for accurate interpretation or because the patterns were too difficult to interpret.

- Growth in valve length decreases with time in all of these species and the annuli laid down at older ages in butter and native littleneck clams were frequently too closely spaced to distinguish. Because of the difficulty in reading the older ages in most large butter clam valves, these were not included in the present database when computing regression coefficients for the von Bertalanffy equation.

It should be emphasized that bivalve aging techniques have not been verified in any of these species by comparing apparent annuli with clams of known ages from setting onward. In addition, the interpretation of annuli is equivocal and requires some training and skill on the part of the researcher – much as the reading of fish scales does. For those readers familiar with reading salmon scales, *crossovers* and *incomplete circuli* are characteristic of annuli in salmon scales. These same characteristics were observed at presumptive annuli in both butter and native littleneck clams from Alaska.

Wet tissue in clams with valve lengths greater than ca. 15 mm were shucked, blotted dry and weighed and then dried at 90° C and reweighed. A dry tissue condition factor equal to 1000*Dry tissue weight)/Length$^{2.1}$ was then determined.

Four to twelve sediment samples were taken from randomly chosen sample stations at each beach surveyed. The depth of the Reduction Oxidation Potential Discontinuity (RPD) was determined using a clear corer and centimeter rule. Approximately 250 grams of surficial sediment (upper 2 centimeters of the sediment column) were placed in centrifuge vials and stored on ice. Large cobble and gravel greater than 2 cm diameter was excluded from the samples, but noted on the data sheets. This was done because it was considered inappropriate to attempt to transport several hundred pounds of rock and cobble from remote beaches to the laboratory. In addition, bivalves are likely more influenced by the structure of sediment fractions finer than 2 cm particle size than they are by the larger components, excepting that large rock may provide a partial refuge from some predators.

Sediment grain size samples were stored at 4° C until they were analyzed. The sediments were dried in an oven at 92° C and processed using the dry sieve and pipette method (Tetratech, 1987). The sieves used for the sediment analysis had mesh openings of 2, 0.89, 0.25 and 0.063 mm. Particles passing the 0.063 mm sieve were analyzed by sinking rates in a column of water (pipette analysis). In addition, sediments were evaluated in the field for color, presence of attached macroalgae, presence of oil sheens and odors indicating hydrogen sulfide or petroleum.

A separate, 50 gram surficial sediment sample, consisting only of that fraction smaller than coarse sand was taken from the top two centimeters, placed in scintillation vials and stored on ice. These samples were dried at 103 $\pm$ 2° C in aluminum boats that had been pre-cleaned by ashing at 550° C for 30 minutes. Drying continued until no further weight reduction was observed. The samples were then combusted at 550° C until no further weight loss was recorded. Total Volatile Solids were calculated as the difference between the dried and combusted weights and expressed as a proportion of the dry weight.

Three 500 ml water samples were collected at each study site. The samples were collected at mid depth from undisturbed water with a minimum depth of one meter. Samples were placed on ice and shipped via overnight express to Aquatic Environmental Sciences' laboratory for the following analyses:

Total suspended solids (TSS) and total volatile solids (TVS). A 0.45 μm glass filter was combusted at 550°C and weighed. A 350 ml sample of thoroughly mixed water was suction filtered and the residue dried at 103 $\pm$ 2 °C to determine TSS. Total volatile solids were determined following combustion of the sample at 550 °C.

Dissolved oxygen was monitored *in-situ* with a YSI Model 57 Oxygen Meter. The probe had a new membrane and was calibrated with water-saturated air immediately prior to each measurement.

Salinity and temperature were monitored, *in-situ*, with a YSI Model 33 SCT meter that was calibrated at 0.0 and 29.6 ppt the day prior to sampling.

pH was determined using a dual point calibrated (pH 7 and 10) JENCO mP-Vision 6009 meter. The pH meter was calibrated in the field just prior to each set of measurements.

Current speeds were measured by placing a drogue in the water and timing its transit along a two-meter stick. Three replicate measurements were made in succession midway between high and low tides and again at slack tide. The surveys were conducted during spring tides and it is postulated that the observed speeds measured midway between high and low tides are representative of the near maximum surface currents at each site. These point estimates do not provide a definitive understanding of local currents, but they do provide a sense of the minimum and maximum current speeds characteristic along each beach.

Data was entered onto an Excel™ spreadsheet and imported into a STATISTICA™ database. All discrete data was log transformed. Proportional data was transformed using the arcsine-square root transformation (Zar, 1984). An alpha (probability of making a Type I error) of 0.05 was used in all statistical testing and 95% confidence limits are reported where appropriate. Non-linear regression analysis was used to define regression coefficients for the von Bertalanffy growth model. This model was chosen because of its historical use in shellfish population studies and because it is easily interpreted. The Gompertz equation (Boltz and Burns 1996; Pennington 1979) is simply an exponential fit to natural log transformed length data. It has seen use in modeling fish growth as a function of age based on annuli interpreted from otoliths (Boltz and Burns, 1996).

The Gompertz equation might also be appropriate where heteroscedasticity or non-normally distributed residuals require a logarithmic transformation. Regression techniques are fairly robust to deviations from the underlying assumptions (including requirements for homoscedasticity and normality of residuals). However, based on comments received regarding

Brooks (1995b), the residuals in each analysis were examined for homoscedasticity and tested for normality using both the Kolmogorov-Smirnov and Chi-squared goodness of fit tests (Neter *et al.*, 1985). Residuals were not significantly different from a normal distribution in every case at $\alpha = 0.05$ and the von Bertalanffy model was used throughout this analysis.

Results

Baseline survey on the selected study beaches:

Tatitlek: The beach surveyed on August 27, 1995 during a predicted –0.9' MLLW tide. It was located immediately adjacent to the village at 60^{0} 51.82' N by 146^{0} 41.15' W. The surveyed area of beach measured 100 feet wide by 350 feet long. It was bounded on the north by sand and mud substrates covered with a healthy eelgrass (*Zoostera cf. japonica*) bed. Boulders and rock outcroppings to the south hardened the substrate. The area in between contained substrate suitable for native littleneck clams.

Figure (10) is a photograph of the sampled beach. A schematic diagram of the sampling design is provided in Figure (11). All of transect (A) and the lower portions of transect (B) were located in the sandy, eelgrass dominated strata, and six transects (C, D, E, F, G and H) were established on the gravel – cobble beach. Four sample stations were evaluated at 22 to 24' intervals on each of the seven orthogonal transects (A through F and H). Transect G was run parallel to the beach at a tidal elevation of +0.5' (MLLW) with an interval of 60'. Thirty-five shellfish samples were collected on seven transects at Tatitlek.

Figure 10. Traditional bivalve subsistence beach near the village of Tatitlek in South Central Alaska. The black garbage bags contain samples awaiting transport to an upland processing station.

The beach considered suitable for native littleneck clam production has a shallow slope (3.6%) and well-oxygenated substrates to a depth of at least 10 cm. Ten sediment samples were evaluated for sediment grain size and total volatile solids. Excluding large rock and cobble, Tatitlek clam beach sediments were 65.7% gravel, 25.87% sand and 8.33% fines (silt and clay). Tatitlek clam beach sediments contained an average of 1.31 $\pm$ 0.65 percent volatile solids. As might be expected, Total Volatile Solids were moderately well correlated (Pearson Correlation Coefficient = 0.39, P = 0.000) with the proportion fines observed in the sediment. Conditions in the sandy eelgrass meadow were quite different. The Reduction-Oxidation Potential Discontinuity was located at depths as shallow as 4 cm. This was accompanied by a slight hydrogen sulfide smell. Sediments were composed of 8.7 percent gravel, 53.6 % sand and 37.7 % fines (silt and clay). Total Volatile Solids were slightly higher in sediments under the eelgrass beds at 1.7 $\pm$ 0.11 percent. The presence of hydrogen sulfide can be attributed to reduced pore water circulation in the fine-grained sediments.

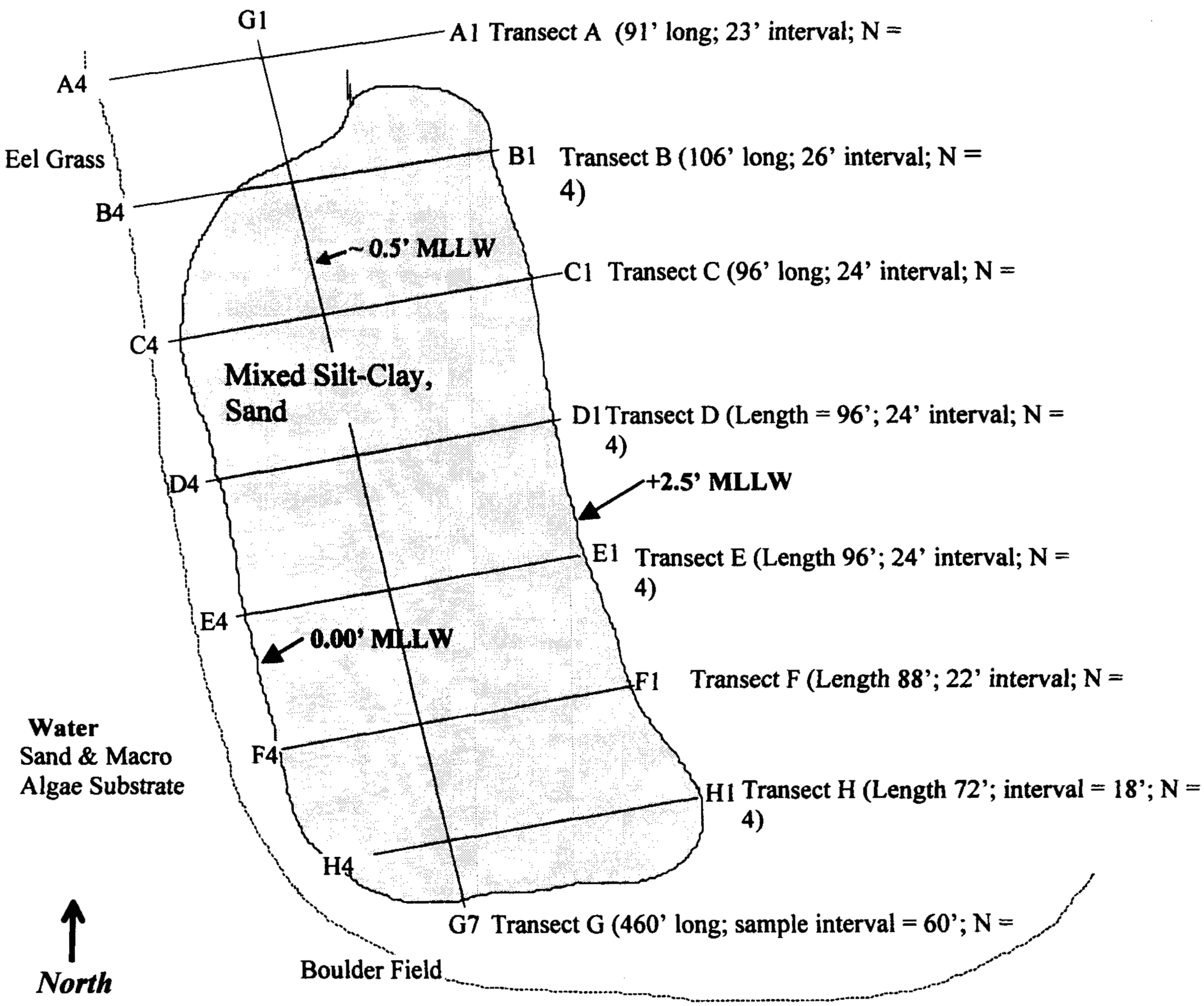


Figure 11. Schematic diagram of the Tatitlek Village shellfish beach, which was surveyed in August 1995.

Water Conditions at Tatitlek were acceptable for native littleneck clam culture. Water temperature was 12.0 °C, salinity equaled 26.0 ppt and dissolved oxygen was 12.5 ppm, which was slightly supersaturated. Currents at slack tide were measured parallel to the beach (085°

Magnetic) at 9.4 cm/sec. However, Village sources stated that currents are generally strong at this location and can exceed six knots (304 $cm\text{-}sec^{-1}$) during strong tidal exchanges. The three water samples collected at this beach averaged 3.27 mg TSS/L and 2.3 mg TVS/L. These values suggest moderate primary productivity and few suspended inorganic particulates.

A total of 660 living bivalves were collected in samples at Tatitlek. The distribution of these is provided in Table (5).

Table 1. Summary of bivalves collected in 35, 0.1 m^2 samples at the Tatitlek Village beach on August 27, 1995.

Species	Number
Protothaca staminea (native littleneck clam)	480
Saxidomus giganteus (butter clam)	97
Macoma inquinata (indented macoma)	72
Macoma nasuta (bentnose macoma)	4
Hiatella arctica (Arctic hiatella)	4
Mya truncata (truncate softshell)	1
Tresus cf. capax (fat gaper)	1
Clinocardium nuttallii (Nuttall's cockle)	1
Unidentified	1

Gaper, butter and native littleneck clams and cockles have potential as subsistence shellfish resources. Local villagers stated a preference for butter clams, native littleneck clams and cockles. Of these, only the butter and native littleneck clams were found in reasonable abundance.

Ninety-seven (97) living butter clams were retrieved from these samples. Their length-frequency distribution is provided in Figure (12). Most clams were small and less than two years old. Only three legal size (>38 mm valve length) butter clams were observed in all 35 samples. Descriptive statistics are provided in Table (2).

Non-linear regression was accomplished on aged living and empty butter clam valves to determine von Bertalanffy model coefficients. The resulting equation explained 92.89% of the variation and the ANOVA determined probability that the regression coefficients were all equal to zero was P = 0.000. The residuals were normally distributed. However, some caution is in order because no clam valves exceeding 79 mm were included in the database. Therefore, the maximum size of 126 mm is not well determined.

$$\text{Length of butter clams (mm)} = 126.5(1 - \exp^{-0.075 \times \text{age in years}})$$

Table 2. Summary descriptive statistics for living and dead butter clams sampled at the Tatitlek Village beach on August 27, 1995. Length and age statistics include 103 empty butter clam valves, which were measured and aged. Other statistics do not.

	Valid N	Mean	Minimum	Maximum	Std. Dev.
Length (mm)	200	34.32	2.00	79.00	23.45
Whole weight (g)	97	2.43	0.0012	47.88	6.88
Age	200	4.52	0.01	12.00	3.47
Dry Condition Factor	45	0.20	0.007	0.94	0.16

Because of their propensity to retain paralytic shellfish poisons and lack of adequate hatchery technology, butter clams are not considered appropriate for enhancement at this time. However, the Washington State Department of Fish and Wildlife shellfish laboratory at Point Whitney has spawned and raised butter clams in their hatchery (Mr. Brady Blake, personal communication). Several year classes (Ricker, 1975) are evident in the length frequency histogram provided in Figure (12), which also demonstrates a lack of legal size butter clams on this beach. Figure (13) suggests that butter clams recruit regularly to this beach, but that they typically do not survive beyond five years of age or to lengths greater than 38 mm. Predator control will be an important element in any effort to enhance shellfish resources on this beach.

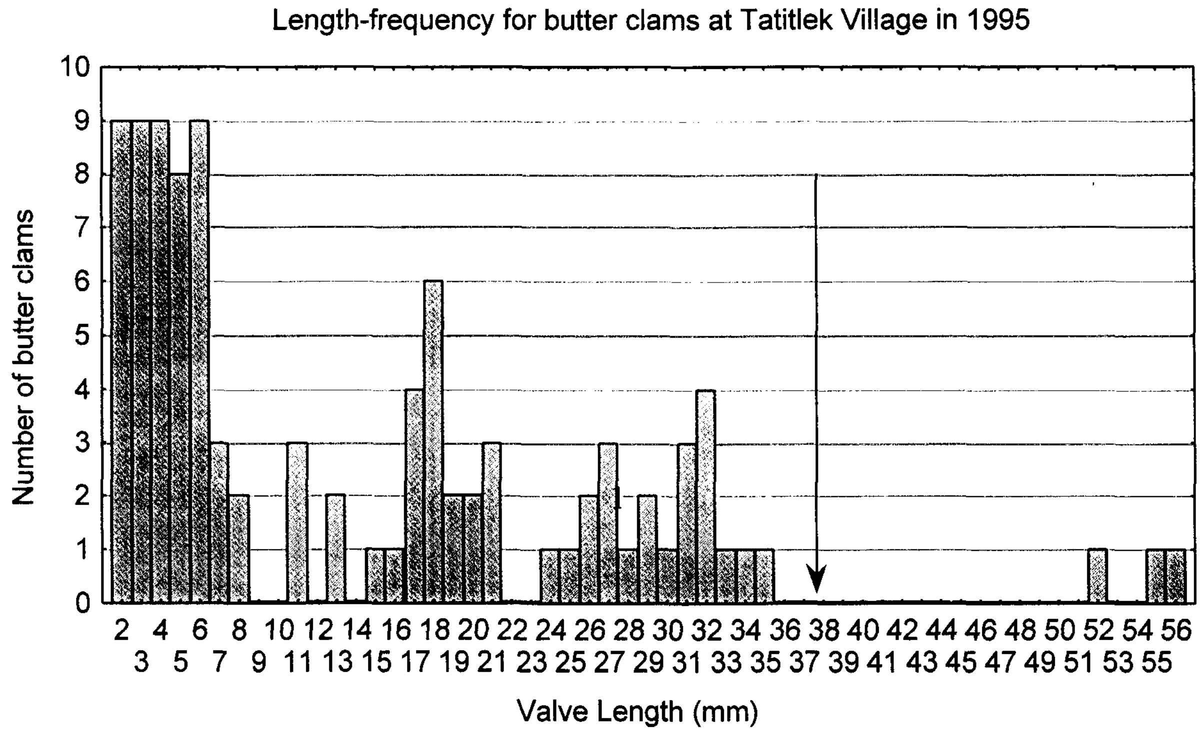


Figure 12. Length frequency histogram for butter clams (*Saxidomus giganteus*) collected in 35, 0.1 m^2 samples at the Tatitlek Village shellfish beach on August 27, 1995. The vertical line describes the minimum legal size (38 mm).

Figure (14) is a photograph taken at low tide on the Tatitlek beach. Large numbers of sunstars (*Pycnopodia helianthoides*) were observed at and below +0.5' MLLW and frilled dogwinkles (*Nucella lamellose*) were observed at tidal elevations greater than ca. +2.0' MLLW. Figure (15) is a photograph of a few of the hundreds of small clams observed on this beach that had been drilled by gastropods. In addition to these predators, numerous shore crabs were observed and sea otters were encountered offshore. Large clams were not found on this beach. However, broken butter clam shells provided equivocal evidence of historical sea otter predation.

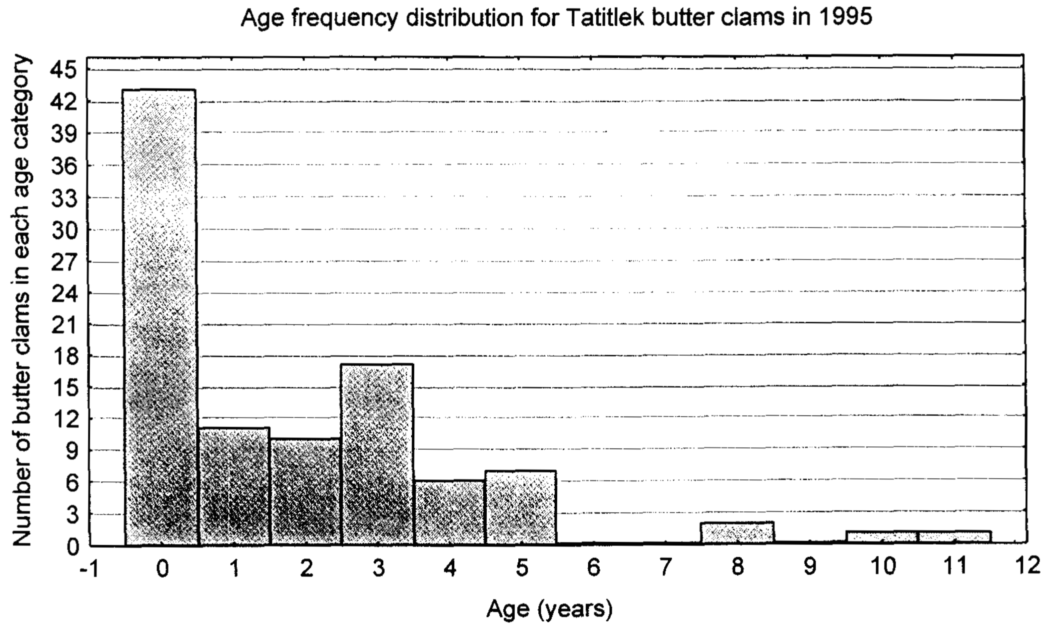


Figure 13. Age-frequency histogram for butter clams (*Saxidomus giganteus*) collected in 35, 0.1 m^2 samples at the Tatitlek Village shellfish beach on August 27, 1995.

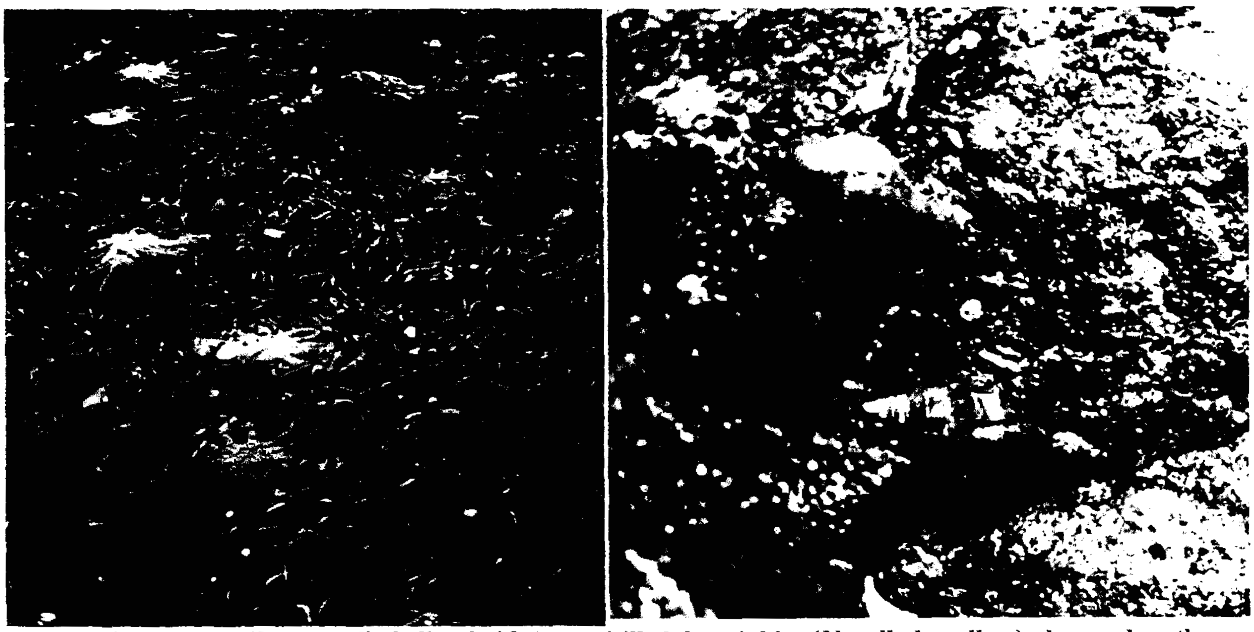


Figure 14. Sunstars (*Pycnopodia helianthoides*) and frilled dogwinkles (*Nucella lamellose*) observed on the subsistence beach adjacent to the native village of Tatitlek in Alaska.

Figure 15. Juvenile butter clams (*Saxidomus giganteus*) collected in sediment samples from the subsistence beach adjacent to the native village of Tatitlek in Alaska.

Four Hundred-eighty (480) native littleneck clams were sieved from 35 Tatitlek sediment samples. Summary statistics describing littleneck clams are presented in Table (3). The largest native littleneck clam had a valve length of 45 mm and weighed 19.34 grams. Seventeen (17) legal size clams (valve length $\geq$ 38 mm) were observed in all 35 samples. This equates to a density of approximately 73.9 g-m^{-2} or 0.016 pounds per square foot. This is approximately one tenth the minimum density considered economical for commercial clam harvests in Washington State (Paul Taylor, personal communication). The conclusion is that there is currently little opportunity for subsistence harvest of butter or native littleneck clams at this Tatitlek village beach.

Comparison of Figures (16) and (17) clearly shows the correspondence between the length and age of at least the first four year classes. Furthermore, these figures suggest that predation, from a variety of sources is taking most clams before they reach 38 mm valve length. No missing year classes are apparent in Figures (16) or (17) suggesting constant recruitment of native littleneck clams to this beach. It appears that shellfish production at this site is limited primarily by predation, disease or loss of clams associated with substrate movement. Based on the history of Manila clams in Puget Sound, a minimum juvenile density of 20 to 30 per 0.1 m^2 is desired for reasonable production. Current native littleneck clam recruitment is approximately four per 0.1

m^2 and survival is unacceptable. The previous discussion regarding predation on butter clams is appropriate for native littleneck clams as well.

Table 3. Summary descriptive statistics for living native littleneck clams sampled in 35, 0.1 m^2 quadrats at the Tatitlek Village beach on August 27, 1995.

	Valid N	Means	Minimums	Maximums	Std. Dev.
Elevation (feet above MLLW)	476	0.84	-1.10	3.12	0.83
Valve length (mm)	579	17.17	1.80	45.00	11.20
Whole weight (gm)	472	2.02	0.001	19.35	3.45
Dry tissue weight (gm)	264	0.69	0.09	3.02	0.69
Wet tissue weight (gm)	264	1.69	0.10	8.11	1.60
Age (years)	576	1.95	0.00	8.00	1.73
Dry Condition Factor	263	0.18	0.02	0.65	0.12

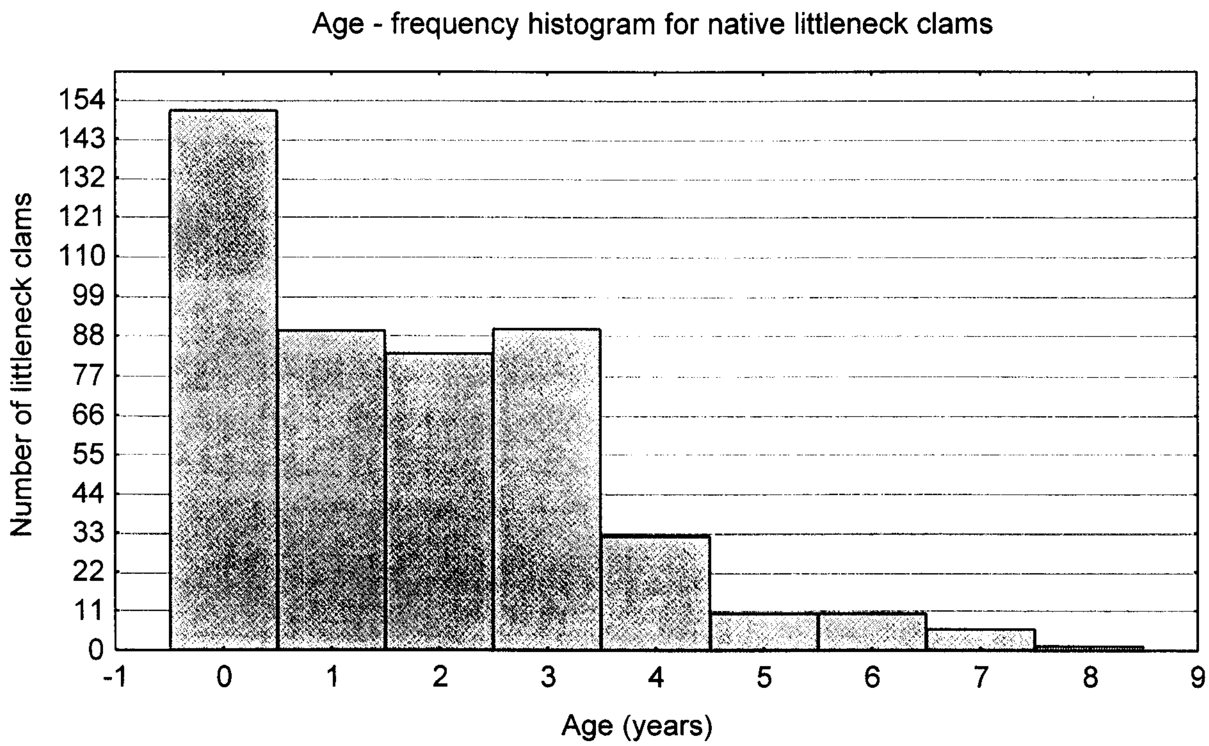


Figure 16. Age – frequency histogram for littleneck clams collected in 35, 0.1 m^2 quadrats at the Tatitlek Village on August 27, 1995.

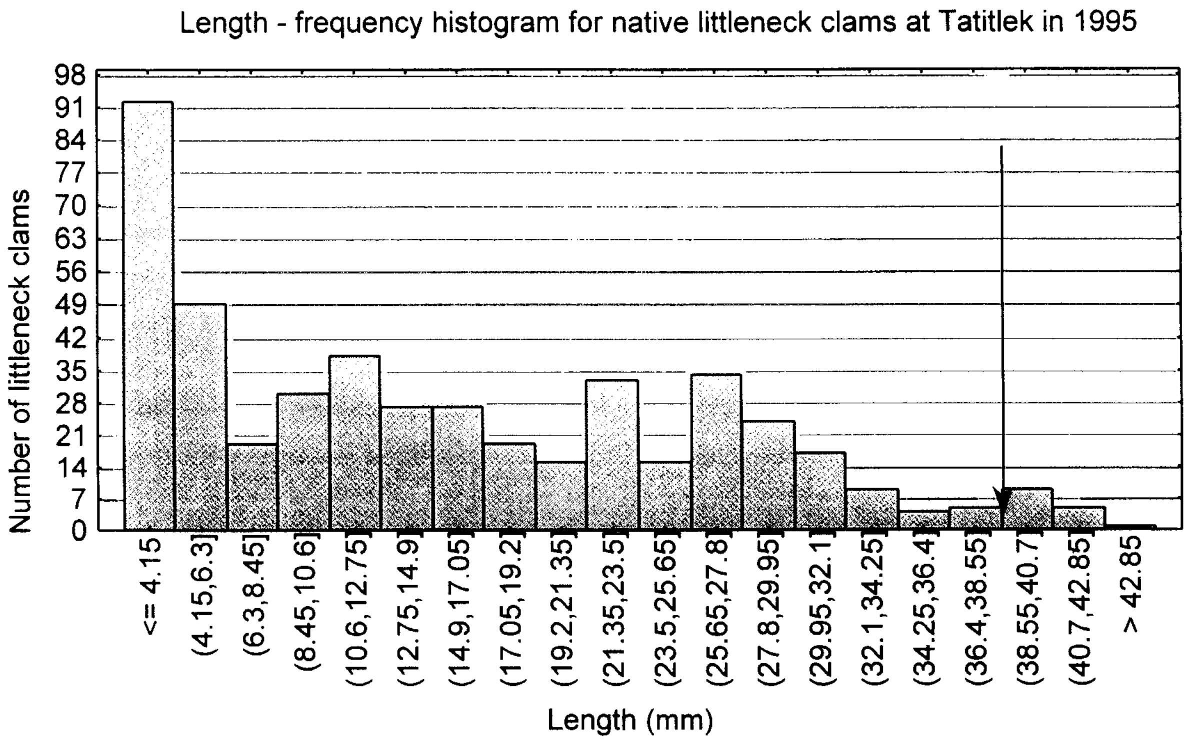


Figure 17. Length – frequency histogram for littleneck clams collected in 35, 0.1 m^2 quadrats at the Tatitlek Village on August 27, 1995. The thin vertical line represents the minimum legal size of 38 mm.

Figures (18) and (19) compare the distribution of butter and native littleneck clams as a function of tidal height at Tatitlek. These figures are interesting in that they indicate an optimum tidal range of approximately 0.0' to +2.0' MLLW for native littleneck clams and an optimum of 0.0' to 1.0' MLLW for butter clams. It should be noted that the substrate changes to primarily sand at tidal elevations less than –1.5' at this beach. This substrate change and the presence of large numbers of starfish at lower intertidal elevations are factors that may be responsible for limiting the clam population in deeper water. Also note that both butter clams and native littleneck clams were found at tidal elevations as high as +3.0' MLLW. The data for native littleneck clams at Tatitlek suggests that the area between –1.0' and +2.5' is suitable for native littleneck clam production on this beach. This is essentially the same range described by Nickerson (1977) and Feder and Paul (1973).

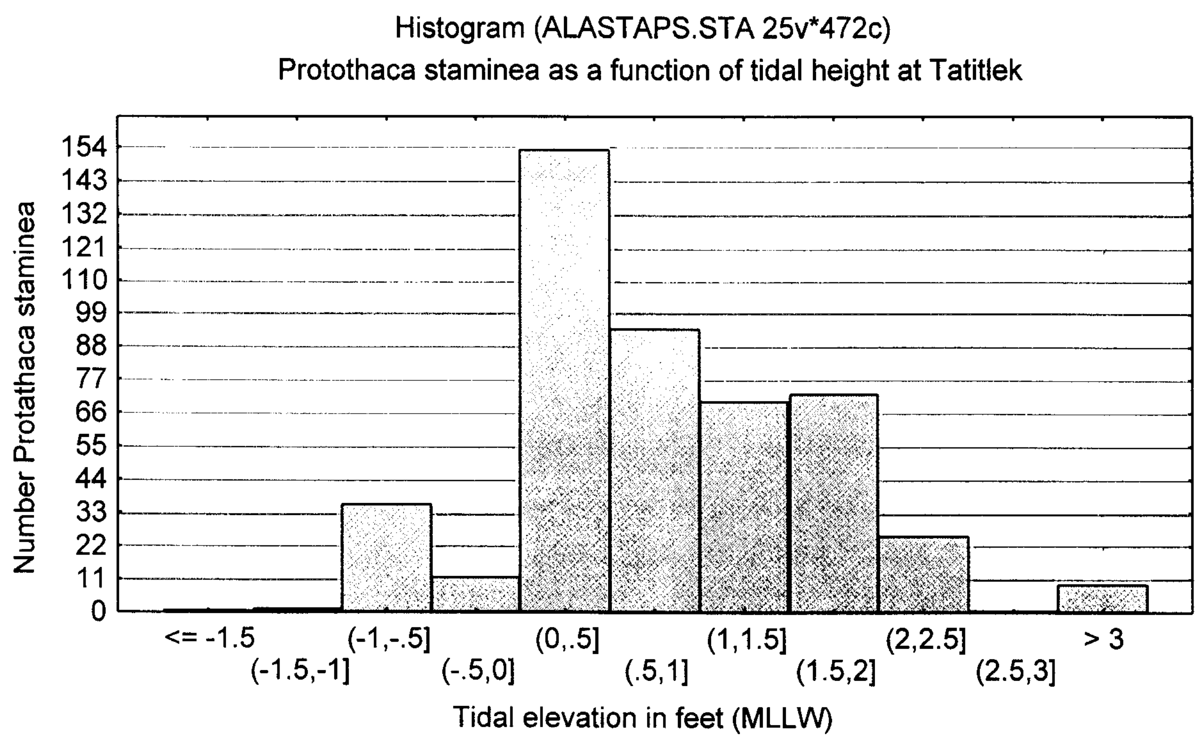


Figure 18. Tidal elevation – frequency histogram for littleneck clams collected in 35, 0.1 m² quadrats at the Tatitlek Village shellfish beach on August 27, 1995.

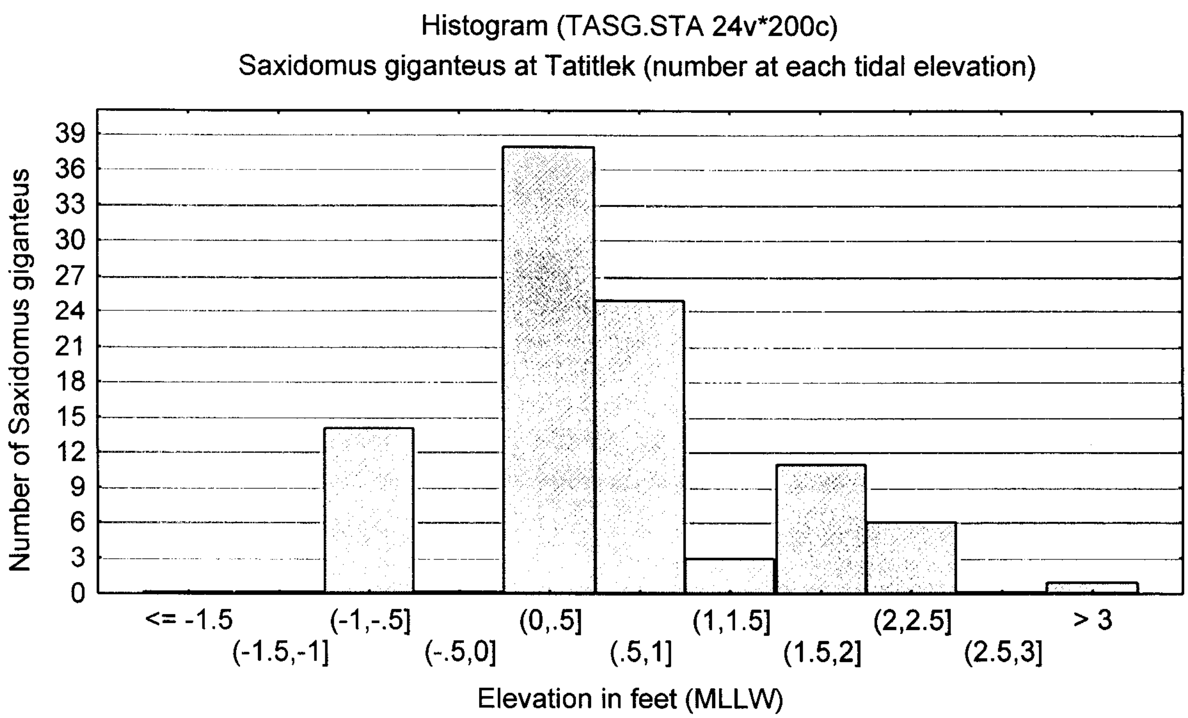


Figure 19. Tidal height – frequency histogram for butter clams (*Saxidomus giganteus*) collected in 35, 0.1 m² quadrats at the Tatitlek Village shellfish beach on August 27, 1995

Average growth increments were calculated by dividing each clam's valve length by its age. This information is presented graphically in Figure (20). The coefficients determined in a linear analysis were statistically significant at $\alpha = 0.05$ but the predictive equation explained less than 3% of the variation in the database. Figure (20) suggests that within the tidal range investigated (which includes all elevations at which clams were found in this survey), mean native littleneck valve growth declined slowly with increasing tidal height. This was particularly true for the clams at the highest elevation (>3.0' MLLW), which apparently grew slower than those found at intermediate elevations. Figure (20) suggests that clam growth should be reasonably constant at beach elevations between –1.5' and +2.5' MLLW.

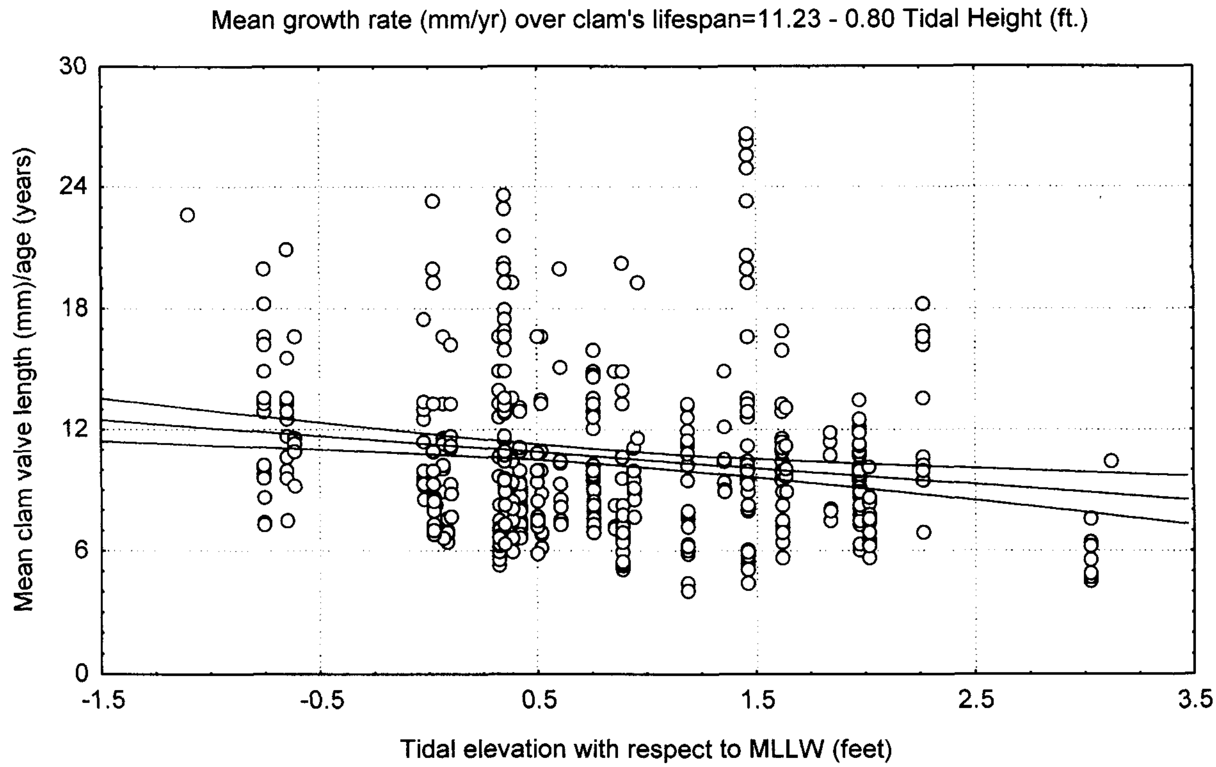


Figure 20. Growth increments (mm/year) as a function of tidal height (feet above MLLW) for native littleneck clams (*Protothaca staminea*) collected in 35, 0.1 m^2 quadrats at the Tatitlek Village shellfish beach on August 27, 1995. 95% confidence limits on the mean are provided as dashed lines in this figure.

To analyze the age-length for the littleneck clams at Tatitlek regression coefficients were developed for the von Bertalanffy model using nonlinear regression. The resulting expression (Figure 21) explained 87.2% of the variation and the ANOVA determined probability that the regression coefficients were all equal to zero was P = 0.000. The residuals appear normal. However, some caution is in order because no clam valves exceeding 45 mm were included in the database. In Puget Sound, native littleneck clams grow to lengths in excess of 65 mm (Brooks, unpublished). However, clams older than 8 years were not observed at Tatitlek and the maximum predicted valve length (47.61 mm) may be inaccurate.

$$\text{Length of native littleneck clams (mm)} = 47.61(1 - \exp^{-0.2548 \text{ x age in years}})$$

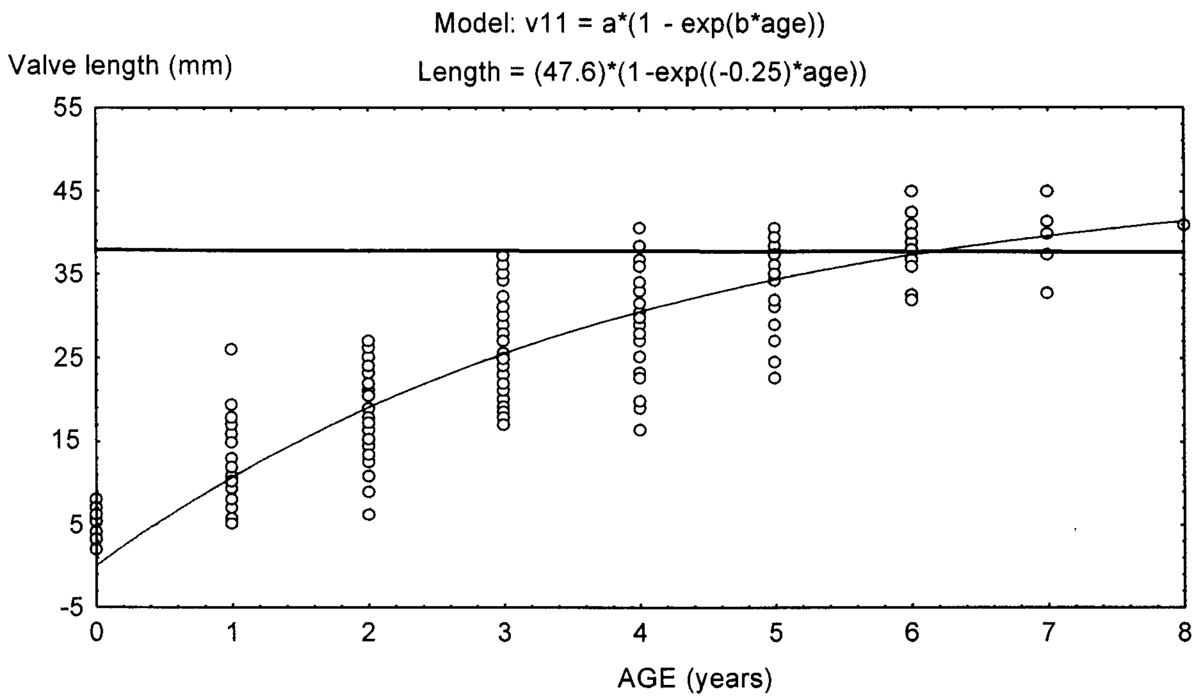


Figure 21. Length (mm) versus age (years) for native littleneck clams (*Protothaca staminea*) collected in 35, 0.1 m^2 quadrats at the Tatitlek Village on August 27, 1995. The solid horizontal line represents the minimum legal size limit ($\geq$ 38 mm). The sample analysis indicates that that Tatitlek clams enter into the legal population between 4 and 7 years with an average of 6 years.

One of the possible management options for an enhanced littleneck clam population would be to harvest the clams at a lower minimum size. To determine the appropriateness of such a management scheme an edible tissue versus clam length analysis was conducted on the Tatitlek sample. A length – wet tissue weight histogram is provided in Figure (22) and an age – wet tissue weight histogram in Figure (23).

An examination of the length-frequency data in Figure (17) suggests that clams are being removed by predation at approximately 30 mm. That length is coincident with the length range where wet tissue weights are beginning to increase significantly as a function of length in Figure (22). Even at 38 mm, clams are still well within the exponential growth phase. In this database, clams that were 8 years old, with a valve length of 42 to 45 mm, had wet tissue weights of approximately 7.5 grams. This is significantly higher than the wet tissue weight of 4.5 grams associated with six-year-old clams just reaching the current minimum harvest size of 38 mm. Reducing the minimum harvest size to 30 mm (a size preceding the heaviest predation) would result in a harvest of approximately 2.5 grams wet tissue weight per clam. Nickerson (1977) observed peak increases in the rate of biomass increase (first derivative of biomass versus time) at an age of approximately 7 years (corresponding to a valve length of ca. 38 mm) with a slow decline in this important rate at older ages. Wet tissues are eaten – not the whole animal, and this discussion suggests that lowering the minimum size at harvest to avoid predation would significantly reduce the subsistence value of the resource to native Alaskans.

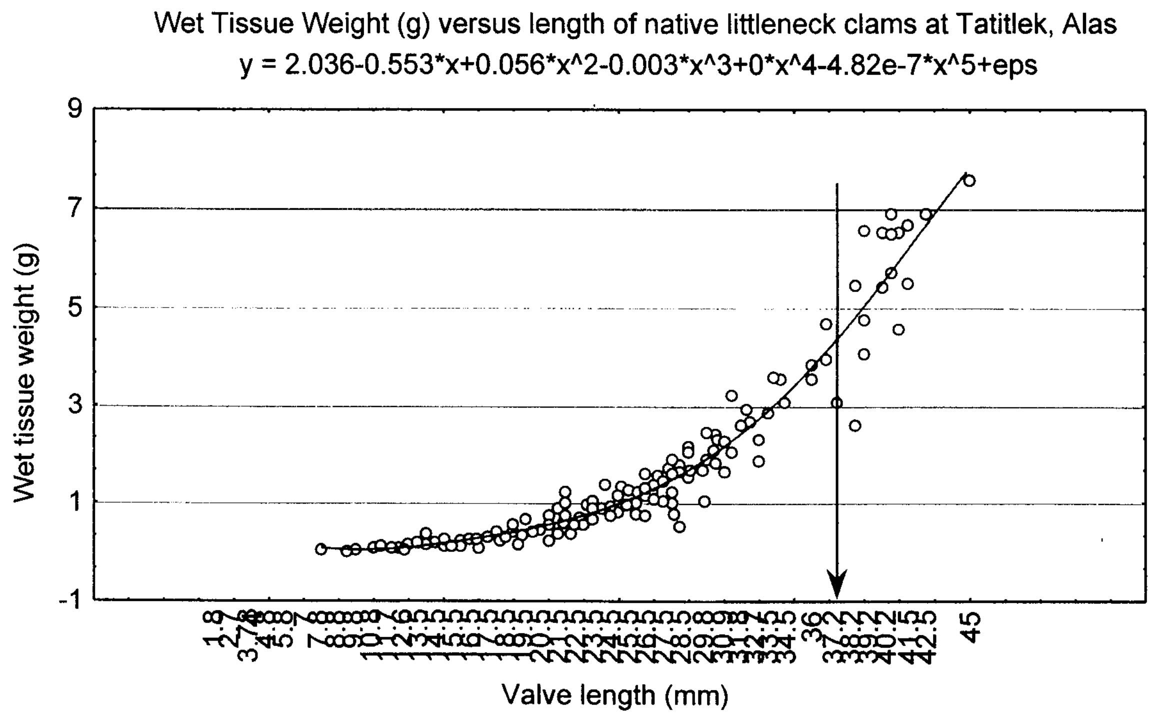


Figure 22. Length (mm) versus wet tissue weight (in grams) for native littleneck clams (*Protothaca staminea*) collected in 35, 0.1 m^2 quadrats at the Tatitlek Village shellfish beach on August 27, 1995. The vertical solid line represents the minimum legal size.

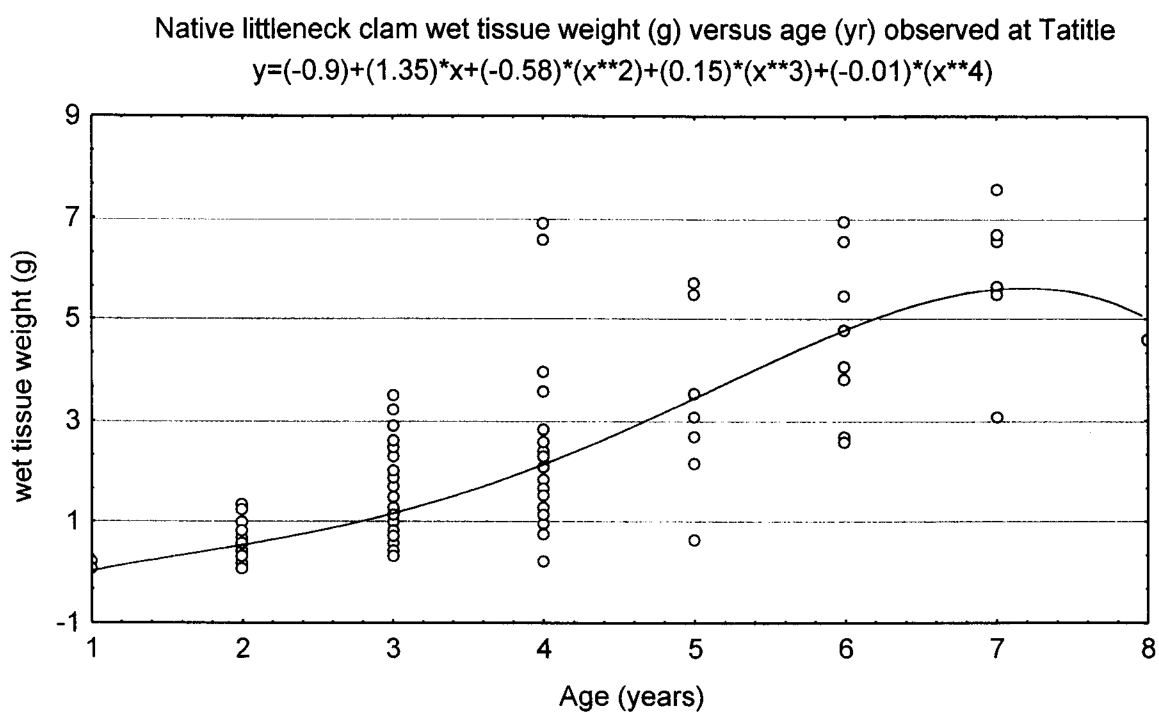


Figure 23. Age (yr) versus wet tissue weight (grams) for native littleneck clams (*Protothaca staminea*) collected in 35, 0.1 m^2 quadrats at the Tatitlek Village shellfish beach on August 27, 1995.

Predators and/or their activities were obvious at the Tatitlek beach. Numerous small round holes (approximately 0.6 meters in diameter and 15 centimeters deep) were found on the beach. Villagers' assured us that these pits were created by sea otters and that no harvests had been conducted at this site for several years. The lack of clams larger than 55 mm on this beach suggests that otters would find little suitable prey here. It appears that many of these holes were created by sunstars (*Pycnopodia helianthoides*), which were very abundant (Figure 69) at the 0.5' MLLW tide level and below. In an attempt to estimate the role of sunstar predation on this beach, three randomly selected stations were established on transect G. At each station, a single quadrat (3 m x 3 m) was established and the number of presumed pits and starfish were counted. The results are presented in Table (8). This examination suggests that starfish and possibly sea otters were having a significant impact on bivalve resources. Interestingly, although there was a significant amount of *Fucus sp.* on this beach, only one small urchin was observed. In addition, gastropods (Figure 10) were consuming many newly recruited clams at Tatitlek.

Table 4. Number of starfish (*Pycnopodia helianthoides, Pisaster ochraceus*) and presumed sea otter (*Enhydra lutris*) pits observed at the Tatitlek village shellfish beach on August 27, 1995. All counts are provided in numbers per square meter.

Sample Station	Pits	*Pycnopodia*	*Pisaster*
G2	0.44	1.0	0
G3	0.22	0.22	0
G6	0.0	0.56	0.11

Nanwalek: The Nanwalek beach selected for this project was located on Passage Island a small island near the village. Coordinates for the study site are 22.11' N by 151° 52.53' W. The site measured 130 feet wide by 140 feet long and covered 0.42 acres (Figure 24). It was bounded on the west by a boulder field and by deep water on all other sides. Brown kelp (*Laminaria sp.)* was abundant in the nearshore area. The beach contained large quantities of broken horse clam (*Tresus capax*) and butter clam (*Saxidomus giganteus*) shells associated with what could have been otter pits. The area contained reasonable substrate for native littleneck clams. Although Passage Island provided some protection, the beach was exposed to storm winds from the southeast and certainly represented a high-energy environment (Figure 25).

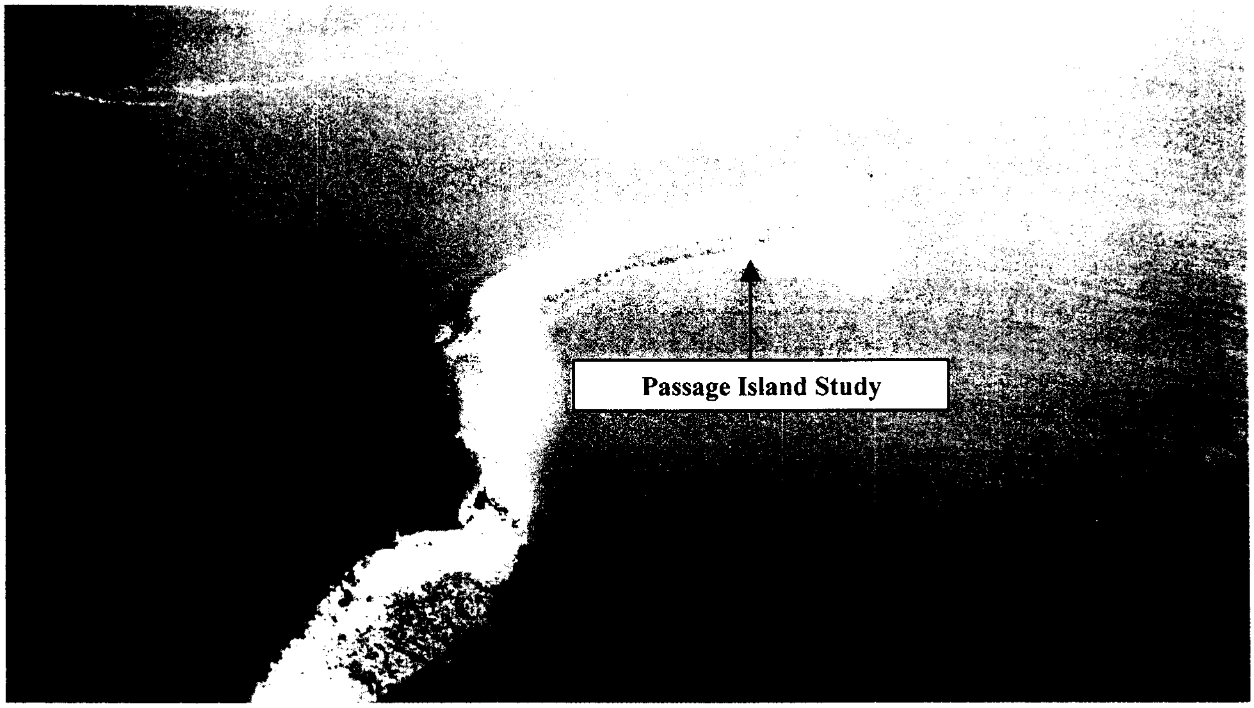


Figure 24. Aerial photograph of the eastern tip of Passage Island with the bivalve study area identified.

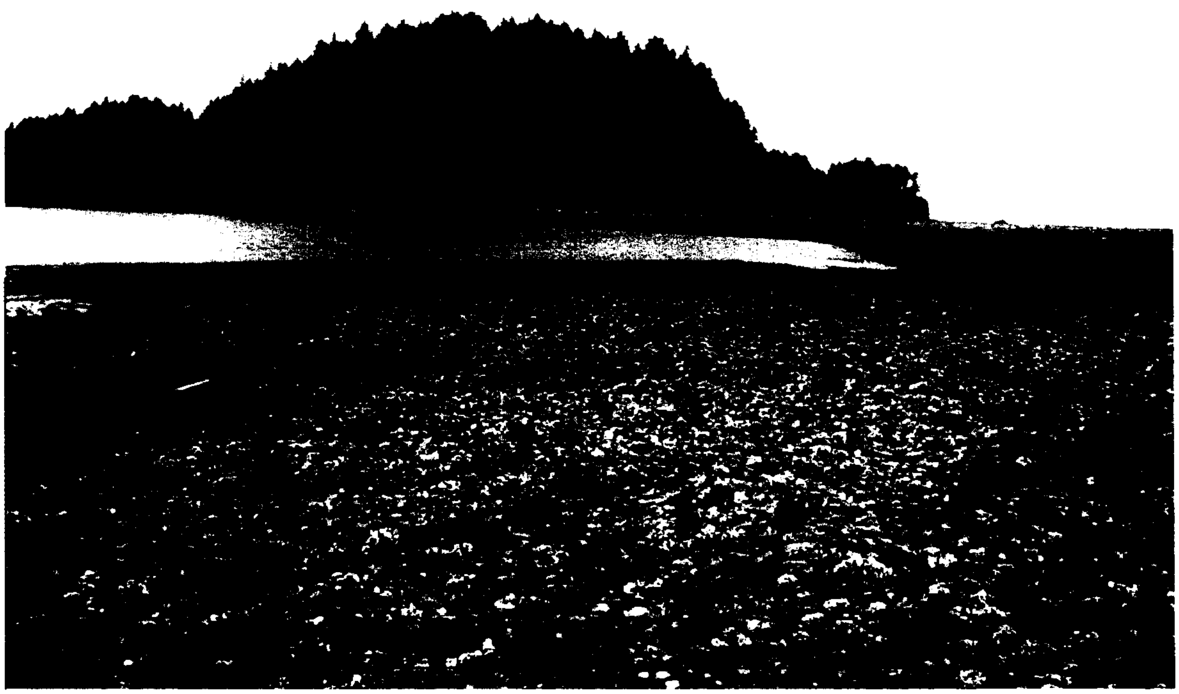


Figure 25. A portion of the beach surveyed at Passage Island.

Figure (26) shows the three transects (A, B and C) that were examined in that part of the beach where clams were found. Six shellfish and three sediment samples were analyzed on each of these transects giving a total of 18 shellfish and 9 sediment samples. In addition, 19 bivalves were collected in a random dig to supplement the growth data. These individuals were not included in assessing bivalve response to environmental parameters such as tidal height.

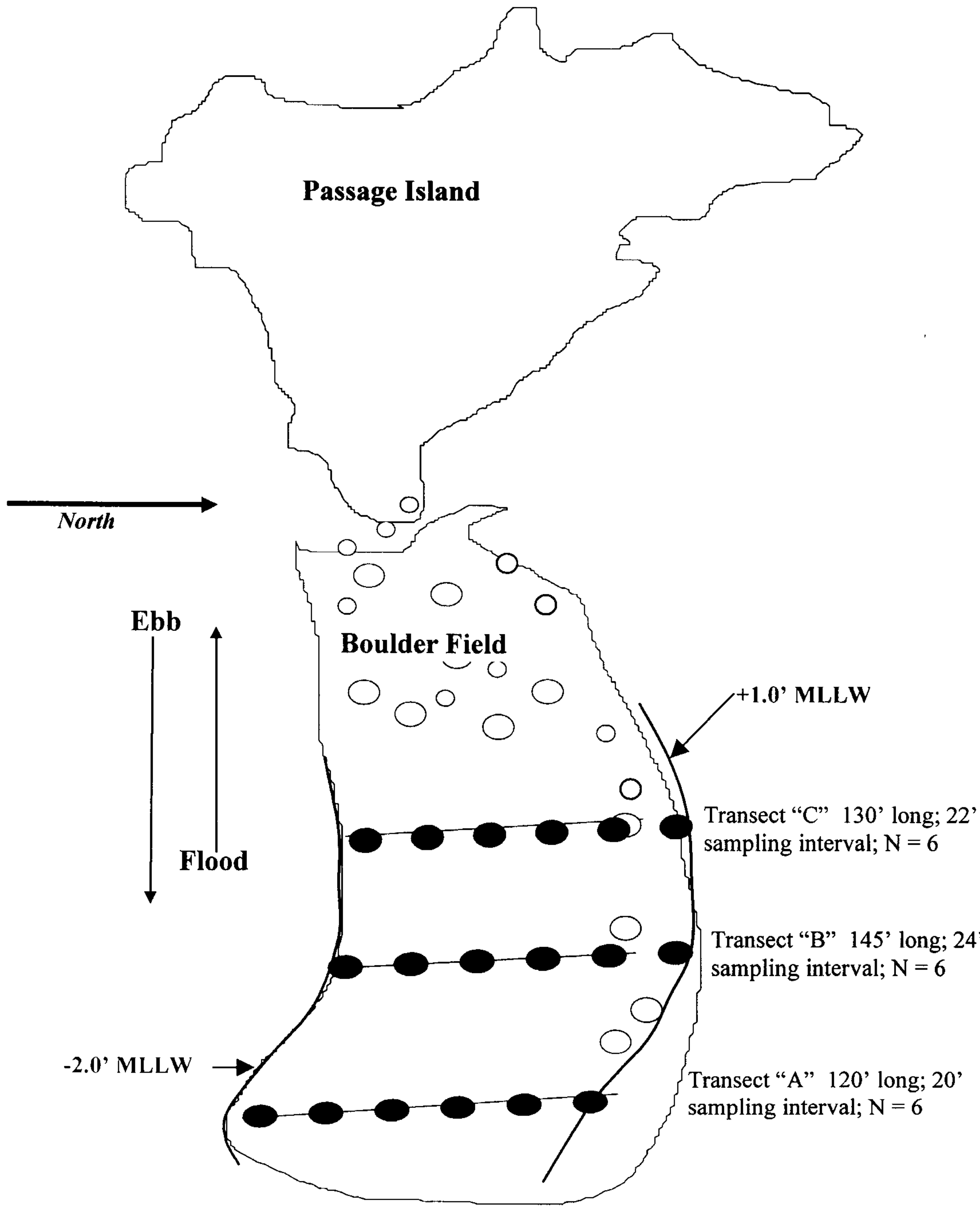


Figure 26. Schematic diagram of the Nanwalek Village shellfish beach at Passage Island. The beach has surveyed in August of 1995.

The beach considered suitable for native littleneck clam production had a shallow slope (2.3%) and well-oxygenated substrates to a depth of greater than 20 cm. Nine sediment samples were evaluated for sediment grain size and total volatile solids. Passage Island clam beach sediments contained 52.1 $\pm$ 39.3 % gravel, 38.7 $\pm$ 34.6% sand and 9.2 $\pm$ 4.83 % fines (silt and clay). Sediment composition was highly variable with the percent gravel ranging from 16 to 80.6%. Sediments contained an average of 1.30 $\pm$ 0.89 percent volatile solids. Total volatile solids at this beach are within an acceptable range for native littleneck clams. There was a very rich infauna at this site and annelids were significantly larger than usually found in Puget Sound.

The water's temperature was 12.0° C, salinity 30.2 ppt, and dissolved oxygen was 11.4 mg/L (which was saturated). Currents near slack flood tide were measured parallel to the beach (090° Magnetic) at 2.8 cm/sec. However, Village sources stated that currents are generally strong at this location. The three water samples averaged 8.77 mg TSS/L and 3.23 mg TVS/L. These values suggest good primary productivity and moderate suspended inorganic particulates on the sample date.

One hundred sixty-two living bivalves were collected in the 18 systematic random samples collected at Passage Island. An additional 19 bivalves were collected in random samples and 49 empty butter and native littleneck clam shells were collected to supplement the age – length analysis. The distribution of shellfish obtained from the systematic survey is provided in Table (5).

Table 5. Summary of bivalves collected in 18, 0.1 m^2 samples at the Nanwalek Village beach at Passage Island on August 26, 1995.

Species	Number
Protothaca staminea (native littleneck clam)	105
Macoma inquinata (indented macoma)	4
Saxidomus giganteus (butter clam)	37
Macoma nasuta (bentnose macoma)	6
Macoma balthica (Baltic macoma)	2
Hiatella arctica (Arctic hiatella)	1
Mya truncata (truncate softshell)	2
Other	5
Total	162

Gaper, butter and native littleneck clams and cockles have potential as subsistence bivalve resources. Local villagers stated a preference for butter clams, native littleneck clams and cockles. Of these preferred species, only the butter and native littleneck clams were found on Passage Island.

Forty-one butter clams were observed in these samples. Their length-frequency distribution is provided in Figure (27). Most of the observed clams were new recruits less than two years old. Six legal size butter clams were observed in the 18 samples. Descriptive statistics for a limited number of variables are presented in Table (6)

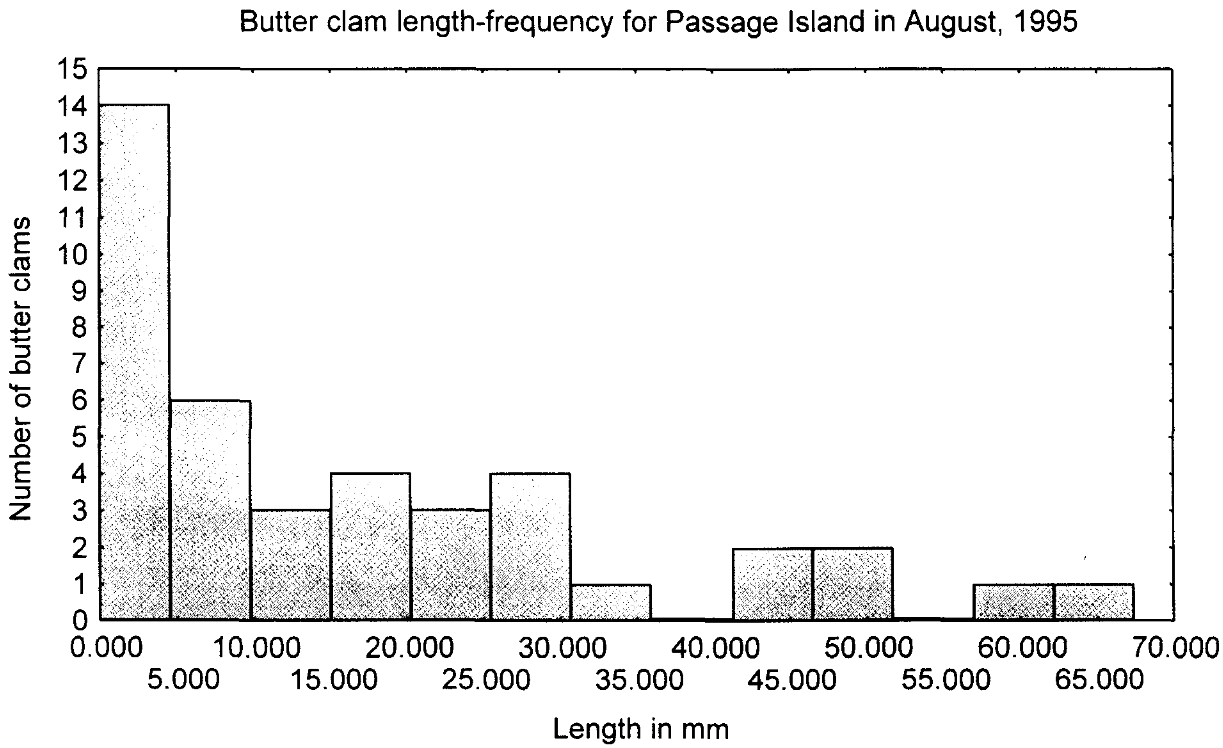


Figure 27. Length frequency histogram for butter clams (*Saxidomus giganteus*) collected in 18, 0.1 m^2 samples at Nanwalek Village's, Passage Island beach on August 26, 1995. The thin vertical line locates the legal limit (≥38 mm).

Table 6. Summary descriptive statistics for living butter clams sampled at the Nanwalek Village's Passage Island beach on August 26, 1995.

	Valid N	Mean	Minimum	Maximum	Std. Dev.
Length (mm)	41	19.97	2.00	70.00	18.19
Whole weight (g)	41	7.22	0.0024	77.00	16.14
Age	41	2.65	0.00	13.00	3.08
Dry Condition Factor	20	0.25	0.06	0.58	0.15

Non-linear regression was accomplished on aged living and empty butter clam valves to determine coefficients for the von Bertalanffy model. The resulting equation explained 94.7% of the variation and the ANOVA determined probability that the regression coefficients were all equal to zero was P = 0.000. Observed and predicted values are presented in Figure (28). The resulting Von Bertalanffy equation for Passage Island is compared with the results from Tatitlek. The results of the Passage Island data reflect the paucity of large clams in these samples. In addition, the larger coefficient on age suggests that butter clams grow more quickly at Passage Island than at Tatitlek.

Butter clam length at Passage Island (mm) = $84.4(1 - \exp^{-0.126 \text{ x age in years}})$
Butter clam length at Tatitlek (mm) = $126.5(1 - \exp^{-0.075 \text{ x age in years}})$

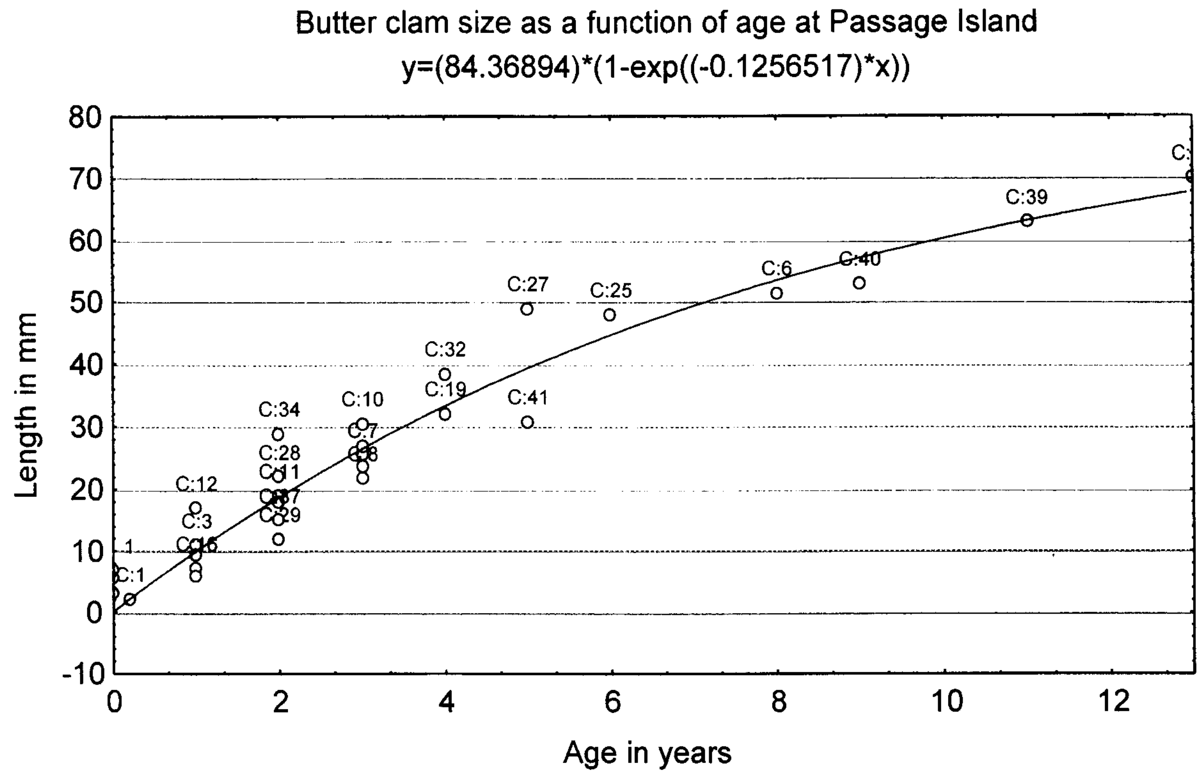


Figure 28. Solution to the von Bertalanffy model for butter clams collected in eighteen, 0.1 m^2 quadrats at Passage Island, Alaska, in August 1995.

An age-frequency histogram for butter clams from Passage Island is presented in Figure (29). Butter clams recruited into the legal size population at between four and five years of age (mean = 4.75 years). However, very few reached a legal size of $\geq$ 38 mm. Most of the mortality occurred at ages less than three years. This suggested that predators such as drills, starfish or birds were taking the small clams. From the presence of possible otter pits on the beach, the otters were exacerbating the situation by taking the few remaining large clams. The There were no apparent missing year classes for ages less than six years and recruitment of butter clams to Passage Island appears to occur regularly. However, recruitment has not been in sufficient numbers to sustain a healthy population in the presence of natural predation and mortality.

Butter clams appear to have grown well on Passage Island. However, because of their propensity to retain paralytic shellfish poisons and lack of adequate hatchery technology, this species is not considered appropriate for enhancement. Therefore, it will not receive further attention in this report. Predator control (especially starfish and drills) could have a positive affect on the number of butter clams eventually available for subsistence harvests.

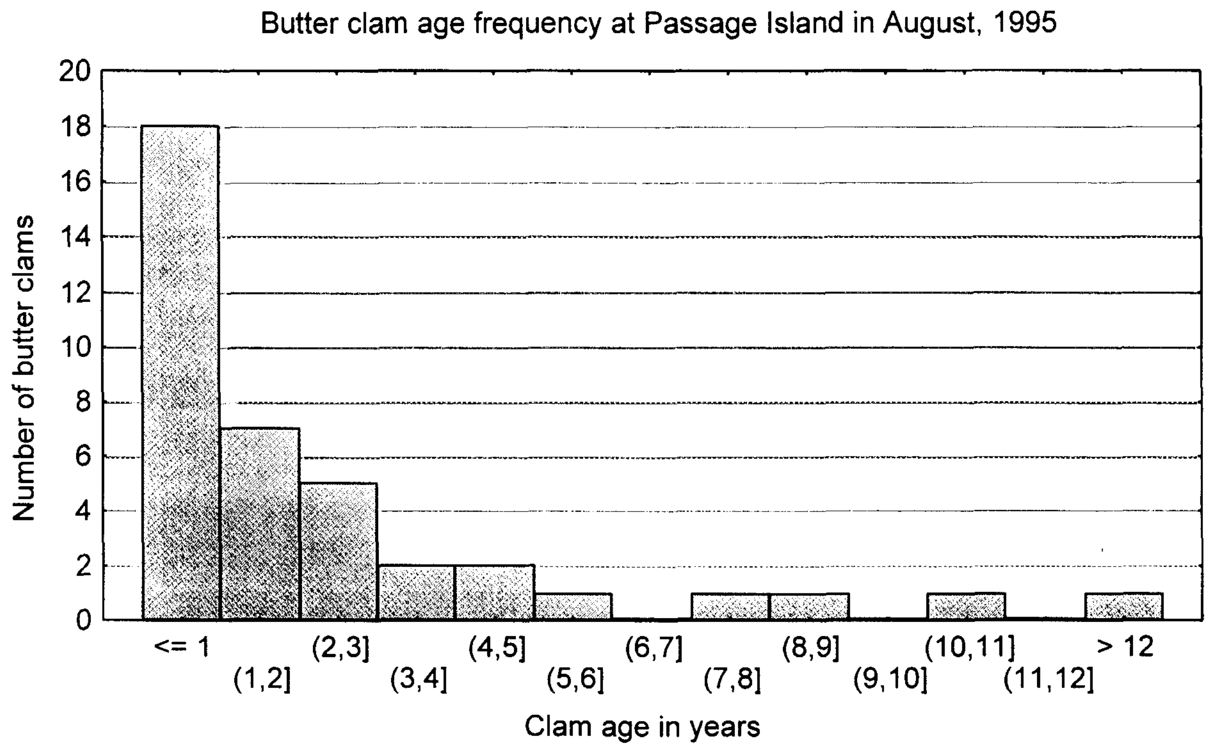


Figure 29. Age-frequency histogram for butter clams (*Saxidomus giganteus*) collected in 18, 0.1 m^2 samples at Nanwalek Village's, Passage Island shellfish beach on August 26, 1995.

One hundred five (105) native littleneck clams were observed in the eighteen samples from Passage Island. Seven additional littleneck clams were obtained in the random digging efforts. Summary statistics for littleneck clams are provided in Table (7).

Table 7. Summary descriptive statistics for living native littleneck clams sampled in 18, 0.1 m^2 quadrats at the Nanwalek Village's beach at Passage Island on August 26, 1995.

	Valid N	Mean	Minimum	Maximum	Std. Dev.
Tidal height (ft)	18	0.099	-1.80	1.03	0.72
Length (mm)	112	26.07	2.30	52.00	9.79
Whole weight (g)	112	6.03	0.001	31.90	6.08
Age (years)	112	3.51	0.00	9.00	1.80
Dry condition factor	101	0.27	0.05	0.51	0.10
Wet tissue weight (g)	101	1.80	0.03	7.96	1.65

The largest native littleneck clam had a valve length of 52 mm and weighed 31 grams (15 per pound). Eight (8) legal size clams were obtained from the 18 quadrats included in the systematic random sample. That is less than one legal size clam per square foot and demonstrates the lack of subsistence harvest available on the beach at Passage Island.

An age frequency histogram for native littleneck clams on Passage Island is presented in Figure (30). The 1994 and 1995 year classes were very low suggesting sporadic recruitment. However, this is confounded by the presence of significant numbers of drilled clamshells in the size range three to four mm. Older clams appeared to be removed from the population shortly after reaching legal size (4 to 5 years).

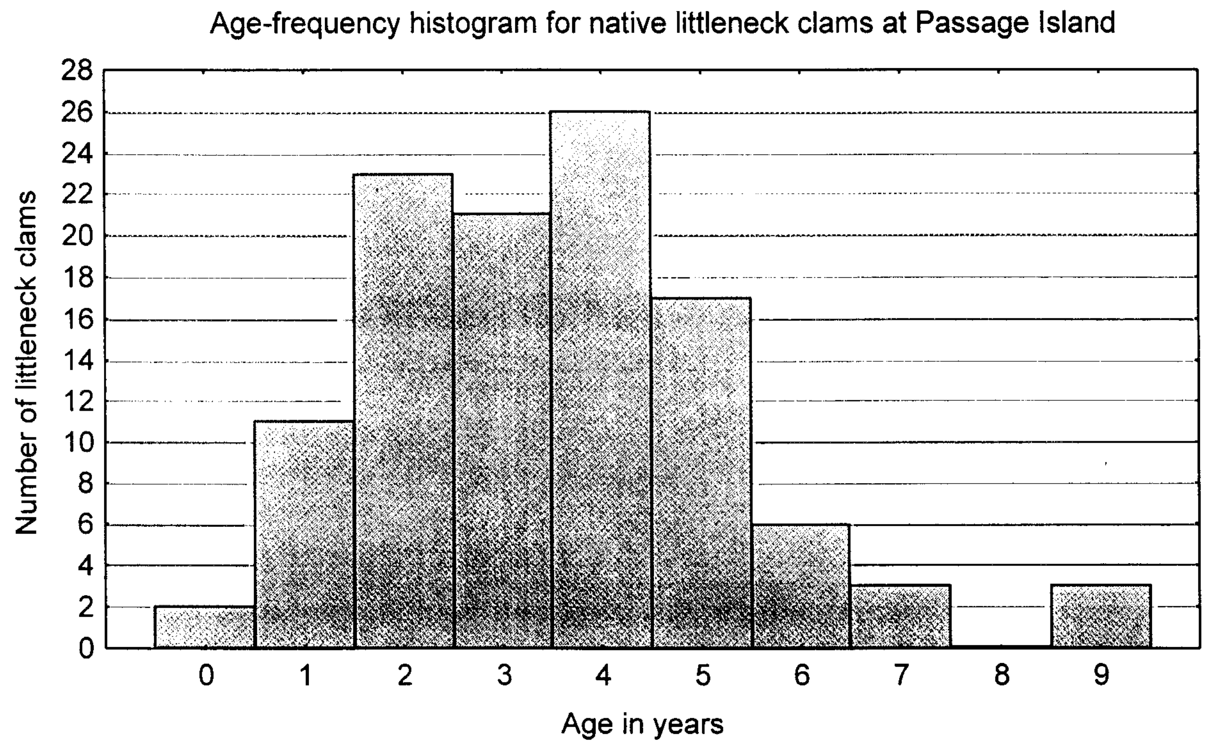


Figure 30. Age – frequency histogram for littleneck clams collected in 18, 0.1 m^2 quadrats at Passage Island on August 27, 1995.

Further examination of the population was accomplished through the length – frequency histogram provided in Figure (31). This histogram also suggests low recruitment in the recent past. The frequency observed in each of the year classes in Figure (30) should be divided by 1.8 to obtain the number of recruits per square meter since the area examined to obtain the data was 0.1 m^2/quadrat x 18 quadrats = 1.8 meters. Doing this suggests that recruitment, on average, was approximately 13 clams per square meter – far below the minimum of 400 to 700 clams per square meter typically seeded to fully utilizes beaches in Puget Sound.

This analysis indicates that current clam densities are insufficient to warrant subsistence harvests at Passage Island. Even if recruitment is enhanced, it appears that predation will still remove most of the clams from the population before they reach a minimum legal size.

Figure (32) describes the distribution of native littleneck clams as a function of tidal height at Passage Island. Most of the clams were found within a narrow tidal range of –0.5' to +1.5' MLLW. Substrates to –1.8' MLLW were included in this survey. However, very few clams were found at these lower elevations.

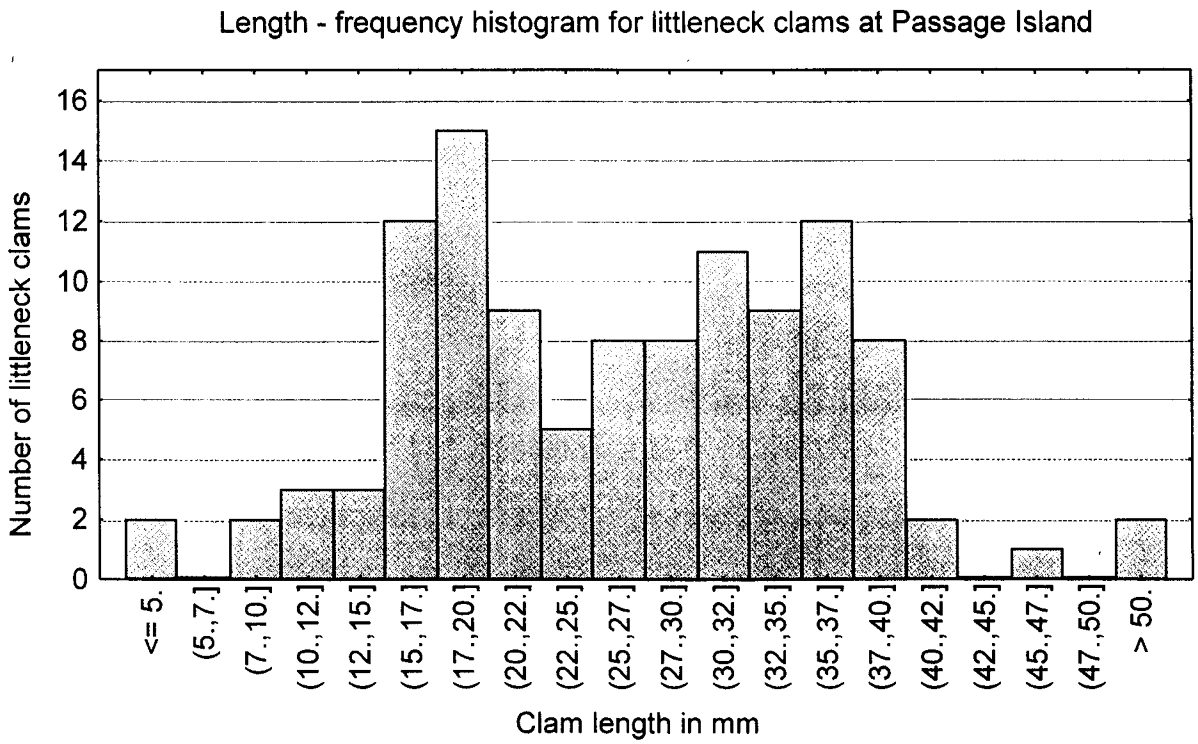


Figure 31. Length – frequency histogram for littleneck clams collected in 18, 0.1 m^2 quadrats at the Passage Island shellfish beach on August 26, 1995. The thin vertical line represents the minimum legal size of 38 mm.

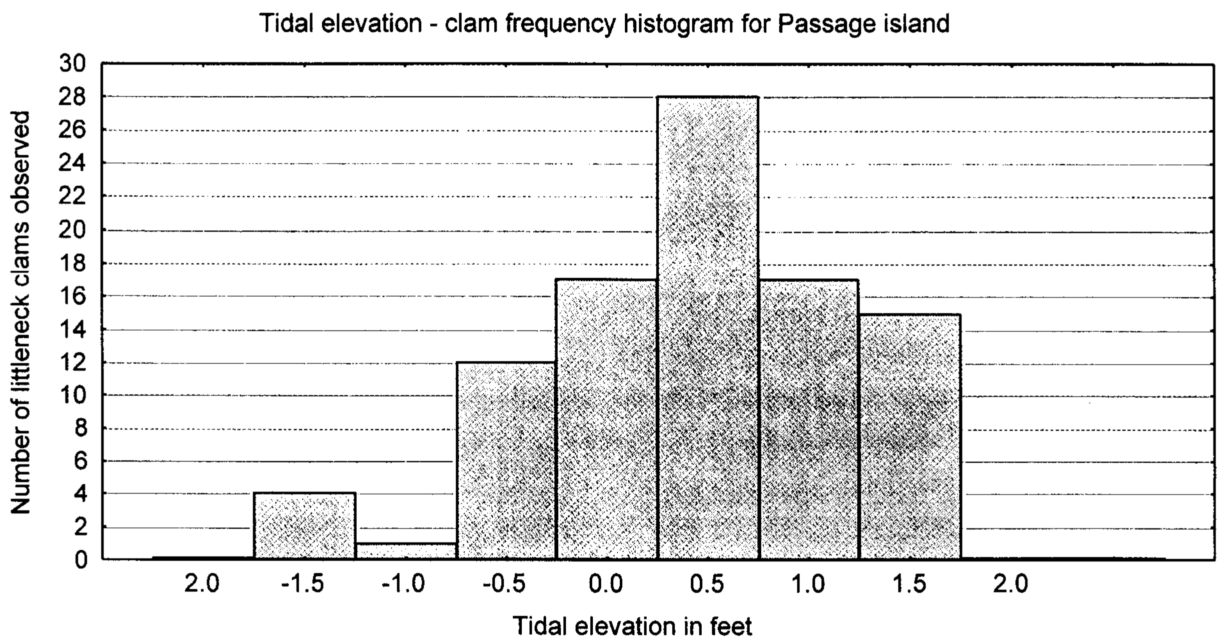


Figure 32. Tidal elevation – frequency histogram for littleneck clams collected in 18, 0.1 m^2 quadrats at Passage Island on August 26, 1995.

To determine the environmental influence on clam size, age and growth parameters with variation were included in a square matrix of Pearson correlation coefficients. This matrix indicated that biological parameters such as total valve length, mean annual growth increments, whole-animal weight, wet tissue weight and condition factor were not significantly ($\alpha = 0.05$) dependent on environmental factors within the tested strata. This conclusion is consistent with that at Tatitlek.

To determine clam growth as a function of age and length average annual growth increments were calculated by dividing the total valve length by clam age and examined as a function of age. Incremental growth of native littleneck clams at Passage Island is described in Figure (33). Some clams in the 10 to 15 mm size range appeared to have achieved that size in a single year. In other clams of the same size, an apparent annulus appears at about 1.5 mm, suggesting minimal growth during the first year. Perhaps those clams were spawned late in the year and over-wintered just after metamorphosis. The larger clams, without the check at 1.5 mm, may have spawned early in the spring or summer and enjoyed an entire growing season before winter. This could explain the large variation observed in growth increments for the one-year-old clams.

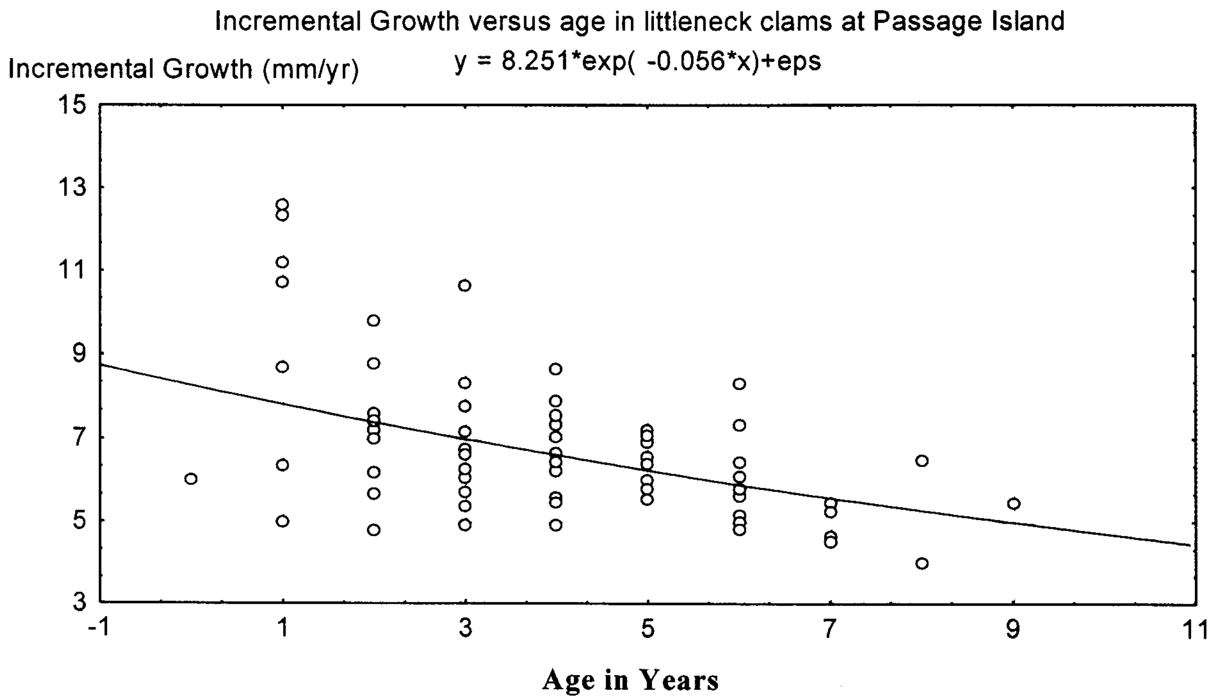


Figure 33. Average annual growth increments (mm/year) as a function of age (years) for native littleneck clams (*Protothaca staminea*) collected in 18, 0.1 m^2 quadrats at Passage Island, Alaska on August 26, 1995.

The data in Figure (33) suggests that incremental growth in valve length decreases significantly after age six. The average incremental growth methodology used in this analysis underestimates the reduction in growth as a function of age. Furthermore, it should be noted that native littleneck clam valve shape changes with age. The clams depth and width increases more that the length increases in older clams. Therefore, wet tissue weights continue to increase significantly in older clams, even though growth in valve length slows. This was nicely demonstrated by Nickerson (1977) who showed peak rates of length increase occurred at about three years of age in littleneck clams while peak increases in biomass occurred at an age of between six and seven years.

Within the area surveyed on Passage Island, clam growth does not appear to be a function of tidal height. The observed growth increments are plotted against tidal height in Figure (34). The regression coefficients were not statistically significant.

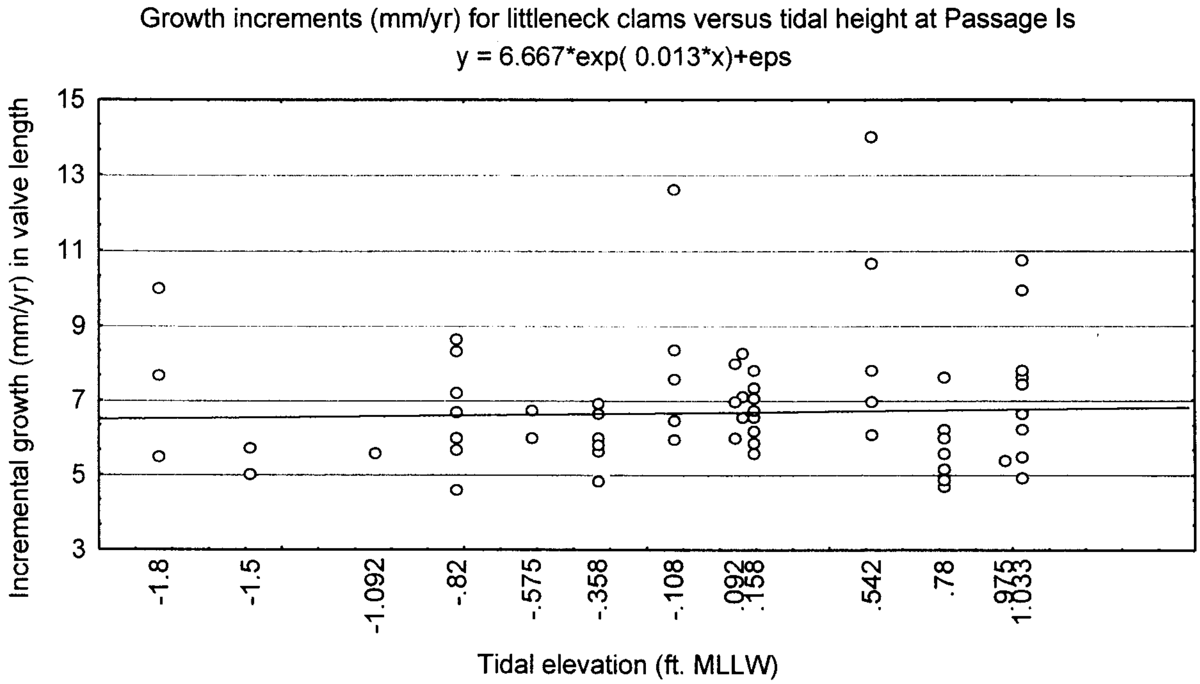


Figure 34. Growth increments (mm/year) as a function of tidal height (feet above MLLW) for native littleneck clams (*Protothaca staminea*) collected in 18, 0.1 m^2 quadrats at Passage Island, Alaska on August 26, 1995.

For the age-length analysis regression coefficients were developed for the von Bertalanffy model using nonlinear regression. The resulting equation explained 81.2% of the variation and the ANOVA determined probability that the regression coefficients were all equal to zero was P = 0.000. The residuals were normally distributed. A full range of clam valve lengths was available for the analysis and it appears valid. Predicted and observed values of valve length, as a function of age, are presented, together with the regression line in Figure (35). This equation was solved for a length of 38 mm to obtain an average age of recruitment into the legal size population of 5.76 years. This was approximately one year longer than was required for butter clams at Passage Island.

$$\text{Length of native littleneck clams at Passage Island (mm)} = 56.45(\exp^{-0.194*\text{age in years}})$$

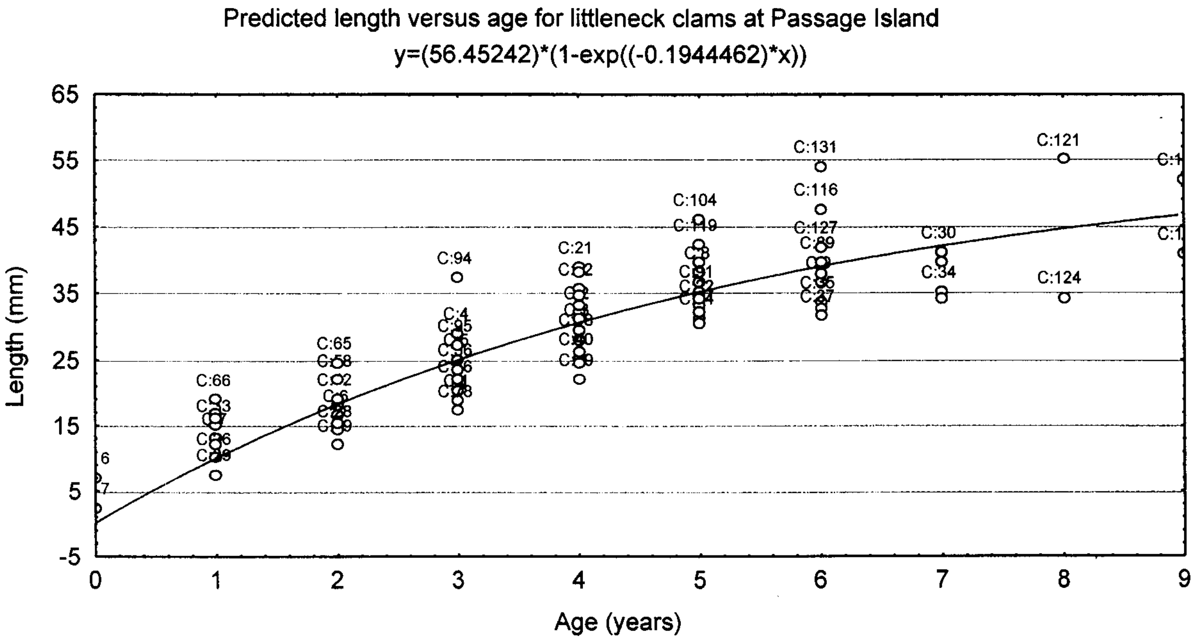


Figure 35. Valve length (mm) as a function of age (years) for native littleneck clams (*Protothaca staminea*) collected in 18, 0.1 m^2 quadrats at Passage Island, Alaska on August 26, 1995.

For the tissue versus length analysis a length – wet tissue weight histogram is provided in Figure (36) and an age – wet tissue weight histogram in Figure (37). We tissue weights were increasing exponentially near the minimum legal size suggesting that harvest should be delayed as long as predation allows.

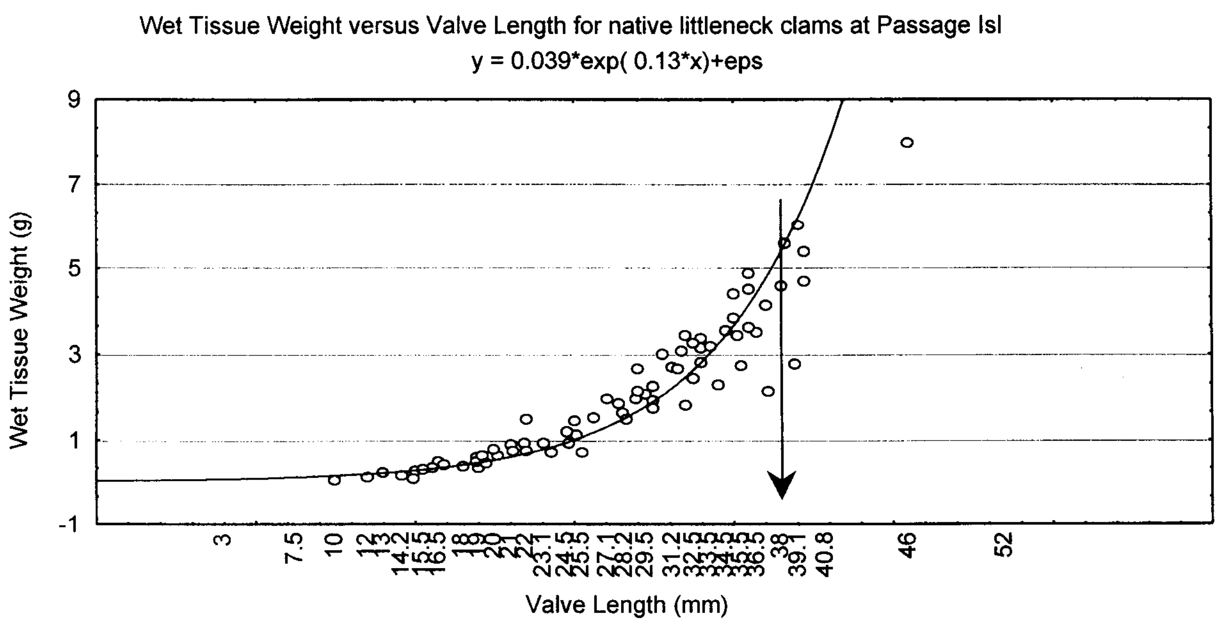


Figure 36. Length (mm) versus wet tissue weight (grams) for native littleneck clams (*Protothaca staminea*) collected in 18, 0.1 m^2 quadrats at Passage Island on August 26, 1995. The vertical solid line represents the minimum legal size.

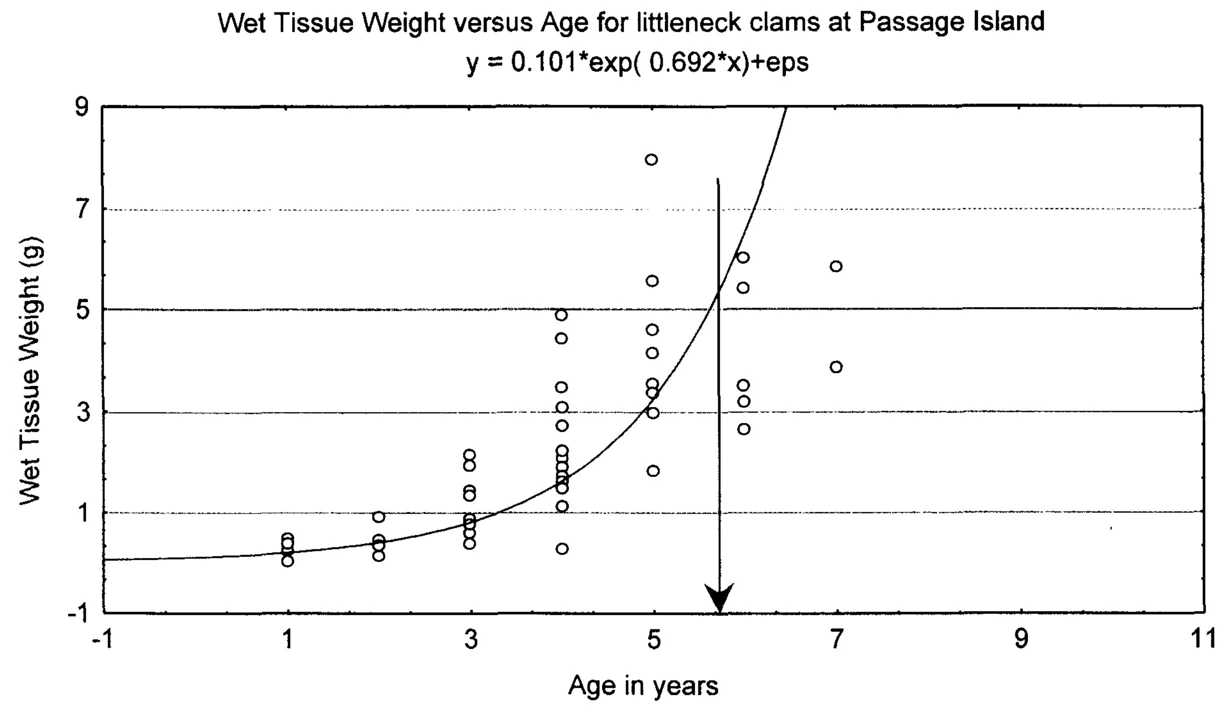


Figure 37. Age (yr) versus wet tissue weight (g) for native littleneck clams (*Protothaca staminea*) collected in 18, 0.1 m^2 quadrats at Passage Island on August 27, 1995. The vertical solid line represents the minimum legal size.

An examination of the data density in Figure (37) suggests a decrease in the rate of accumulation of wet tissues beyond an age of six years. However, there are too few data points for clams larger than 38 mm valve length to have confidence in this hypothesis and the available data suggests that growth is exponential to at least six years.

Large numbers of predators were not observed at Passage Island. Small drills (cf. *Nucella lamellosa*) were observed, as were numerous (100's) of very small (<4 mm) drilled clamshells similar to those observed at Tatitlek (see Figure 15). Numerous, small round pits (approximately 0.6 meters in diameter and 15 centimeters deep) were found on the beach. These pits were very similar to those observed at Tatitlek and may have been associated with either sunstar or sea otter predation. Villagers' assured us that these pits were from sea otters and that no harvests had been conducted at this site for several years.

Port Graham: The site survey was conducted on August 25 and 26, 1995 during a series of –1.3 MLLW tides. Initially, two beaches, one in Duncan Slough and the other in Tulcan Slough were identified for survey. Test digging on the evening of August 25, 1995 found few butter or native littleneck clams in these sloughs, which were expansive, relatively shallow, and crisscrossed by several streams. The substrate was composed of moderate quantities of fines (silt-clay) and significant quantities of small (<3 to 5 cm) broken shale. The angular nature of the shale resulted in a more tightly packed substrate that would likely inhibit the burrowing of bivalves. No butter or littleneck clams were found anywhere in Duncan or Tulcan Sloughs. The clam in greatest abundance was the truncated softshell (*Mya truncata*). These clams were 4 to 6 cm in valve length. They could provide the basis for a very limited subsistence shellfishery.

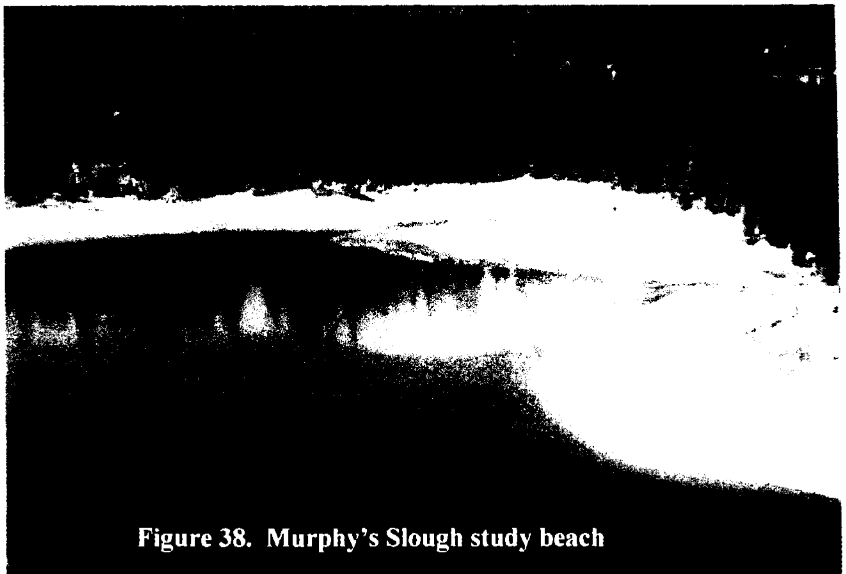


Figure 38. Murphy's Slough study beach

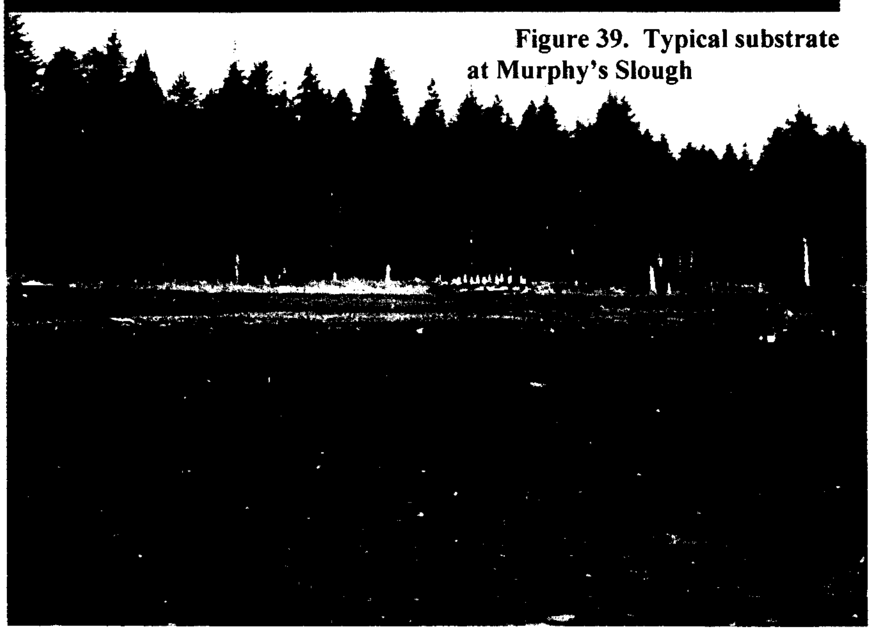


Figure 39. Typical substrate at Murphy's Slough

However, this species does not appear to be prized and the clam density was very low – making subsistence harvests difficult.

Because of the paucity of shellfish in Duncan Slough, a beach located around the point to the east of Tulcan Slough called Murphy's Slough (Figures 38 and 39) was surveyed. This beach measured 200' wide by 1000' long and covered approximately five acres. The beach slopes gradually into deep water and was very well protected from storm winds. The substrate was composed of moderately coarse, broken, shale. It was not compacted and a significant quantity of pore water was present. Murphy's Slough appeared to be a good beach for shellfish enhancement or intensive culture. Figure (38) is an aerial photograph of the beach; Figure (39) describes the substrate; and Figure (40) is a schematic diagram describing the systematic random sample used to evaluate this beach.

Four sediment samples were collected on each transect (12 total) and sieved on 1.0 mm screens to identify clams. In addition, four sediment samples were collected from randomly chosen sample stations for physicochemical analysis. The beach considered suitable for native littleneck clam production had a moderately shallow slope (3.9%) and the substrate was essentially homogeneous throughout the survey area. Sediments were loosely packed and contained significant amounts of pore water. They were well oxygenated to a depth of greater than 20 cm. Murphy's Slough beach sediments were composed of 66.8 ± 27.8 % gravel, 21.3 ± 22.3% sand, 11.9 ± 5.6 % fines (silt and clay) and contained 1.21 ± 0.99 percent volatile solids. Sediment composition at this beach was considered suitable for native littleneck clam culture.

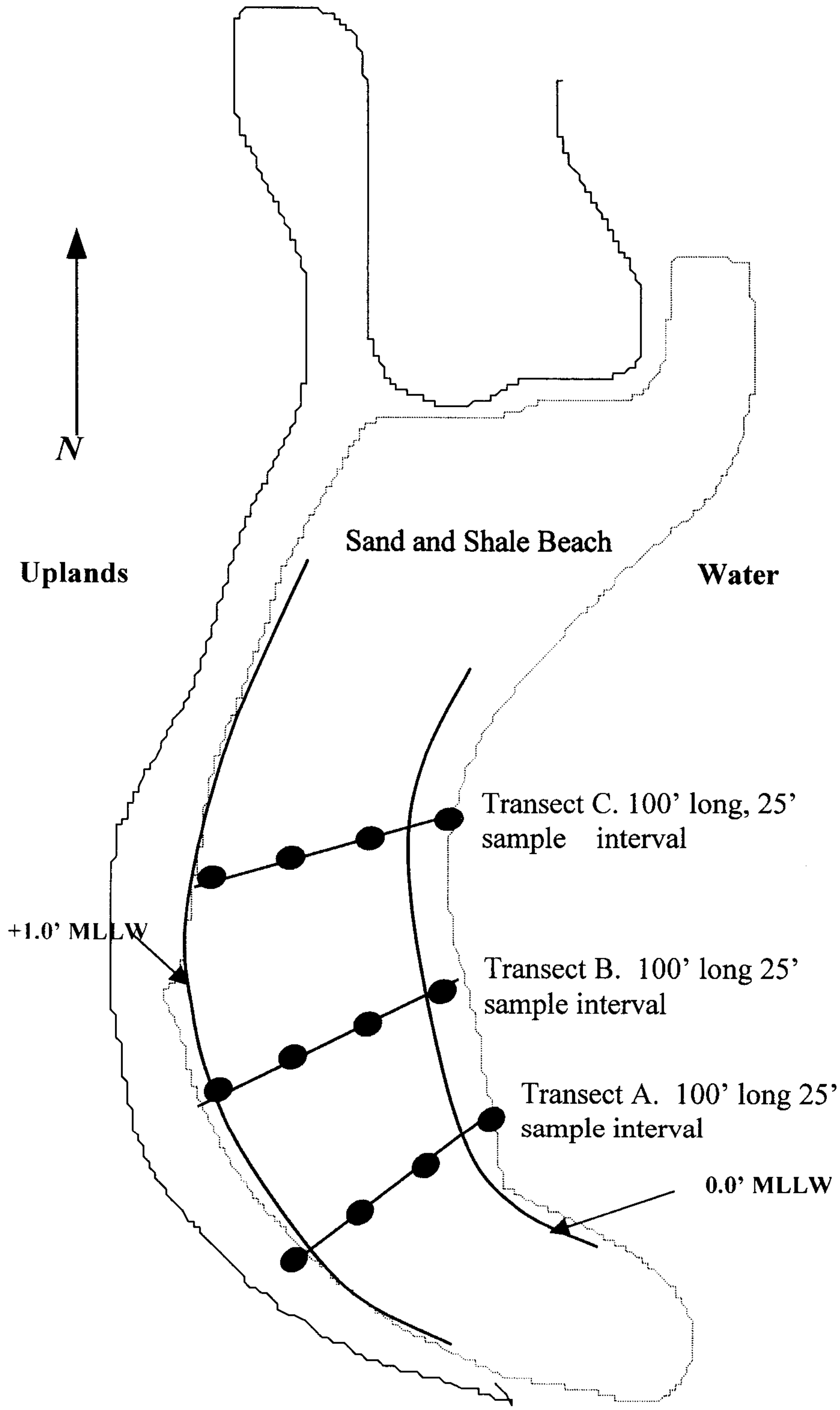


Figure 40. Schematic diagram of the Port Graham Village shellfish beach at Murphy's Slough. The beach has surveyed in August of 1995. The 12 each 0.1-m2 samples collected during the survey are identified in green.

The water's temperature was cooler than at other beaches (10.8 °C) and the salinity was 29.5 ppt. Dissolved oxygen was unexpectedly low at 7.9 ppm. Currents near slack flood tide were measured parallel to the beach at less than three cm/sec. This slough is located near the head of Port Graham. Strong currents are not anticipated and an insufficient volume of phytoplankton rich water flowing over the bed may inhibit shellfish growth. The three water samples collected at this beach averaged 15.2 mg-L^{-1} TSS and 4.6 mg-L^{-1} TVS suggesting a moderate quantity of inorganic and organic material in the water column.

Shellfish were not abundant at this site and only 65 living bivalves were collected in twelve systematic random samples at Murphy's Slough near Port Graham. An additional 41 empty bivalve shells were collected at random locations on the beach. The distribution of clams obtained from the systematic survey is provided in Table (8).

Table 8. Summary of living bivalves collected in 12, 0.1 m^2 samples from Murphy's Slough on August 26, 1995.

Species	Number
Macoma inquinata (indented macoma)	2
Saxidomus giganteus (butter clam)	39
Macoma nasuta (bentnose macoma)	17
Mya truncata (truncate softshell)	4
Clinocardium nuttallii (Nuttall's cockle)	2
Other	1

Gaper, butter and native littleneck clams and cockles have potential as subsistence shellfish resources. Local villagers stated a preference for butter clams, native littleneck clams and cockles. Of these, only the butter clam was found in Port Graham. However, all of the 39 butter clams collected were new recruits with valve lengths of less than 3.5 mm. The deposit feeding bentnose clam, *Macoma nasuta* prefers sandy sediments and tolerates low levels of dissolved oxygen. Most of the relatively large (to 38 mm) clams were of the genus *Macoma.* This species is not considered a valuable human food. The four softshell clams collected in these samples ranged in size from 27 to 51 mm valve length. However, their abundance was too low to warrant subsistence harvests.

Approximately 20 acres of what Port Graham residents identified as traditional shellfish beaches were examined in this survey. Clams were essentially absent from Duncan slough and Tulcan slough. Traditional subsistence species were essentially absent from Murphy's Slough. A third beach located approximately three nautical miles east of Murphy's slough was also investigated. This beach was small and was qualitatively sampled by digging a large area. Only a few butter clams were recovered together with perhaps two-dozen soft shell clams.

No beaches currently supporting a subsistence fishery were identified in this survey. Native littleneck clams were absent in nearly all samples and only two cockles were observed. A small number of butter clam recruits were observed at Murphy's Slough. Because of the paucity of clams taken in Port Graham, a meaningful analysis of the population is not possible.

The head of Port Graham is relatively shallow and contained an extensive intertidal area that appeared suitable for clam production. Because this survey was conducted on a marginal low tide, the suitable substrate lying at elevations less than –1.3' MLLW were not surveyed. It is possible that subsistence quantities of clams are available at these lower elevations.

Baseline Surveys for Future Enhancement

Chenega Bay: Chenega Bay village was one of the first two villages under this project to have an intertidal area surveyed and cataloged for future clam enhancement. The selection of the survey site was based on interviews with village residents. The site selected (Figure 41) is located in Crab Bay at 60° 04.24' N by 147° 59.80' W. It is accessible from the village by either boat or four-wheel drive vehicle via an overland route. The site was surveyed on June 29, 1996.

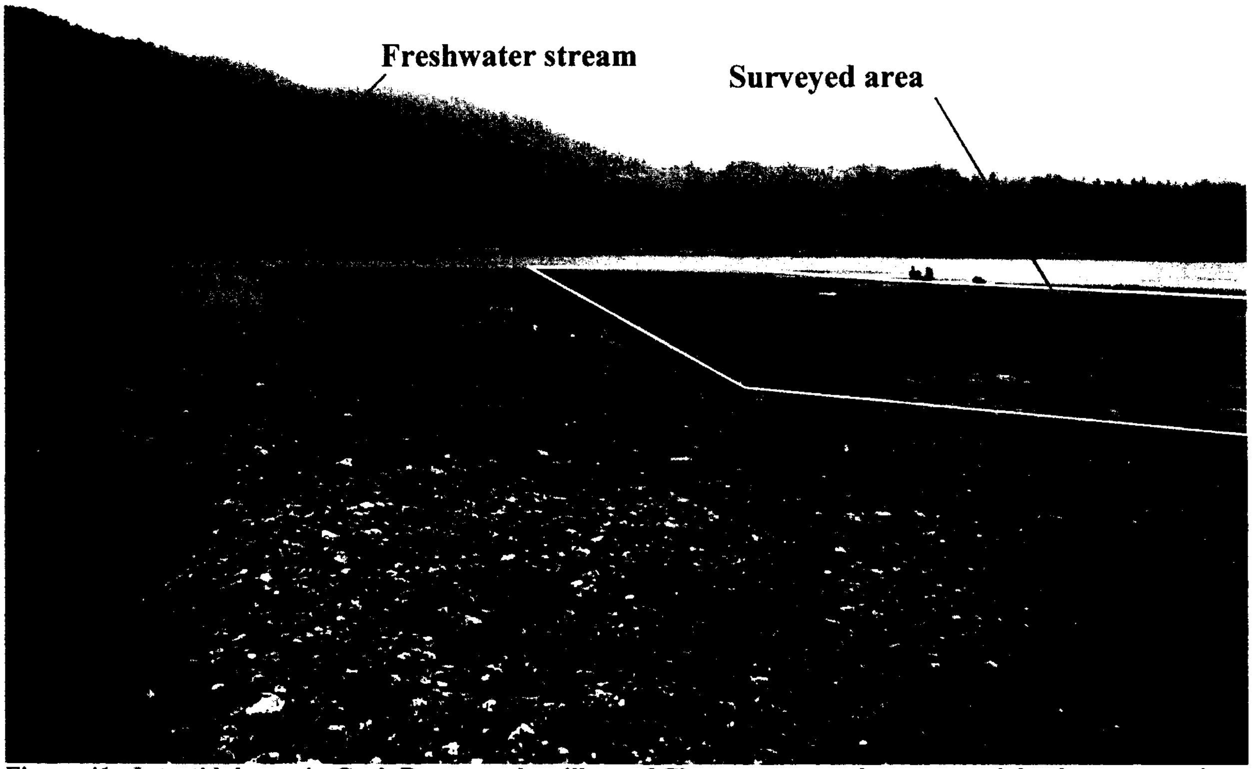


Figure 41. Intertidal area in Crab Bay near the village of Chenega surveyed as a potential enhancement site on June 29, 1996.

The total area of Crab Bay is about 40 acres. An unnamed stream enters from the north and numerous, abandone channels were observed running across a broad expanse of the intertidal area. These channels suggested that much of the area was unsuitable for clam culture because of the periodic scouring effect of the stream. The bay contains a patchy distribution of eelgrass (*Zoostera marina*) at tidal levels below ca. –2.0' MLLW. Numerous excavations, attributed to sea otters by village residents, were observed. Starfish (*Pycnopodia helianthoides*) and drills (*Nucella lamellosa*) were present, but in low numbers. The surveyed area measured approximately 115' wide by 236' deep (Figures 41 and 42). It laid in front of a substantial berm, which was currently carrying the stream well to the east. It appeared to be relatively stable and there was no evidence of recent stream erosion in the surveyed area. Much of the bay's substrate was composed of broken shale that was too hard for burrowing species. The surveyed area contained a suitable mix of fines and gravel for hardshell clams. Beach substrates were biologically active with large numbers of *Nereis sp.* and sipunculids. A preliminary reconnaissance survey supported the author's visual assessment that the chosen area contained the highest abundance of bivalves in this bay.

As illustrated in Figure (42), three transects (A, B and C) were laid out normal to the beach and a fourth transect was examined parallel to the beach at the 0.0' MLLW tide level. Four samples were collected on transects A and D and six samples on Transects B and C for a total of 20, 0.1 m^2 quadrats.

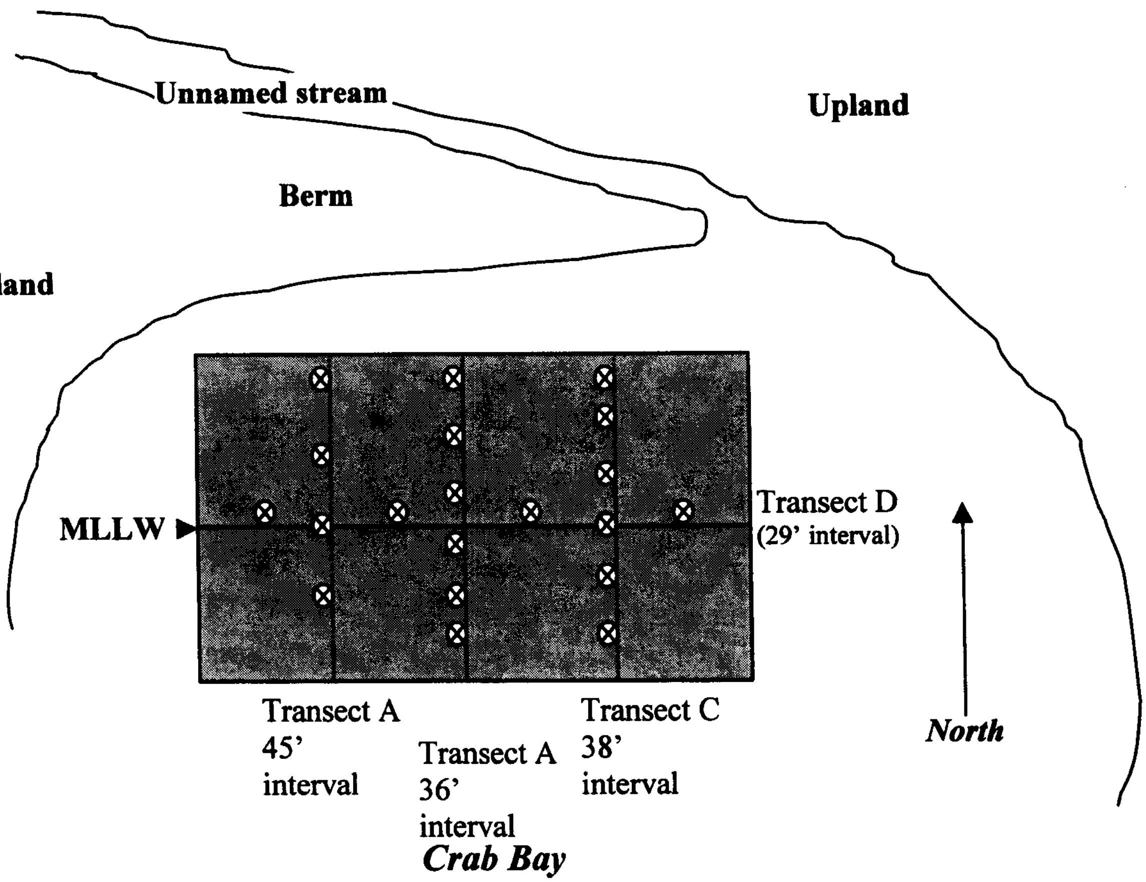


Figure 42. Schematic diagram of the Village of Chenega shellfish beach on Crab Bay. The beach has surveyed on June 29, 1996.

The beach considered suitable for native littleneck clam production had a very shallow slope ranging from 2% along Transect A to 1% along Transect C. The reduction oxidation potential discontinuity was deeper than 10 cm at all stations. Eight sediment samples were evaluated for sediment grain size and total volatile solids. These samples contained 57.5 $\pm$ 8.3% gravel, 33.6 $\pm$ 8.5% sand, 8.5 $\pm$ 2.6% silt and clay, and 2.8 $\pm$ 0.8 percent total volatile solids. Macroalgae (*Fucus* and *Enteromorpha*) contributed to the TVS content.

Water temperature was 13.8 °C and salinity varied from 28.0 ppt at Transect (A), located furthest from the stream to 25.0 ppt at Transect C, which was closest to the stream. Currents at slack tide were measured parallel to the beach at 2.5 cm/sec. The pH varied between 7.75 and 7.76.

The three water samples collected at this beach averaged 6.7 mg TSS/L and 3.8 mg TVS/L Turbidity (nephelometric units) varied between 0.69 and 1.00 NTU. These values suggest moderate quantities of organic seston and suspended inorganic particulates. These results provide no basis for eliminating this beach from consideration for enhancement.

One hundred and nine (109) living bivalves were retrieved from samples at Crab Bay. These bivalves are enumerated in Table (9). Clams were not found in sufficient abundance to support subsistence harvests.

Table 9. Summary of bivalves collected in 20, 0.1 m^2 samples at Crab bay near the Village of Chenega on June 29, 1996.

Species	Number
Protothaca staminea (native littleneck clam)	97
Saxidomus giganteus (butter clam)	6
Clinocardium nuttallii (Nuttall's cockle)	6
Total living bivalves	**109**

Six butter clams were observed in these samples. Their length-frequency distribution is provided in Figure (43). Most of the observed butter clams were new recruits less than two years old. Only one legal size butter clam was observed in the 20 samples. Descriptive statistics for a limited number of variables are presented in Table (10).

Table 10. Summary descriptive statistics for living butter clams retrieved from Crab Bay sediment samples near the Village of Chenega on June 29, 1996.

	Valid N	Mean	Minimum	Maximum	Std. Dev.
Length (mm)	6	12.80	3.82	46.5	16.6
Whole weight (g)	5	4.33	0.14	21.4	9.6
Age	6	2.17	0.00	8.0	2.9
Dry Condition Factor	2	0.38	0.01	0.69	0.44

Non-linear regression was accomplished on aged living and empty butter clam valves to determine von Bertalanffy model coefficients. Residuals were normally distributed (Kolmogorov-Smirnov; $d = 0.054$; P is n.s. @ $\alpha = 0.05$) and there was no evidence of heteroscedasticity. The resulting equation explained 96.13% of the variation and the ANOVA determined probability that the regression coefficients were all equal to zero was $P = 0.000$. A broad range of clam lengths and ages were included in the analysis (many of which were measured from empty valves) and the longest clam (123.4 mm maximum length) exceeded the maximum predicted by the von Bertalanffy equation. This expression is likely a good predictor of butter clam length as a function of age.

$$\text{Length of butter clams in Crab Bay, Chenega (mm)} = 113.5(1 - \exp^{(-0.0672 \times \text{age in years})})$$

The paucity of living butter clams with valve lengths ≥ 38 mm attests to the lack of a subsistence resource on this beach. It should be noted that despite the fact that most of the observed butter clams were new recruits, recent recruitment was very low at this beach (2.0/m^2 in 1995). Therefore, predator control (especially starfish and sea otters) may have a minor, but positive affect on the number of butter clams eventually available for subsistence harvest.

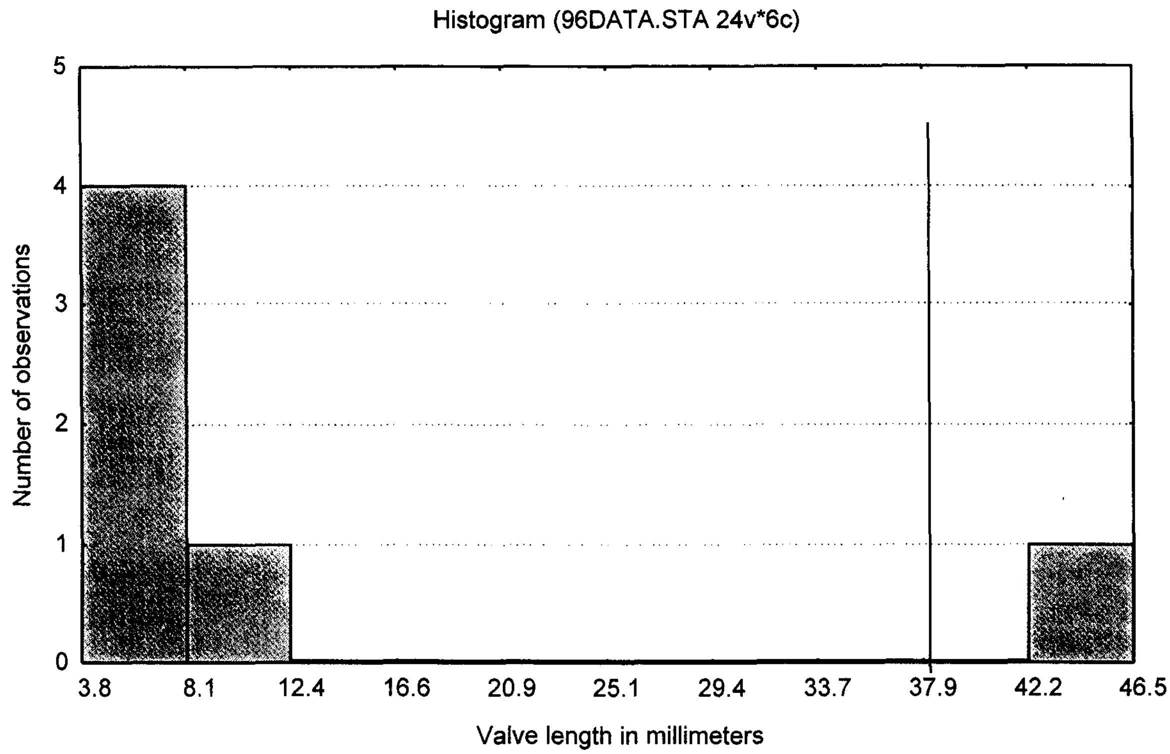


Figure 43. Length frequency histogram for butter clams (*Saxidomus giganteus*) collected in 20, 0.1 m^2 samples at the Chenega Village shellfish beach on June 29, 1996. The thin vertical line locates the legal limit (>38 mm).

Six cockles (*Clinocardium nuttallii*) were observed in these samples. Summary statistics are presented in Table (15) and a length-frequency histogram is provided in Figure (44).

Table 11. Summary descriptive statistics for living cockles sampled in 20, 0.1 m^2 quadrats at the Chenega Village shellfish beach in Crab Bay on June 29, 1996.

	Valid N	Mean	Minimum	Maximum	Std. Dev.
Valve length (mm)	6	27.90	11.56	49.09	13.36
Whole weight (gm)	6	7.20	0.26	23.92	8.65
Age (years)	5	2.40	2.00	4.00	0.89
Dry Condition Factor	4	0.34	0.232	0.41	0.08

The largest cockle had a valve length of 49.1 mm and weighed 23.9 grams. Only one legal size cockle (valve length $\geq$ 38 mm) was observed in the 20 samples. There is currently no opportunity for subsistence harvest of cockles at this Chenega Village beach.

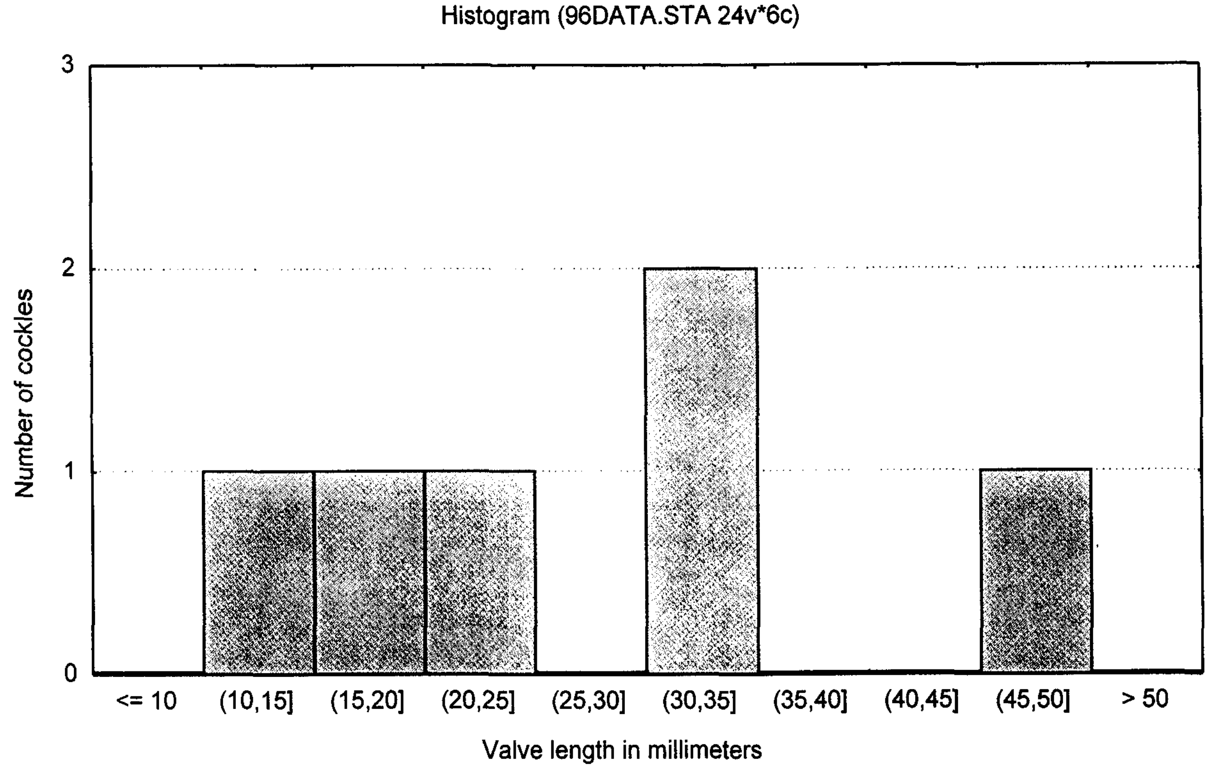


Figure 44. Length-frequency histogram for living cockles (*Clinocardium*) collected in 20, 0.1 m^2 samples during the bivalve survey in Crab Bay near the village of Chenega on June 29, 1996.

Ninety-seven (97) native littleneck clams were observed in Crab Bay sediment samples. Very pronounced circular sculpture, apparently not associated with growth checks was observed in eight of these clams. Summary statistics describing native littleneck clams are presented in Table (12).

Table 12. Summary descriptive statistics for living native littleneck clams sampled in 20, 0.1 m^2 quadrats at the Chenega Village shellfish beach in Crab Bay on June 29, 1996.

	Valid N	Mean	Minimum	Maximum	Std. Dev.
Valve length (mm)	97	21.89	2.63	47.90	7.68
Whole weight (gm)	97	5.64	0.036	25.84	3.77
Age (years)	95	4.00	0.00	7.00	4.41
Dry Condition Factor	82	0.28	0.19	0.40	0.08

Figure (45) presents an age - frequency histogram for Crab Bay native littleneck clams. The native littleneck population is dominated by three and four year old clams that likely settled in 1992 and 1993. Figure (45) suggests that recruitment is sporadic at this site (or juvenile survival is poor). It appears that relatively strong year classes set in 1992 and 1993 but that recruitment is poor). It appears that relatively strong year classes set in 1992 and 1993 but that recruitment since then has been minor. Juvenile clams should be found at a minimum density of 20 to 30 per 0.1 m^2 for optimum production. Current recruitment is estimated at 3.5 per 0.1 m^2 - or about 15% of optimum. This is close to the value of four recruits per m^2 observed at Tatitlek in the

1995 survey (Brooks, 1995).

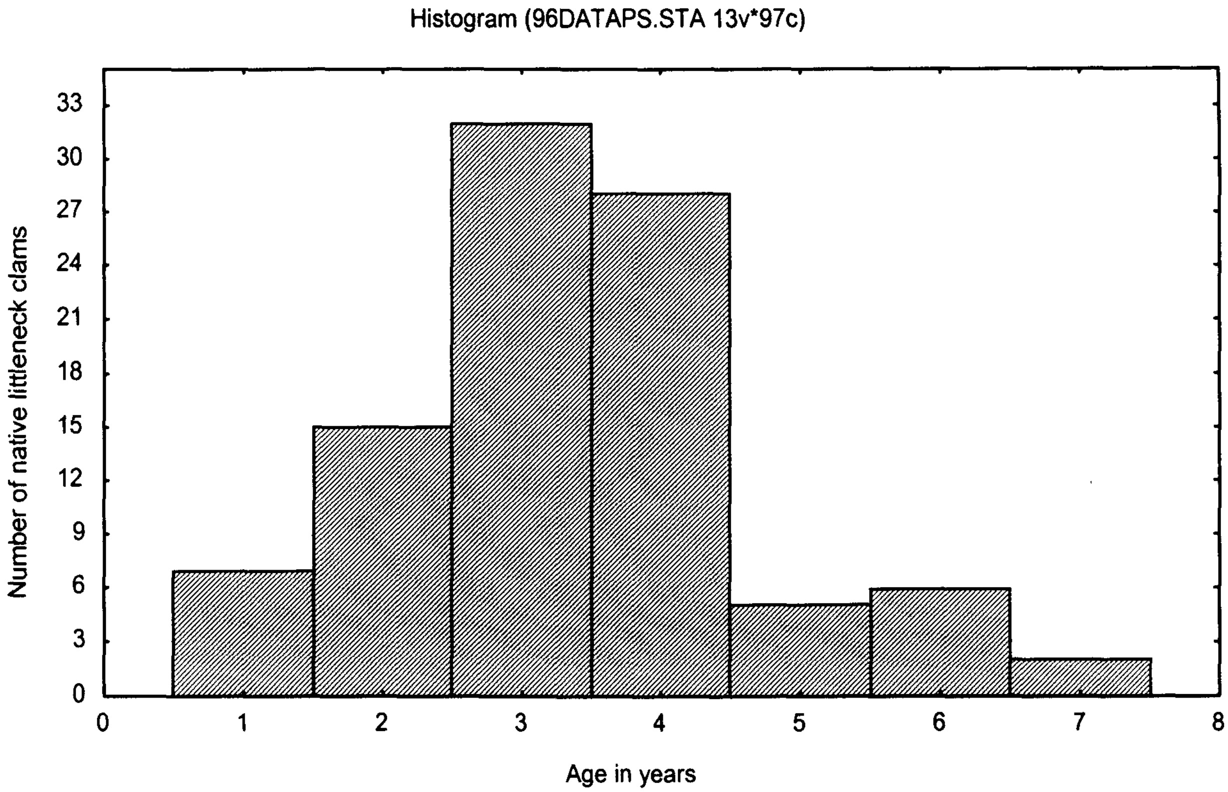


Figure 45. Age – frequency histogram for littleneck clams collected in 20, 0.1 m^{-2} quadrats at Crab Bay on June 29, 1996.

Further examination of the population was accomplished using the length - frequency histogram provided in Figure (46), which indicates that larger clams are being eliminated from the population, either by predation or because of local harvest. Fewer than five legal size littleneck clams (valve length >38 mm) were obtained in the entire survey. Insufficient edible shellfish (butter, native littleneck clam and cockles) are available at this site for subsistence harvests. This suggests that under natural conditions, shellfish production at this site is limited primarily by inadequate recruitment, and perhaps by over harvest or predation.

Figure (47) describes the distribution of native littleneck clams as a function of tidal height in Crab Bay. This figure supports previous surveys indicating that the optimum tidal elevation for native littleneck clams is ca. 0.0' MLLW. It should be noted that the substrate changes to primarily sand at tidal elevations less than -1.5' at this beach. Therefore, it was expected that native littleneck and butter clams would be absent below this elevation. It is also interesting to note that both butter clams and native littleneck clams were found at tidal elevations near +3.0' MLLW. The data for native littleneck clams suggests that the area between -1.5' and +0.5' is suitable for native littleneck clam production on this beach.

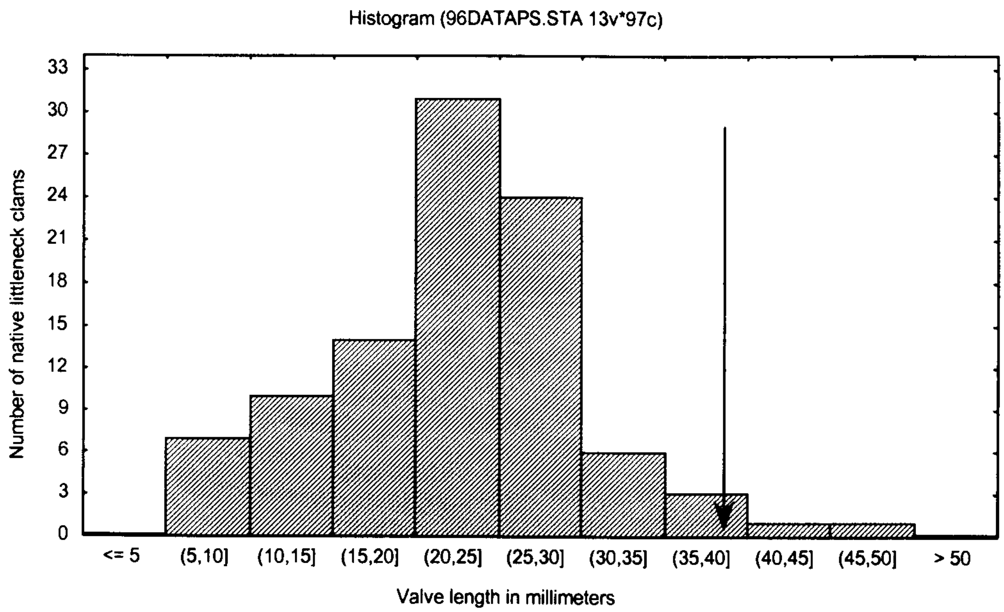


Figure 46. Length - frequency histogram for littleneck clams collected in 20, 0.1 m^2 quadrats at Crab Bay on June 29, 1996. The thin vertical line represents the minimum legal size of 38 mm.

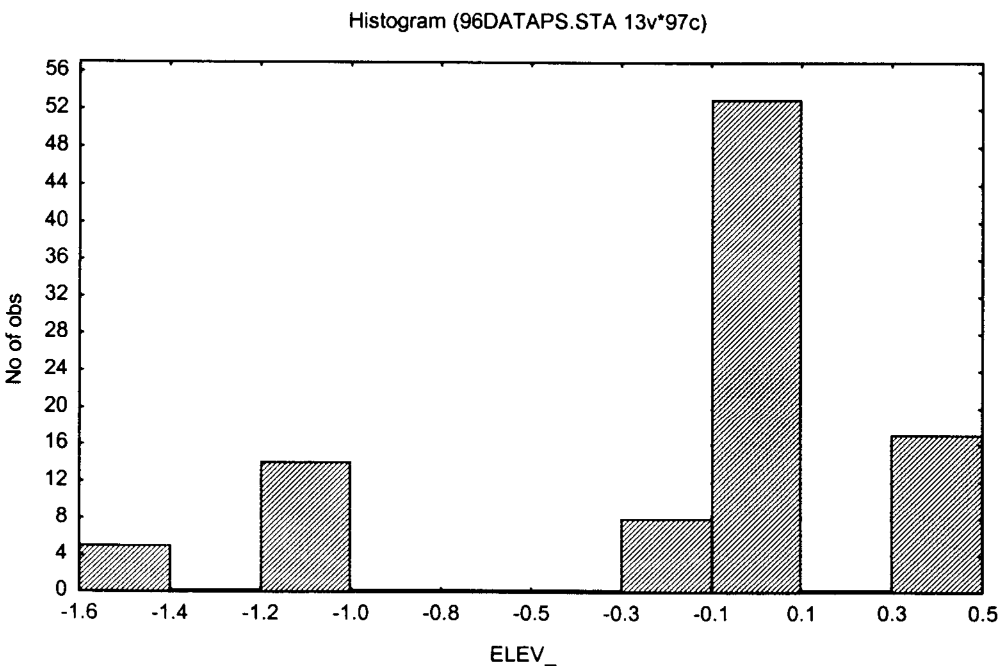


Figure 47. Tidal elevation – clam frequency histogram for littleneck clams collected in 20, 0.1 m^2 quadrats in Crab Bay near the village of Chenega on June 29, 1996.

To determine the influence of environmental factors on growth of littleneck clams the physicochemical and biological variables evaluated in this study were included in a square matrix providing Pearson correlation coefficients. This matrix suggested that biological parameters such as length, average annual incremental shell growth, whole-animal weight, wet tissue weight, and condition factor were not strongly dependent on environmental factors within the tested strata. Even though some of the correlation coefficients are significant, the corresponding Coefficients of Determination indicate that they explained a very small part of the variation in dependent physiological variables. This conclusion was supported by cluster analysis, principle components analysis, regression analysis and Analysis of Variance. Only AGE was a truly significant factor effecting clam size, growth and condition. A summary of the most pertinent correlation's is provided in Table (13).

Table 13. Summary of most relevant Pearson correlation coefficients. The probability (p) that the coefficient equals zero is also provided. Significant coefficients (at $\alpha = 0.05$) are bolded. For all variables, the valid number of cases was 88.

	Tidal elevation	Sediment TVS	Salinity
Length	0.013 P = 0.290	**0.088** **p = 0.005**	**0.352** **p = 0.000**
Growth increment	0.009 P = 0.370	0.000 P = 0.990	0.001 P = 0.730
Whole animal weight	0.008 P = 0.410	**0.220** P = 0.000	**0.550** P = 0.000
Age	0.017 P = 0.230	**0.090** **P = 0.004**	**0.310** **P = 0.000**
Dry Condition Factor	0.013 P = 0.290	0.016 P = 0.230	**0.120** **p = 0.001**

Clam length was positively correlated with sediment total volatile solids (TVS) and salinity. There was a moderate size stream flowing into Crab Bay behind a berm lying between the upland and the intertidal. This stream entered the bay to the east where it was having a small effect on salinity during this summer sampling period. It likely has a much larger effect during the winter and spring. In addition, it possibly breaches the berm periodically resulting in a disruption of intertidal sediments, which either buries or exposes clams. There was evidence of several old stream channels meandering across the eastern part of this beach. The presence of this stream likely reduces the number of older clams in its meander plain. This is suggested by the positive correlation between length, whole-animal weight, and age, with salinity in Table (13). The positive correlation between dry condition factor and salinity is likely because higher condition has been observed in older clams and older clams were more prevalent in the western part of the survey area where salinities are highest and the stream has least influence. If the budget had allowed a determination of actual internal valve volume, rather than relying on length, then this correlation would likely not have been as significant. However, it can also be postulated that periodically reduced salinities may reduce feeding times, resulting in the positive correlation between salinity and condition factor.

Physiological parameters (length, wet tissue weight, condition index, whole animal weight) were not significantly correlated with tidal elevation. That is likely the result of the rather narrow intertidal band within which *Protothaca sp.* was found on this beach (-1.6' to + 0.5' MLLW) with the large majority of the littleneck clams being found at 0.0' MLLW.

Average growth increments were calculated by dividing the valve length by the clam's age. This procedure should be viewed as a crude approximation of growth because it does not recognize that incremental growth is negatively correlated with age ($r^2_a = -0.16$; $P = 0.000$). However, for purposes of determining the average growth increment as a function of tidal height, it gives a reasonable assessment of the optimum tidal height at which to cultivate clams on this beach. This information is presented graphically in Figure (48). The line represents a best polynomial fit to the data with 95% confidence limits on the mean displayed. Figure (48) suggests that within the tidal range investigated (which includes all elevations at which clams were found in this survey), native littleneck valve growth is acceptable for culture purposes. A decline in incremental growth was observed at tidal elevations below ca. –1.0' MLLW. These observations are consistent with those reported by Brooks (1995b) for beaches near Tatitlek, Port Graham and Nanwalek.

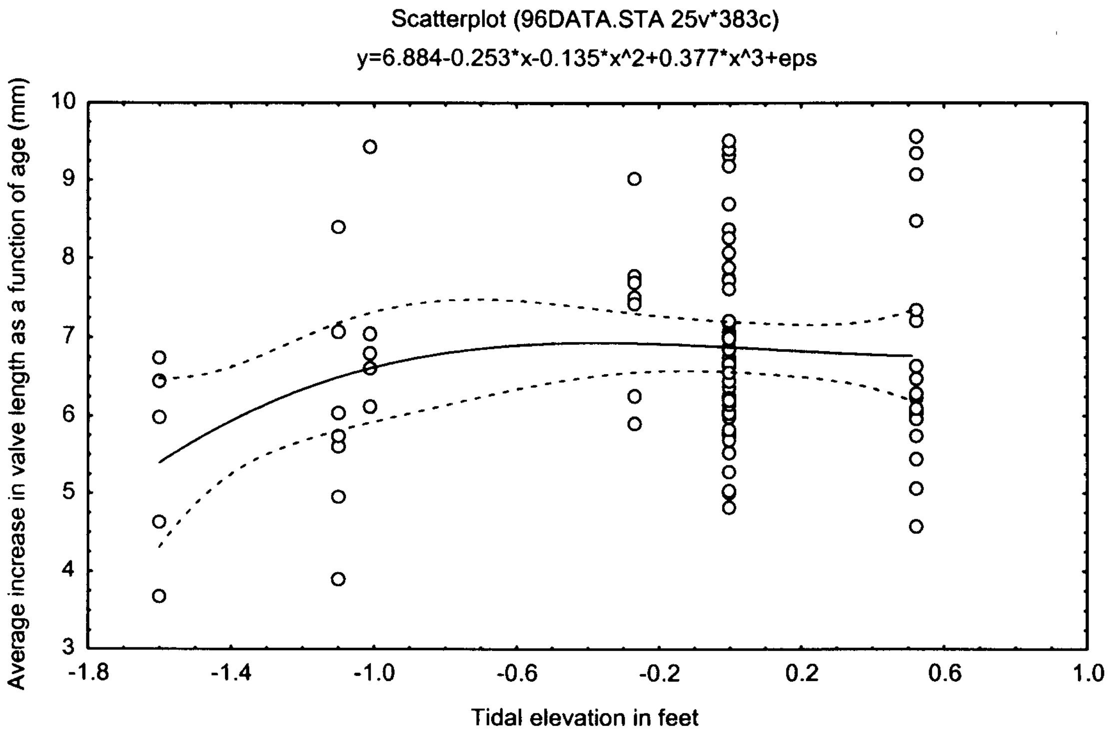


Figure 48. Growth increments (mm/year) as a function of tidal height (feet above MLLW) for native littleneck clams (*Protothaca staminea*) collected in 20, 0.1 m^2 quadrats at the Chenega Village shellfish beach on June 29, 1996. Ninety-five percent confidence limits on regression predictions are provided.

For the age at length determination regression coefficients were developed for the von Bertalanffy model using non-linear regression. The resulting regression explained 87.2% of the variation and the ANOVA determined probability that the regression coefficients were all equal to zero was $P = 0.000$. The regression residuals were not significantly different from a normal distribution (Kolmogorov-Smirnov, $d = 0.0508$), P is n.s. at $\alpha = 0.05$). However, some caution is in order because no clam valves exceeding 47.9 mm were included in the database. In Puget Sound, native littleneck clams grow to lengths in excess of 65 mm (Brooks, unpublished).

However, native littleneck clams older than seven years were not observed at Crab Bay for unknown reasons. A scattergram, including the regression line is provided in Figure (49). The von Bertalanffy equation, and accompanying scatterplot, suggests that native littleneck clams begin recruiting into the legal size population at six years of age and the average age of recruitment is seven years.

Littleneck clam von Bertalanffy model for Crab Bay   Length = 55.9(1 - exp$^{-0.155 \text{ x age in years}}$)

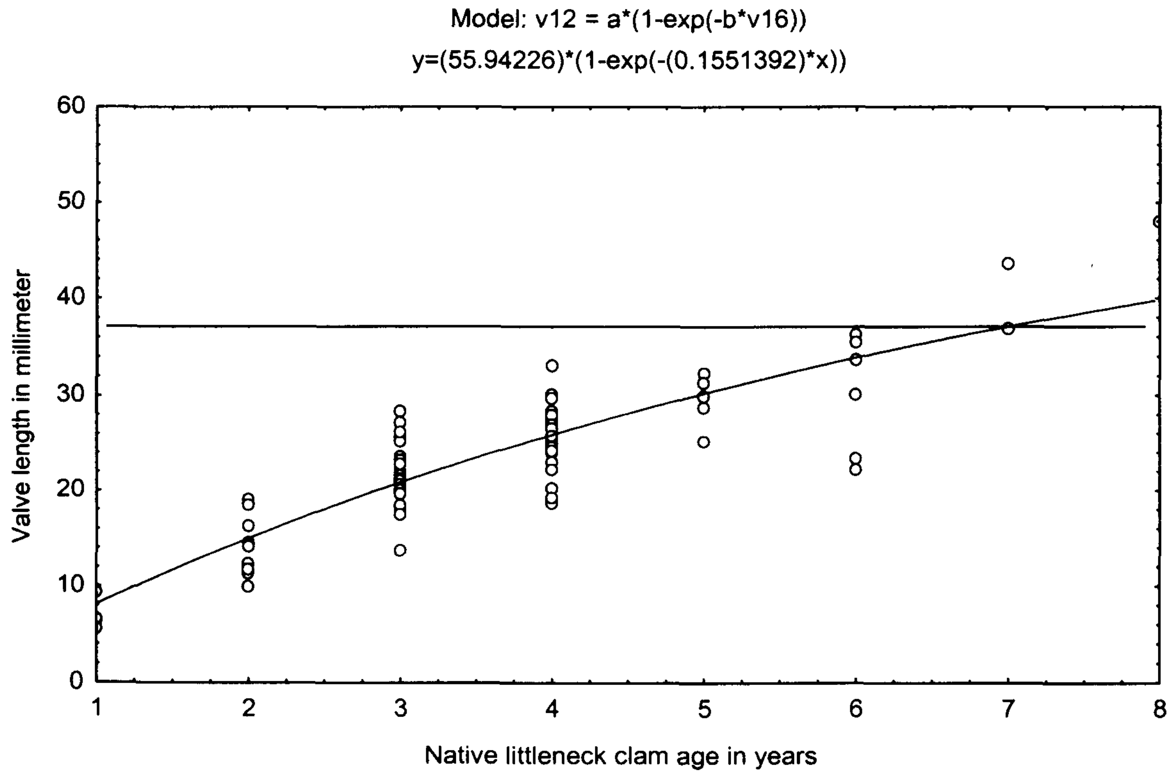


Figure 49. Length (mm) versus age (years) for native littleneck clams (*Protothaca staminea*) collected in 20, 0.1 m^2 quadrats at Chenega Village on June 29, 1996. The solid horizontal line represents the minimum legal size limit ($\geq$ 38 mm).

A length - wet tissue weight histogram is provided in Figure (50) and an age - wet tissue weight histogram in Figure (51). These results are consistent with those presented earlier and demonstrate that wet tissue weights are increasing exponentially near 38 mm valve length. This suggests that if predation and/or disease can be controlled, then the clams should be allowed to grow to at least 45 mm prior to human harvest.

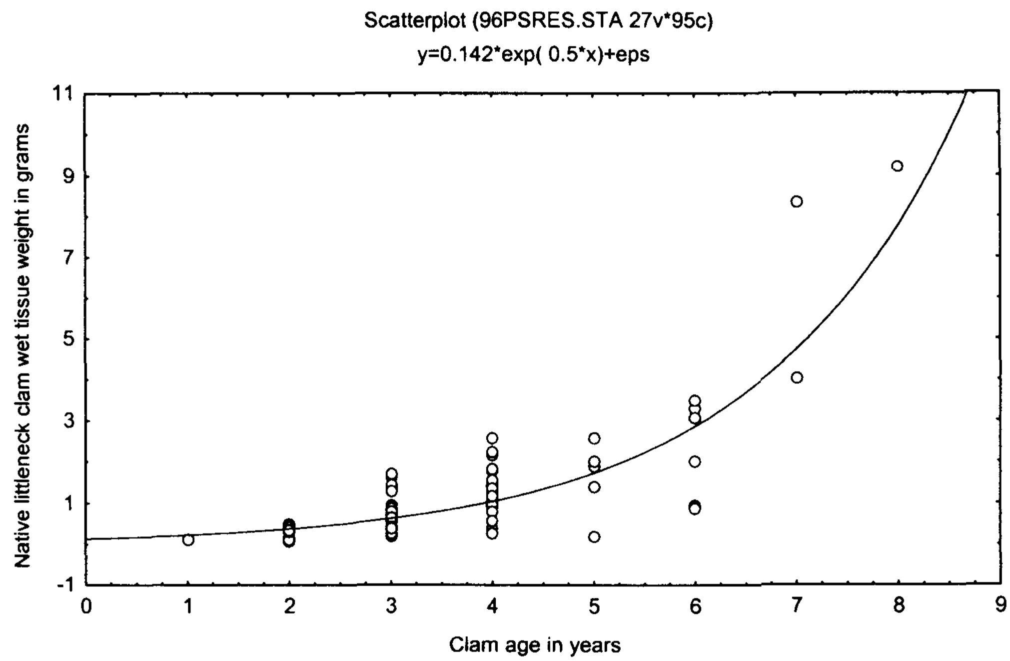


Figure 50. Wet tissue weight (grams) versus age (years) for native littleneck clams (*Protothaca staminea*) collected in 20, 0.1 m^2 quadrats at the Chenega Village shellfish beach on Crab Bay surveyed on June 29, 1996.

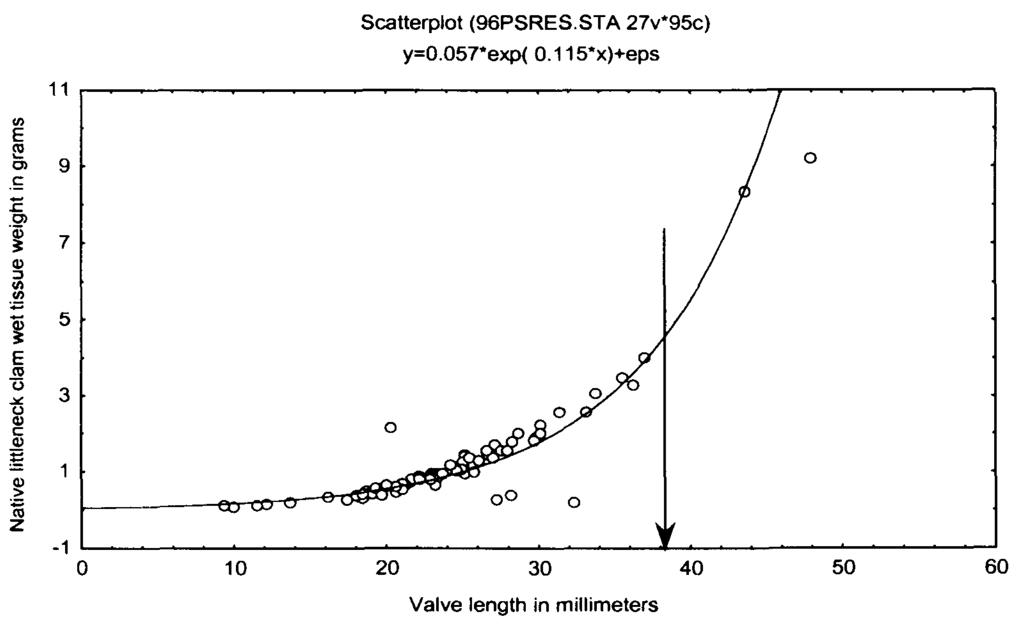


Figure 51. Wet tissue weight (grams) versus length (mm) for native littleneck clams (*Protothaca staminea*) collected in 20, 0.1 m^2 quadrats at the Chenega Village shellfish beach on June 29, 1996. The vertical solid line represents the minimum legal harvest size.

An examination of the length-frequency data provided in Figure (46) suggests that clams are being removed from the population at between four and five years of age and at a size of ca. 30 to 32 mm. Figure (51) indicates that wet tissues are accumulating rapidly between ca. 25 mm and at least 43 mm. A clam that is 8 years old with a valve length of approximately 42 to 45 mm will have wet tissue weights of approximately 7.5 grams. This is significantly higher than the wet tissue weight of 4.5 grams associated with a six-year-old clam just reaching the current minimum harvest size of 38 mm. Reducing the minimum harvest size to 30 to 32 mm (a size preceding the heaviest predation) would result in a harvest of approximately 2.5 grams wet tissue weight per clam. This discussion suggests that reducing the minimum harvest size is not an appropriate management tool to increase the subsistence food value of the existing clam population at Crab Bay. These conclusions are identical to those resulting from an analysis of the Tatitlek, Port Graham and Nanwalek data reported in Brooks (1995b).

Very few starfish were observed on this beach at the time of the survey. A small number of drills (*Nucella lamellosa*) were present in a patchy distribution throughout the bay. The intertidal associated with Crab Bay was covered with holes approximately 0.5 m in diameter and 15 to 20 cm deep. Village residents noted that some harvesting has occurred there. However, they associated most of the holes with sea otter predation. It was not possible to partition larger clam losses between human harvest and predation based on observation and the information received. However, several areas appeared to have been heavily disrupted.

Three water samples were collected at Chenega and shipped, on ice to Aquatic Environmental Sciences where they were examined for fecal coliform bacteria using the five tube MPN system. Observed fecal coliform levels were <2 in all three samples indicating no evidence of contamination during the period of this survey. Shellfish enhancement should coincide with the collection of sufficient water samples to certify this beach in accordance with procedures established in the National Shellfish Sanitation Program, Part I.

Ouzinke: The village of Ouzinke, located on the northeast tip of Kodiak Island (figure 52), is the other of the first two villages under this project to have an intertidal area surveyed and cataloged for future clam enhancement. As with the Chenega Bay village the selection of the survey site near Ouzinke was based on interviews with village residents.

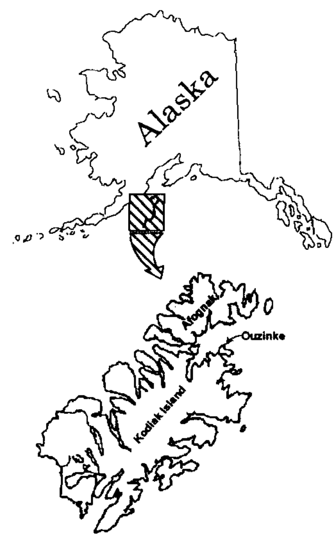


Figure 52. Ouzinke

The selected beach is located on Percoda (Cat) Isalnd at 57° 48.12' N and 152° 30.05'W, which is about 2.7 kilometers from the village. The area judged suitable as littleneck clam habitat measured 15 to 22 meters wide and 37 meters long (0.07 hectares). It was bounded on the west by a cobble field and on the east by a small stream flowing through fine sediments. Brown kelp (*Fucus cf. distichus* and *Laminaria cf. saccharina.)* was abundant in the nearshore area. The beach contained large quantities of broken butter clam (*Saxidomus giganteus*) shells. No "otter pits" were observed on this beach. Beach substrates consisted of mixed gravel (28 to 51%), sand (44 to 67%), and lesser amounts of silt and clay (5 to 6%). This mix is suitable for native littleneck clams. This beach is not suitable for cockles. However, a discontinuous eelgrass meadow within Camel Bay contained numerous cockle shells and appeared prime habitat for *Clinocardium*

Figure 53a. Intertidal area located on the northern side of Narrow Strait near the native village of Ouzinke surveyed on July 2, 1996. The inset depicts the algae covered substrate typical of this beach.

The area judged suitable as littleneck clam habitat measured 15 to 22 meters wide and 37 meters long (0.07 hectares). It was bounded on the west by a cobble field and on the east by a small stream flowing through fine sediments. Brown kelp (*Fucus cf. distichus* and *Laminaria cf. saccharina.)* was abundant in the nearshore area. The beach contained large quantities of broken butter clam (*Saxidomus giganteus*) shells. No "otter pits" were observed on this beach. Beach substrates consisted of mixed gravel (28 to 51%), sand (44 to 67%), and lesser amounts of silt and clay (5 to 6%). This mix is suitable for native littleneck clams. This beach is not suitable for cockles. However, a discontinuous eelgrass meadow within Camel Bay contained numerous cockle shells and appeared prime habitat for *Clinocardium* enhancement. Figure (53a) is a photograph of the beach. It was surveyed on July 2, 1996 during a –1.7 MLLW tide.

Figure (53b) describes the four transects (A, B, C and D) that were examined in the most suitable clam habitat observed at this beach. Six 0.1 m^2 shellfish samples were collected at 10' intervals (with a random start) along Transects A, B and C. Four 0.1 m^2 shellfish samples were collected along Transect D, surveyed at the 0.0' MLLW tidal elevation. A single sediment sample was analyzed, at a randomly chosen sample station, on each of transects A, C and D. This design resulted in a total of 22 shellfish and 3 sediment samples. In addition, the valves from 22 empty butter, softshell and littleneck clams were collected to supplement the age-length database. Data resulting from the analysis of empty valves was used only to determine coefficients for the von Bertalanffy model.

The beach considered suitable for native littleneck clam production had a shallow slope (2%) and aerobic sediments to a depth of greater than 20 cm. The foreshore consisted of a sand and gravel dunefield that had been stabilized by vegetation. This foreshore separates two embayments. A significant amount of seawater was observed percolating through intertidal sediments in the survey area.

Three sediment samples were evaluated for sediment grain size and total volatile solids. Sediments averaged 41.2 $\pm$ 29.6 % gravel, 53.2 $\pm$ 29.3% sand, 5.6 $\pm$ 1.7% fines (silt and clay) and 1.92 $\pm$ 0.85% TVS. Sediment composition on the surveyed portion of this beach is suitable for native littleneck culture. However, sediments on either side of the surveyed area are either too coarse or too fine to provide optimum culture conditions.

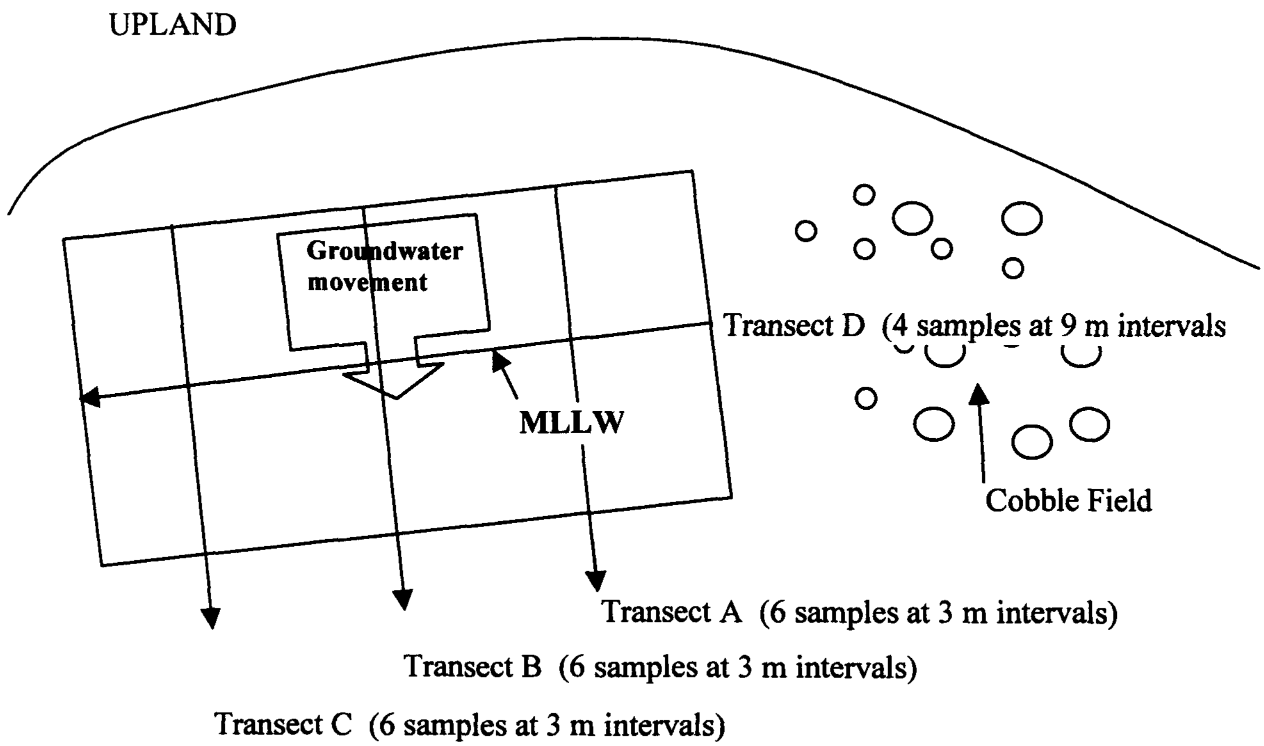


Figure 53b. Schematic diagram of the Ouzinke Village shellfish beach located on the southern shore of Narrow Strait.

The water temperature was 13.2 °C and salinity 31.2 ppt. Currents measured on the early ebb tide averaged 3.9 cm/sec and flowed east. The three water samples collected at this beach averaged 6.43 mg TSS/L and 2.33 mg TVS/L. These values suggested moderate to low levels of both primary productivity and suspended inorganic particulates. They do not suggest any reason why this beach would not be suitable for clam enhancement.

Eighty-three living bivalves were collected in the 22 systematic random samples from this beach (Table 14). An additional 19 bivalves were collected in random samples.

Table 14. Summary of bivalves collected in 22, 0.1 m^2 samples at the Ouzinke Village beach at Narrow Strait on July 2, 1996.

Species	Number
Protothaca staminea (native littleneck clams)	19
Saxidomus giganteus (butter clams)	61
Mya truncata (truncate softshell clams)	3

Softshell, butter and native littleneck clams have potential as subsistence shellfish resources. Local villagers stated a preference for butter clams, native littleneck clams and cockles. Of these, only the butter and native littleneck clams were found on the surveyed beach. Large, empty valves of *Clinocardium nuttallii* were observed in an eelgrass meadow and intertidal area at Camel Bay (local name) located three kilometers west of the surveyed beach.

Sixty-one (61) butter clams were observed in these samples. Over half of the observed butter clams were new recruits less than two years old. Twenty-two legal size butter clams were observed in the 22 samples. Descriptive statistics for a limited number of variables are presented in Table (15). Figure (54) provides a length-frequency summary for butter clams collected during this survey. A vertical line is displayed at the minimum legal size of 38 mm valve length.

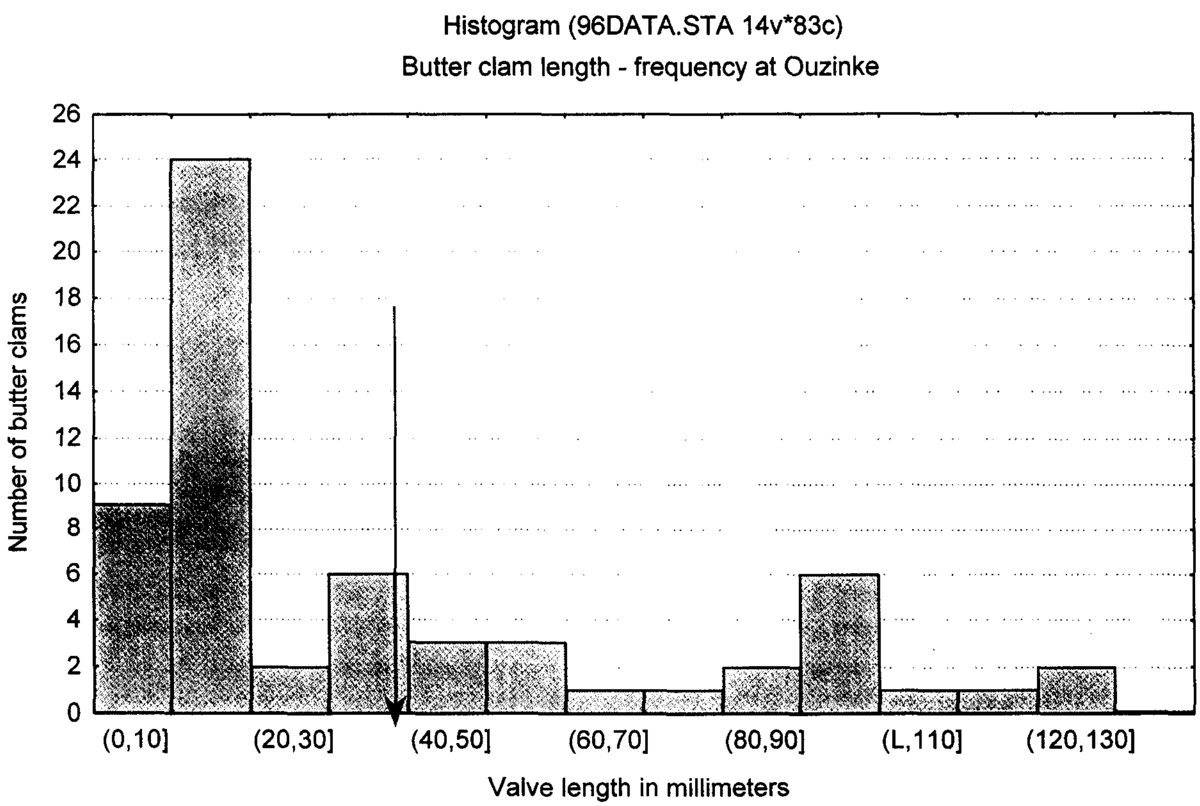


Figure 54. Length frequency histogram for butter clams (*Saxidomus giganteus*) collected in 22, 0.1 m^2 samples at the Ouzinke Village shellfish beach on July 2, 1996. The vertical line locates the legal limit (≥38 mm).

Non-linear regression was accomplished on aged living and empty butter clam valves to determine coefficients for the von Bertalanffy model. The resulting equation explained 94.1% of the variation and the ANOVA determined probability that the regression coefficients were all equal to zero was P = 0.000. Residuals in the analysis were not significantly different from a normal distribution (Kolmogorov-Smirnov; d = 0.087; p = n.s. @ $\alpha = 0.05$). Observed and predicted values are presented in Figure (55).

The resulting Von Bertalanffy growth equation for Ouzinke is compared with the results from Tatitlek and Nanwalek below. Large clams were not observed at either Passage Island or Tatitlek, but were observed in this survey. The larger asymptotic size predicted for Ouzinke may be due to the inclusion of larger clams in the database or it may reflect reduced predation (or other hypotheses). Living butter clams as large as 123 mm valve length were collected at Ouzinke. However, the valves on several of these were too worn for aging. The smaller coefficient on age suggests that butter clams grow more quickly at Ouzinke than at either Passage Island or Tatitlek or it may result from the inclusion of older and larger clams in this database.

Length of butter clams at Ouzinke (mm) $= 171.3(1 - \exp^{-0.050 \text{ x age in years}})$

Length of butter clams at Passage Island (mm) $= 84.4(1 - \exp^{-0.126 \text{ x age in years}})$

Length of butter clams at Tatitlek (mm) $= 126.5(1 - \exp^{-0.075 \text{ x age in years}})$

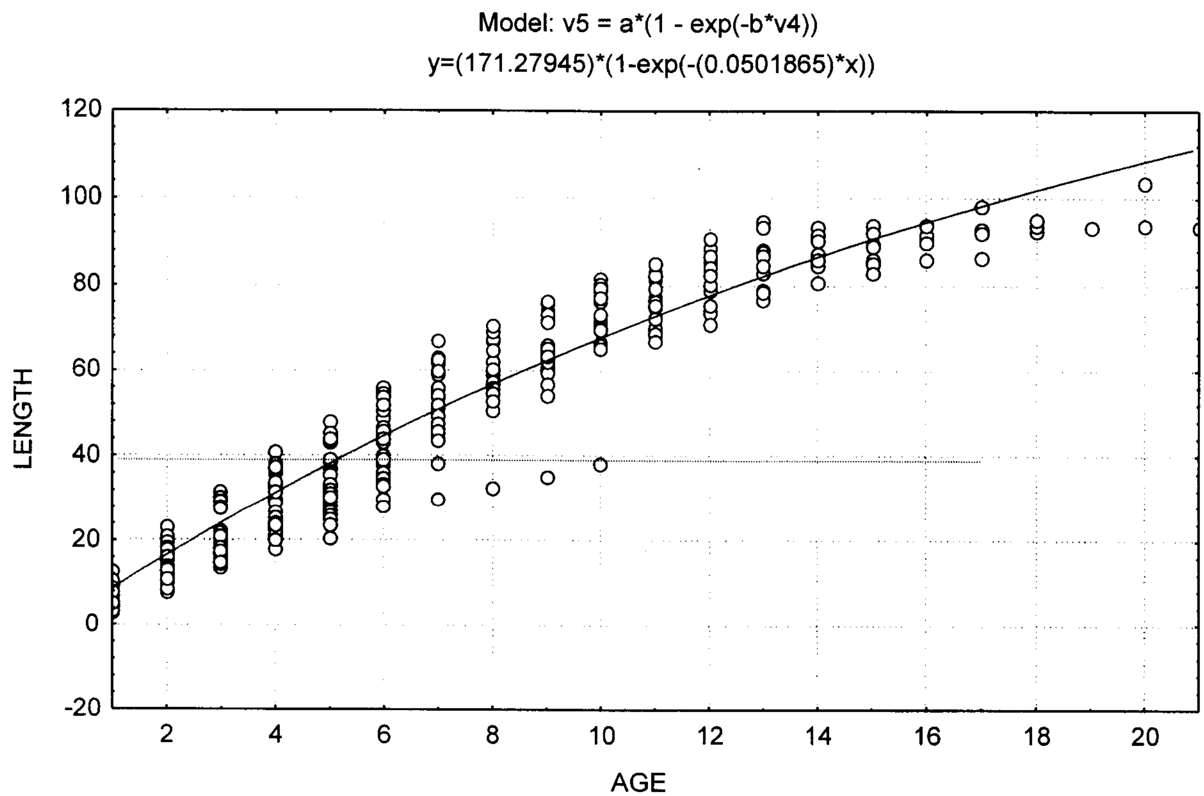


Figure 55. Solution to the von Bertalanffy model for butter clams collected in 22, 0.1 m^2 samples at the Ouzinke Village shellfish beach on July 2, 1996. The horizontal line represents the minimum legal size (38 mm).

Table 15. Summary descriptive statistics for living butter clams sampled at the Ouzinke Village's shellfish beach on July 2, 1996.

	Valid N	Mean	Minimum	Maximum	Std. Dev.

Length (mm)	61	37.9	4.22	123.4	35.3
Whole weight (g)	61	53.3	0.16	444.1	104.3
Age	60	6.1	0.00	21.0	5.7
Dry Condition Factor	34	0.9	0.13	2.2	6.2

An age-frequency histogram for butter clams is presented in Figure (56). Butter clams appeared to recruit into the legal size population at between age four and seven years (mean = 5.0 years). Recruitment of butter clams to this Ouzinke beach appears to occur regularly, but not in sufficient numbers to sustain subsistence harvests. If recruitment in 1994 and 1995 was indicative of other years, a significant proportion of the new recruits appear to have survived and entered the harvestable population. A number of hypotheses could be invoked to explain the

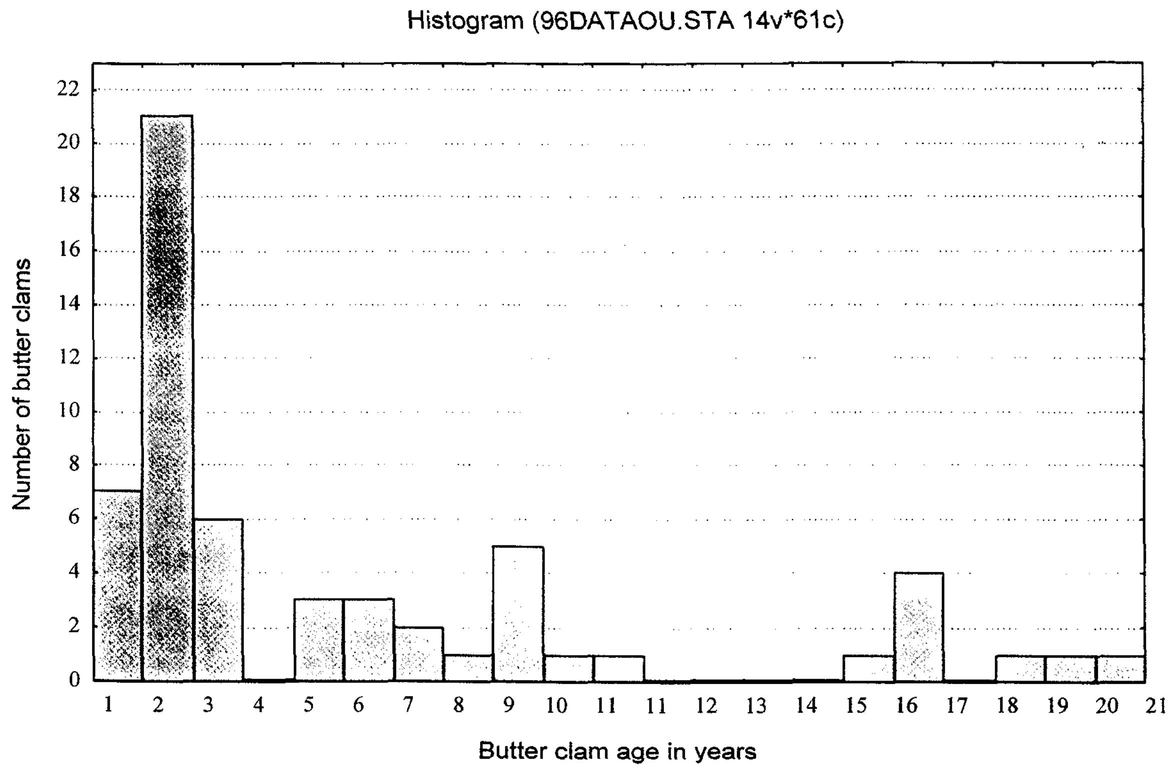


Figure 56. Age-frequency histogram for butter clams (*Saxidomus giganteus*) collected in 22, 0.1 m^2 samples at the Ouzinke Village, Narrow Strait, shellfish beach on July 2, 1996.

higher survival in this location. It is remote from the Exxon Valdez oil spill and may represent undisturbed conditions. However, presumptive otter pits were not found on this beach and very few drills or starfish were observed. Therefore, it is also possible that reduced predation is responsible for the increased number of large clams. Numerous other hypotheses could be invoked. None of these was investigated as part of this study.

Butter clams were growing and apparently surviving well on this Ouzinke beach. However, because of their propensity to retain paralytic shellfish poisons and lack of adequate hatchery technology, this species is not considered appropriate for enhancement. It should be noted that recruitment of butter clams is low but occurs regularly on this beach. This suggests that significant harvests of any kind would quickly deplete the standing biomass. A sound harvest management plan, developed and implemented by the elders of the Village of Ouzinke could help sustain these stocks.

This is the first beach surveyed by the CRRC study team that contained subsistence quantities of shellfish. The average sample weight of butter clams in each sample was 93.1 grams. The harvestable biomass (including 95% confidence limits on the mean), within the 60' x 120' survey area was 670.3 $\pm$ 297.3 kilograms. Most of these clams were collected near 0.0' MLLW.

Nineteen (19) native littleneck clams were observed in the 22 samples collected at the Ouzinke shellfish beach on Narrow Straits. Summary statistics describing littleneck clams are presented in Table (16).

Table 16. Summary descriptive statistics for living native littleneck clams sampled in 22, 0.1 m^2 quadrats at the Ouzinke Village's beach on Narrow Strait on July 2, 1996.

	Valid N	Mean	Minimum	Maximum	Std. Dev.
Length (mm)	19	29.6	6.97	55.01	16.61
Whole wt. (g)	19	12.1	0.07	43.03	13.91
Age (years)	19	4.9	1.00	11.00	3.36
Dry Condition	14	0.48	0.23	0.79	0.18
Wet Tissue Wt (g)	14	6.96	0.55	18.53	5.83

The largest native littleneck clam had a valve length of 55 mm and weighed 43 grams (10.5 per pound). Eight (8) legal size native littleneck clams were obtained from the 22 quadrats included in the systematic random sample. That is less than one legal size clam per square foot and demonstrates the lack of subsistence littleneck harvest available on this beach. Figure (57) suggests steady, but low recruitment (or survival of recruits past settlement) at this beach.

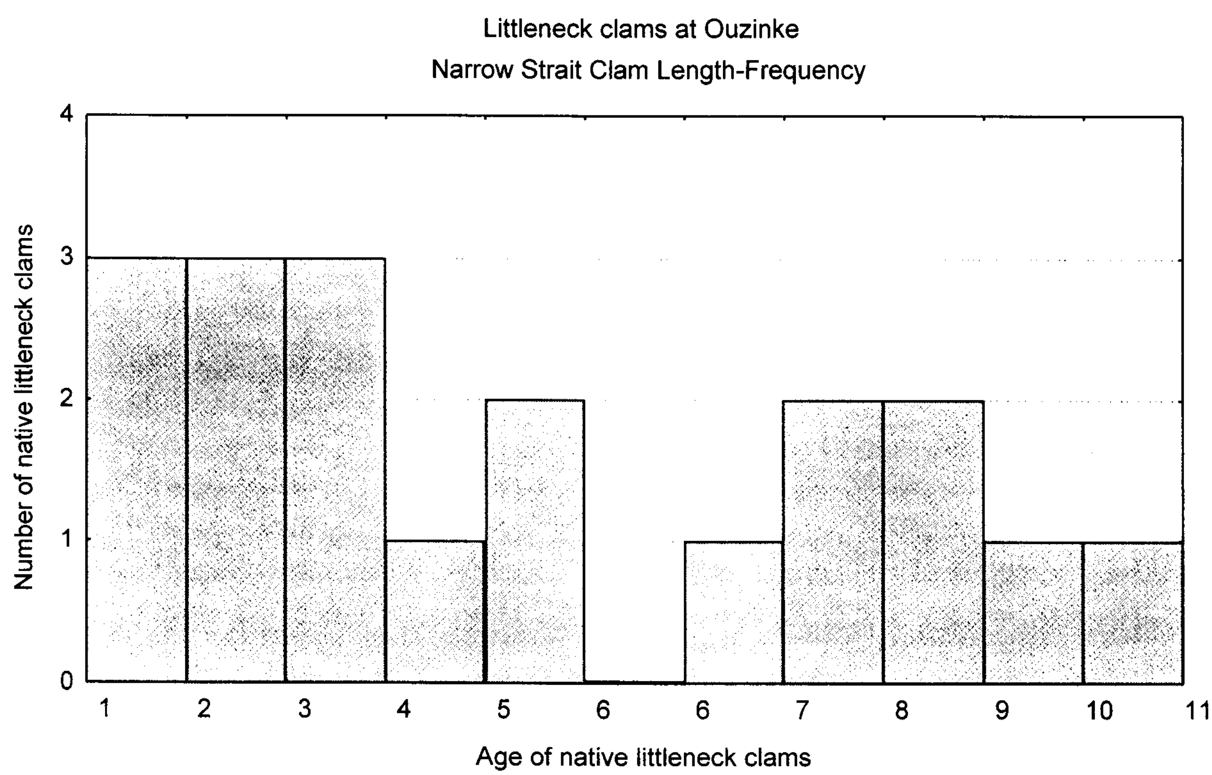


Figure 57. Age – frequency histogram for littleneck clams collected in 22, 0.1 m^2 quadrats at the Ouzinke shellfish beach on July 2, 1996.

Further examination of the population was accomplished using the length - frequency histogram provided in Figure (58). These two histograms suggest that recruitment is generally reliable but low at this site. It also appears reasonable to conclude that (assuming current recruitment reflects past recruitment) survival is good. The frequency observed in each of the year classes in Figure (54) should be divided by 2.2 to obtain the number of recruits per square meter. Doing this suggests that recruitment in 1993, 1994 and 1995 resulted in between one and two littleneck clams surviving per square meter until 1996. This is far below the minimum of 200 to 300 clams per square meter needed to fully utilize a quality habitat such as this. It appears that supplemental seed would benefit future bivalve harvests at this beach.

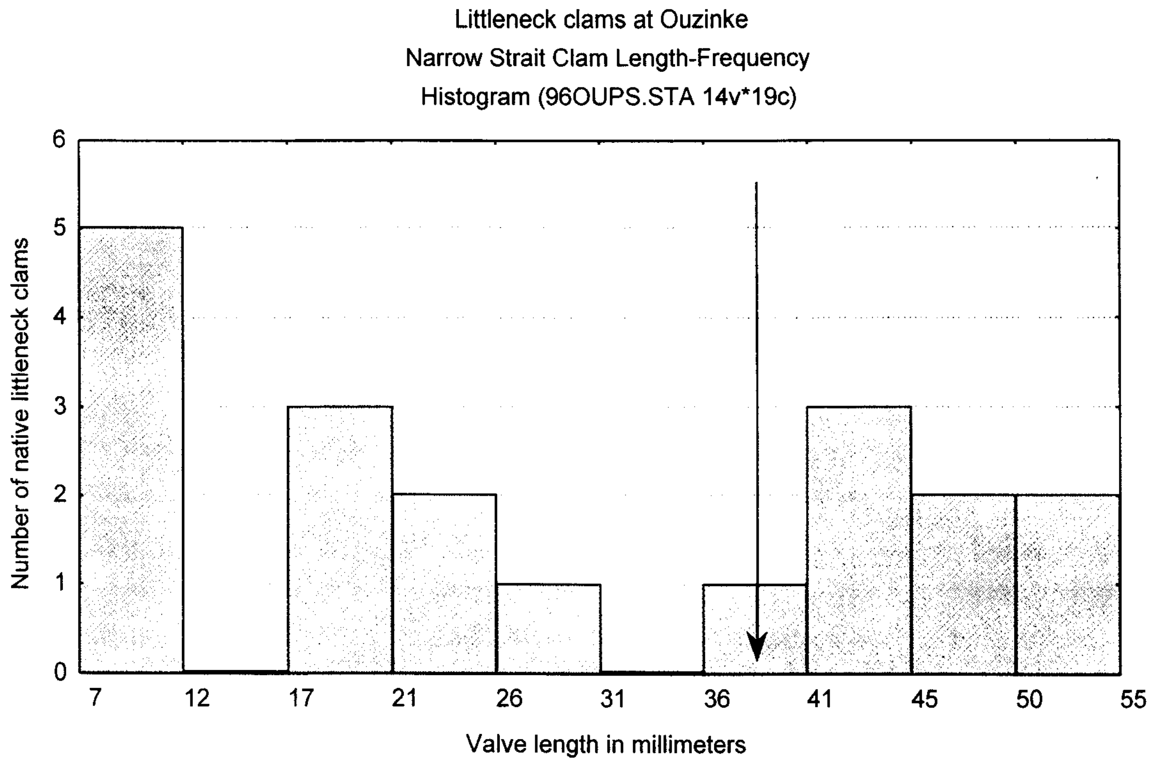


Figure 58. Length - frequency histogram for littleneck clams collected in 22, 0.1 m^2 samples collected at this Ouzinke beach on July 2, 1996. The vertical line represents the minimum legal size of 38 mm.

Current clam densities are insufficient to warrant subsistence harvests of littleneck clams at this Ouzinke beach. However, a few littleneck clams will be retrieved during a butter clam harvest. Older native littleneck clams are present as a significant proportion of recent recruitment. However, too few native littleneck clams were obtained in this survey to warrant any conclusion regarding survival. The relative absence of predators suggests that extensive cultivation without a need for predator exclusion netting may be appropriate on this beach.

Regression coefficients were developed for the von Bertalanffy model using nonlinear regression. The resulting equation explained 93.7% of the variation and the ANOVA determined probability that the regression coefficients were all equal to zero was P = 0.000. The residuals were not significantly different from a normal distribution (Kolmogorov-Smirnov; d = 0.11; p = n.s. @ $\alpha = 0.05$). Clam lengths to 55 mm were available for the analysis. Predicted and observed values of valve length, as a function of age, are presented, together with the regression line in Figure (59). This equation was solved for a length of 38 mm to obtain the average age of recruitment into the legal size population. Based on the von Bertalanffy model, the average age of recruitment to a size $\geq$ 38 mm was 6.13 years. The unexpectedly high maximum length of 73.8 mm may be associated with higher growth rates throughout the lifespan of this species in this part of Alaska. Under any circumstances, clams with valve lengths longer than 55 mm were not included in the database and extrapolation to lengths greater than that is inappropriate.

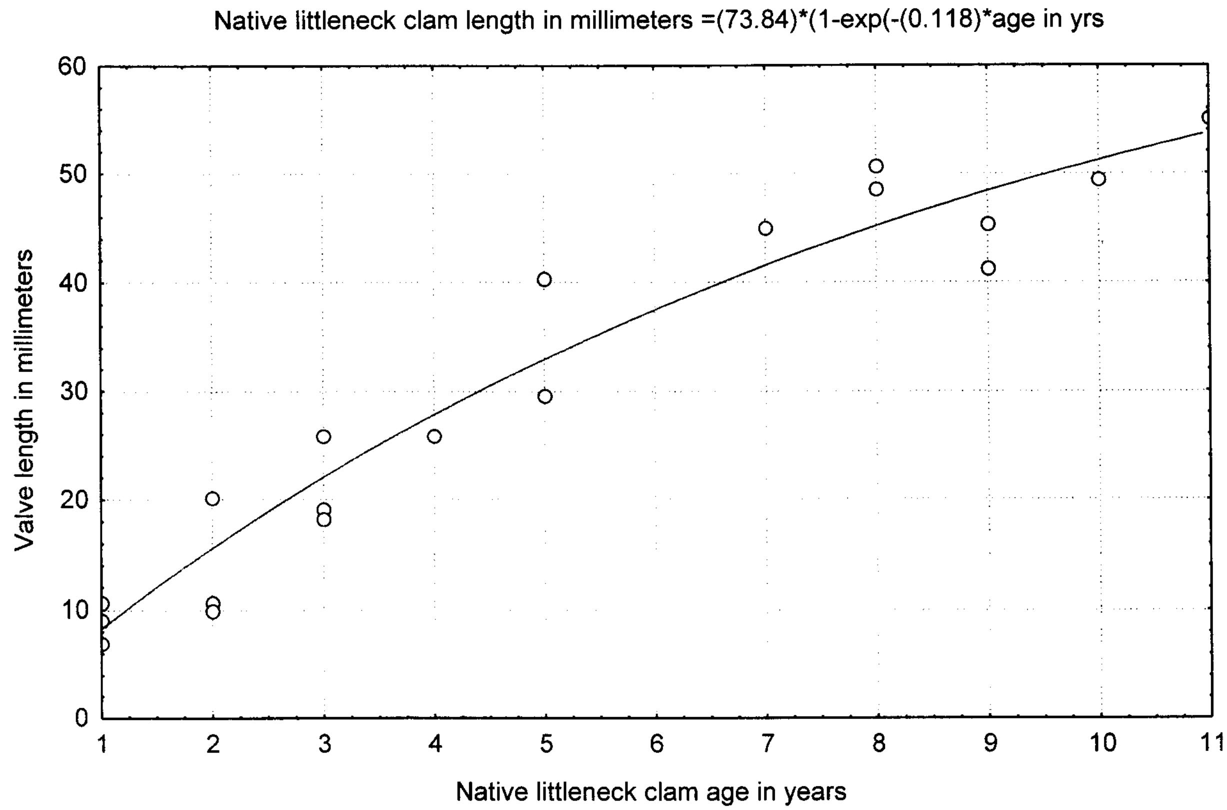


Figure 59. Valve length (mm) as a function of age (years) for native littleneck clams (*Protothaca staminea*) collected in 22, 0.1 m^2 quadrats at the Ouzinke shellfish beach on Narrow Strait on July 2, 1996.

$$\text{Native littleneck clam length at Ouzinke (mm)} = 73.8(1 - \exp^{-0.118*\text{age in years}})$$

Three water samples were collected at the survey beach and returned to Aquatic Environmental Sciences at 4°C where they were examined for fecal coliform bacteria using the five tube MPN method. Fecal coliform bacteria were < 2/100 ml in all samples. This analysis does not satisfy the needs of the National Shellfish Sanitation Program. However, it suggests that there is no continuing source of fecal coliform bacteria at this beach.

Discussion

- **Existing bivalve resources:** The numbers of clams at the Nanwalek site were too few to warrant a subsistence harvest. There were also few clams available for harvest at the Tatitlek village beach, although there were significant quantities of small mussels

(*Mytilus edulis trossulus*), along the extreme high tide line. There were no harvestable clams found on the Port Graham beach or at the Chenega Bay beach.

There is currently a significant shellfish biomass available for harvest on the Ouzinke beach. Butter clams comprise the majority of the harvestable biomass. The total biomass on this single beach has been estimated at 670.3 $\pm$ 297.3 kilograms. The majority of these are large (older) butter clams.

- **Natural recruitment:** On all beach sites surveyed the natural recruitment of littleneck clams to the legal harvest size was deemed to be insufficient to sustain a subsistence harvest. It appears that the main reasons for the low recruitment are slow growth and wild predation.
- **Age at harvest size:** The average age at harvest size for littleneck clams at all five survey sites and tidal elevations (-1.5 to +1.5 MLLW) combined was around 6 years with a range of 4 to just over 7 years. As expected, growth was slightly slower at the higher tidal elevations.
- **Predation:** There appeared to be a significant level of invertebrate predation at the Tatitlek site, mainly by starfish although crabs and drills were also observed. Far fewer, and in some cases no, invertebrate predators were observed at the other sites. There were signs of what appeared to be sea otter predation at all the sites except Ouzinke. It was not possible to differentiate sea otter predation from human activity by the small round pits that were observed at the survey sites, but the local residents attributed them to sea otters.
- **Optimum minimum harvest size:** Starting at around 20 mm in valve length the wet tissue mass of a littleneck clam begins to increase nearly exponentially. A 50% increase in valve length from 20 mm to 30 mm results in a 200% increase in wet tissue mass. An additional 27% increase in valve length from 30 mm to the commercial legal harvest size of 38 mm results in an additional 200% increase in wet tissue mass. Although the large increase in wet tissue mass versus valve length appears to continue through a valve length of at least 45 mm the sampling conducted at the project sites indicates that clams this size are rare.

  An optimum minimum harvest size would be the largest size still well represented in the population. At the sites sampled under this project that size would be about 30 mm. Unfortunately a clam that size yields very little meat. A reduction in predation may allow more clams to reach a larger size.

Clam Enhancement Studies:

Methods

Educational workshops were held for the villages of Tatitlek, Nanwalek and Port Graham prior to establishing the culture studies at each village. These workshops consisted of two parts. The first session began with a discussion of the 1995 surveys at each Village and a description of what was learned, including management recommendations specific to each village. This was followed with a detailed description of native littleneck clam biology, culture techniques (largely borrowed from the culture of manila clams (*Tapes philippinarum*)) and enhancement recommendations for each Village. The importance of shellfish sanitation and the requirements of the National Shellfish Sanitation Program were reviewed, as was the need for monitoring for paralytic shellfish poisoning (PSP). Three copies of the books *Introduction to Shellfish Aquaculture in the Puget Sound Region* (Magoon, Washington Department of Natural Resources, undated) and *Guide to Manila Clam Culture* (Toba, *et al.*, 1995) were distributed in each village.

The second part of each workshop was devoted to introducing village participants to the shellfish enhancement studies being undertaken at each village. The reason for each protocol element was discussed and precision and fidelity in completing the quarterly sampling emphasized. Each village was provided with a set of tools, protocols and data sheets necessary for conducting the quarterly sampling. The following equipment was provided to each village:

- Two sets of stainless steel Vernier calipers and two cafeteria trays for sorting shellfish
- One hand trowel and two clam harvest rakes
- One hard bristle brush for cleaning clam cages
- All bags, nets, electrical ties, rebar, tags, data sheets and data transmittal sheets necessary to complete the first years' sampling.

Villagers were instructed in the use of the Vernier calipers. Hands-on practice was obtained as the participants measured each of the 900 clams used in the caged growth and mortality studies. Nine village residents attended the combined Nanwalek (4) – Port Graham (5) session and six people were present at Tatitlek. These same people participated in preparing the study sites and planting seed. A great deal of interest (questions and discussion) was expressed by participants with regard to the biology of clams, the time required to reach legal size, and the potential for increasing subsistence harvests through enhancement.

The enhancement study design illustrated in Figure 60 was used at the Nanwalek, Port Graham and Tatitlek sites. Approximately 8,100 seed averaging about 12.5 mm in valve length was used at each site. The design included three replicates of each of the following treatments laid out using a properly leveled transit, aluminum stadium and a 300-foot fiberglass tape.

- One hundred native littleneck seed clams were individually measured and placed in each of nine half Norplex™ bags. These were raised at three tidal heights (-1.5', 0.0' and +1.5' MLLW). Nine hundred clams were grown in bags at each beach. One hundred littleneck seed clams were individually measured and placed in each of nine half Norplex™ bags for the detailed growth and mortality study. The valve lengths of all clams placed in these bags was measured to the nearest 0.1 mm using vernier calipers. Clams placed in bags were a random sample from the seed used in other parts of the study. Therefore, the mean lengths of clams in the bags were used as the mean lengths of the clams seeded into other parts of the study. Measurement of these clams provided a chance for village culturists to use the vernier calipers and to record data. Clam bag ends were secured with four electrical ties on one end and a 1-1/4" piece of split PVC pipe on the other end. Each bag received a shovel full of sieved (½" sieve) gravel. Bags were then nestled into the substrate to a minimum depth of 4". The top surfaces of each bag extended one inch above the substrate. Each bag was secured with extra large electrical ties, to a piece of ½" rebar driven into the substrate to a minimum depth of 18" or when hitting bedrock. These were placed at three tidal heights (-1.5', 0.0' and +1.5' MLLW). This part of the study required measurement of 900 clam seed per village.

sprinkled on top of the sediment in the bag prior to securing the open end with split PVC pipe and electrical ties. The villager crews were cautioned to retrieve clam bags individually and to measure and replace the clams in one bag before removing the next bag.

Sampling during the winter quarter was very difficult due to weather and darkness and was curtailed. The summer sample was considered less important than the spring and fall samples and was canceled to reduce costs. The actual sampling dates are presented in table 17.

Table 17. Sampling dates for growout trials. Dates in growout are provided in parentheses.

Nanwalek	Port Graham	Tatitlek
July 5, 1996 (0)	July 4, 1996 (0)	June 29, 1996 (0)
	October 24, 1996 (112)	September 27, 1996 (90)
May 6, 1997 (307)	March 11, 1997 (250)	January 14, 1997 (199)
July 22, 1997 (384)	July 22, 1997 (383)	July 25, 1997 (391)
	November 15, 1997 (499)	November 26, 1997 (504)
April 24, 1998 (660)	April 25, 1998 (660)	April 24, 1998 (652)
	March 20, 1999 (989)	December 12, 1998 (896)
September 8, 1999 (1162)	September 8, 1999 (1162)	September 10, 1999 (1168)

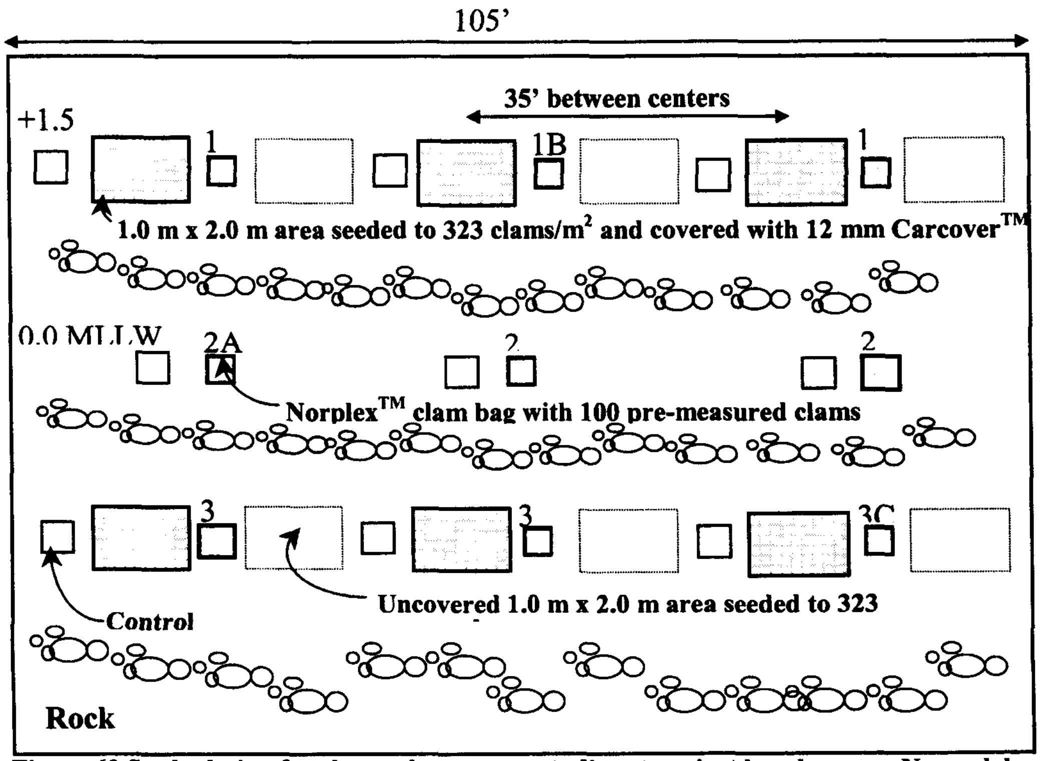


Figure 60 Study design for clam enhancement studies at project beaches near Nanwalek, Port Graham and Tatitlek.

- Clams were seeded at a density of $323/m^2$ into three replicated plots that had been cultivated to a depth of 15 cm to remove existing clams, large rock and to loosen the substrate. Three replicates were placed at each of two tide levels (-1.5' and +1.5' MLLW). A minimum of 4' was left between each treatment and 10' between each block. This provided access to the various treatments for sampling without disturbing adjacent plots. All large (>10.0 cm diameter) rock and cobble was removed from the area to be seeded. The area was dug to remove all clams larger than 1.0 cm and raked to provide a smooth surface. Plastic netting was precut to a dimension of 9' x 6'. It was secured in a trench on all four sides of each 1.0-meter by 2.0-meter plot. Each plot was marked with PVC pipe. Each piece of PVC pipe had the plot number written on it (i.e. A +1.5, etc.). Sediment samples were taken adjacent to each set of treatments for baseline analysis of total volatile solids and sediment grain size. In addition to treatment samples, control stations were sampled annually and processed in a similar manner.
- Clams were also seeded at a density of $300/m^2$ into replicated plots identical to those described above – but without protective plastic netting. This treatment was established to examine the efficacy of extensive enhancement with minimum labor and ongoing management.
- For the seeding of the netted and uncovered areas the clam seed were divided into 12 sub-samples of 600 clams each by determining the number of clams held in a four ounce beaker, followed by volumetric division. Clams were sprinkled onto the netted and un-netted sites as the flood tide covered them. This required 600 clams/station x two treatments (netted and uncovered) x two tidal heights (+1.5 feet and -1.5' MLLW) x three replicates = 7,200 clams per village.
- An untouched control area was established at each of the nine blocks to provide a natural reference.
- For sampling the covered, uncovered and control areas a coffee can quadrat with a diameter of 6" (0.0182 m^2) was used to remove all substrate and clams to a depth of approximately 15 cm. This material was carefully sieved on 1.0 mm screens and the length of all clams measured using an electronic caliper. The clams were returned with the sieved sediment to the location from which they were taken. A systematic random sampling plan was used in this evaluation. The distance above and to the right of the lower left-hand corner of a PVC pipe quadrat was randomly determined for each site. The intersection of these two coordinates described the location of the sample. Samples were taken from the upper right hand quadrant of the intersection. This arrangement is described in Figure (61). Only two samples were collected from each plot to minimize disturbance of the small culture areas. The length and identity of each bivalve was recorded. Thirty-six samples were collected at Murphy's Slough and at Passage Island. Fifty-four samples were collected at Tatitlek.

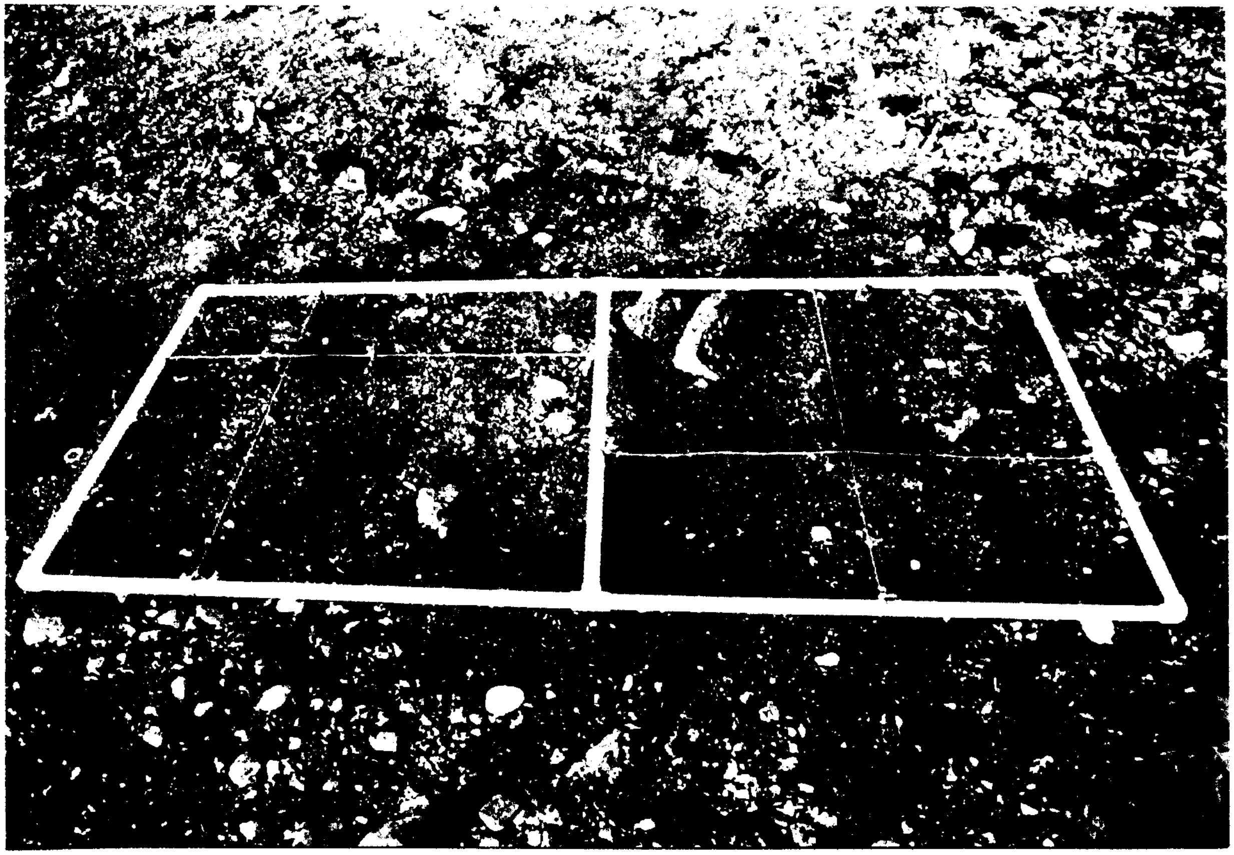


Figure 61. Apparatus used to define the sample location in unseeded control and the protected and unprotected seeded areas.

In addition to sampling the clams at the growout sites the sediment in the protected, unprotected and control areas of each site was sampled in 1998 and 1999 for sediment grain size distribution (SGS), total volatile solids content (TVS) and total sulfide. The SGS was obtained by removing the top two centimeters of the sample area. The sample was then examined for clams, homogenized in a stainless steel bowl, and then placed in a pre cleaned 250 ml HDPE bottle. Approximately 35 grams of the sample were dried in an oven at 92° C and processed using the sieve and pipette method of Plumb (1981). The sieves used for the SGS analysis had mesh openings of 2.0, 0.89, 0.25 and 0.063 mm. Particles passing the 0.063 mm sieve during initial wet sieving were analyzed by sinking rates in a column of water (pipette analysis). Data were arcsin(sqrt(proportion)) transformed prior to analysis.

For the TVS analysis a 50-gram surficial sediment sample, excluding material $\geq$ 2.0 cm was taken from the top two centimeters of the substrate. These samples were dried at 103 $\pm$2° C in aluminum boats that had been pre-cleaned by ashing at 550° C for 30 minutes. Drying continued until no further weight reduction was observed. The samples were then ignited at 550° C until no further weight loss was recorded. Total Volatile Solids were calculated as the difference between the dried and ashed weights as a proportion of the sample dry weight. Data were arcsin(sqrt(proportion)) transformed prior to analysis.

Sediment samples for sulfide analysis were fixed in the field by adding 0.5 ml of two normal zinc acetate. Sulfide analysis was accomplished using an Orion™ ISE/pH/mV/ORP/temperature meter model 290A with a Model 9616 BNC *ionplus* Silver/Sulfide electrode. The meter has a concentration range of 0.0000 to 19900 µmoles and a relative accuracy of $\pm$ 0.5% of the reading. Detailed procedures for standards and buffer preparation, and analysis are contained in Brooks (2000b).

Water samples were collected in April 1998 at each project beach site to determine the concentration of fecal coliform bacteria and to analyze the total volatile solids (TVS) and total suspended solids (TSS).

For the fecal coliform bacteria test three samples were collected at each project beach site in autoclaved, 500 ml HDPE sample bottles by immersing the covered sample bottle to a depth of 0.5 meters in undisturbed water. The bottle cap was then removed and the bottle filled to the top with no headspace. Clean, shoulder length gloves were used during this sampling. Care was taken to not disturb sediments by wading or poling of the skiff during water sampling. Samples were held on ice at 4° C until examined within 96 hours (holding time exceeded the recommendations of APHA, 1975). The number of fecal coliform bacteria was determined in each sample using the five-tube MPN method (APHA, 1975, Method 908A). The recorded values were compared with the requirements of the National Shellfish Sanitation Program Manual of Operations, Part I (NSSP, 1995).

For the TVS and TSS analyses separate 500 ml samples of water were collected from each site. The samples were collected at mid depth from undisturbed water with a minimum depth of one meter and held at 4° C until analyzed. TSS was determined by filtering a homogeneous sample through a Whatman glass fiber filter (0.45 µm particle retention) that had been ashed at 550° C for 20 minutes and pre-weighed. The filter, with the residue from a 350 ml water sample, was repeatedly dried at 103° C and weighed until no further weight loss was observed (generally one hour). The filter, with dried and weighed residue, was then ignited in a muffle furnace at 550° C for twenty minutes. TVS and TSS were recorded as mg/L.

Results

Tatitlek: The study site at Tatitlek lies within easy walking distance of the Village. The intertidal consists of shale outcroppings that have been broken into angular rock, cobble, gravel and finer material. Substrates tended to be somewhat compacted and coarse, and they were considered suitable for enhancement only with substantial cultivation effort. This is particularly true with intensive culture techniques that require use of plastic bags or netting. In addition, a moderate amount of substrate movement was experienced during the winters of 1997-98 and 1998-99. However, the residents of Tatitlek maintained the integrity of the study site through regular maintenance. Figure (62) depicts the enhancement beach and its relationship with the village.

Figure 62. Traditional subsistence beach and the site of the 1995 – 1999 native littleneck clam enhancement studies at the Village of Tatitlek.

Figure (63) is a photograph of one of the netted replicates, taken in 1998, after a winter storm. The upper 5 to 7 cm of sediments around the plastic netting had been eroded and moved to other areas of the beach. The storms causing this erosion would have also washed small clams out of the sediments and deposited them elsewhere. Native littleneck clams were not found in the adjacent area that had been seeded but not protected. In this instance, the light plastic netting was effecting in stabilizing the area seeded with clams and an average of 65% of the seeded clams survived until last surveyed on October 27, 2000. No native littleneck clams were found in seeded but unprotected plots at the +1.5' MLLW level in 2000 and only five native littleneck clams were retrieved in nine samples collected from similarly seeded but unprotected areas at the 0.0' MLLW tide level. The storms that caused this erosion also damaged several of the netted plots. The nets were replaced during the 1998 field season.

Figure 63. Enhancement plots (1A) and (1B) on the Tatitlek shellfish beach. Beach substrates were stabilized under the seeded area that was protected with plastic netting. The unprotected area, located to the right in this photograph, was badly eroded and no clams were retrieved in two replicate samples from the unprotected plot in 1999 or 3 samples in 2000.

Protected and Unprotected trials were installed at three tidal elevations at Tatitlek (-1.5' MLLW, 0.0' MLLW and +1.5' MLLW) in 1996. Sediment grains size and sediment TVS were evaluated in 18 samples from Protected, Unprotected, and Control areas on April 26, 1998. Total volatile solids and total sediment sulfides were evaluated in twelve samples on September 9,1999. Proportional data (TVS and fines) were arcsine (square root) transformed (Zar, 1984) and analyzed using ANOVA and *t-tests*. Statistically significant differences ($\alpha = 0.05$) were not observed for the proportion fines (silt and clay) or TVS as a function of treatment (protected or unprotected), beach elevation (tidal height), or replicate (horizontal position on the beach) during either year. Sediment total sulfides were the most sensitive indicator of organic loading. While not statistically significant ($p = 0.27$), mean sulfide concentrations were nearly three times higher under plastic netting (76.3 µmoles) compared with the seeded, but unprotected, area (27.9 µmoles). The major effect of protecting clams with lightweight plastic netting at Tatitlek was to stabilize the substrate preventing its movement during storm events. These data suggest that fines and TVS do not accumulate under small plots protected with plastic netting on moderate to high-energy beaches.

Figure (64) describes the survival of native littleneck clams in bags at Tatitlek between 1996 and 1999. Significant differences in survival as a function of tidal elevation between –1.5' and + 1.5'

MLLW were not observed (ANOVA, F = 1.05, p = 0.35) at the end of the study. The increases in mean number of clams observed on July 1997 and December 1998 were due to recruitment into the bags where metamorphosed clams were protected from starfish, gastropod and possibly other predators. The decreases observed during winter months are pointed out in blue. The team leader did not examine these cultures in 1997 due to weather. Therefore, new recruits and species other than native littleneck clams were not removed from the bags in 1997. Butter clams (*Saxidomus giganteus*) and native littleneck clams less than 10 mm valve length were removed from the bags by the CRRC field team during the summer of 1998 and 1999. This problem is pointed out because it is likely that clams recruiting into the cages in 1997 may have grown beyond a size where they could be distinguished from the original 1996 seeding. This would cause an overestimation of clam survival and an underestimation of the samples' mean size.

The mean number of surviving clams was relatively constant during the summer months and declined most during winter. Either this may have been due to cold air temperatures during low tides or to stress associated with sediment movement around the protected cultures. No cause and effect relationship was determined for these small winter losses during this study. The number of clams counted in bags at the end of the study on September 9, 1999, was 65 percent of the 900 clams originally seeded into the nine bags

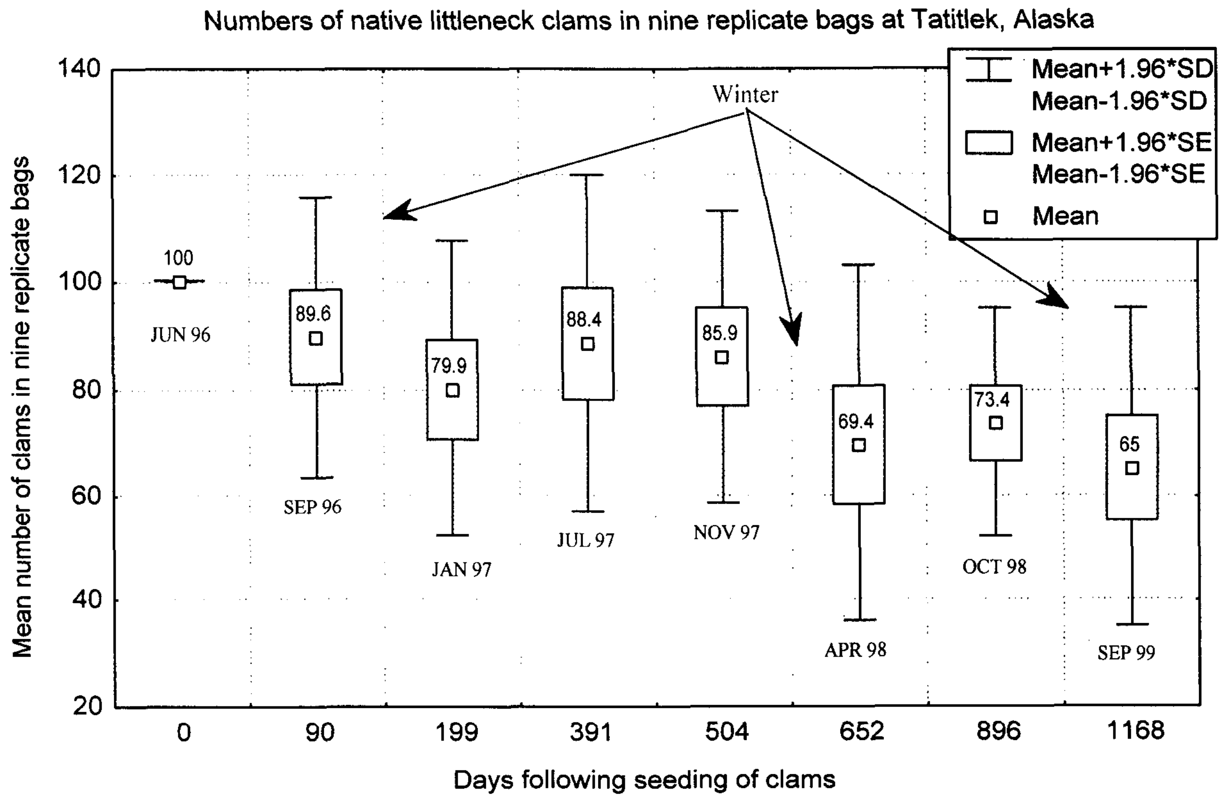


Figure 64. Mean number of surviving native littleneck clams in bags as a function of time (days) following planting on June 29, 1996 at the beach adjacent to the village of Tatitlek, Alaska. Significant differences in survival as a function of tidal height were not observed and the data was pooled.

Native littleneck clam seed was planted in Protected and Unprotected two square meter plots on July 5, 1996 at Tatitlek. Planting density was 300 clams/m^2. These clams were not sampled until April 26, 1998 when two 0.0186 m^2 samples were collected from each of three replicates at each of three tidal heights. This effort resulted in 6 samples per tidal height and 18 samples for each treatment (54 samples total). The mean proportion of surviving clams in each seeded treatment on April 26, 1998 is summarized in Figure (83). Five native littleneck clams were retrieved from Control Plot (A) and six from Control Plot (B) at the highest tide level (+1.5'). No native littleneck clams were retrieved from other Control plots. Figure (65) suggests that unprotected native littleneck clam seed survived adequately (mean for all elevations of 21% through the first 18 months of growout) on this beach. However, unprotected native littleneck clams did not survive as well at the lowest tidal height tested (-1.5' MLLW). This may be due to the large number of *Pycnopodia helianthoides* observed at the lower intertidal elevations. It would be interesting to monitor this area during high tides to determine how high this echinoderm ranges. The author has frequently observed sunflower stars subtidally in Puget Sound and less frequently intertidally where *Pisaster, Mediaster and Evasterias* species are more frequently observed. The survival of native littleneck clams in bags and under Carcover™ at Tatitlek is excellent and these techniques appeared valuable for enhancing subsistence harvests of native littleneck clams. Paired sample *t-tests* indicated that the number of clams surviving with protection was significantly higher than without (p = 0.05).

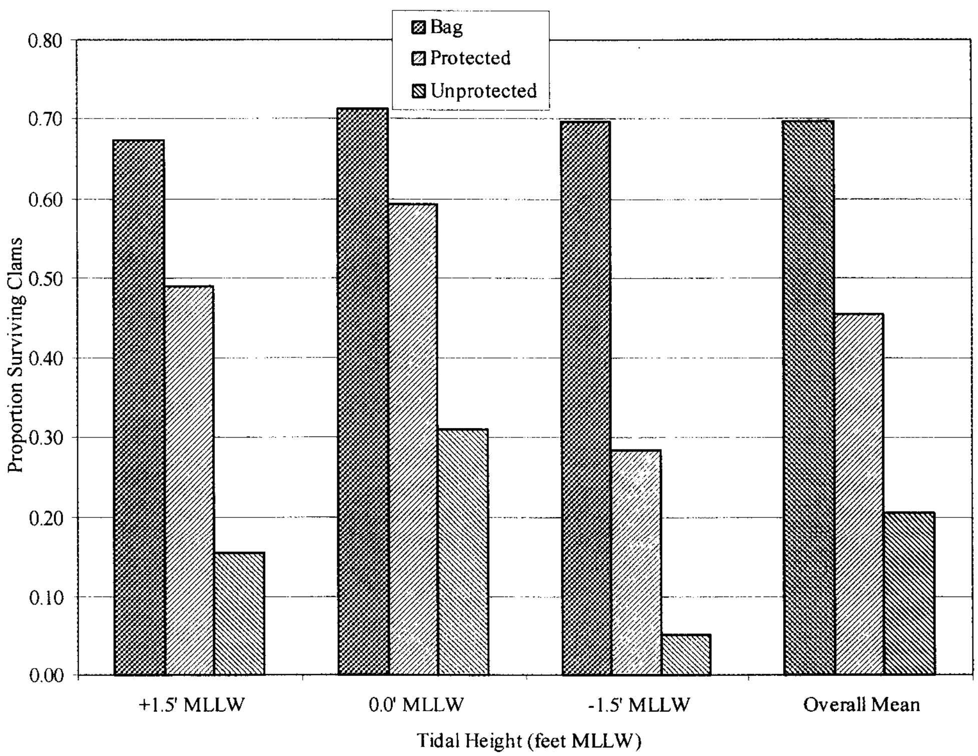


Figure 65. Proportion surviving native littleneck clams at Tatitlek as a function of tidal height and treatment (Bags, Protected with Plastic netting, or seeded but left Unprotected).

Table (18) provides summary statistics for survival and valve length observed in 54 sediment samples collected on September 9, 1999. The ratio of the number of clams observed in each of six replicate 0.0182 m^2 samples randomly collected in each treatment at each tidal height to the number seeded in 1996 is provided. This data must be interpreted with caution because as described in Brooks (1995b), recruitment of wild clams to the Tatitlek beach occurred on a regular basis from ca. 1991 to 1995. In addition, the storm during the winter of 1998 redistributed sediments and likely the clams in them over much of the beach that was not protected with plastic netting.

The discrete survival count data was transformed to continuous data using a Log(n + 1) transformation. The mean number of clams retrieved in 1999 samples differed significantly as a function of treatment (ANOVA, $F = 3.83$, $p = 0.036$). Post hoc testing using Scheffe's test indicated that significantly more clams were retrieved from under plastic netting when compared with the unseeded control areas ($p = 0.04$). The density of clams retrieved from protected and unprotected areas that had been seeded in 1996 were not significantly different ($p = 0.67$); nor were differences between seeded and unprotected areas and the control ($p = 0.21$).
The 1998 and 1999 results suggest that seeded areas contained significantly more clams at the end of three years than unseeded areas. However, while more clams were retrieved from seeded and protected areas when compared with seeded areas left unprotected, the differences were not significant at $\alpha = 0.05$. These data also support the 1995 report of consistent native littleneck clam recruitment at this beach. Together, these reports suggest that factors other than recruitment are responsible for the paucity of clams >38 mm observed on this beach.

Table 18. Proportion surviving native littleneck clams determined in six replicate 0.0182 m^2 samples collected at each of three tidal levels on September 9, 1999 following three years of field growout. The clams were originally seeded at a density of 300 clams per square meter in three replicate plots located at each of three tidal elevations. The seeded areas were cultivated and either protected with plastic netting or left unprotected.

Tidal Elevation	Type protection	Mean length (mm)	Number of clams	Proportion of seed
				+1.5'
Unprotected	18.7	22	0.58	
+1.5'	Protected	27.7	17	0.45
+1.5'	Unseeded control	12.8	4	NA
+1.5'	Bags	24.0	159	0.53
0.0'	Unprotected	17.6	16	0.42
0.0'	Protected	22.8	31	0.81
0.0'	Unseeded control	8.3	6	NA
0.0'	Bags	23.9	195	0.65
-1.5'	Unprotected	12.2	10	0.26
-1.5'	Protected	25.1	21	0.55
-1.5'	Unseeded control	9.6	5	NA
-1.5'	Bags	22.8	231	0.77

Figure (66) describes the growth of native littleneck clams in bags at Tatitlek with predictions from the von Bertalanffy model developed from the analysis of length and age during the 1995 baseline survey.

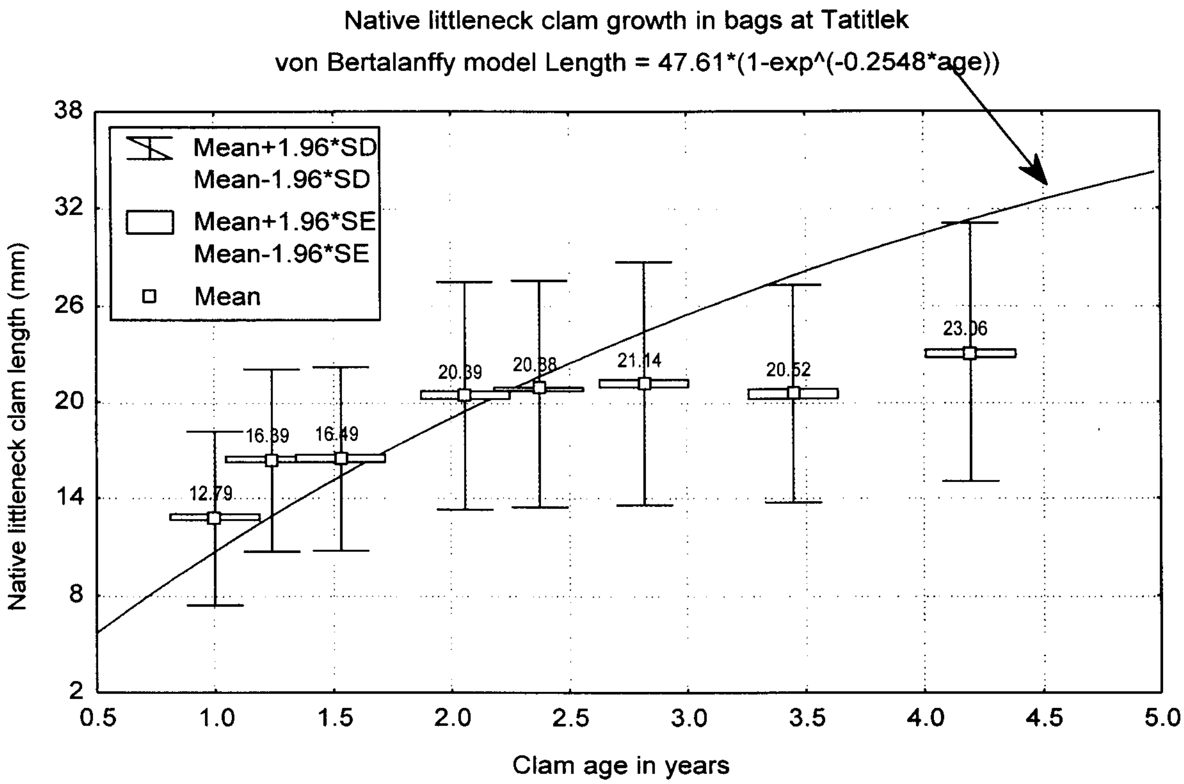


Figure 66. Mean lengths of native littleneck clam cohorts cultured at all tide heights in bags at Tatitlek between June 27, 1996 and September 9, 1999. Clams in bags were measured quarterly for the first two years during this study.

Von Bertalanffy predictions are greater than the mean for all ages greater than 2.2 years and little increase in the mean valve length of clams retrieved from bags was observed until the last year of the study. However, clams in the upper five percent of the observed sizes for clams grown in bags, as evidenced by the 1.96*standard deviation whisker in Figure (66), were growing in a manner similar to the von Bertalanffy predictions from 1998 until the end of the study.

Analysis of covariance with initial length as the covariate indicated that valve lengths on September 9, 1999 were significantly different as a function of treatment ($F = 44.20$; $p = 0.000$). Similar to the results from Port Graham, clams grown under netting had the longest mean length (27.2 mm) followed by clams grown in bags (23.49 mm). Native littleneck clams retrieved in samples from seeded, but unprotected, plots had the shortest mean valve length (17.26 mm). Post hoc testing using Scheffe's test indicated that the differences between mean valve lengths of native littleneck clams grown in bags or under plastic netting were not significant at $\alpha = 0.05$ ($p = 0.41$). The mean length of native littleneck clams from unprotected areas was significantly shorter than the mean length from bags ($p = 0.000$) or from under netting ($p = 0.000$).

These results are likely the result of recruitment of new clams into these cultures during the study. As previously discussed, recruitment of native littleneck clams at Tatitlek appears to occur in most years. The addition of these small clams into the cultures would cause an increase in the estimated survival and a decrease in estimated growth. Native littleneck clams less than the minimum size in the previous quarterly sample were removed from the bags by the author during each annual CRRC field season. However, the 1997 fieldwork was cancelled due to weather and new recruits were not removed from the bags until April 24, 1998. It is likely that some native littleneck clams recruiting after June 29, 1996 would have grown to a size that would be indistinguishable from the original seed. It is also likely that the significant disturbance in sediments caused by storms during 1997-98 and again in 1998-99 created stress in all hardshell clams on this beach. The significantly reduced clam size in the seeded but unprotected areas was likely caused by the loss of the planted seed during storm-associated redistribution of sediments (and the clams in them). As previously noted, sediments (and the clams seeded into them) were effectively stabilized under the plots seeded and protected with netting. Each of these factors likely contributed to these results.

The purpose of this effort was to evaluate the potential for enhancing native littleneck clam subsistence resources at native Alaskan villages. Figure (67) describes the length-frequency of native littleneck clams observed at Tatitlek on September 9, 1999 as a function of the type enhancement. Native littleneck clams retrieved from reference sediments were all less than 20 mm valve length and likely represent clams less than two years old. Clams retrieved from areas

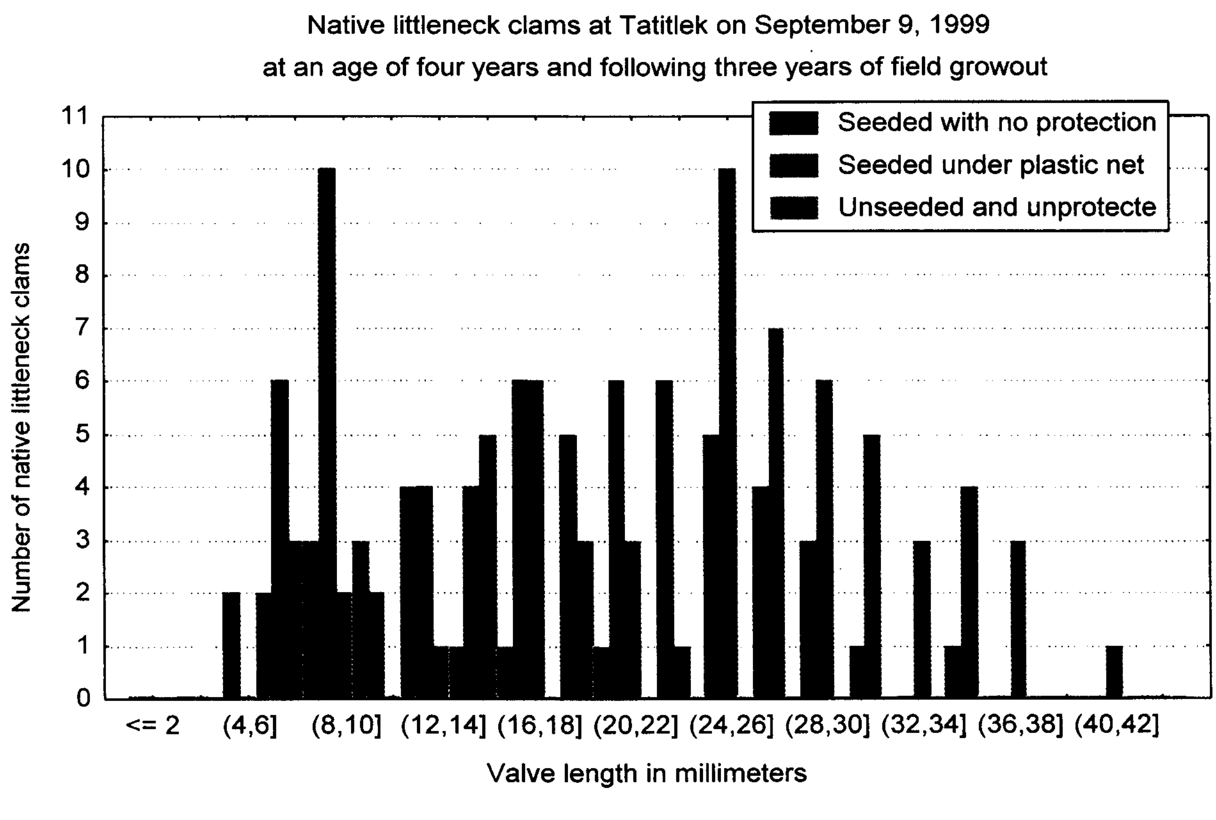


Figure 67. Length-frequency histogram describing the distribution of native littleneck clams retrieved on September 9, 1999. Significant differences in valve length as a function of tidal height were not observed and the results pooled.

that were seeded in 1996 and not protected with plastic netting show one mode at 8 mm valve length. These likely represent 1999 recruits. There is an apparent second cohort with a mode at 16 mm and a third at 20 to 22 mm. The largest clam in the seeded, but unprotected, area had a valve length of 34 mm. In contrast, the population of native littleneck clams retrieved from the seeded area that was protected with plastic netting was dominated by clams with valve lengths in the 24 to 26 mm range. One native littleneck clam retrieved from protected sediment samples recruited into the minimum legal harvest size of 38 mm during 1999 following 3 years of growout at an age of four years.

The field team evaluated native littleneck clams in three replicate 0.0182 m^2 sediment samples from under plastic netting at each treatment plot located at the 0.0' and +1.5' MLLW tidal heights during November 2000 (18 samples total). The marginal low tide prevented sampling the three replicates located at –1.5' MLLW. The results are presented in the length-frequency histogram provided in Figure (68). The location of the apparent year classes is based on a qualitative evaluation of the distribution and location of apparent modes. The median lengths associated with each year class are consistent with the growth observed at Murphy's Slough where the data was not confounded by natural recruitment. All clams were removed from the substrate during cultivation prior to seeding in 1996. Note that seven native littleneck clams were found with valve lengths exceeding the minimum harvest size. Despite the significant

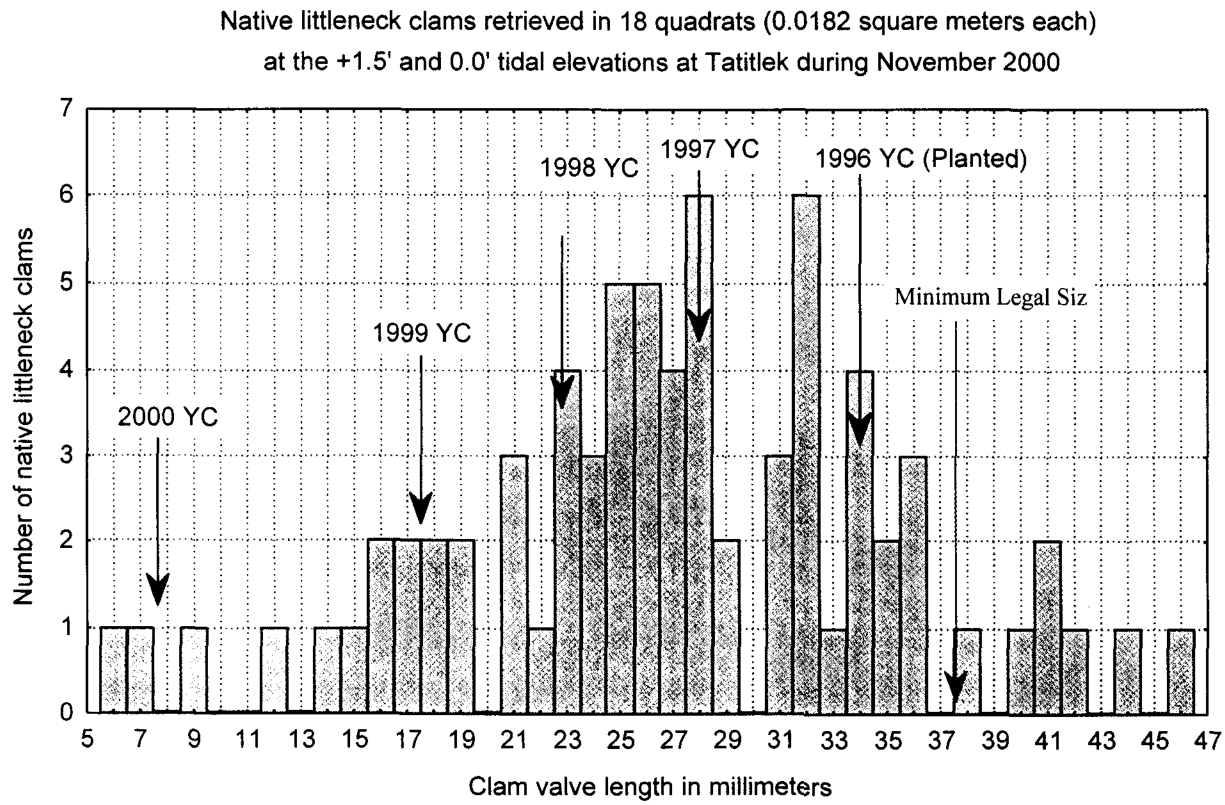


Figure 68. Mean lengths of native littleneck clams cultured under plastic netting at Tatitlek between June 27, 1996 and September 9, 1999. These clams were sampled once each year in 1998, 1999 and 2000.

sediment instability observed on this beach at the end of four years of growout, 7.1 percent of the clams originally seeded under plastic netting had survived to harvest size.

Native littleneck clam survival and growth data was confounded by the annual recruitment of clams into these cultures. However, this analysis indicates that in high-energy intertidal environments, plastic netting was effective in stabilizing the substrate and in retaining clams. In 2000, following four years of field growout, 7.1 percent of the number of clams originally seeded under plastic netting had valve lengths exceeding the minimum harvest size. The number of clams recovered from bags at the end of three years of growout averaged 65% of those seeded. However, an unknown number of those clams were likely new recruits added during the late summer of 1996 or in the spring and summer of 1997 when the bags were not screened by the principal investigator. The point is that survival in bags in this stressful environment was likely less than 65%. Very few clams recruited to and survived beyond the first two years in control areas and the population of clams resident in the seeded and unprotected treatments were smaller and less numerous than those in the seeded and protected area. Statistically significant (α = 0.05) differences in either growth or number of clams were not observed as a function of tidal height between –1.5' MLLW and + 1.5' MLLW.

Fecal coliform (FC) bacteria were detected in all three replicate water samples from Tatitlek taken on April 26, 1998. The Most Probable Number (MPN) was 55.4 FC/100 ml, which exceeded the NSSP standard MPN of 14.0 FC/100 ml for an Approved Harvest Classification. The second part of the NSSP standard states than no more than 10% of the samples can exceed 43 FC/100 ml. Two of the three samples exceeded this value (50 and 170). The source of this fecal contamination was not determined.

The water temperature at Tatitlek on April 26, 1998 was 6.5° C. Summer temperature measured on June 27, 1996 was 12.0° C. Total Suspended Solids were measured at 193.8 $\pm$ 95.7 mg/L and the mean TVS content was 14.1 $\pm$ 10.9 mg/L (mean $\pm$ one standard deviation). The source of the particulate inorganic matter is unknown. The high TVS suggested that there was a rich food resource in the water on this early spring day. Summer values recorded on June 27, 1996 were significantly lower at 3.27 mg TSS/L and 2.3 mg/L TVS/L.

Gastropod egg cases, likely from *Nucella cf. lamellosa*, were abundant and numerous adult gastropods were observed at Tatitlek. An army of *Pycnopodia helianthoides* was present below the +0.5' MLLW tide level during every field trip to this beach. *Pycnopodia helianthoides* was observed at a mean density of 0.6/m^2 at the 0.5' MLLW tide level during 1995 and four to six *P. helianthoides* were counted per square meter in front of the enhancement area on April 26, 1998. Figure (69a) depicts this assemblage, as it existed on the morning of April 26, 1998. Figure (69b) is a photograph of one of four-bushel baskets of starfish removed from the enhancement beach and deposited above high tide during 1996. Numerous shallow circular pits, possibly made by either sea otters or *P. helianthoides*, have been observed on this beach. It should be noted that no direct evidence of sea otter predation on clam cultures was observed during this study. *Pycnopodia helianthoides* has been observed excavating shallow depressions on this beach and several sunflower stars have been observed with intact clams (i.e. including the valves) in their guts.

Control of predatory gastropods and starfish is easily accomplished and should be part of any shellfish enhancement program. It is possible that removal of the large numbers of starfish on the beach would allow a larger portion of the naturally set native littleneck clams to reach harvest size.

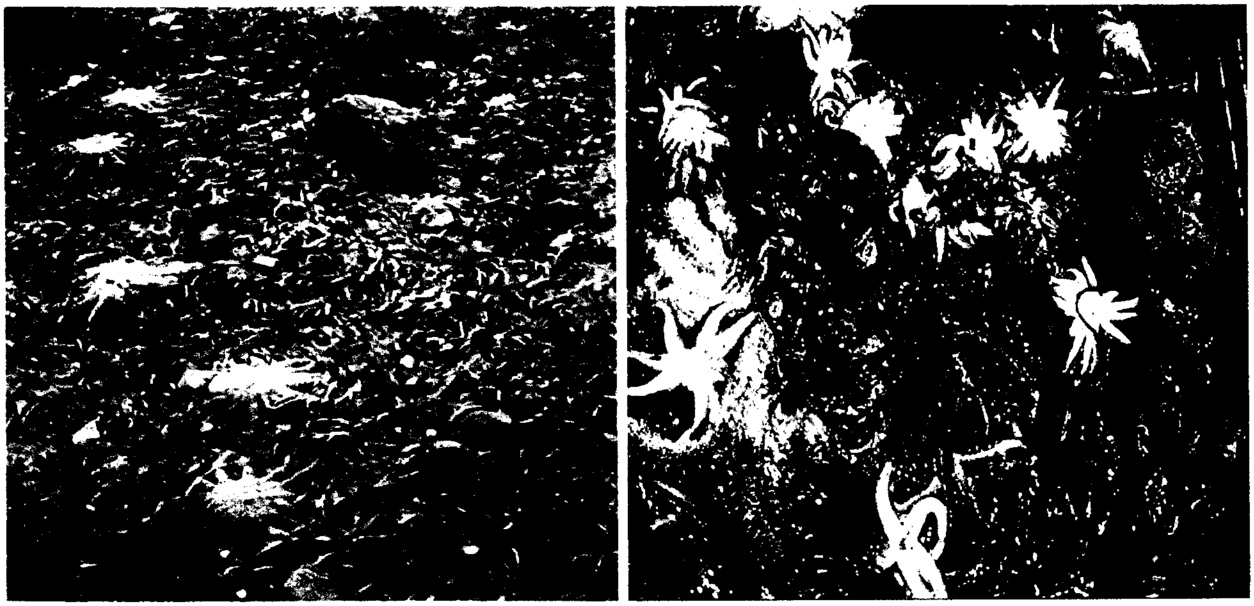


Figure 69. a) Pycnopodia helianthoides below the Tatitlek enhancement beach on April 26, 1998. b) Seastars removed from the Tatitlek enhancement beach prior to initial seeding in 1996. This is one of four-bushel baskets of starfish that were removed to an upland area during one morning of predator control.

Nanwalek: The beach at Passage Island is located approximately 11.5 nautical miles (nm) from the Village of Nanwalek (English Bay). Access is along an unprotected coastline of Cook Inlet. This discouraged access to the beach during winter low tides that occur at night. Consequently, the cultures were not adequately tended and three scheduled sampling events were missed during this study. The lack of maintenance was exacerbated by the exposure of this beach to strong wave action. The consequences were that significant substrate movement occurred during the winter of 1997 – 1998. Three of the bags (1A, 2A, and 3A) were buried under 10 to 15 cm of coarse gravel and cobble as were several of the sites protected with plastic netting. Bags 2B and 2C were buried to a depth where they could not be located (>30 cm). Experience gained at this site reinforces the site selection parameters defined at the beginning of this study. Sites that are difficult to access and sites that are subject to significant substrate instability should simply be rejected for enhancement purposes.

Figure (70) describes the survival of native littleneck clams in bags at Passage Island. Survival was excellent at this site until the storm event(s) of the winters of 1997-98 and 1998-99 buried some bags and left others completely uncovered. If this enhancement site were more accessible, the Villagers' might have been able to recover the buried bags and rebury the exposed bags before the clams died. However, that is conjecture. The lesson to be learned from this experience is that inaccessible and weather exposed sites are not suitable for intensive enhancement.

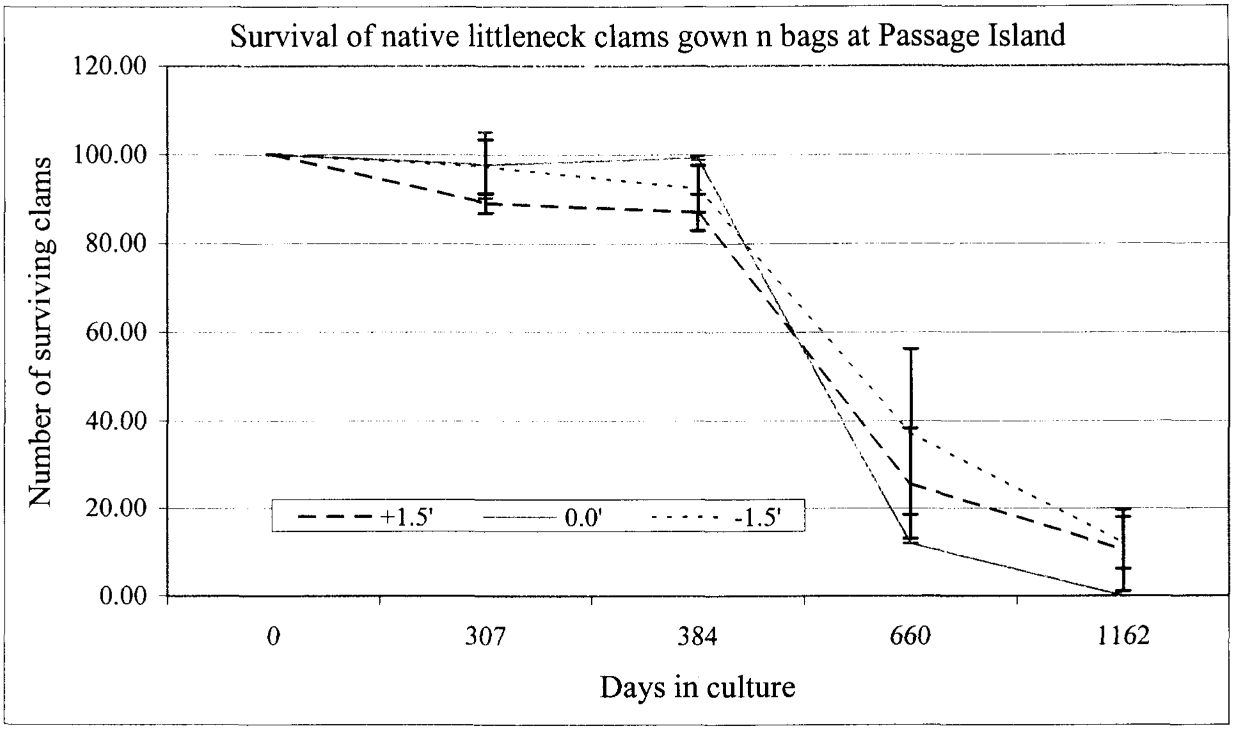


Figure 70. Number of surviving clams grown in bags at Passage Island, Alaska through September 8, 1999.

Plastic netting (Carcover™) has the potential to protect bivalves from many predators. As discussed in the results for Tatitlek, plastic netting also functions to stabilize substrates subject to movement. Clams were seeded at a density of 300 clams/m^2 into replicated, cultivated, plots covering two square meters each in 1996. Two samples covering an area of 0.018 m^2 were collected from each of the three replicates at +1.5' MLLW and -1.5' MLLW on April 24, 1998, providing six samples from each treatment at each tidal height. All count data were Log(N + 1) transformed prior to analysis.

Figure (71) describes the results of sampling each of these plots during April 1998. Two of the bags were lost and three were buried. However, more clams survived in bags than in the other types of culture. Plastic netting increased survival at Protected sites. Forty-five native littleneck clams were retrieved in all Passage Island samples (not including bags). Thirty-seven (37) of these were from seeded areas protected with Carcover™, one was from the seeded, but unprotected area and seven were retrieved from control plots. The netting did help stabilize the substrate and it is likely that native littleneck clam seed was washed out of the unprotected treatments or was buried too deeply to survive. The nearly total loss of clams from the seeded and unprotected treatments suggests that simply broadcasting seed onto a cultivated, but unprotected, intertidal area is not a practical enhancement technique at this high-energy site. Approximately 66 native littleneck clams were seeded in 1996 into the twelve 0.0182 quadrats sampled in April of 1998. Thirty-seven (37) of these survived, suggesting a gross survival rate of 56% in the Protected treatment. This was surprising considering the visual evidence of significant sediment movement during the winter of 1997-98 at this beach.

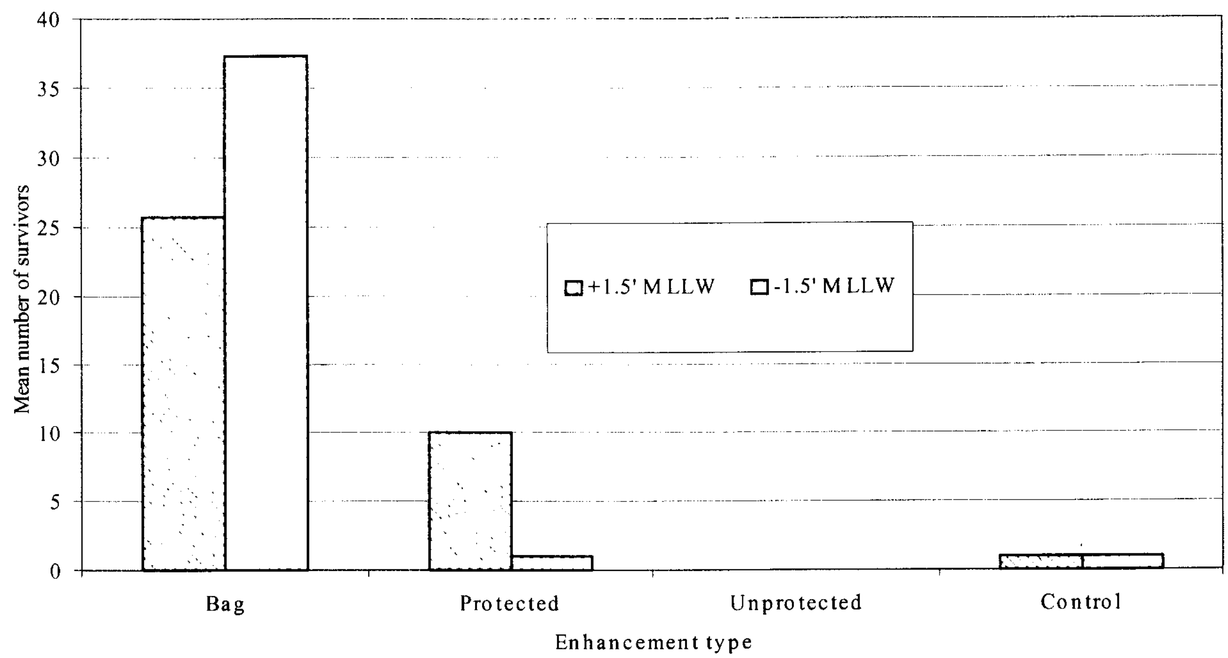


Figure 71. Survival of native littleneck clam (*Protothaca staminea*) seed planted in the intertidal area of Passage Island during 1996 and evaluated on April 24, 1998.

Paired sample *t-tests* comparing the types of enhancement indicated that significantly more clams were found under Carcover when compare with either the control (p = 0.028) or the unprotected enhancement trial (p = 0.001). Significant differences between the seeded, but unprotected trial and the control were not significant (p = 0.720). These results suggest that unstable substrates may have caused a significant loss of unprotected native littleneck clams at Passage Island and that Carcover™ netting was effective in reducing these losses.

At the end of the study, analysis of covariance with initial clam length as the covariate indicated that there were significant differences as a function of treatment (F = 17.51, p = 0.000) but not as a function of tidal height (F = 1.15, p = 0.29). The mean length of native littleneck clams grown in bags (23.05 mm) was significantly less (P = 0.000) than that of clams grown under plastic netting (26.6 mm). The valve length of clams at the end of the study that were seeded without benefit of protection was intermediate and not significantly different from those grown in bags or under netting. These results are summarized in Figure (72). Figure (73) describes the growth of native littleneck clams in bags at Passage Island. The clams were originally planted on July 3, 1996 at an age of one year. They were last sampled on September 8, 1999 at an age of 1532 days (4.2 years) and three years of growout.

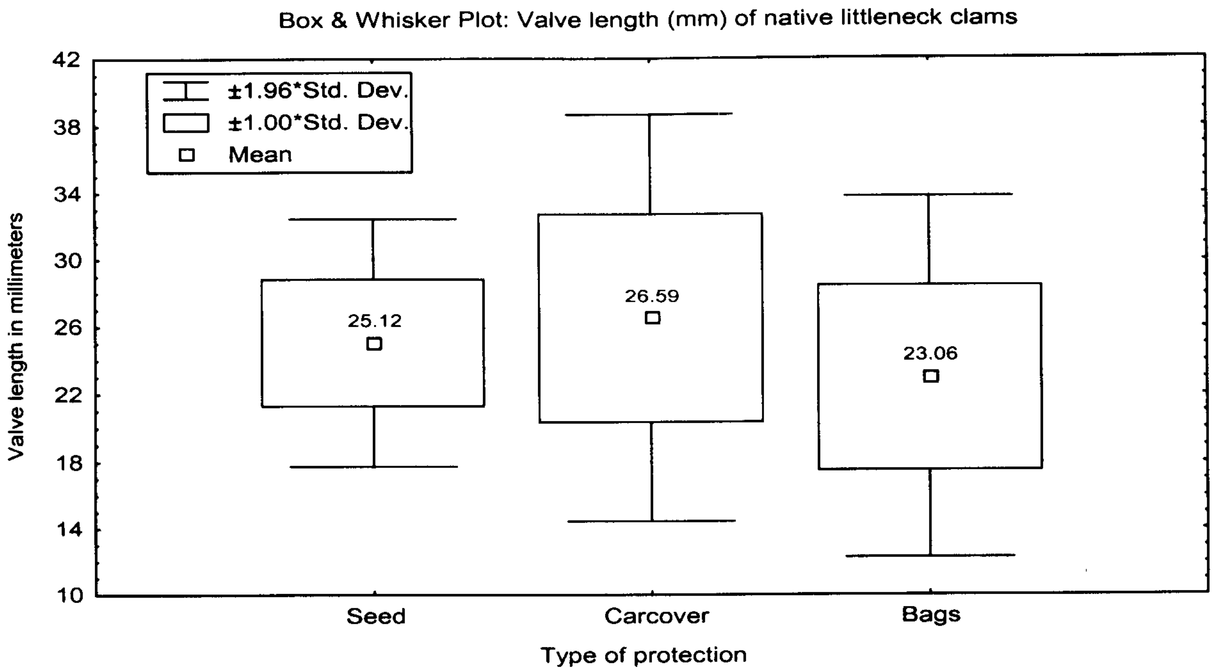


Figure 72. Final valve lengths of native littleneck clams grown at Passage Island for three years. Clams were seeded into cultivated sediments and either protected with plastic netting (Carcover™) or unprotected (Seed). Nine additional cohorts of 100 clams each were grown in plastic clam cages. Differences in growth as a function of tidal height (-1.5' to +1.5' MLLW) were not observed.

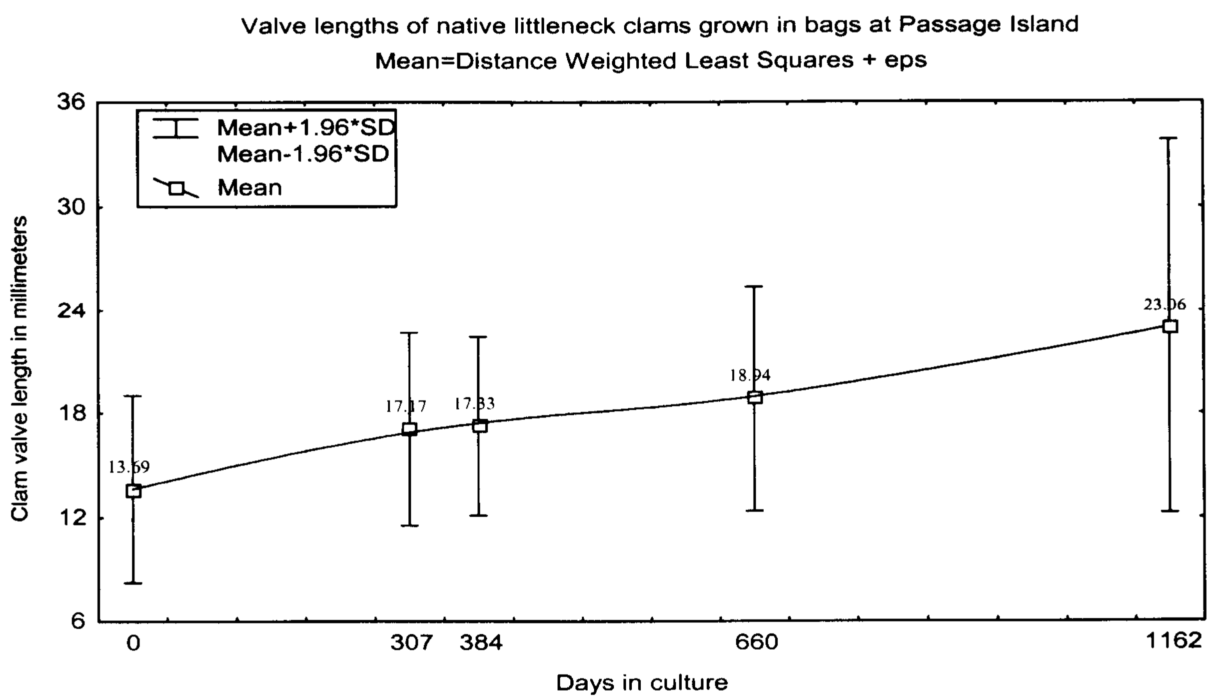


Figure 73. Mean length (mm) of clams grown in bags at all tidal elevations on Passage Island, Alaska as a function of seed age.

Figure (74) provides a length-frequency histogram for clams collected on September 8, 1999. Four clams ≥ the minimum legal length of 38 mm were observed. Small and recently recruited native littleneck clams were observed during the 1995 baseline survey at this site and new recruits are apparent in Figure (94). Newly recruited bivalves of a number of species were observed in bags at Passage Island during annual CRRC evaluations. Bivalve species other than native littleneck clams were removed from the bags during each annual field survey by the CRRC team. Native littleneck clams with valve lengths less than 8 mm were also removed, as this was the smallest size clam originally planted. However, it is likely that some new recruits became members of the cohort of clams counted in the bags. Because these recruits were younger (and smaller) than those planted in 1996, their inclusion would decrease the mean valve lengths observed. It has been suggested that the clams planted in 1996 should have been marked. However, the experience gained in this study supports the author's original opinion that marking techniques (tags, etching, paint, vital stains) appropriate for seed clams (12 mm valve length) will not remain visible for the duration of studies designed to last four years or more.

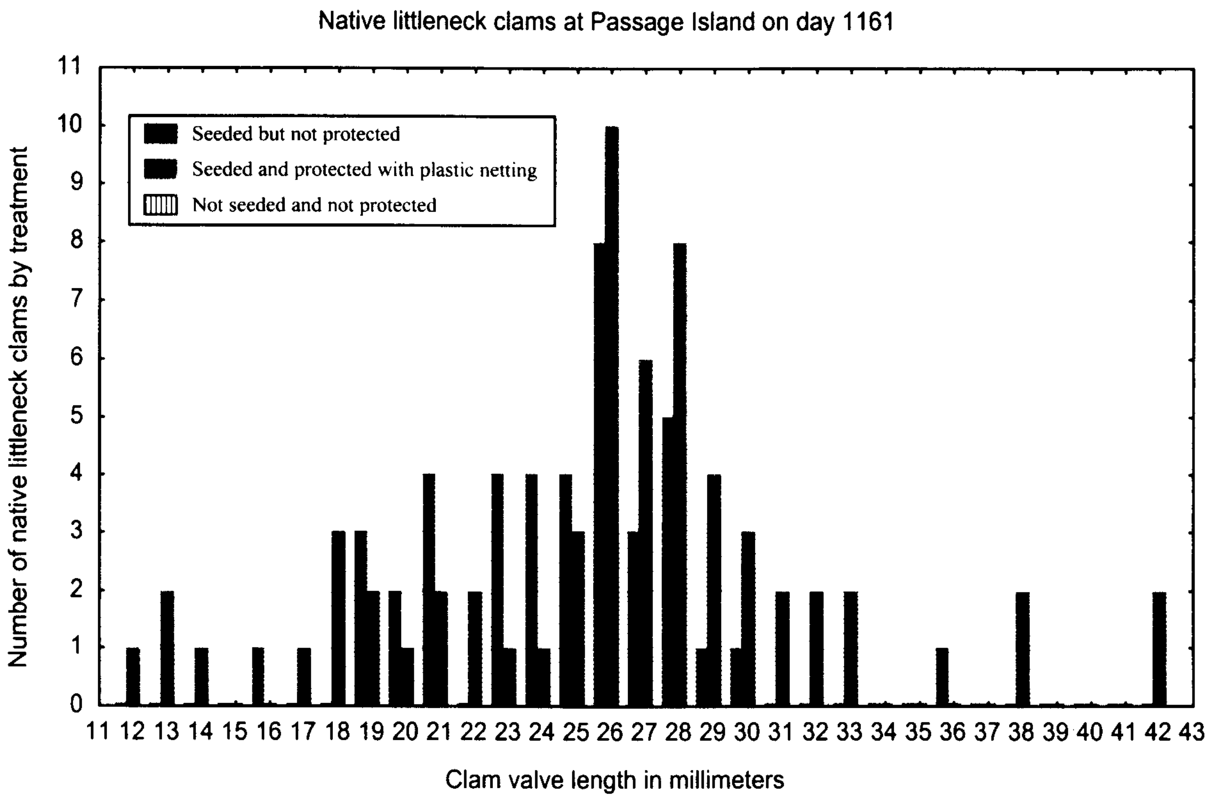


Figure 74. Length frequency histogram describing the population of native littleneck clams observed on September 8, 1999 at Passage Island, Alaska. Clams depicted in green were retrieved from plots protected with plastic netting. Clams in blue were seeded but not protected. No native littleneck clams were found in control areas during the 1999 survey.

Sediment physicochemical characteristics are summarized for the various treatments in Table (19). The proportion fines observed under Carcover™ was significantly higher ($p = 0.013$) from the proportion observed in the seeded, but unprotected, site. No other significant differences were observed with the probability of rejecting the null hypotheses varying between 0.42 and 0.72.

Table 19. Summary of the proportion fines (silt and clay < 64 μm particle size), total volatile solids (TVS) as a proportion of sediment dry weight, and depth (cm) of the reduction oxidation potential discontinuity (RPD) observed in control areas, in seeded areas under plastic netting and in unprotected but seeded areas. All values are means of three replicates ± one standard deviation.

Type of treatment	Proportion fines	Proportion TVS	Depth of RPD (cm)
Control	0.076 ± 0.028	0.024 ± 0.007	>15
Seeded and unprotected	0.066 ± 0.005	0.022 ± 0.006	>15
Seeded and protected	0.082 ± 0.011	0.023 ± 0.007	>15

Fecal coliform bacteria were not detected in any of the water samples (all samples were < 2.0 FC/100 ml). This was consistent from year to year suggesting that this area would likely meet the requirements for an Approved Classification as defined in Part I of the NSSP Manual of Operations.

The water at Passage Island was very clear on April 24, 1998. Total Suspended Solids were measured at 1.5 ± 0.9 mg/L and the mean Total Volatile Solids was 0.70 ± 0.03 mg/L (mean ± one standard deviation). These data suggest that about half of the suspended particles retained on a 0.47 μm glass filter were organic and half were inorganic. The TVS value of 0.70 mg/L was unexpectedly low during this spring sampling period when higher phytoplankton production was expected.

Port Graham: The site is located across sheltered water approximately 1.0 km from the Village of Port Graham. The beach at Murphy's Slough was considered ideal for several types of intensive and extensive bivalve enhancement efforts. The intertidal area suitable for clam culture documented in the 1995 bivalve inventory had a gentle slope and covered several acres. The substrate consisted of a mixture of 59% small gravel less than 2 cm diameter, 30% sand and 11 percent silt and clay. Sediment TVS averaged 2.05 ± 0.4 percent. In 1995, this beach had a high volume of subsurface porewater observed during low tide. The RPD was consistently >10 cm and predators were restricted to a few starfish and possibly otters – as evidenced by the large number of pits, the absence of large butter clams, and the number of broken butter clam valves. Figure (75) is an aerial photograph of the study area.

Two of the bags (3B and 3C) holding clams used in the growth and mortality study disappeared from this site in 1997. All other study components remained in good condition and all required samples were collected during the course of this study.

Native littleneck clams were not observed on this beach during the 1995 baseline study and none were observed outside the seeded plots during the study. The lack of an existing native littleneck clam population was of concern during the site selection process. However, the decision to use this site was based on the observed sediment physicochemistry, which typically supports littleneck clams in Washington State, British Columbia and Alaska. It was hypothesized that the lack of native littleneck clams in the area was due to lack of recruitment – perhaps associated with unfavorable surface currents during the spring and summer months. From a study perspective, the lack of native littleneck clam recruitment provided an opportunity to examine growth and survival of this species in Alaska without interference from the constant recruitment of new native littleneck clams observed at Tatitlek and Passage Island.

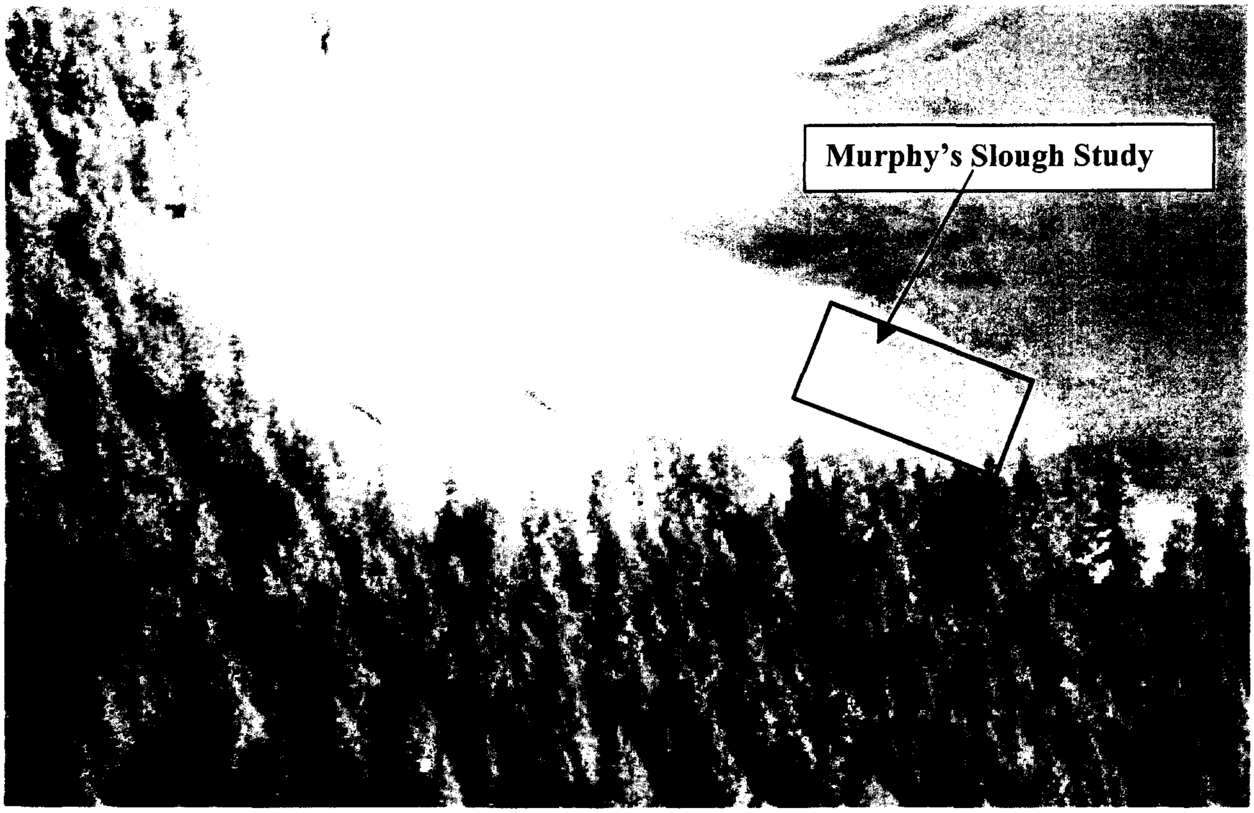


Figure 75. Native littleneck clam enhancement site in Murphy's Slough near the Village of Port Graham, Alaska.

The native littleneck clams in Murphy's Slough were all of known age. The presence of apparent annuli on the exterior of the valves was supported by an extension of the inner lamellar matrix secreted by the mantles inner surface through the outer prismatic layer (Morton, 1979). These dark lines of lamellar $CaCO_3$ were frequently present as doublets separated by several hundred microns. As previously noted, sectioned valves required very careful preparation or the first annulus was not recognizable because of the thinness of the prismatic layer – even in these clams that were grown in substrate for only three years. Figure (62) depicts the differing sculpturing observed in clams from the same cohort grown at two intertidal levels.

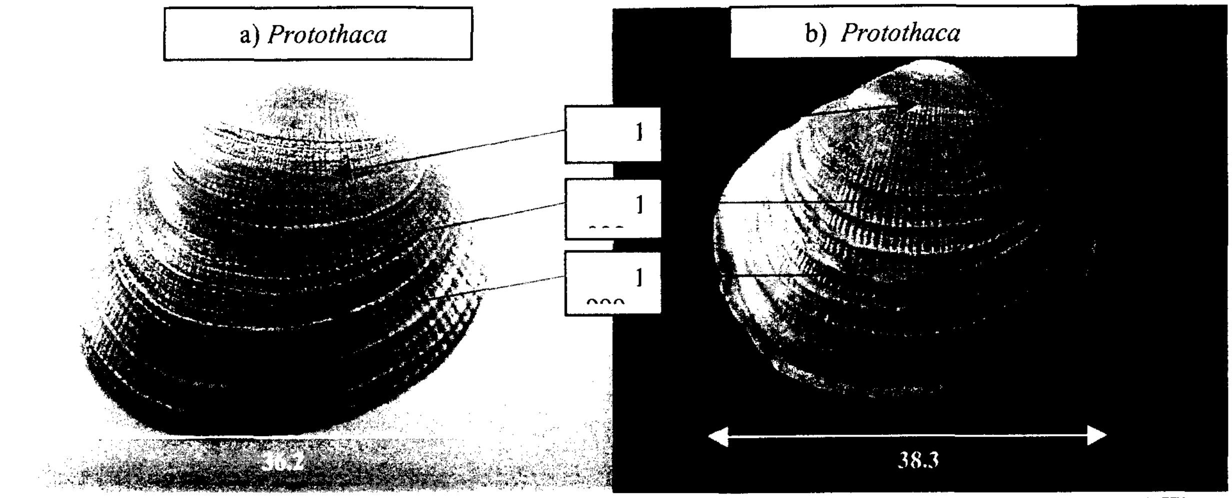


Figure 76. Native littleneck clam planted in 1996 in Murphy's Slough at a tidal height of a) +1.5' MLLW and b) –1.5' MLLW and collected on September 9, 1999 following 1162 days (3.2 years) of growout. Winter annuli formed in January of 1997, 1998 and 1999 are marked. Annuli are assigned to the month of February in the year indicated.

Table (20) summarizes survival of native littleneck clams between July 4, 1996 and August 1, 2000 at Murphy's Slough. Two of the three bag replicates at –1.5' MLLW were missing in 1997. One of these was recovered from deep water in 1999. However, all but two of the clams in that recovered bag had died by 2000. This compromised data from the –1.5' MLLW block. After four years of field growout, average survival was 42% at +1.5' MLLW and 48.7% at 0.0' MLLW. Figure (77) graphically describes the survival of native littleneck clams grown in bags at Murphy's Slough. It should be noted that significant winter mortality was not observed in bag cultures at the +1.5' MLLW tide level. This is important because the winter of 1998-99 was unusually cold and the clams survived well – suggesting that this factor should not inhibit bag culture at this site. Survival under plastic netting was significantly higher than survival of clams seeded and afforded no protection ($p = 0.000$). Differences in survival between clams grown in bags and those grown under plastic netting were not significantly different.

Table 20. Survival of clams grown in Murphy's Slough at three tidal elevations. Mean numbers of surviving clams in three replicate bags and the standard deviation is provided for each tidal elevation on each day. Only one bag was found on days 499, 660 and 989 in the –1.5' MLLW block. One of the two missing bags was retrieved from deep water on day 1162.

DAY	+1.5'	+1.5' STDS	0.0'	0.0' STDS	-1.5'	-1.5' STDS
0	100.00	0.00	100.00	0.00	100.00	0.00
112	91.00	6.98	102.70	8.81	99.33	2.87
250	82.30	9.98	91.00	0.82	73.30	23.42
383	73.30	15.06	86.70	4.99	74.70	25.94
499	72.30	13.72	85.33	8.18	66.00	0.00
660	60.30	16.01	70.67	7.93	55.00	0.00
989	58.00	20.02	66.33	12.39	52.00	0.00
1162	53.30	22.88	58.00	16.05	51.00	14.00
1489	42.00	14.76	48.70	11.09	14.00	12.00

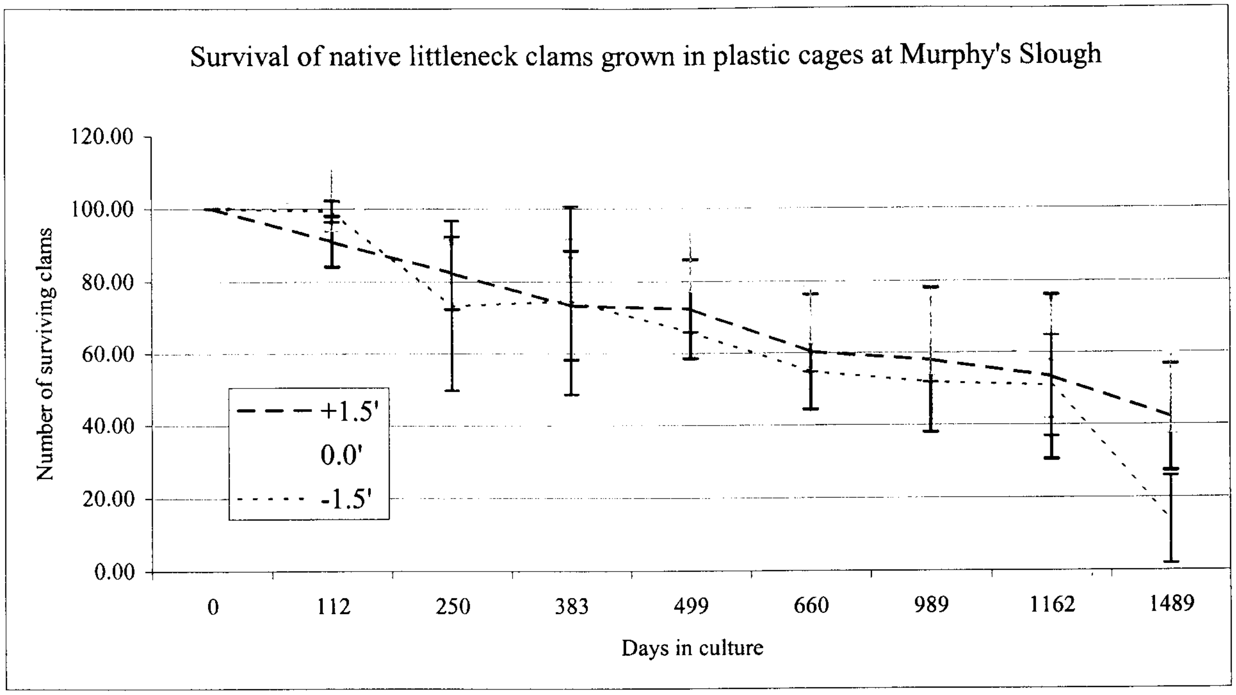


Figure 77. Mean number of surviving clams in replicate bags at three tidal heights in Murphy's Slough, Port Graham, Alaska as a function of date.

The intertidal area being evaluated in Murphy's Slough was stable throughout this study with no observable substrate movement. The primary purpose of the plastic netting at this site was to discourage predation by gastropods, starfish, crabs and birds. The lightweight plastic could not withstand the determined efforts of marine mammals like sea otters. However, it was thought that light to moderate algal fouling on the nets might camouflage the clams and ameliorating predation by otters. This fouling is described in Figure (78).

Clams were originally seeded in the protected and unprotected plots at a density of 300 clams per square meter. Two samples, covering an area of 0.0182 m^2 each, were collected from each of the three replicates at +1.5' MLLW and –1.5' MLLW giving six samples from each treatment at each tidal height (36 samples total). All count data were Log(N+1) transformed prior to analysis.

Figure 78. Fouled Carcover™ netting protecting native littleneck clam seed planted in 1996 at Murphy's Slough, Port Graham, Alaska.

Figure (79) describes the percent of the original 300 clams/m^2 surviving in six 0.0182 m^2 samples collected from each of the replicates at two different tidal heights (+1.5' and –1.5' MLLW) on September 9, 1999 following 1162 days of field growout. No littleneck clams were retrieved from unseeded control plots. That was consistent with the lack of native littleneck clams found in the 1995 baseline survey. Two native littleneck clams were found in the six samples collected from areas seeded but not protected with plastic netting and 31 clams were found in sediments collected from under the protected plots.

Analysis of variance indicated that tidal level within the tested range (-1.5' to + 1.5' MLLW) was not a significant factor affecting survival ($p = 0.38$). The type of protection afforded (bags, plastic netting, or unprotected) did significantly affect survival ($p = 0.000$). Post Hoc testing using Scheffe's test indicated that there was not a significant difference in survival when comparing bags and plastic netting. However, both of these forms of protection afforded statistically significantly higher survival than those seeded into cultivated ground but not protected ($p = 0.000$). The survival rates of 40 to 55 percent observed at Murphy's Slough following 3 years of growout under plastic netting were similar to those reported by *Toba et al* (1992) for Manila clams grown for two years in Puget Sound.

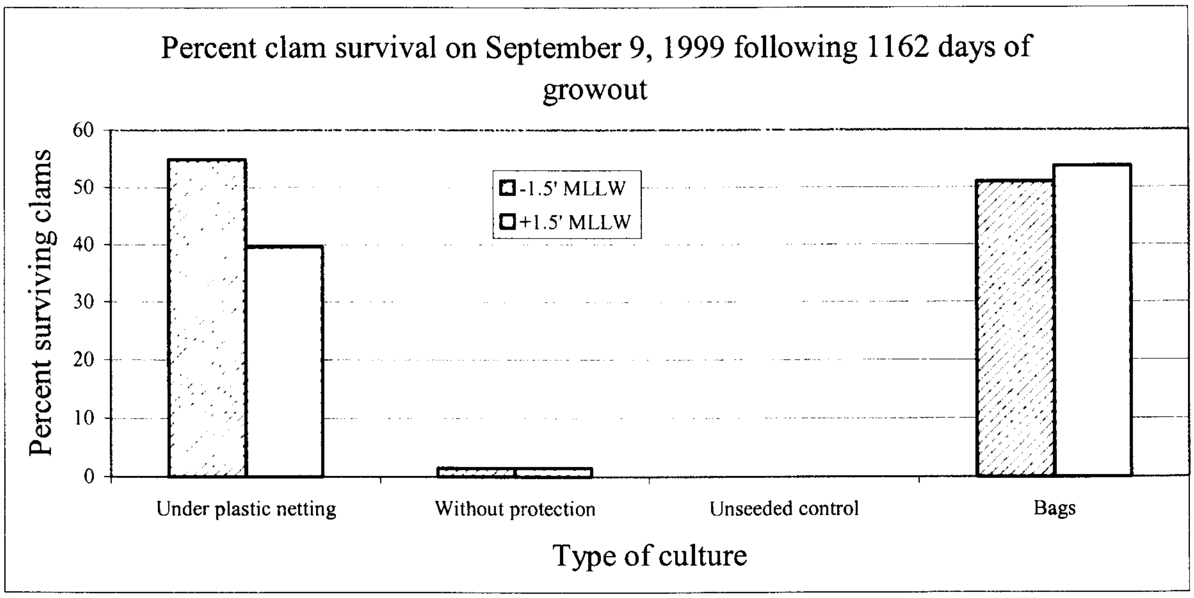


Figure 79. Percent surviving native littleneck clams cultivated in Murphy's Slough. Data compare survival on September 9, 1999 with planting density on July 4, 1996.

Figure (80) describes the growth of all native littleneck clams in bags at Murphy's Slough during this study. The clams were originally planted on July 5, 1996 at an age of one year. They were last sampled on August 1, 2000 following 1489 days (4.1 years) of field growout (a total age of 5.1 years). The von Bertalanffy model developed using data from all living native littleneck clams collected at Tatitlek and Passage Island (Brooks, 1995) is included for reference.

Statistically significant differences in growth as a function of treatment were observed (ANCOVA, $F = 65.7$; $p = 0.000$) in the September 9, 1999 data. Post hoc testing using Scheffe's test indicated that that native littleneck clams grown in bags were significantly smaller (27.03 $\pm$ 3.14 mm) and slower growing than those grown under plastic netting (34.74 $\pm$ 4.17 mm).

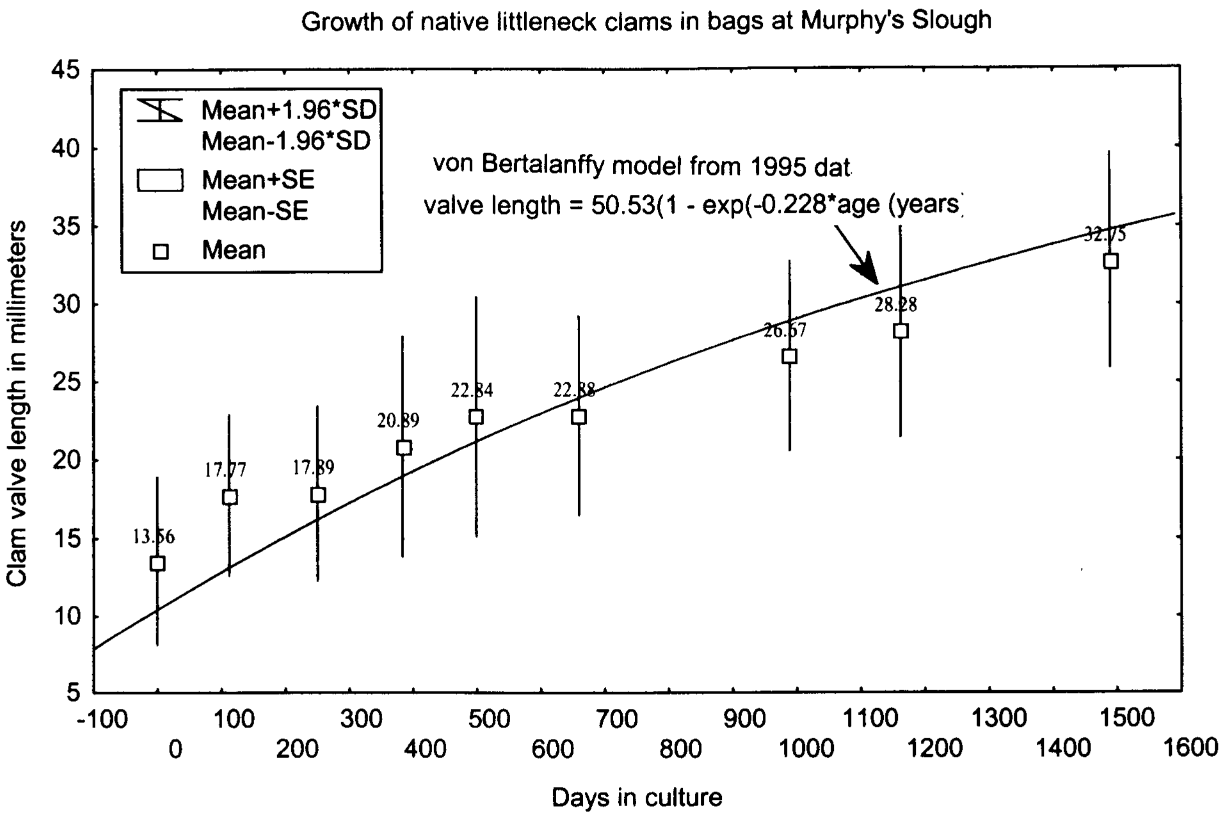


Figure 80. Mean lengths of native littleneck clams cultured at all tidal elevations in bags at Murphy's Slough between July 5, 1996 and August 1, 2000. The von Bertalanffy growth model developed for native littleneck clams from the baseline bivalve inventories conducted in 1995 as part of this effort is included for reference (Brooks 1995).

Figure (81) compares the valve lengths of native littleneck clams sampled under plastic netting with the von Bertalanffy model developed in Brooks (1995b). Clams grown under plastic netting had somewhat longer maximum valve lengths at all ages than predicted. However, the fit is remarkably similar and not significantly different. A solution to the von Bertalanffy model was defined for the clams grown under plastic netting in Murphy's Slough. The resulting model explained 74% of the variance. The residuals were normally distributed and there was no evidence of heteroscedasticity. The resulting model, presented graphically in Figure (68), is:

$$\text{Native littleneck clam valve length (mm)} = 54.1*(1 - \exp^{(-0.24*\text{age in years})})$$

The mean length of the 47 native littleneck clams recovered from beneath plastic netting in Murphy's Slough on August 1, 2000 by ADFG, following four years of growout, was 38.09 mm – slightly exceeding the minimum legal harvest size. Figure (83) is a length-frequency histogram describing the valve lengths of clams sampled under plastic netting in 1999 and Figure (84) provides similar data for 2000. Native littleneck clams began recruiting into the minimum legal harvest size in 1999, following three years of growout and more than half (57.4%) of these clams exceeded the minimum harvest size of 38 mm when last surveyed in 2000.

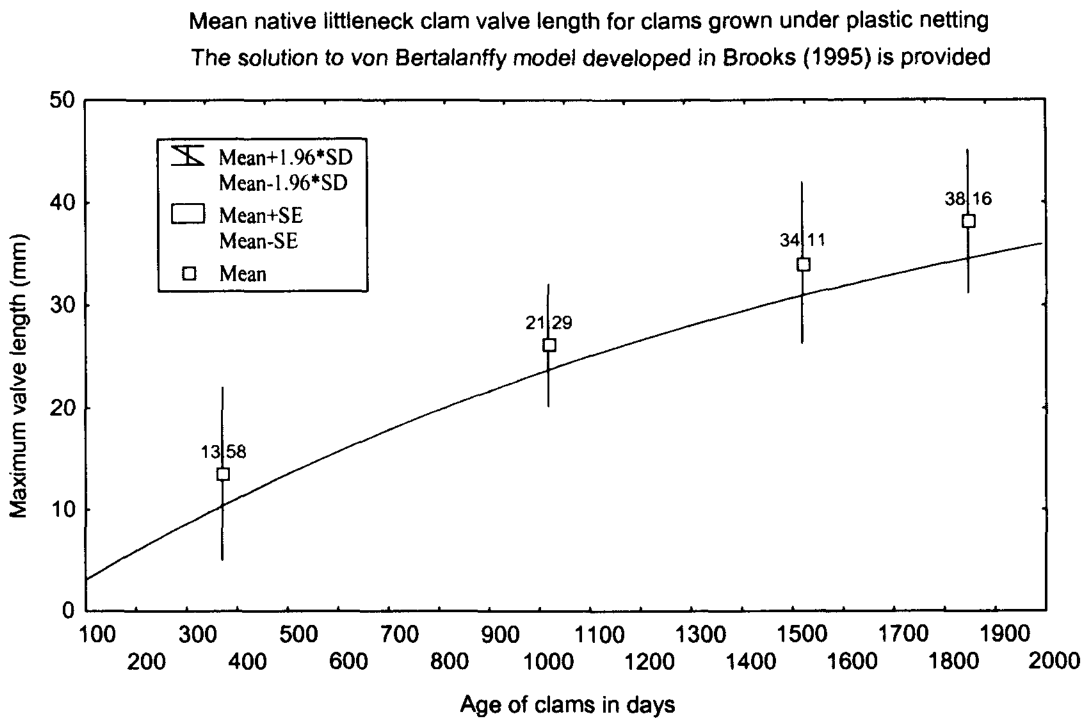


Figure 81. Comparison of the observed growth of native littleneck clams under plastic netting in Murphy's Slough with the von Bertalanffy model predictions based on the 1995 baseline surveys at Tatitlek and Passage Island.

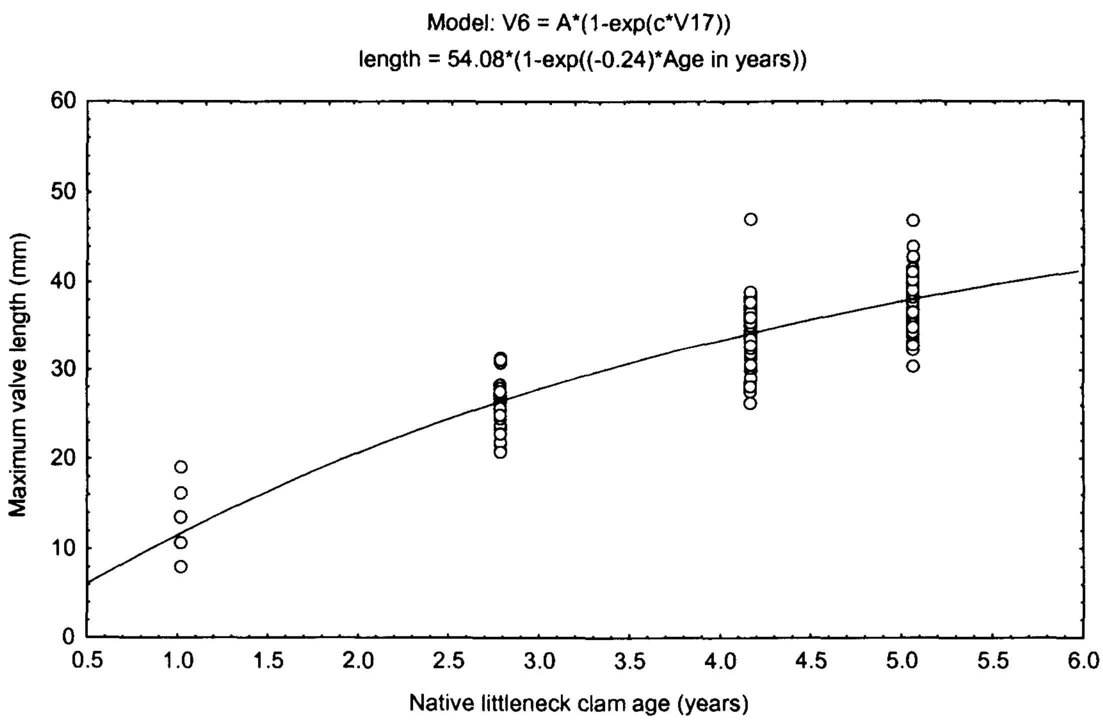


Figure 82. Solution to the von Bertalanffy model for native littleneck clams grown in Murphy's Slough under plastic netting. The clams were spawned in 1995, seeded on the beach in 1996 and monitored in 1998, 1999 and 2000.

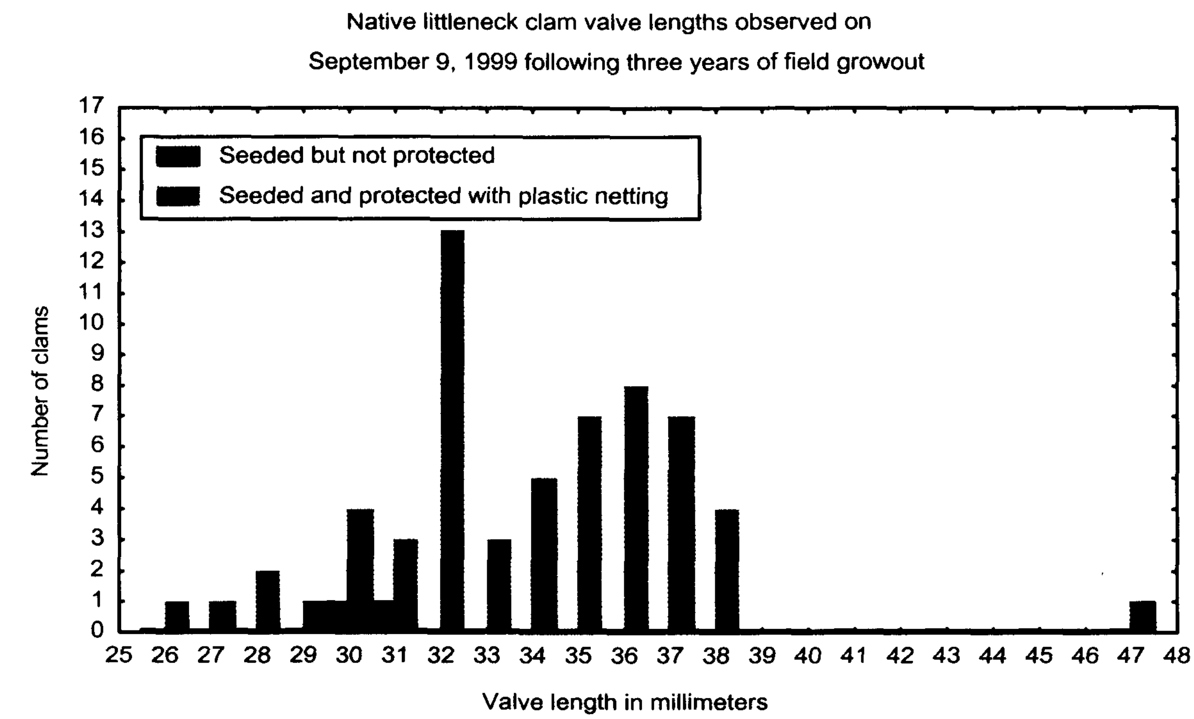


Figure 83. Length-frequency histogram describing artificially propagated native littleneck clams sampled from areas protected by plastic netting (green) and without protection (blue). The culture was initiated in 1996 and sampled in 1999.

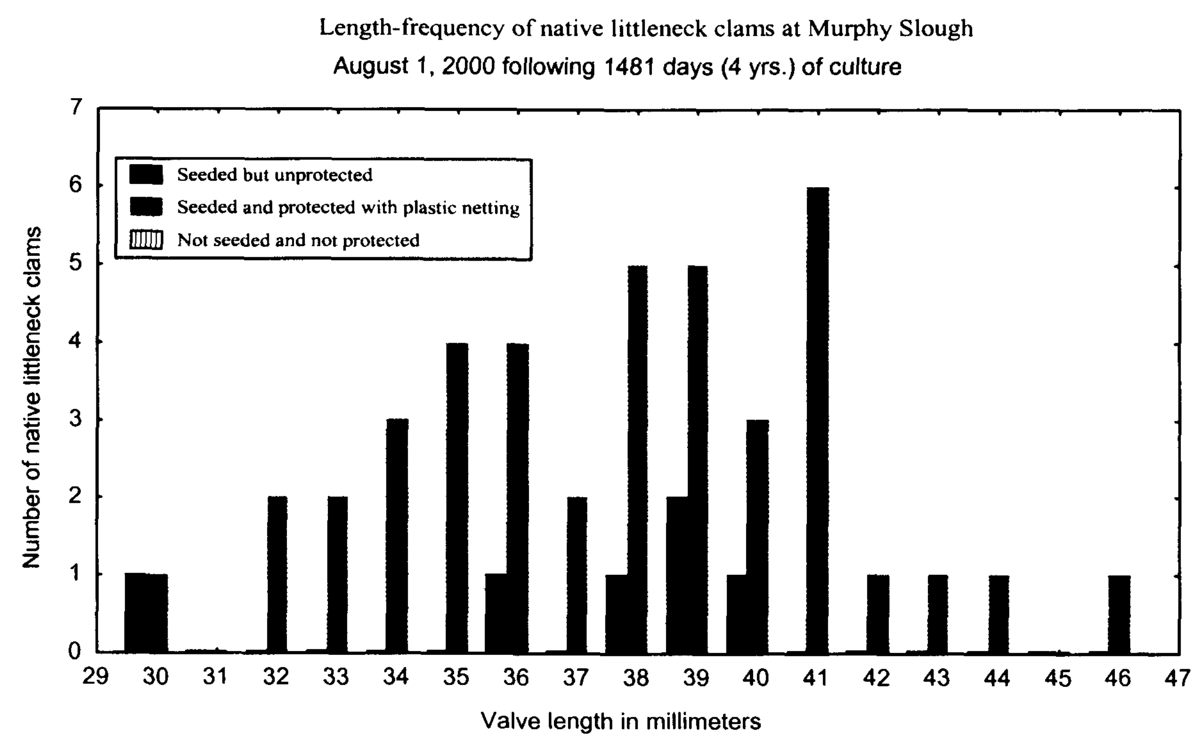


Figure 84. Length-frequency histogram describing artificially propagated native littleneck clams sampled from areas protected by plastic netting (green) and without protection (blue). The culture was initiated in 1996 and sampled in 2000.

Analysis of covariance with initial clam length as a covariable indicated that the tidal level at which clams were grown had a significant effect on their size on each date ($F = 32.7$; $p = 0.000$). To simplify presentation of these effects, a new variable (Incremental Length) equal to the clams' length on each date minus the mean initial length of clams placed into that bag was invoked. This variable was submitted to analysis of variance and throughout most of the study, tidal effects were a significant factor affecting the incremental growth of clams. By the end of the study (August 1, 2000), differences in incremental growth of clams in bags were not as significant (ANOVA; $F = 4.2$; $p = 0.016$). Post hoc analysis using Scheffe's test (Zar, 1984) indicated that the incremental change in valve lengths for clams grown at the 0.0' MLLW tide level was significantly lower than for those grown at –1.5' MLLW ($p = 0.03$). These results are presented graphically in Figure (85). It should be noted that these results were confounded by the loss of two of the three replicate bags at the –1.5' MLLW tide level and subsequent retrieval of one of those bags.

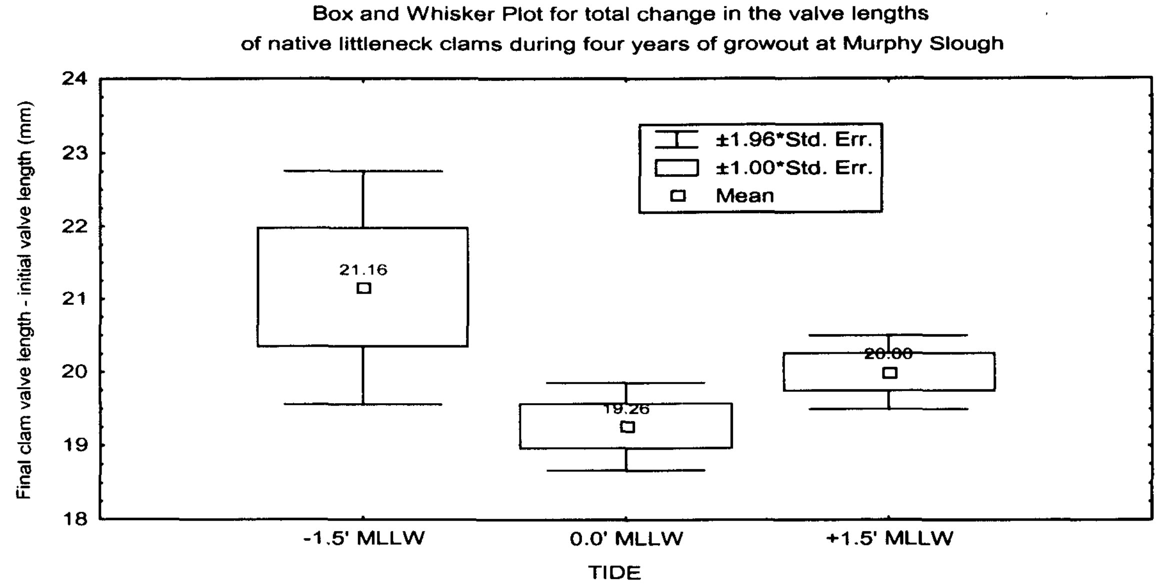


Figure 85. Box and whisker plots describing the difference in initial and final mean valve lengths of native littleneck clams grown in bags at Murphy's Slough from 1996 until 2000 as a function of tidal height.

All clams were returned to the various treatments following measurement until 1999. Native littleneck clams collected from under plastic netting during the 1999 field season were frozen until 2001 when their lengths and whole-animal weights were determined. All of the frozen clams lost their pallial water – but there was no evidence of freezer burn. Clams retrieved from under the plastic netting in Murphy's Slough during 2000 by ADFG were similarly weighed. That data was used to construct the length-weight scattergram provided in Figure (86). The data was fitted to a logistic regression model using the general nonlinear algorithm provided in Statistica™. The resulting regression explained 89.7% of the variation in the database and the residuals were normally distributed. The model predicts that whole-animal weights double between 30 mm and 38 mm and that they redouble between 38 and 47 mm valve length. These values are not significantly different ($\chi^2 = 0.12$, $\chi^2_{critical = 26.3}$, $\nu = 16$) from the distribution described by Feder and Paul (1973) for total native littleneck clam weight versus length. In fact, they are essentially identical.

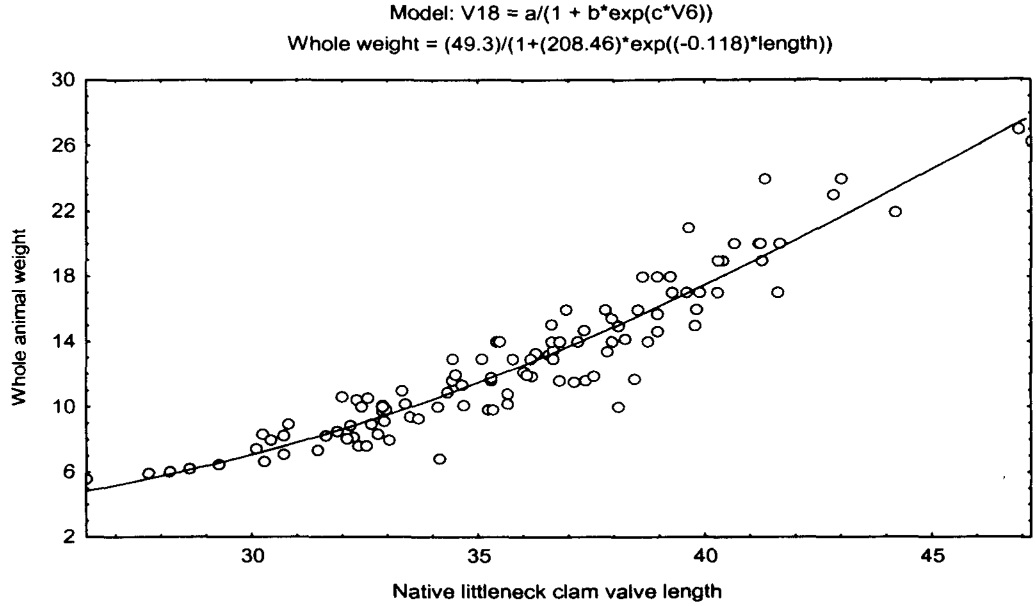


Figure 86. Logistic growth curve model fit to whole-animal weights (grams) and valve lengths (mm) observed in clams collected grown under plastic netting at Murphy's Slough, Alaska.

Wet tissue weights as a proportion of whole-animal weights for native littleneck clams determined in this study are provided in Figure (87). These data indicate that the proportion of total clam weight that is edible (wet tissues) increased from 28% at a valve length of 30 mm to 60% at a valve length of 47 mm.

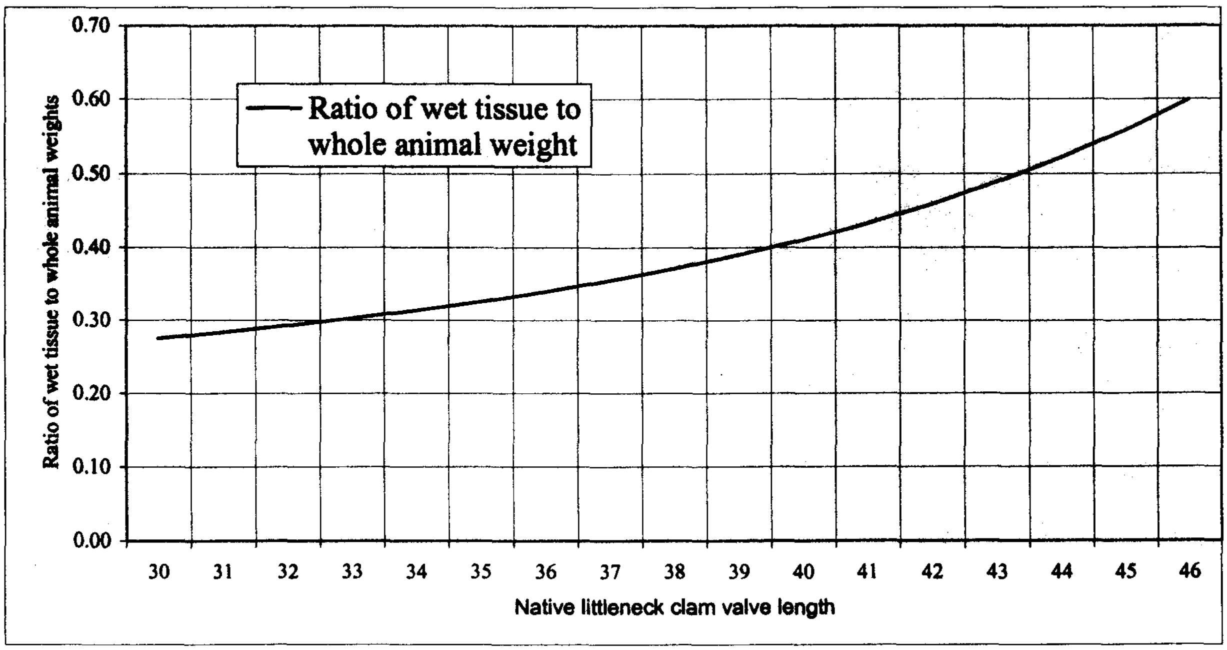


Figure 87. Ratio of wet tissue to whole-animal weights for native littleneck clams as a function of a function of valve length (mm).

Murphy's slough represents a low energy environment compared with Passage Island and Tatitlek. Some increase in the proportion fines was expected at sites protected with plastic netting when compared with unprotected plots. *T-tests* were used to assess differences in these physicochemical data. Significant differences were not observed in either the percent fines (silt and clay with particle size $\leq$63 microns) or in the proportion sedimented total volatile solids during either 1998 or 1999.

Sediment sulfides were evaluated in three replicate samples from unprotected cultures and under plastic netting at Murphy's Slough during the 1999 CRRC field season. The results are depicted graphically Figure (88). While not statistically significant at $\alpha = 0.05$ ($p = 0.066$), higher concentrations of sulfides were observed under the netting, suggesting that this parameter may be useful in further assessing the effects of this culture practice. It is also possible that the analysis of additional samples would reveal a significant relationship. However, the two square meter areas covered with netting to protect native littleneck clam cultures in Murphy's Slough did not significantly effect the concentrations of total volatile solids, sediment grain size distribution, or sediment total sulfides.

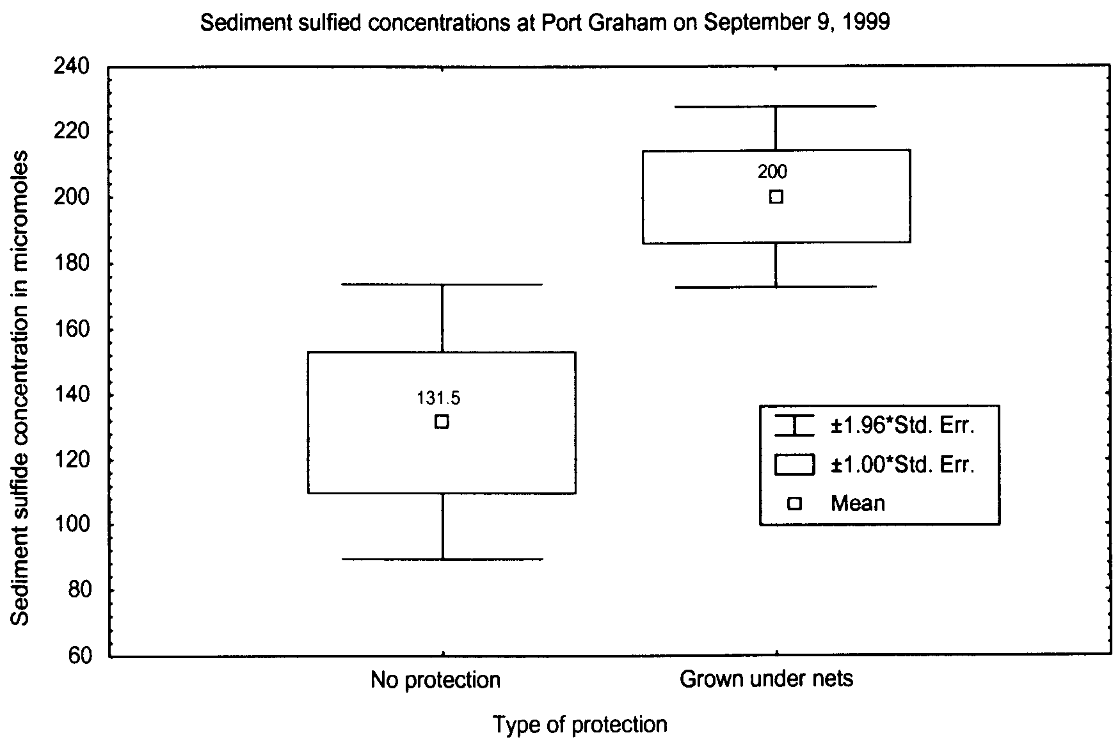


Figure 88. Box and whisker plot comparing the concentration of total sediment sulfides in Murphy's Slough sediments under plastic netting with sediments from unprotected treatment plots.

The water temperature at Murphy's Slough on April 25, 1998 was 6.5 °C. Total Suspended Solids were measured at 2.9 $\pm$ 0.8 mg/L and the mean Total Volatile Solids was 1.3 $\pm$ 0.6 mg/L (mean $\pm$ one standard deviation). These data suggest that about half of the suspended particles retained on a 0.47 µm filter were organic and half were inorganic. The TSS and TVS concentrations observed at Murphy's Slough were approximately twice those observed at Passage Island during the same time frame.

Fecal coliform bacteria were not detected (< 2.0 fecal coliform bacteria/100 ml water) in any of the water samples collected during this study. This suggests that Murphy's Slough would likely meet the requirements for an Approved Classification as defined in Part I of the NSSP Manual of Operations. However, the 15 samples collected do not constitute an adequate survey in compliance with Part I of the NSSP Manual of Operations.

Sea Otters were observed in groups of three to four animals throughout Port Graham and near Murphy's Slough. However, no evidence of sea otter predation on the study cultures was observed. Numerous (>50) starfish (*Pycnopodia helianthoides*) were counted at the –4.0' tide level in front of the enhancement area. They were not observed at tidal elevations greater than –1.5' MLLW where the studies cultures were placed. Clams in two of the bags suffered severe predation by the gastropods (*Natica clausa*) and crabs (*Cancer oregonensis*) shown in Figure (75). The third predatory gastropod (*Nucella lamelossa*) shown in Figure (89) was not present in Murphy's Slough, but was abundant in the rocky intertidal environments at Passage Island and Tatitlek. The drilled valves of native littleneck clams are characteristic of predation by mollusks in the family Naticidae and the broken valves are typical of crab predation in bags. Sediments were sieved on ¼" sieves prior to seeding. The clams were drilled at valve lengths of 9.6 to 17.2 mm suggesting that this predation occurred following a period of growth. Whether the predators were introduced as very small juveniles passing the ¼" sieve or as new recruits is unknown.

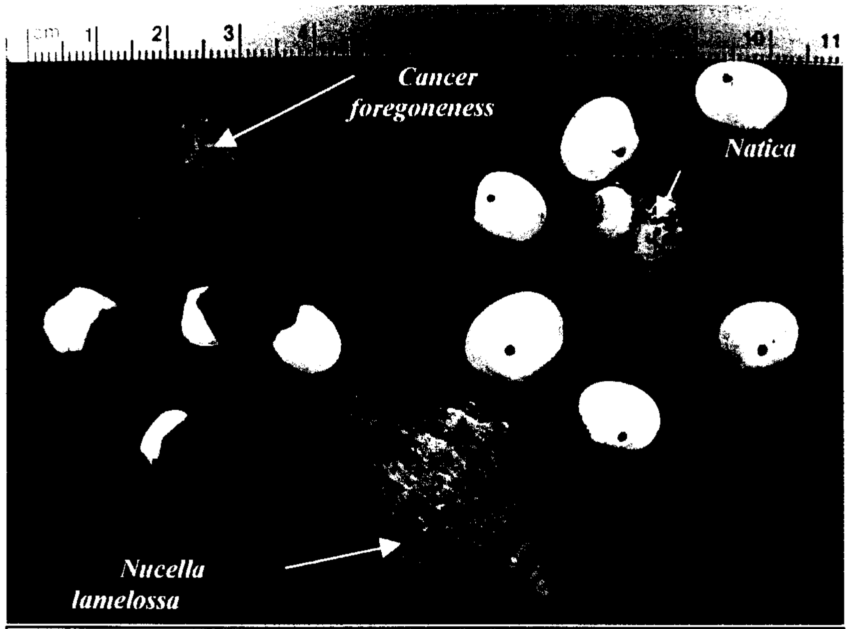


Figure 89. Gastropods (with drilled native littleneck clams) and *Cancer oregonensis* (with characteristic broken clam shells) found in bags at Murphy's Slough and Tatitlek during 1999.

Discussion

This study implemented proven techniques for raising Manila clams in Washington State to the culture of native littleneck clams in Alaska. Growth and mortality studies were confounded at Tatitlek and Nanwalek by the constant recruitment of native littleneck clams into the cultures. However, the results from these two higher energy environments did provide valuable insight into the benefits of various enhancement techniques. There was no recruitment of native clams into the Port Graham study area and those results provide unequivocal evidence of the potential for native littleneck clam enhancement in Alaska.

The study results suggest that littleneck clams under culture grow at about the same rate as wild clams. An estimation of growth beyond the three years the clams were in growout in this study indicates that it would take an average of six years in the oil spill region from the time it was spawned for a littleneck clam to reach the legal commercial harvest size of 38 mm. This is the same growth rate that was found for littleneck clams sampled during the site surveys.

The growth rate for cultured clams could likely be increased if a broodstock was developed for which rapid growth was a major selection criterion. However, a more rapid growth rate would be of little importance over the long run as long as a satisfactory level of survival can be maintained.

It is not a good idea harvest littleneck clams below the commercial harvest size of 38 mm. Because of the nearly exponential increase of wet tissue in clams between 20 and 45 millimeters reducing the harvest size to 30 mm would require nearly 3 times as many clams to obtain the same amount of wet tissue as it would if the harvest size was 38 mm.

Clams grown under plastic netting, or in the Norplex™ bags, had a much better survival rate than clams grown without the benefit of protective netting. The survival rate for clams grown under Carcover™ at the Port Graham site ranged from 40% to 55% among the three replicates. The estimated survival rate for clams grown under Carcover™ at Tatitlek was 46%. This is consistent with survival rates for cultured Manila clams in the Puget Sound. The clams grown in bags had similar survival rates. The survival rate for unprotected clams at the Port Graham site was around 3% with most of the loss attributed to predation.

The survival rate for unprotected clams at the Tatitlek site was estimated to be around 20%. The survival rate for unprotected clams grown at Tatitlek could likely be enhanced if an active predator removal program was initiated, however it would be less expensive to grow clams under netting. Clam survival rates at the high energy Nanwalek site were poor for all treatments because of beach movement during storms.

Plastic netting and bags enhance clam survival in two ways. First, they restrict access to the clams by predators. They are quite effective against invertebrate predators. The netting was more effective against crabs and drills than the bags were probably because these predators could enter the bags at a small size or during their larval stage and grow inside the bags to a size large enough to consume the clams. This study shed no light on the effectiveness of Carcover™ or bags against sea otters. Experience in the state's mariculture industry indicates that the netting would offer little or no protection from sea otter predation, but the bags may.

The second advantage of plastic netting and bags is that they have a stabilizing effect on the substrate. This is an especially useful trait for clams grown in higher energy areas. A more stabilized substrate enhances clam growth as well as survival probably because the clams don't need to expend as much energy maintaining an optimal location in the substrate. Plastic netting and bags are most effective if they are maintained on a regular basis – especially after storms.

Consistent differences in survival and growth were not observed as a function of tide height within the tested range of -1.5 feet MLLW to +1.5 feet MLLW. There was an increase in clam mortality at the Tatitlek and Port Graham sites during the winter, but not catastrophic. Winter loss for protected clams from both freezing and storms ranged between 8 and 15 percent per year during the study. There was a very high loss from winter storms at the Nanwalek site due to the high energy status of the beach and the inability to access the site during the winter to repair storm damage. The study was unable to determine what role storms and freezing played in growth and survival of unprotected clams due to the high total loss of these clams.

Culturing littleneck clams for subsistence use is feasible, but what about the cost? The cost estimate developed here is based on the assumptions presented in Table 21.

Table 21: Assumptions for developing subsistence littleneck clam enhancement program cost estimate.

Description	Value	Comments
Village population	200	
Per capita consumption	480 clams/year	20 meals @ 24 clams(5 oz. of meat) per meal
Harvest efficiency	75% of available clams	
Survival rate in FLUPSY	75%	3 mm to 9 mm growth in one season
Growout planting density	323 clams/m^2	Same as growout study
Growout survival to harvest size (38 mm)	40%	Average clam size is 38+ mm after four growing seasons
Cost of 3 mm seed	\$4/1000	Will also require \$150 transport cost
Annual FLUPSY depreciation	\$800	
Materials and supplies	\$0.65/m^2	Plastic netting, stakes, etc.
Labor and local transport	No charge to program	

Based on these assumptions around 425,000 seed would be placed in the FLUPSY each spring. Seventy-five percent or about 320,000 would survive to a 9 mm size and be planted in a 990 m^2 growout area in early autumn. The clams would remain undisturbed for four growing seasons with the growout opened for harvest in late spring of the fifth growing season when approximately 128,000 clams would be available for harvest. The cost estimate to produce these clams is presented in Table 22.

Table 22: Littleneck clam enhancement program cost estimate.

Item	Cost	Comments
Hatchery seed	\$1,850	Seed at \$4/1000 plus \$150 transport cost
FLUPSY depreciation	\$800	
Materials & supplies	\$645	990 m^2 x \$0.65
Total	**\$3,295**	About \$0.82/meal (a meal is roughly equivalent to a pound of 38 mm whole clams)

Whether or not the cost of operating a clam enhancement program is reasonable and worthwhile is a determination that the individual villages will need to make. Clams are a favorite source of high quality protein. Compared with other forms of subsistence protein an enhanced clam population would have the advantage of being easily accessible and thus relatively inexpensive to obtain. However, even if a clam enhancement program is an attractive investment, a village may not have the funds to make the commitment.

A current unknown about clam enhancement that may make it very unattractive is the potential impact of sea otter predation. The unknown is whether or not sea otters will key in on clams under plastic netting. If they do, something far stronger than Carcover™ will be needed to keep sea otters out. The cost of this material would be much higher than Carcover™ and may be enough to put a clam enhancement project out of reach.

Conclusion

- It takes about 25 weeks in a hatchery for littleneck clam seed to reach 3 mm to 5 mm in size after being spawned. About 25% of the fertilized eggs survive to reach 3 mm to 5 mm in size.
- Spawning littleneck clams in October and November produces 3 mm to 5 mm seed in April and May. The seed placed in a tidal FLUPSY at this time will reach an average size of 9 mm on average (the minimum planting size) by late summer and can be planted.
- A tidal FLUPSY can pay for itself in as little as one season through the difference in cost between 3 mm to 5 mm seed and 9 mm seed from the hatchery.
- The survival rate of littleneck clam seed in a tidal FLUPSY can be greatly increased if the seed are checked and stirred once a week instead of once a month.
- The natural recruitment to legal sized clams on all the beaches surveyed under this project was deemed to be insufficient to sustain a long term subsistence harvest pressure. The main reason appears to be slow growth coupled with heavy predation.
- An optimum minimum harvest size would be the largest size still well represented in the population. At the sites sampled under this project that size would be about 30 mm. Unfortunately a clam that size yields very little meat. A reduction in predation may allow more clams to reach a larger size.
- Under an enhancement program it will take 5+ years from being spawned for a littleneck clam to reach the minimum harvest size of 38 mm – not much different than in the wild.
- The survival rate from hatchery seed (3 mm to 5 mm) to minimum harvest size with anti predator nets is about 35%. This is two to four times better than without the nets. However, the nets require regular maintenance to retain their effectiveness.
- It will cost around $0.85 (assuming free labor and local transport) to produce a pound of littleneck clams in an enhancement program using anti-predator netting.
- Sea otter predation, if it becomes serious, could make a subsistence clam enhancement program impractical.

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Most of all the authors want to acknowledge the interest and dedication of the Native village residents who participated in this study. The significance of these people achieving success in culturing and cultivating a new species in a new environment cannot be underestimated.

It is hoped that Native villages in the oil spill region will turn the potential discovered in this study into reality. An adequate supply of wholesome clams will surely help these Native Alaskans sustain the heritage and culture they so obviously cherish.

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Appendix

Appendix A: Results of Razor Clam Survey for the Village of Eyak, 1996

Appendix B: Results of Razor Clam Survey for the Village of Eyak, 1997

Appendix C: Development of Hatchery, Nursery and Growout Methods for Nuttall's Cockle (*Clinocardium nuttallii*)

Appendix D: Synopsis of Littleneck Clam (*Protothaca staminea*) Life History, Culture Techniques and Commercial Fisheries Management in Southcentral Alaska

Appendix E: Training materials developed for village workshops in preparation for growout studies at the villages of Tatitlek, Nanwalek and Port Graham, Alaska.

Appendix F: 1999 Survey and Enhancement Protocols for the Tatitlek, Nanwalek and Port Graham Village Shellfish Restoration Program.

Appendix G: Draft Nanwalek/Port Graham/Tatitlek Clam Restoration Environmental Assessment, October 1995

Chugach Regional Resource Commission
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Results of Razor Clam Survey for the Village of Eyak

EVOS Project 96131

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April, 1997

Results of Razor Clam Survey
for the Village of Eyak

Table of Contents

List of Figures

List of Tables

List of Appendices

Nickerson selected eight study sites near Cordova for sampling during his study. Study plots were identified and sampled over a 5 month period. Some of the applicable highlights from his exhaustive work are as follows:

- 1st sexual maturity occurs at the third annulus. 2 ½ years old. Found May- September
- Sexual maturity is related to size more than age.
- Spawning is governed by time and temperature.
- Spawning initiates at 42 F to 48 F which appears to be related to accumulated temperature units. 48 F appears to be a triggering temperature for releasing gametes
- Spawning in our research area occurred between July 5 and July 24.
- Clams reached legal harvest size 4" (102mm) by age 6
- Percentage of ova increases with age and size
- Evidence of clay and heavy silting causes mortality, 1964 earthquake exposed clay.
- Survivals from age 1 to 2 is estimated to be 10%, from age 2-3 is estimated to be 30% and from age 3 to age 8 is estimated to be 40%.
- Clams from different areas show phenotypic difference thought to be caused by micro environments that effect coloration and shape of shell.

These insights into the razor clam populations near Corodva should prove valuable as this study progresses

3. Materials and Methods

Survey and interviews

The razor clam project was started at the request of Eyak tribal members whoduring a meeting with the Chugach Regional Resource Commission (CRRC) requested assistance in restoring their razor clam populations. At that time members expressed concern that the only razor clams available were subsize.

Mr. Bud Janson, lifetime Cordova resident and member of the Eyak tribe has been involved with the project since its inception. Through Mr. Janson, Eyak and Cordova elders were interviewed about the following:

- traditional use and harvest rates of shellfish especially razor clams.
- identifying traditional harvest areas on maps and determining "local" names
- identifying access to beaches and anchorages and describing landmarks
- the members understanding of recent harvests and reasons for declining populations

Similar questions were asked of Alaska Department of Fish and Game staff and researchers from the University of Alaska. This information was useful in preparing 1997 work plans.

Physical and chemical characterization of beach substrates

The survey began several hours before low tide on August 31, 1996. The tide in the Cordoba area was projected to be -1.8' tide. A series of test digs were made trying to locate razor clam populations and evaluate the substrate within the designated area. It was decided to sample stations between +1.5' to -1.5' tide range. The length of the sampled areas was 150 feet by 150 feet. The length was then divided by three plus one to obtain a transect interval. A random number between zero and the interval length was then selected and the first transect placed at the random distance from the margin. Each transect was run normal to the water line (Figure 1).

The width of the beach was divided by the number of samples to be collected (3) to obtain a sample station interval. The first sample was taken at a random distance from the -1.5 tide. Red wire flags were labeled with the station number designation and placed in the substrate at the appropriate point. The flags were used as labels for the samples collected at each station. Nine stations were sampled.

Samples were dug at each station. A square aluminum plate covering 0.1m2 was placed at each station and pushed into the substrate to prevent sloughing. Each station was dug to a depth of 40 cm.

The beach study area was profiled to determine elevations, tidal markers and slope. The minus 1.5 tide height was estimated using local tide books. The beach slope was measured using a transit to estimate elevations.

Photographs were taken and notes kept identifying substrate color, presence of macro algae and predators, odor and evidence of beach stability.

Substrate samples were collected from each of the nine sampling sites. The samples were submitted to Alaska Test Labs for particle size distribution. The published methods for the tests are included in Appendix 1.

Physical and chemical characterization of water column

Two 500 ml samples were collected at the beach site. Samples were collected from undisturbed water at a depth of approximately .5 meter. Samples were stored on ice and sent to Northern Testing Labs for analysis of Total Suspended Solids (TSS) and Total Volatile Solids (TVS). The protocol for these tests are outlined in Appendix 2.

Dissolved oxygen was monitored *in situ* with an Aquatic Ecosystems DO-III oxygen meter. Samples were collected at the surface and 1 meter. Salinity and temperature were also measured *in situ* with a YSI Model 33 SCT meter.

Current speeds were measured by placing a drogue in the water and measuring its movement over time.

Shellfish population characterization

Each of the nine sampled stations were evaluated for shellfish. All shellfish in the stations were to be collected and saved for weight, length and age sampling. Substrate from each of the station was sifted through a 6mm screen to attempt to find juveniles

Predator Control

Shellfish collected during the survey were saved and placed in the predator control area. A small section of beach was cleared of debris and marked. Shellfish were placed in the 3 meter by 4 meter area and covered with ½" plastic mesh. The edges were buried with sand at a depth of 6". (Figure 2)

4. Results

Survey and Interviews

Mr. Janson's family had long participated in razor clam harvests in the Cordova and his parents, Bud Sr. and Stella, provided pictures and videos of family clamming trips. The Maxwell family and the late Bill Melvin also provided valuable insight into areas where substantial populations once existed. Without exception all individuals expressed concern that the razor clams are scarce. When asked for explanation as to why to the razor clams and other shellfish were not plentiful anymore the most common explanation was the sea otter. Harvest of razor clams is still possible at their favorite sites but the effort is much greater and the yield smaller than the "old days". Because razor clams were once so plentiful is was difficult to ascertain precisely what was a good made a "good clam beach". The area identified by this project for study was supported because of it's proximity to Cordova however it was characterized was as "average" compared to areas further from town. In addition, the area was supposed to have large populations of subsize clams (not legally harvestable) which would make it an ideal situation to test predator control methods.

The Alaska Department of Fish and Game which manages the commercial and recreational fishery of razor clams provides an annual summary of harvests in the area. There has been no commercial fishery for many years. Recreational and subsistence harvests are very limited also because of the paucity of clams. Since the fisheries is essentially nonexistent little effort goes into its management. To date the definitive work remains to be the research conducted by Richard "Dick" Nickerson between 1969 and 1971.

The University of Alaska had little information to share on razor clam populations or biology in the Cordova area.

Physical and chemical characterization of beach substrates

The study area, named "Bud's Beach" fits the classic razor clam beach of high density sand, sloughs and troughs, heavy tidal action and flow. The beach was very clean devoid of any flotsam, kelp or other debris. There were no otters near the area during the sampling period, however there was a raft of otters near the Cordova boat harbor a few miles away.

As described in Figure 1 all three transects (ABC) were uniform in slope (4%) and substrate characterization. The samples collected for particle size analysis revealed similar results. Graphs and charts of specific sites are located in Appendix 3.

Table 1. Percent of Sample Passing by Weight

Sample	No. 60	No. 100	No. 200
1A -1.5'	88	25	3.9
2A 0'	97	26	2.2
3A 1.5'	94	13	1.9
1B -1.5	96	14	1.6
2B 0'	97	22	1.5
3B 1.5'	97	20	1.8
1C -1.5'	89	9	1.5
2C 0"	97	18	2
3C 1.5'	98	25	1.8

Silt and clay particles pass through #200 screen. Silt particles are considered to be less than 0.02mm and clay particles are less than .005mm. The relatively low percentage of particles passing through the #200 screen suggests that fine particles which may clog sand and prevent adequate flow of water and oxygen is not a problem and juvenile clams would not be affected after setting.

A sample from 1B was so submitted to Northern Testing labs for Total Volatile Solids which yielded a result of 5200 mg/dry per kg. This suggests a moderately high level of organic content. Laboratory personnel suggested additional testing ot identify the source of the high organiz material.

No samples were taken for Reduction Oxidation Potential Discontinuity (RPD) however there was a slight smell of hydrogen sulfide at two stations B1 and C2 at depths of approximately 10cm which suggest poor circulation and lack of oxygen in the fine grain sediments. This was not noticed at other stations and there was nothing unusual about B1 and C2 to account for this phenomenon.

Physical and chemical characterization of water column

The water conditions at the sampled beach appeared to be ideal for shellfish. The water temperature was 10.5 C, salinity 28.5 parts per thousand and the dissolved oxygen was 10.8 mg/liter which is slightly supersaturated. Water movement was low at slack tide which would be expected at .5m/min, however when the tide began to flow it was obvious that there was a significant tidal flush in the area. Movement of the tide was parallel to the beach.

Results from water samples submitted to Northern Testing Labs for Total Suspended Solids (TSS) were 12.0 mg/L (+/- 1mg/L) and Volatile Suspended Solids (VSS) 2.00 mg/L (+/-1mg/L). These values suggest good primary productivity and a few suspended particulates.

Shellfish population characterization

No shellfish were found in any of the nine sampling stations.

A foot survey was conducted on the remainder of the beach. There was very little evidence of shellfish in the area. Two diggers covering approximately 1 km of beach recovered 4 razor clams and 3 cockles. The razor clams measured 80mm, 95mm, 108mm and 92mm respectively. All of the clams recovered were above the +1.5 tide level. No age or weight measurements were taken. The shellfish collected were placed in the predator control study area. Work conducted by Nickerson would suggest these clams were 4+ years old.

The cockles were not precisely measured but were adult size (+50mm).

The absence of any shellfish, including razor clams was a surprise. Although the lack of large amounts of razor clams was well known, and the probability of not finding clams in randomly selected areas could be expected, not finding many clams on the foot survey was bewildering. Subsequent foot surveys were also unproductive in finding razor clams. This was contrary to what had been discovered the previous season prior to the project starting and also with what locals had said relative to an abundance of subharvestable size clams .

The presence of a few scattered adult size razor clams and cockles suggest predation may be a factor. Large razor clams would probably reside at depths were predators such as otters and birds would have trouble catching them as would residing at higher tide levels.

The substrate was screened through 6 mm mesh. No juveniles were found. All of the material passed through the screen. The substrate was visually observed for smaller shellfish and none were found. The paucity of juveniles suggest a recruitment problem. The problem could be 1) lack of a critical mass of spawning adults in the vicinity 2) predation or 3) habitat deficiency such as too many fines causing suffocation.

Predator Control

The razor clams (4) and cockles (3) captured were placed in a 4m by 3m predator control area. The shellfish were spread out and then covered by 12mm mesh netting. The edges were buried under sand. The site was checked several times during the winter. When checked no otters were in the area. On April 4, 1997 the site was checked and the netting was found to be matted up. One cockle and 2 clams were recovered. They measured 82 mm and 106mm. It is possible the cockles migrated from the area. The "missing clams" possibly did not show or were lost two predation when the net matted up.

5. Recommendations

1. Continue the project as planned. Although not finding many clams is disappointing it offers an opportunity to evaluate enhancement techniques without the "noise" of local populations.

2. Continue to survey local areas, concentrating on areas where locals still find razor clams or where Nickerson studied to find sufficient clams for testing predator control methods. Carefully observe gamete development, spawning activity and recruitment near the study area.

3. Collect as many different size razor clams as possible and transfer them to the area for growth and mortality studies.

4. Explore the possibility of seeding newly set juveniles produced form a hatchery or collected from the wild.

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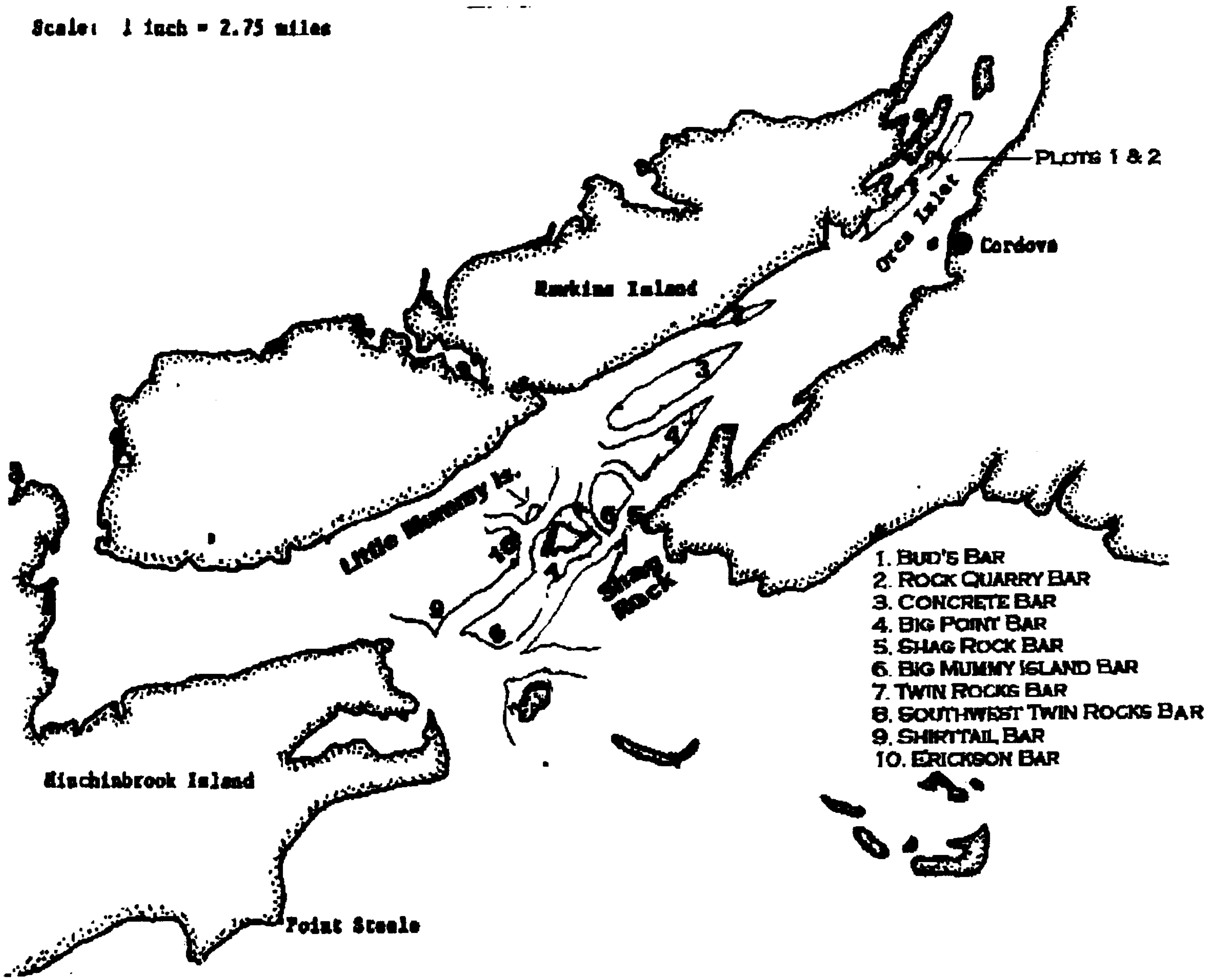
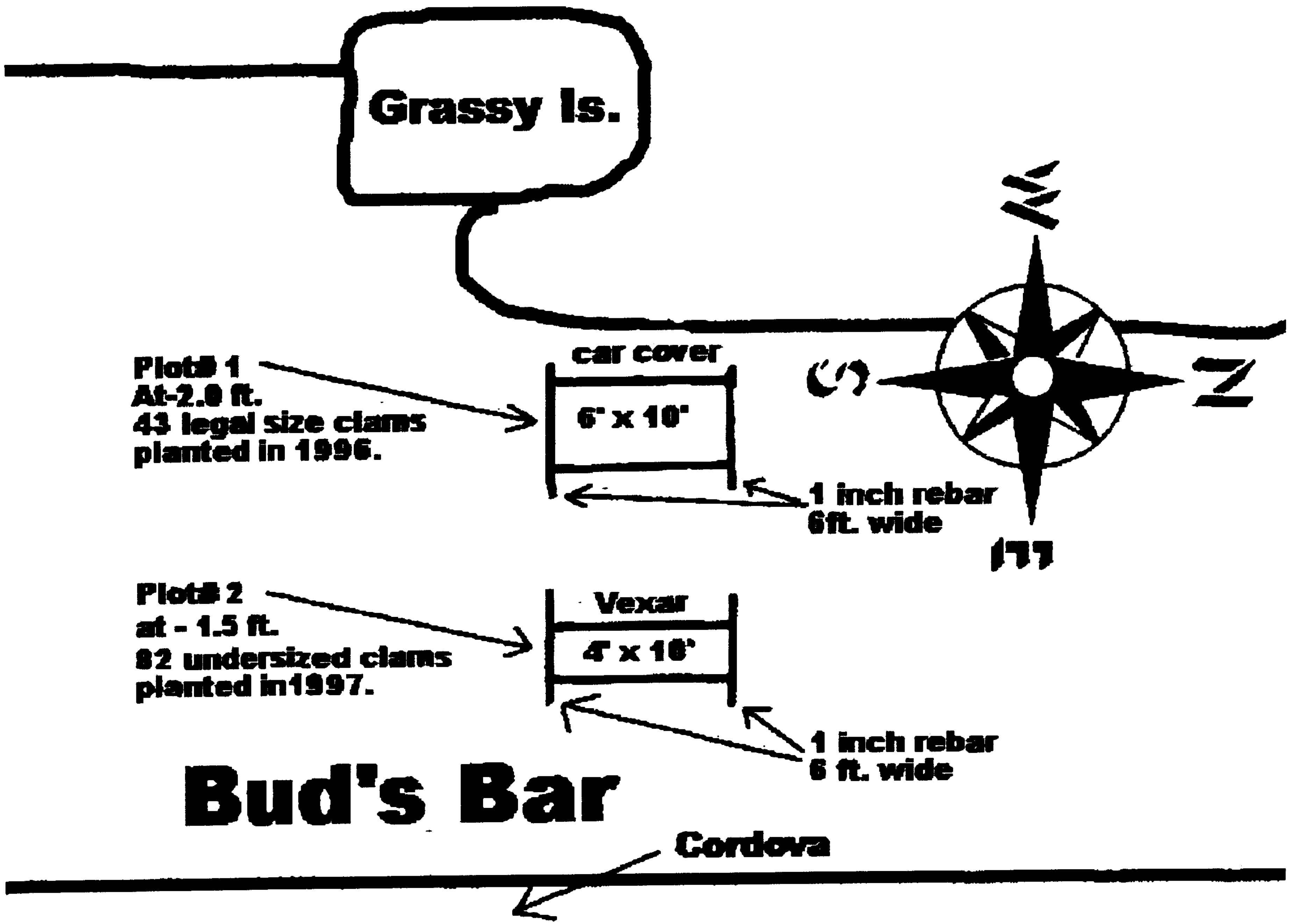
7. Appendices


Scale: 1 inch = 2.75 miles
PLOTS 1 & 2
Orca Inlet
Cordova
Hawkins Island
Little Mummy Is.
Shag Rock
Hinchinbrook Island
Point Steele
1. BUD'S BAR
2. ROCK QUARRY BAR
3. CONCRETE BAR
4. BIG POINT BAR
5. SHAG ROCK BAR
6. BIG MUMMY ISLAND BAR
7. TWIN ROCKS BAR
8. SOUTHWEST TWIN ROCKS BAR
9. SHIRTTAIL BAR
10. ERICKSON BAR


Grassy Is.
Plot# 1
At-2.0 ft.
43 legal size clams
planted in 1996.
car cover
6' x 10'
1 inch rebar
6ft. wide
Plot# 2
at - 1.5 ft.
82 undersized clams
planted in1997.
Vexar
4' x 10'
1 inch rebar
6 ft. wide
Bud's Bar
Cordova

NORTHERN TESTING LABORATORIES, INC.

3330 INDUSTRIAL AVENUE — FAIRBANKS, ALASKA 99701 — (907) 456-3116 • FAX 456-3125
8005 SCHOON STREET — ANCHORAGE, ALASKA 99518 — (907) 349-1000 • FAX 349-1016

January 27, 1997

TOTAL SUSPENDED SOLIDS/VOLATILE SUSPENDED SOLIDS

SM Method: 2540D AND 2540E

Detection Limit: 1.0

Interferences: Excessive residue in the sample may clog the filter, so limit the sample size to avoid clogging filter.

Preservation and Storage: Filters and foil pans should be kept in a desiccator to ensure that their weights remain constant. Filters should be washed with 60 mLs deionized water by means of filtration and dried in 104 C oven for one hour.

Equipment: Aluminum pans, 65mm diam.
4.7 cm glass-fiber filter disks
Glass membrane filter funnel (Whatman 934AH) rinsed with 60mLs of deionized water
drying oven; 103-105 degrees Celsius
Tweezers
Graduated Cylinders (TD)
Oven- 500 +/- 50 degrees Celsius

Procedure: Prepare filters and aluminium pans by heating in 104 oven for one hour or heating at 500 +/- 50 degress Celsius for additional volatile analysis. Dessicate pans and filters. Weigh each pan with filter and record results. This should be recorded as your tare weight.

Place filter with wrinkle side up on funnel. Apply vacuum. Shake sample 20 times and quickly pour out sample into a graduated cylinder. Estimated amounts to funnel for effluents use: 100-200 mLs, influent: 25 mLs, and streams: 200mLs. Pour measured sample into funnel. Rinse the graduated cylinder three times with deionized water, and pour each rinse into funnel. Rinse funnel three times with deionized water to ensure that all suspended solids have been trapped in the filter. Turn off vacuum and remove filter from funnel and place in aluminum planchet. Repeat process for each sample .

After ~~funneling~~ filtering samples and quality control standard, your last 2 filters should be used to rinse out the funnel. These two are the blanks.

TSS.DOC

NORTHERN TESTING LABORATORIES, INC.

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8005 SCHOON STREET ANCHORAGE, ALASKA 99518 (907) 349-1000 • FAX 349-1016

Dry in an oven at 103 to 105 degrees Celsius for one hour. Place pans in desiccator until constant weight is maintained. The constant weight should be recorded as your gross weight.

Refer to VSS method to obtain volatile values.

Calibration: The gross weight of each blank should be equal to its tare weight. Subtract the tare weight of each blank from its gross, and find the average net weight of the blanks. If the average net weight is a negative number, your correction factor is a positive number. If the average net wt. of the blanks is a positive number, your correction factor is a negative number.

TSS Calculation: **GROSS - TARE = NET**

$$\frac{(\text{NET} +/- \text{BLANK C.F.}) \times 10^6}{\text{mLs}} = \text{TSS mg/L}$$

VSS Calculation: **Gross TSS Weight - Pan Weight after ignition = NET**

$$\frac{(\text{NET} +/- \text{BLANK C.F.}) \times 10^6}{\text{mLs of Sample}} = \text{VSS mg/L}$$

Quality Control:
A sample of known value from an independent source should be analyzed before analyzing the samples. The value found for the sample should be within 20% of the true value. Analyze at least one duplicate for every 10 samples analyzed. The percent relative difference for duplicates should not be greater than 20%. Calculate the percent relative difference as follows:

$$\frac{\text{difference between samples}}{\text{avg. of samples}} \times 100 = \text{\% relative difference}$$

Bibliography: Standard Methods 18th ed.

TSS.DOC

January 17, 1997

VOLATILE SUSPENDED SOLIDS

Standard Method: SM 2540 E

Detection Limit: 1.0

Interferences: Excessive residue in the sample may clog the filter, so limit the sample size to avoid clogging filter. Limit residue to 200 mg or increase ignition time.

Preservation and Storage: Filters and foil pans should be kept in a desiccator to ensure that their weights remain constant. Filters should be washed with 60 mLs deionized water by means of filtration.

Equipment: Aluminum planchets, 65mm diam.
4.7cm glass-fiber filter disks (Whatman 934AH)
Glass membrane filter funnel
drying oven; 103-105 degrees Celsius
drying oven; 550 degrees Celsius

Procedure: Heat filters and planchets at 550 degrees Celsius for one hour. Place the filters and planchets in the desiccator to cool. Weigh each pan with filter and record results. Place filter with wrinkle side up on funnel. Apply vacuum. Shake sample 20 times and quickly pour out sample into a graduated cylinder. Suggested amounts for effluents use: 100-200 mLs, influent: 25mLs, and streams: 200 mLs. Pour measured sample into funnel. Rinse the graduated cylinder three times with deionized water, and pour each rinse into funnel. Rinse funnel three times with deionized water to ensure that all suspended solids have been trapped in the filter. Remove filter from funnel and place in aluminum planchet. Repeat process for each sample. After filtering samples and quality control standard, your last 2 filters should be rinsed with deionized water only. They will be blanks.

Dry in an oven at 103 to 105 degrees Celsius for at least one hour. Dessicate pans and weigh. Record this weight as the tare weight.

Heat filters and planchets in oven already heated to 550 degrees Celsius for 20 minutes. Remove filters and planchets from oven and cool in desiccator for at least 1 hour. Weigh planchets with filters and record as gross weight.

VSS.DOC

January 17, 1997

Calibration: The gross weight of each blank should be equal to its tare weight. Subtract the gross weight of each blank from its tare, and find the average net weight of the blanks. If the average net weight is a negative number, your correction factor is a positive number. If the average net wt. of the blanks is a positive number, your correction factor is a negative number.

Calculation: **TARE - GROSS = NET**

Tare- weight of planchets after filtration and drying in 104 oven.

Gross- weight of planchets after heated to 550 Degree C.

$$\frac{\text{NET +/- BLANK C.F. x } 10^{6}}{\#m^{L}s.} = \text{Mg/L}$$

Quality Control:

A sample of known value from an independent source should be analyzed before analyzing the samples. The value found for the sample should be within 20% of the true value. Analyze at least one duplicate for every TSS run. The percent relative difference for duplicates should not be greater than 20%. Calculate the percent relative difference as follows:

$$\frac{\text{difference between samples}}{\text{avg. of samples}} \times 100 = \%\text{ relative difference}$$

Bibliography: Standard Mthds ed. 18.

VSS.DOC

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Jeff Hetrick
P.O. Box 7
Moose Pass, AK 99631

Attn: Jeff Hetrick

Report Date: 09/10/96
Date Arrived: 09/03/96
Date Sampled: 08/30/96
Time Sampled:
Collected By:

Our Lab #: A146885
Location/Project:
Your Sample ID:
Sample Matrix: Water
Comments:

** Definitions **
B = Present in Blank
H = Above Regulatory Max.
E = Estimated Value
M = Matrix Interference
D = Lost to Dilution
MDL = Method Detection Limit

Lab Number	Method	Parameter	Units	Result	*	MDL	Date Prepared	Date Analyzed
A146885	SM 2540D	Total Suspended Solids	mg/L	12.0		1.00		09/06/96
A146985	SM 2540E	Volatile Suspended Solids	mg/L	2.00		1.00		09/10/96

Reported By: Julie Schaefer
Environmental Analyst

NORTHERN TESTING LABORATORIES, INC.

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8005 SCHOON STREET ANCHORAGE, ALASKA 99518 (907) 349-1000 • FAX 349-1016

Jeff Hetrick
P.O. Box 7
Moose Pass, AK 99631

Report Date: 09/10/96
Date Arrived: 09/03/96
Date Sampled: 08/30/96
Time Sampled:
Collected By:

Attn: Jeff Hetrick

* Definitions *
ND = Non Detected
H = Above Regulatory Max.
E = Estimated Value
M = Matrix Interference
D = Lost to Dilution
MDL = Method Detection Limit

Our Lab #: A146885
Location/Project:
Your Sample ID:
Sample Matrix: Water
Comments:

Lab Number	Method	Parameter	Units	Result	*	MDL	Date Prepared	Date Analyzed
A146885	SM 2540D	Total Suspended Solids	mg/L	12		1.0		09/06/96
A146885	SM 2540E	Volatile Suspended Solids	mg/L	2.0		1.0		09/10/96

Julie Schaefer
Reported By: Julie Schaefer
Environmental Analyst

NORTHERN TESTING LABORATORIES, INC.

3330 INDUSTRIAL AVENUE FAIRBANKS, ALASKA 99701 (907) 456-3116 • FAX 456-3125
8005 SCHOON STREET ANCHORAGE, ALASKA 99518 (907) 349-1000 • FAX 349-1016

Jeff Hetrick
P.O. Box 7
Moose Pass, AK 99631

Report Date: 09/19/96
Date Arrived: 09/10/96
Date Sampled: 09/09/96
Time Sampled:
Collected By: JH

Attn: Jeff

** Definitions **
B = Present in Blank
NA = Not Analyzed
E = Estimated Value
M = Matrix Interference
D = Lost to Dilution
MDL = Method Detection Limit

Our Lab #: A146976
Location/Project:
Your Sample ID: Soil Sample
Sample Matrix: Soil
Comments:

Lab Number	Method	Parameter	Units	Result	*	MDL	Date Prepared	Date Analyzed
A146976	EPA 160.3	Solids		77.0				09/13/9
A146976	SM 2540E	Total Volatile Solids	mg/dry Kg	5200		1.00		09/13/9

Reported By: Anthony J. Lange
Chemistry Supervisor

NORTHERN TESTING LABORATORIES, INC.

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8005 SCHOON STREET ANCHORAGE, ALASKA 99518 (907) 349-1000 • FAX 349-1016

Report Date: 09/19/96
Date Arrived: 09/10/96
Date Sampled: 09/09/96
Time Sampled:
Collected By: JH

Jeff Hetrick
P.O. Box 7
Moose Pass, AK 99631

Attn: Jeff Hetrick

** Definitions **
B = Present in Blank
H = Above Regulatory Max.
E = Estimated Value
M = Matrix Interference
D = Lost to Dilution
MDL = Method Detection Limit

Our Lab #: A146976
Location/Project:
Your Sample ID: Soil Sample
Sample Matrix: Soil
Comments:

Lab Number	Method	Parameter	Units	Result	*	MDL	Date Prepared	Date Analyzed
A146976	EPA 160.3	Solids		77.0				09/13/96
A146976	SM 2540E	Total Volatile Solids	mg/dry Kg	5200		1.00		09/13/96

Julie Schaefer

Reported By: Julie Schaefer
Environmental Analyst

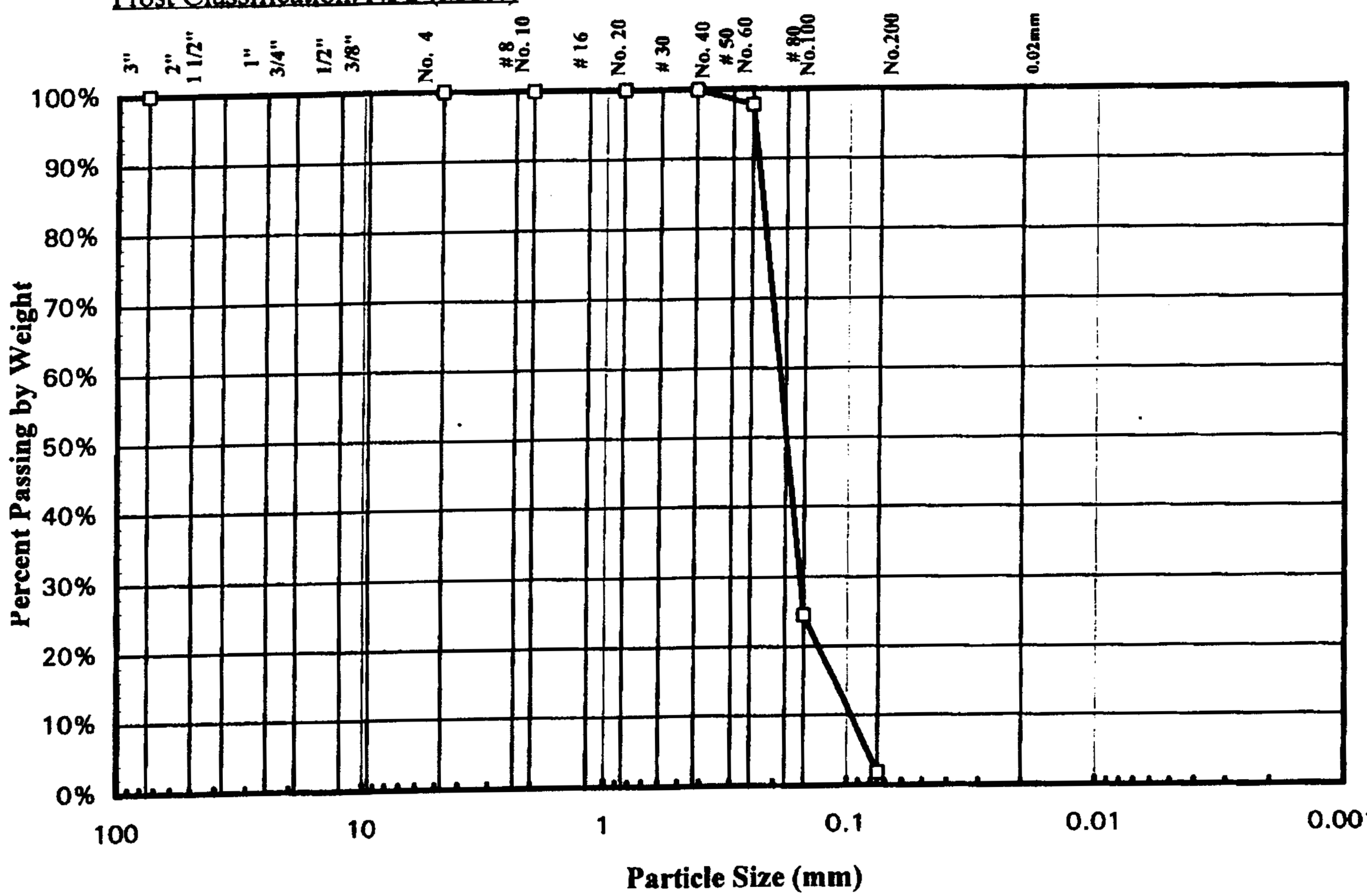
ALASKA TESTLAB
Division of DOWL, Incorporated
40 B Street Anchorage, Alaska 99503
)7) 562-2000 FAX (907) 563-3953

Client: Northern Testing Laboratories
Project: Trail Lakes Hatchery
Location: Sample 3C @ 1.5'
Submitted by Client

PARTICLE-SIZE DISTRIBUTION

W.O. A27041
Lab No. 1306
Received: September 19, 1996

Engineering Classification: Poorly Graded SAND , SP
Frost Classification: NFS (MOA)



SIZE	PASSING	SPECIFICATION
+3 in Not Included in Test = ~0%		
3"		
2"		
1 1/2"		
1"		
3/4"		
1/2"		
3/8"		
No. 4	100%	
Total Wt. of Coarse Fraction = 353.3g		
No. 8		
No. 10	100%	
No. 16		
No. 20	100%	
No. 30		
No. 40	100%	
No. 50		
No. 60	98%	
No. 80		
No.100	25%	
No.200	1.8%	
Total Wt. of Fine Fraction = 353.3g		
0.02 mm		

ALASKA TESTLAB
Division of DOWL, Incorporated
0 B Street Anchorage, Alaska 99503
) 562-2000 FAX (907) 563-3953

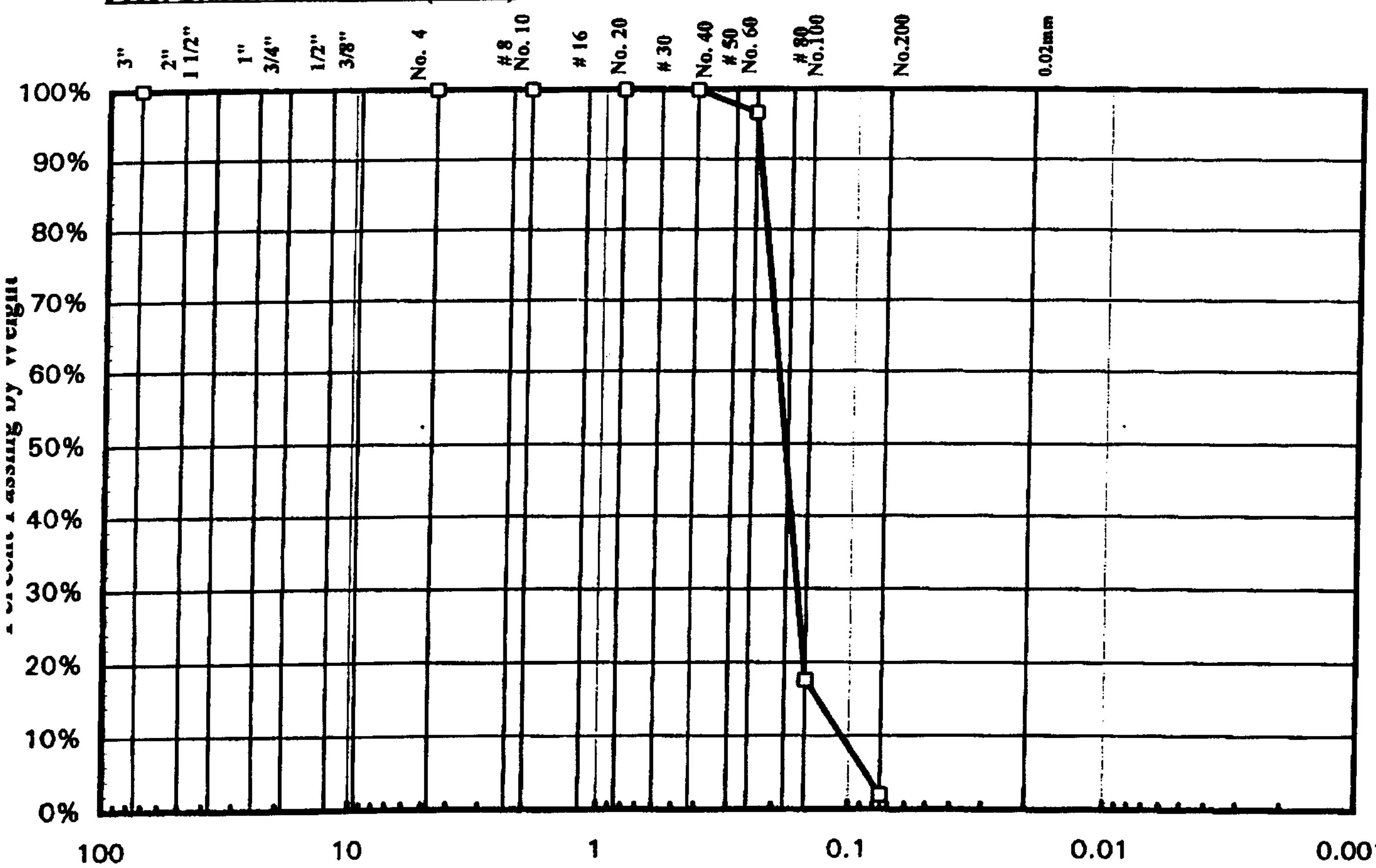
Client: Northern Testing Laboratories
Project: Trail Lakes Hatchery

Location: Sample 2C
Submitted by Client

PARTICLE-SIZE DISTRIBUTION

W.O. A27041
Lab No. 1305
Received: September 19, 1996

Engineering Classification: Poorly Graded SAND , SP
Frost Classification: NFS (MOA)



SIZE	PASSING	SPECIFICATION
+3 in Not Included in Test = ~0%		
3"		
2"		
1 1/2"		
1"		
3/4"		
1/2"		
3/8"		
No. 4	100%	
Total Wt. of Coarse Fraction = 224.6g		
No. 8		
No. 10	100%	
No. 16		
No. 20	100%	
No. 30		
No. 40	100%	
No. 50		
No. 60	97%	
No. 80		
No.100	18%	
No.200	2%	
Total Wt. of Fine Fraction = 224.6g		
0.02 mm		

ALASKA TESTLAB
Division of DOWL, Incorporated
) B Street Anchorage, Alaska 99503
') 562-2000 FAX (907) 563-3953

Client: Northern Testing Laboratories

Project: Trail Lakes Hatchery

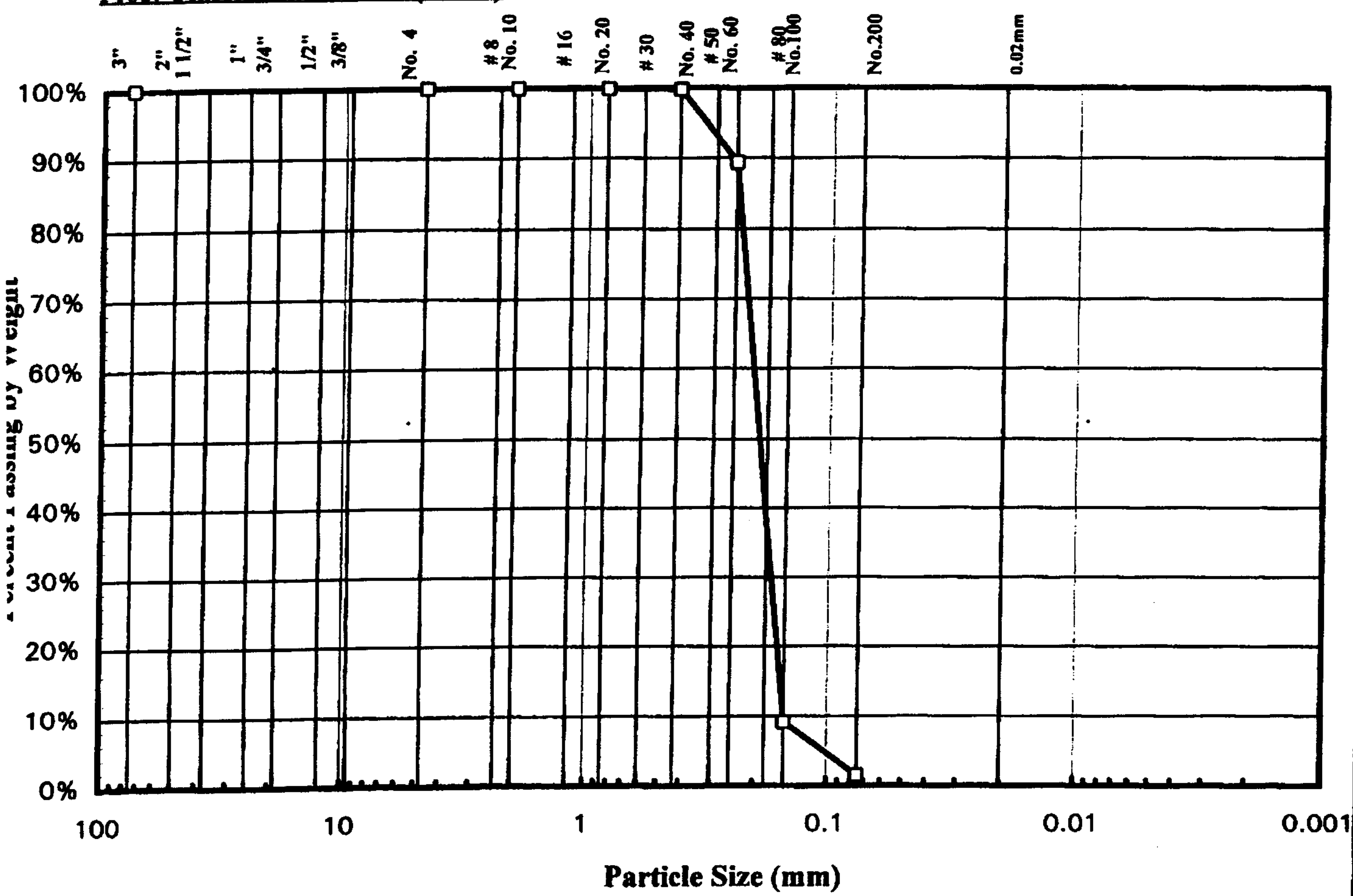
Location: Sample 1C @ 1.5'
Submitted by Client

PARTICLE-SIZE DISTRIBUTION

W.O. A27041
Lab No. 1304
Received: September 19, 1996

Engineering Classification: Poorly Graded SAND , SP

Frost Classification: NFS (MOA)



SIZE	PASSING	SPECIFICATION
+3 in Not Included in Test = -0%		
3"		
2"		
1 1/2"		
1"		
3/4"		
1/2"		
3/8"		
No. 4	100%	
Total Wt. of Coarse Fraction = 428.9g		
No. 8		
No. 10	100%	
No. 16		
No. 20	100%	
No. 30		
No. 40	100%	
No. 50		
No. 60	89%	
No. 80		
No.100	9%	
No.200	1.5%	
Total Wt. of Fine Fraction = 428.9g		
0.02 mm		

ALASKA TESTLAB
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Client: Northern Testing Laboratories

Project: Trail Lakes Hatchery

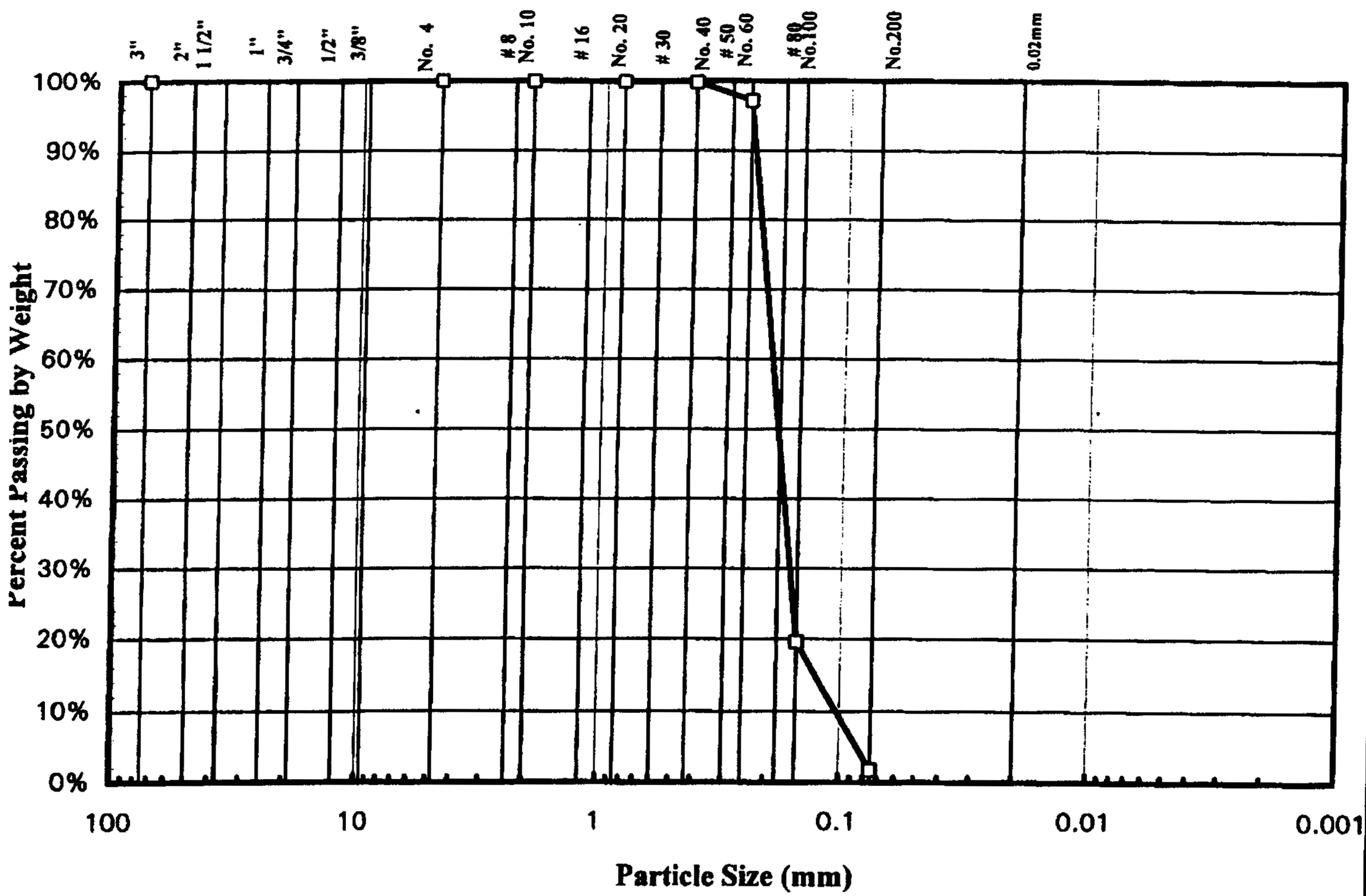
Location: Sample 3B @ 1.5'
Submitted by Client

PARTICLE-SIZE DISTRIBUTION

W.O. A27041
Lab No. 1303
Received: September 19, 1996

Engineering Classification: Poorly Graded SAND , SP

Frost Classification: NFS (MOA)



SIZE	PASSING	SPECIFICATION
+3 in Not Included in Test = ~0%		
3"		
2"		
1 1/2"		
1"		
3/4"		
1/2"		
3/8"		
No. 4	100%	
Total Wt. of Coarse Fraction = 171.3g		
No. 8		
No. 10	100%	
No. 16		
No. 20	100%	
No. 30		
No. 40	100%	
No. 50		
No. 60	97%	
No. 80		
No.100	20%	
No.200	1.8%	
Total Wt. of Fine Fraction = 0g		
0.02 mm		

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Client: Northern Testing Laboratories

Project: Trail Lakes Hatchery

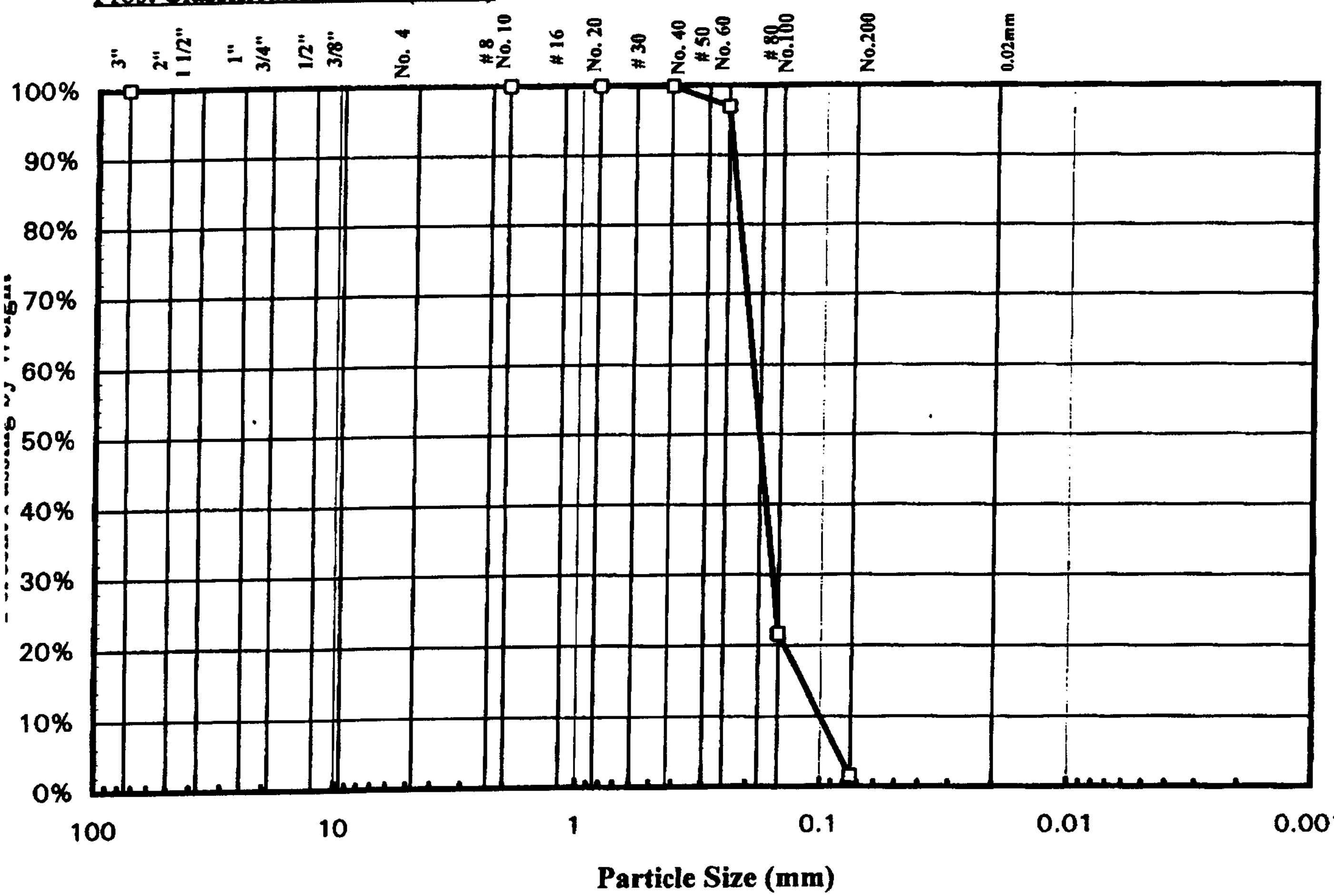
Location: Sample 2B
Submitted by Client

PARTICLE-SIZE DISTRIBUTION

W.O. A27041
Lab No. 1302
Received: September 19, 1996

Engineering Classification: Poorly Graded SAND , SP

Frost Classification: NFS (MOA)



SIZE	PASSING	SPECIFICATION
+3 in Not Included in Test = -0%		
3"		
2"		
1 1/2"		
1"		
3/4"		
1/2"		
3/8"		
No. 4		
Total Wt. of Coarse Fraction = 148.8g		
No. 8		
No. 10	100%	
No. 16		
No. 20	100%	
No. 30		
No. 40	100%	
No. 50		
No. 60	97%	
No. 80		
No.100	22%	
No.200	1.5%	
Total Wt. of Fine Fraction = 0g		
0.02 mm		

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Client: Northern Testing Laboratories

Project: Trail Lakes Hatchery

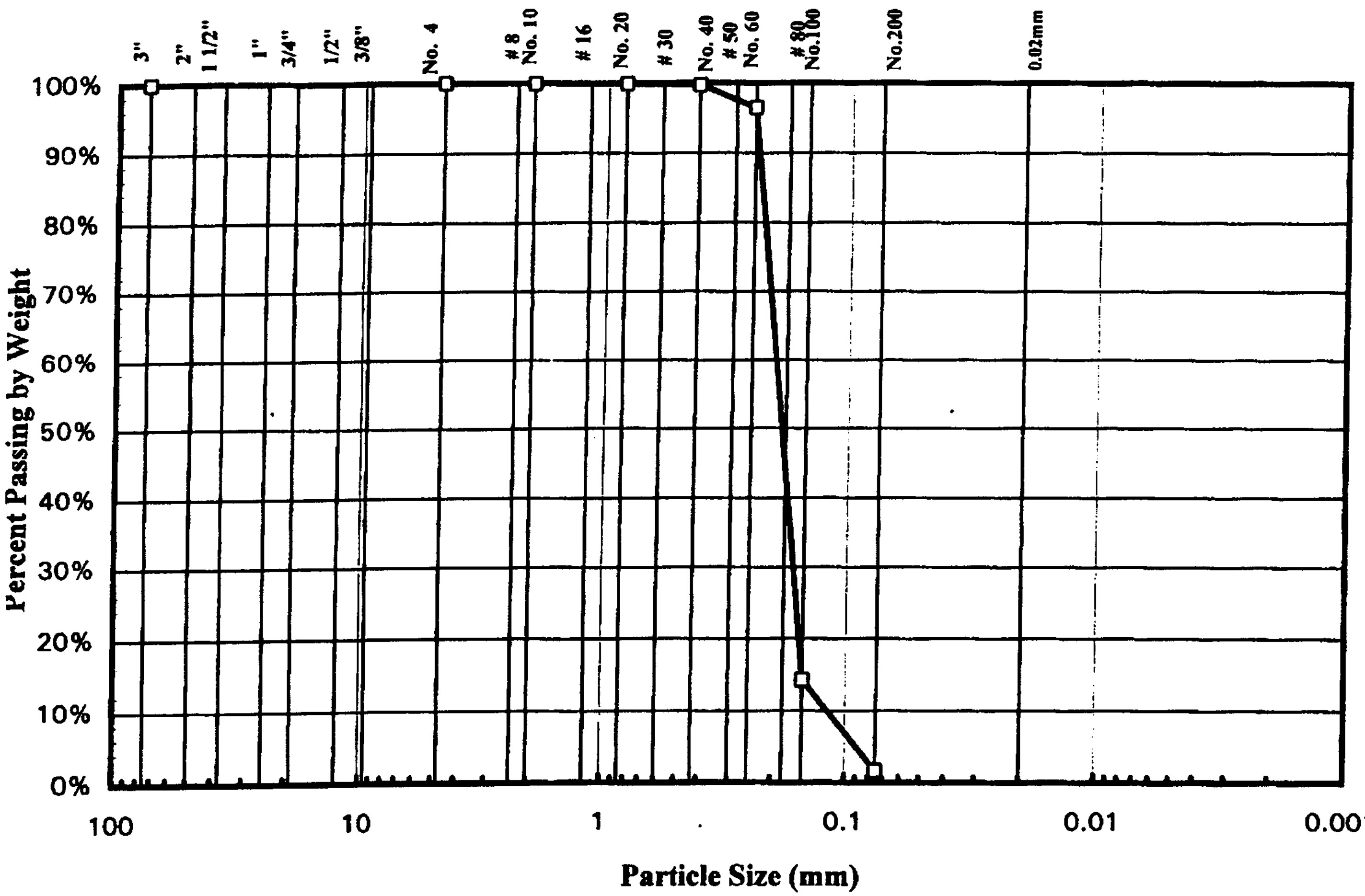
Location: Sample 1B @ 1.5'
Submitted by Client

PARTICLE-SIZE DISTRIBUTION

W.O. A27041
Lab No. 1301
Received: September 19, 1996

Engineering Classification: Poorly Graded SAND , SP

Frost Classification: NFS (MOA)



SIZE	PASSING	SPECIFICATION
+3 in Not Included in Test = ~0%		
3"		
2"		
1 1/2"		
1"		
3/4"		
1/2"		
3/8"		
No. 4	100%	
Total Wt. of Coarse Fraction = 281g		
No. 8		
No. 10	100%	
No. 16		
No. 20	100%	
No. 30		
No. 40	100%	
No. 50		
No. 60	96%	
No. 80		
No.100	14%	
No.200	1.6%	
Total Wt. of Fine Fraction = 0g		
0.02 mm		

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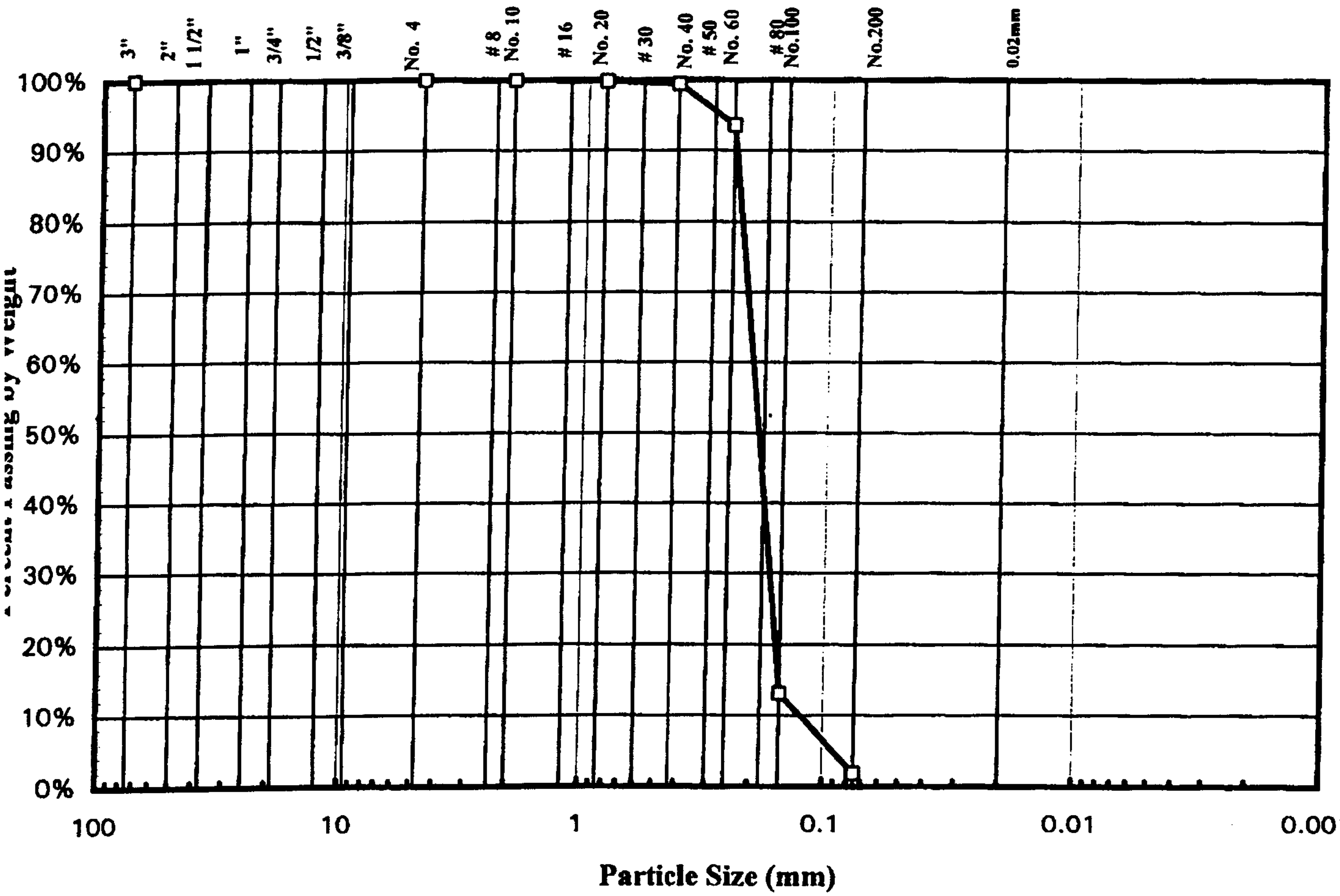
Client: Northern Testing Laboratories
Project: Trail Lakes Hatchery
Location: Sample 3A @ 1.5'
Submitted by Client

PARTICLE-SIZE DISTRIBUTION

W.O. A27041
Lab No. 1300
Received: September 19, 1996

Engineering Classification: Poorly Graded SAND , SP
Frost Classification: NFS (MOA)



SIZE	PASSING	SPECIFICATION
+3 in Not Included in Test = ~0%		
3"		
2"		
1 1/2"		
1"		
3/4"		
1/2"		
3/8"		
No. 4	100%	
Total Wt. of Coarse Fraction = 310.7g		
No. 8 .		
No. 10	100%	
No. 16		
No. 20	100%	
No. 30		
No. 40	99%	
No. 50		
No. 60	94%	
No. 80		
No.100	13%	
No.200	1.9%	
Total Wt. of Fine Fraction = 0g		
0.02 mm		

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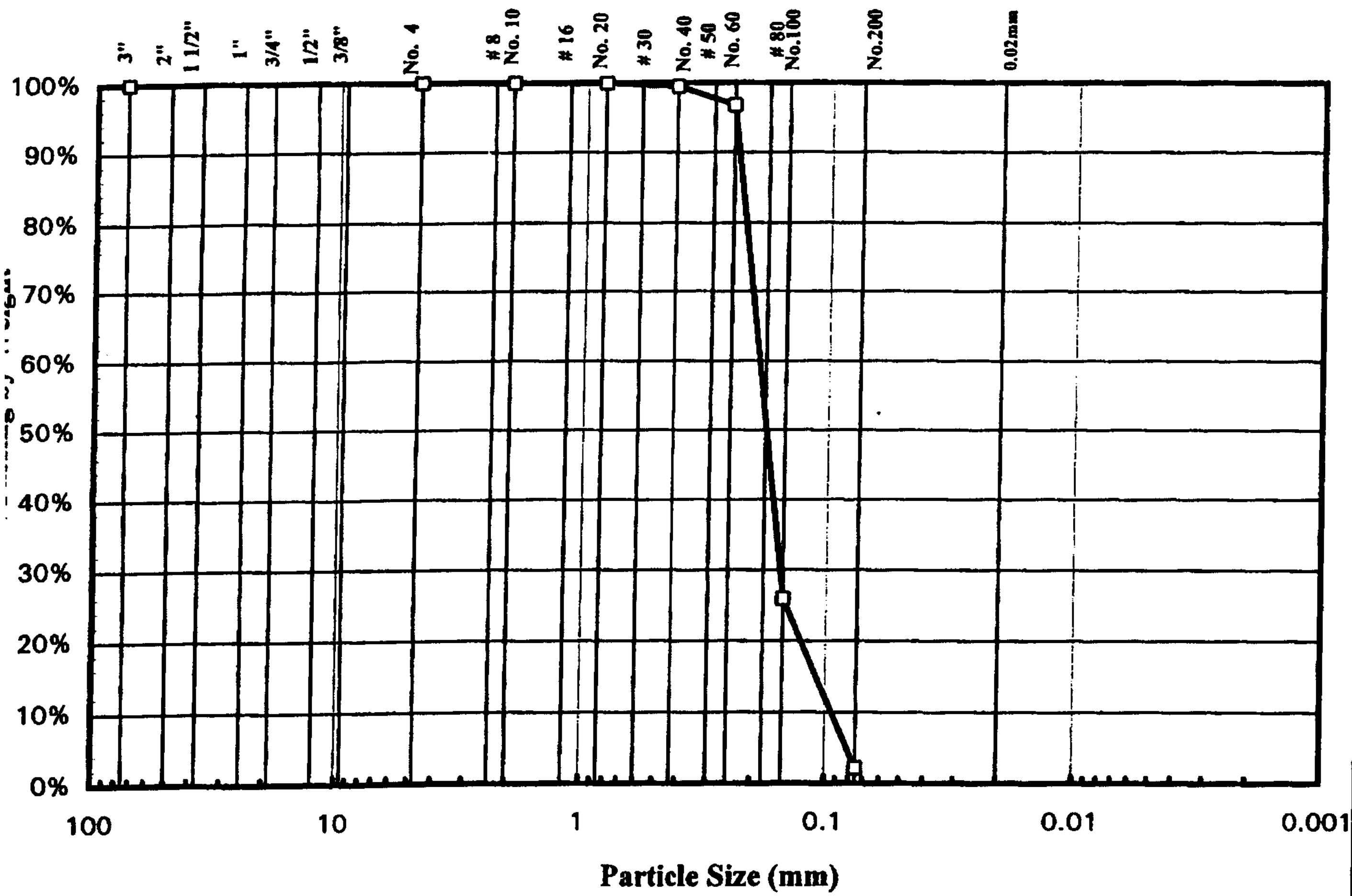
Client: Northern Testing Laboratories
Project: Trail Lakes Hatchery
Location: Sample 2A,
Submitted by Client

PARTICLE-SIZE DISTRIBUTION

W.O. A27041
Lab No. 1299
Received: September 19, 1996

Engineering Classification: Poorly Graded SAND , SP
Frost Classification: NFS (MOA)



SIZE	PASSING	SPECIFICATION
+3 in Not Included in Test = ~0%		
3"		
2"		
1 1/2"		
1"		
3/4"		
1/2"		
3/8"		
No. 4	100%	
Total Wt. of Coarse Fraction = 342.2g		
No. 8	.	
No. 10	100%	
No. 16		
No. 20	100%	
No. 30		
No. 40	99%	
No. 50		
No. 60	97%	
No. 80		
No.100	26%	
No.200	2.2%	
Total Wt. of Fine Fraction = 342.2g		
0.02 mm		

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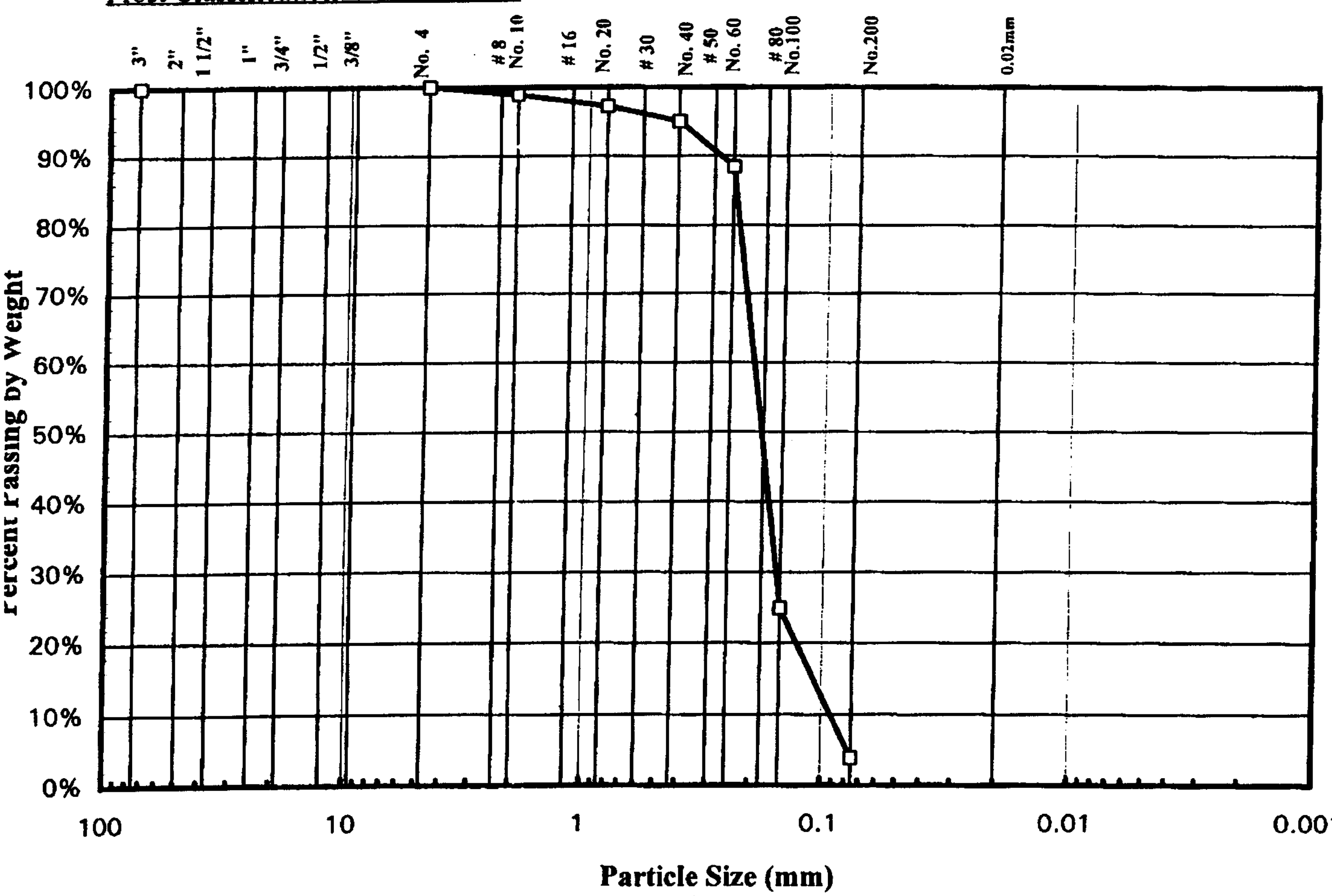
Client: Northern Testing Laboratories
Project: Trail Lakes Hatchery
Location: Sample 1A, Submitted by Client

PARTICLE-SIZE DISTRIBUTION

W.O. A27041
Lab No. 1298
Received: September 19, 1996

Engineering Classification: Poorly Graded SAND , SP
Frost Classification: Not Measured



SIZE	PASSING	SPECIFICATION
+3 in Not Included in Test = ~0%		
3"		
2"		
1 1/2"		
1"		
3/4"		
1/2"		
3/8"		
No. 4	100%	
Total Wt. of Coarse Fraction = 18.1g		
No. 8		
No. 10	99%	
No. 16		
No. 20	97%	
No. 30		
No. 40	95%	
No. 50		
No. 60	88%	
No. 80		
No.100	25%	
No.200	3.9%	
Total Wt. of Fine Fraction = 0g		
0.02 mm		

Appendix B

Chugach Regional Resource Commission
4201 Tudor Centre Drive, Suite 300
Anchorage, Alaska 99508

Results of Razor Clam
Studies for the Village of Eyak

EVOS Project 97131
Chugach Region Clam Restoration

Produced By:
Jeff Hetrick
P.O. Box 7
Moose Pass, Alaska 99631
and

Bud Janson
P.O. Box 2332
Cordova, Alaska 99574

Results of Razor Clam
Studies for the Village of Eyak

Table of Contents

List of Tables

List of Figures

1. Introduction and Background

This is the second year of a project designed to provide baseline information for future efforts to restore and enhance razor clam populations *Siligua patula* for subsistence use and harvest for the Village of Eyak near Cordova. This effort is part of Exxon Valdez Oil Spill (EVOS) Restoration Project 97131 **Chugach Region Clam Restoration.**

Razor clams were once the basis for an important commercial, subsistence and recreational fishery near Cordova known as the "razor clam capital of the world" with annual harvests of several million pounds. Presently, populations are so low that no commercial fishery has been prosecuted since 1988 and recreational harvests are minimal. The decline is attributed to environmental changes in flow from the Copper River, land shifts from the 1964 earthquake and sea otter predation.

Members of the Eyak tribe located near the City of Cordova expressed a desire to reestablish razor clam populations within the area to restore a traditional subsistence food source.

Review of 1996

The objectives and results for the first year of the project are summarized below:

1) Conduct Survey and Interviews
- determined traditional areas of use and harvest of shellfish especially razor clams.
-identified traditional harvest areas on maps and determined "local names".
-identified access to beaches and anchorages and described landmarks.
- developed an understanding of local perspectives of recent harvests and reasons for declining populations.

2) Physical and chemical characterization of selected beach substrates
- substrate samples were collected at a test beach site and analyzed for particle size and organic content.

3) Physical and chemical characterization of beach area water column
- water chemistry such as temperature, salinity and dissolved oxygen were collected.
- water samples were collected for Total Suspended Solids (TSS) and Volatile Suspended Solids (VSS). The results suggest good primary productivity and a few suspended particulate,

4) Shellfish population characterization
- evaluated shellfish populations on a selected beach, very few shellfish were found. - sampled beach areas for existing populations of razor clams, no clams were found. - selected "Bud's Beach" for enhancement.

5) Predator Control
- transferred local razor clams to the study area.
- began study of a predator control method utilizing "car cover".

The project was successful in accomplishing all of the tasks outlined in the 1996 Detailed Project Description (DPD). A year end report was submitted to the Exxon Valdez Oil Spill Trustee Council in March 1997.

The 1996 field work was successful in providing a basis for further work, The test area being void of significant numbers of razor clams offered an opportunity to work in an area that appears to be excellent razor clam habitat but does not have any "noise" from resident populations. The results of the 1996 field season provided the basis for the goals outlined in the 1997 DPD.

1997 Objectives

The DPD outlined for 1997 focused on predator control. Work done in Puget Sound and Canada suggests that it may be possible to enhance clam populations by applying predator control screening.

Because of the inability to locate clams on randomly selected areas during the 1996 field season the 1997 DPD was modified, Random sampling was eliminated as a means of capturing razor clams for the study. A concerted eff ort was made to dig adjacent areas to try to capture as many clams as possible and transfer them to the test plots for testing the predator netting.

Because of the migratory nature of cockles, they were eliminated from the 1997 DPD.

The main objectives of the 1997 work plan were to capture as many razor clams as possible, preferably juveniles, and transport them to a growout area and conduct a growth and mortality study while continuing to evaluate predator control methods.

2. Materials and Methods

A growout area (4 ft x 10 ft) was prepared at "Bud's beach" at 1.5 ft. below the MLLW line. A higher tide location, at 1.0 ft below the MLLW line, was selected for the second test plot to allow for more frequent access. The plot selected in 1996 was at 2.0 ft below MLLW and was not accessible during most of the tide sequences. The area was prepared by removing debris off of the surface and was dug to 6" to remove any miscellaneous material and loosen the substrate. The area appears to be suitable since the razor clams collected in 1996 and cultured nearby over wintered and had survived to this point.

After the area was cleared hard plastic netting (Vexar) with 7 mm meshwas placed over the area and anchored at both ends with rebar. Hard plastic cover was used in place of Carcover™. During the 1996 season the Carcover™ used was hard to work with because it tore easily and was difficult to uncover. Also, although there was no evidence of predation, hard plastic would probably over more protection from predators.

Areas within 5 miles of Bud's Beach were dug at very low tides (2 ft below MLLW or greater) through July. (Diagram #1). Nickerson had previously identified these areas as having substantial razor clam populations. During low tide sequences two to four diggers would walk the beach looking for razor clams to show.

Any clams captured during the digs were removed, measured, aged and placed under the hard plastic cover at plot #2. The razor clams were measured using Manostat vernier calipers. The razor clams valves were measured between the longest points. The age of the razor clams were estimated by counting rings on the exterior of the valves, This is not a very good method to use however the clams would have to be sacrificed to accurately estimate their age. After the clams were sampled, the shells were dried and numbered using white and red fingernail polish.

While digging for clams special attention was made to sift through the sand and try to find small razor clams. Random areas were dug with the shovel and the overturned sand was examined for small clams.

The two plots, **1996 #1 and 1997 #2,** were checked on a regular basis. The test plots were checked for a final time for this project in March 1998.

3. Results

Mr. Bud Janson, who is a member of the Native Village of Eyak, was responsible for collecting the razor clams for this study. Mr. Janson and his crew dug during six low tides attempting to locate as many razor clams as possible. Ten local sand bars (Diagram #1) were dug during this effort. Many of the bars yielded no clams, which was surprising since they once supported large populations (Nickerson, 1975). The lack of clam was much worse than expected. Razor clams can be difficult to find, however Mr.

Janson and his crew are experienced diggers that would have been able to locate any clams that were there.

Area beaches were dug during several tides and captured razor clams were transferred to the test site. All captured clams were measured, their age estimated and then numbered with fingernail polish and placed in the growout study area. Samples that were difficult or confusing to age were not estimated.

A total of 82 clams were captured near the study area during the 1997 field season (Diagram #2). The 82 clams were placed in rows at 6" intervals under the cover after they were captured (Table 1).

No clams smaller than 45mm were found. Three empty shells, which were approximately 15mm in length, were found in July near the surface, This was the only appearance of juvenile razor clams in the area. There appears to have been no significant recruitment to the beach for several years. It also appears that most of the razor clams captured may be from the same year class since the estimated ages and relative uniformity of the clams lengths suggests that they all may be cohorts.

The 43 clams captured in 1996 were checked at plot #1 throughout the 1997 field season. The northern side of the car cover had been buried under 6" inches of sand and had to be dug out and replaced. There were clams still under the cover but they were not sampled. They were scheduled to be sampled and numbered in 1998 prior to the removal of funding

The test plots were checked for a final time in 1997 on September 17th and 18th. No damage was noticed and razor clams were showing under the cover.

The final sampling of the test plots occurred on March 31, 1998. Sampling razor clams is extremely difficult because it is hard to locate the clams and mortality is likely to occur from the digging and handling. To completely sample an area would take an extensive effort. 15 clams were observed at Plot #1 (1996) but they were not sampled,

Fourteen clams were retrieved and measured from plot #2 and placed back in the test area. Of the 14 clams recovered 4 had lost their numbers or were illegible. It is likely that many of the clams will lose their markings by the next sampling period. A different method of numbering should be devised.

Table 1. Age and lengths of razor clams captured at Bud's Beach, 1997

Sample #	Length (mm)	Est. Age	Sample #	Length(mm)	Est. Age
1	90	4	42	65	3
2	95	4	43	70	3
3	100	4	43	70	3
4	100	4	45	83	4
5	100	4	46	78	4
5	100	4	47	80	4
7	100	4	48	82	4
8	108	4	49	85	4
9	105	4	50	81	4
10	108	?	51	77	4
11	75	4	52	80	4
12	80	4	53	71	4
13	80	4	54	73	4
14	80	4	55	82	4
15	83	4	56	45	?
16	89	4	57	73	3
17	85	4	58	75	4
18	85	4	59	93	4
19	85	4	60	78	4
20	90	4	61	86	4
21	90	4	62	87	4
22	60	3	63	76	3
23	65	3	64	86	4
24	58	3	65	64	3
25	90	4	66	81	4
26	85	4	67	50	3
27	74	?	68	83	4
28	85	4	69	45	3
29	103	5	70	65	3
30	78	4	71	65	3
31	60	4	72	90	4
32	85	4	73	65	3
33	84	4	74	61	3
34	88	4	75	52	3
35	82	4	76	78	4
36	88	4	77	85	4
37	80	4	78	78	4
38	85	4	79	85	4
39	85	4	80	77	4
40	82	4	81	75	4
41	65	3	82	60	3

Table 2 shows the results of the clam sample in March 1998. All of the clams sampled had grown, The lowest measured growth was 1.2% and the largest was 20.2 %. The average was approximately 10%. This is lower than would be expected based on information from Nickerson. The slower growth could be attributed to stress from handling or possible poorer growing conditions under the predator cover.

Scmple #	Length (mm)	Est.	% Growth	Sample #	Length (mm)	Est. Age	% Growth
26	92	4	8.2%	NR	102	5	
58	81	4	8.0%	68	100	5	20.5%
7	112	5	4.7%	28	91	4	7.1%
53	82	4	15.5%	NR	78	4	
24	65	3	12.1%	15	91	4	9.6%
19	86	4	1.2%	NR	89	5	
NR	102	5		78	86	4	10.3%

Unfortunately, the funding for this portion of the Exxon Valdez Oil Spill (EVOS) Restoration Project 97131 **Chugach Region Clam Restoration** was not made available for FY98, The plan was to dig the total area of the test plots in July 1999 which would have given a minimum of one full year of growth and survival data.

4. Recommendations

1. Seek additional funding to finalize the current growout and predator protection studies.

2. Complete studies of the specific life histories of Razor Clams in the Cordova area.

3. Look at additional enhancement techniques such as transplanting with juvenile clams from other areas.

4, Investigate hatchery techniques for producing juvenile razor clams.

5. References Nickerson, R. B. 1975. A critical analysis of some razor clam (Siliqua patula Dixon) populations in Alaska. Alaska Dep. Fish and Game, Juneau. 194 PP.

6. Appendices

Trip Reports April 5 1997 Preparation work was done to rebuild the clam project site. The covering was twisted and did not cover all of the study area. One inch rebar was cut to 6' lengths to be wire tied to the ends of the covering.

April 6 Tide 7:46 A.M. -2.5 1 went to the project site to redo the covering. Upon arrival at the site, the covering was balled up. I dug the covering out of the sand and tore large holes in it as I dug it out. The solution to this problem is to use heavier covering because if I can tear holes in it easily then so can predators.

There are 4 clams observed under the old covering and 2 were recovered and planted under the new covering. I placed the new covering next to the old one and attached I" rebar with wire ties. I then surveyed the area around the site and dug seven legal size clams and planted them under the cover for a total of nine clams.

April 7 8:01 A.M. -2.1' tide
Left town around 7:00 A.M. arrived 15 minutes later, Went to grassy island bar where the razor clam project is located. I found the plastic covering balled up. I don't know if it was from sea otter or tidal activity. The solution would be to stake the covering down better. After I straightened out the covering I went and surveyed the beach for razor clams and found a total of five legal size clams (44), no undersized.

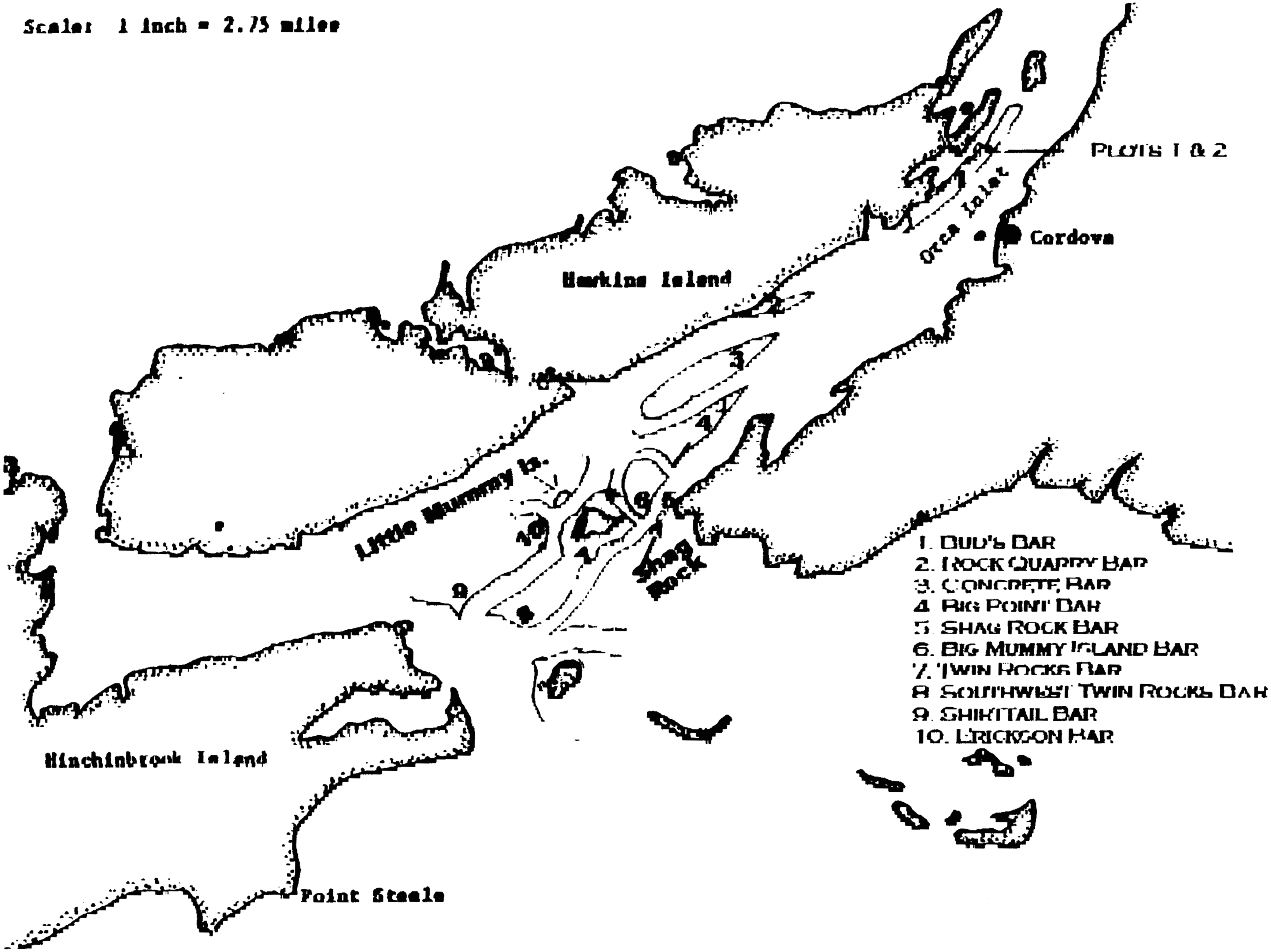
April 8 No work due to weather.

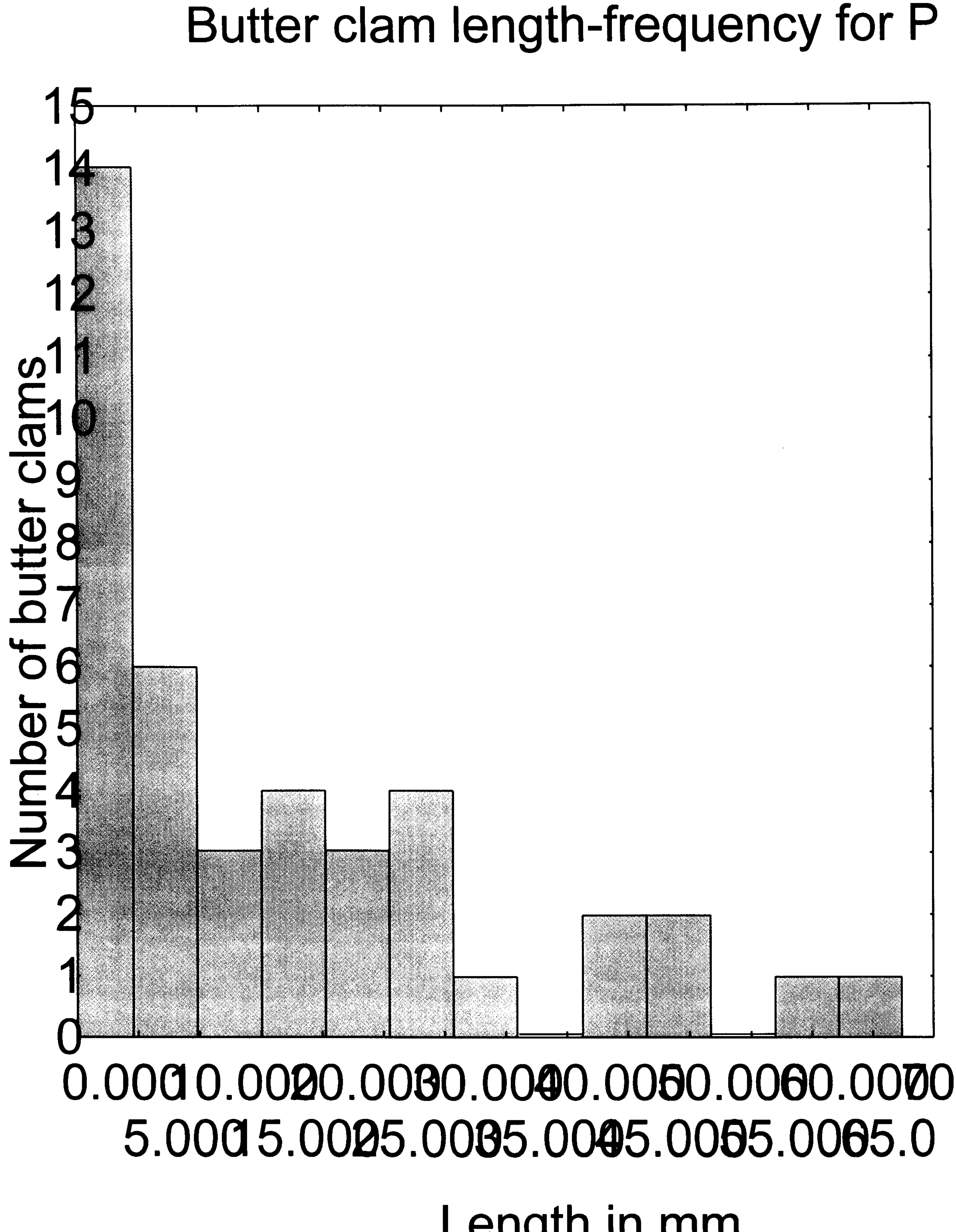
April 9 9:29A.M. -2.5' tide
The first bar I went to was Big Point Bar. 1 undersized clam was found. The second bar I went to was the north end of concrete Bar, no clams were found. The third bar was Rock Quarry Bar and 0 clams were found here also. The one thing I did notice was a lot fresh dead clams, That is I found a lot of shells on all three bars. I also went back to Grassy Island Bar and found another 3 legal sized clams and 0 undersized.

April 10 10:14 A.M. -2.0' tide
The first bar I surveyed was Shag Rock and 2 undersized clams were found. The second was Big Mummy Island Bar. No clams were found on this bar. Also noted was about a dozen sea otters hauled out on these bars and more feeding in the channels by the bars.

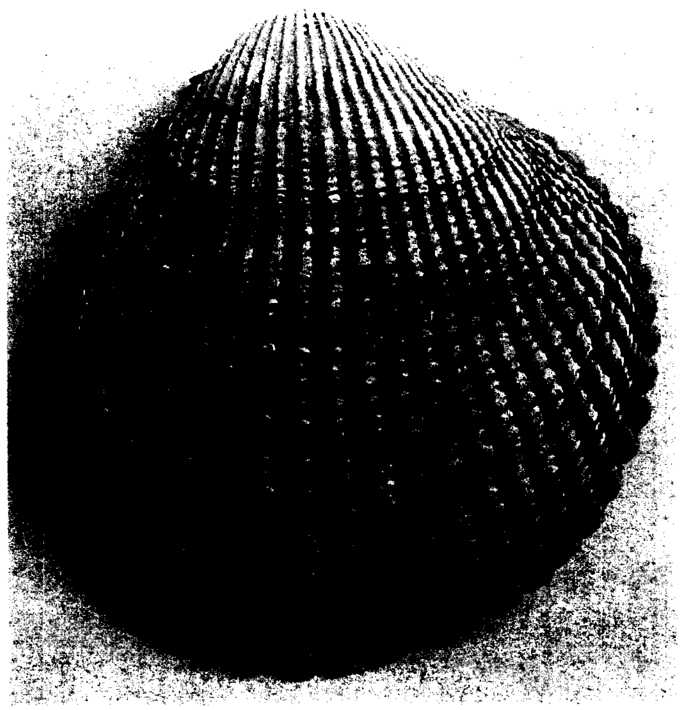
April 11 1997 10:59 A.M. -1.1' tide
The bar and area surveyed was the Hartney Bay region. No clams were found. Noted a couple of depressions in the sand that appeared to be the remains of sea otters digging clams. The next run of tides are 4/23 to 4/26 and 5/5 to 5/10.

Diagram 1. Map of Sampling Areas




Butter clam length-frequency for P
Number of butter clams
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Length in mm

Development of Hatchery, Nursery and Growout Methods for Nuttall's Cockle (*Clinocardium nuttallii*).



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February 22, 2001

Development of Hatchery, Nursery and Growout Methods for Nuttall's Cockle (*Clinocardium nuttallii*).

Table of Contents

List of Figures

List of Tables

Introduction: During the 1995 shellfish surveys at the Alaskan Native villages of Tatitlek, Port Graham and Nanwalek, villagers repeatedly expressed a preference for cockles (*Clinocardium nuttallii*). Residents of Port Graham reported that cockles were common in the 1970's and early 1980's, but virtually disappeared several years <u>before</u> the *Exxon Valdez* oil spill. Very few cockles were observed in any of the quantitative or qualitative surveys conducted at Port Graham, Tatitlek, or Nanwalek. Excellent cockle habitat was observed in qualitative shellfish surveys at Port Graham and Tatitlek. The common cockle from the Eastern Atlantic (*Cerastoderma edule*) is prized in some areas of Europe and blood cockles of the genus *Anadara* are grown and marketed in Asia. However, Nuttall's cockle, common in sandy intertidal areas of the eastern Pacific, is not cultivated and is not commonly harvested commercially. In part, that is because this bivalve does not keep well under refrigeration (author's personal experience) and therefore has a limited commercial shelf-life. The result is that little work has been accomplished with respect to developing hatchery techniques for propagating this animal. A search of the ASFA and BIOSYS bibliographic databases revealed few citations dealing with the genus *Clinocardium.* All of those identified in the search were obtained from the University of Washington library system together with many of the references pertaining to other cockle species.

Background. In addition to being a favored food of Alaskan Natives, cockles appear to grow rapidly in Washington State. Little information regarding aging techniques appropriate to cockles (*Clinocardium nuttallii*) was obtained in the literature and no age at length data was available for either Washington or Alaska. Gallucci and Gallucci (1982) observed "the Pacific cockle's checks or growth lines are known to be unreliable for aging purposes. They opined that apparent "false checks" were a consequence of a spawning period that extends over 2/3 of the year and an existence at the sediment surface, which accentuates the impact of environmental fluctuations. The authors did not provide a reference supporting their assertion regarding the unreliability of apparent annuli in cockles and used the von Bertalanffy growth model to predict a size of 34.3 to 50.3 mm at the end of one year and 65.4 to 76.8 mm at three years of age in Oregon. Cockle valves do show very distinct checks in Washington State and Alaska. Cockle valves were collected at Chenega and Ouzinke in Alaska and at Thorndyke Bay in Washington State and the apparent annuli used to determine a length at age relationship. The results are presented in Figure (1) for Thorndyke Bay and in Figure (2) for Chenega. The results suggest that a minimum harvest size of 38 mm was reached in between 3.5 and 4.0 years. This initial interpretation, based on apparent checks, suggested that cockles reached a valve length of only 1.0 cm during their first year. That is significantly less than the size predicted by Gallucci and Gallucci (1982). In addition, the coefficients describing maximum valve length derived from the von Bertalanffy model were unrealistically high at 17.2 and 26.4 cm. Cockles are commonly found to valve lengths of 7 to 8 cm in the Pacific Northwest and a few reach 10 cm (Brooks, unpublished). The unrealistically large predicted length could be due to counting false checks as annuli or it could be associated with relatively fast growth throughout the cockle's life with death occurring before the animals exceed 10 cm. Resolution of these hypotheses requires an analysis of the length of cockles of known age.

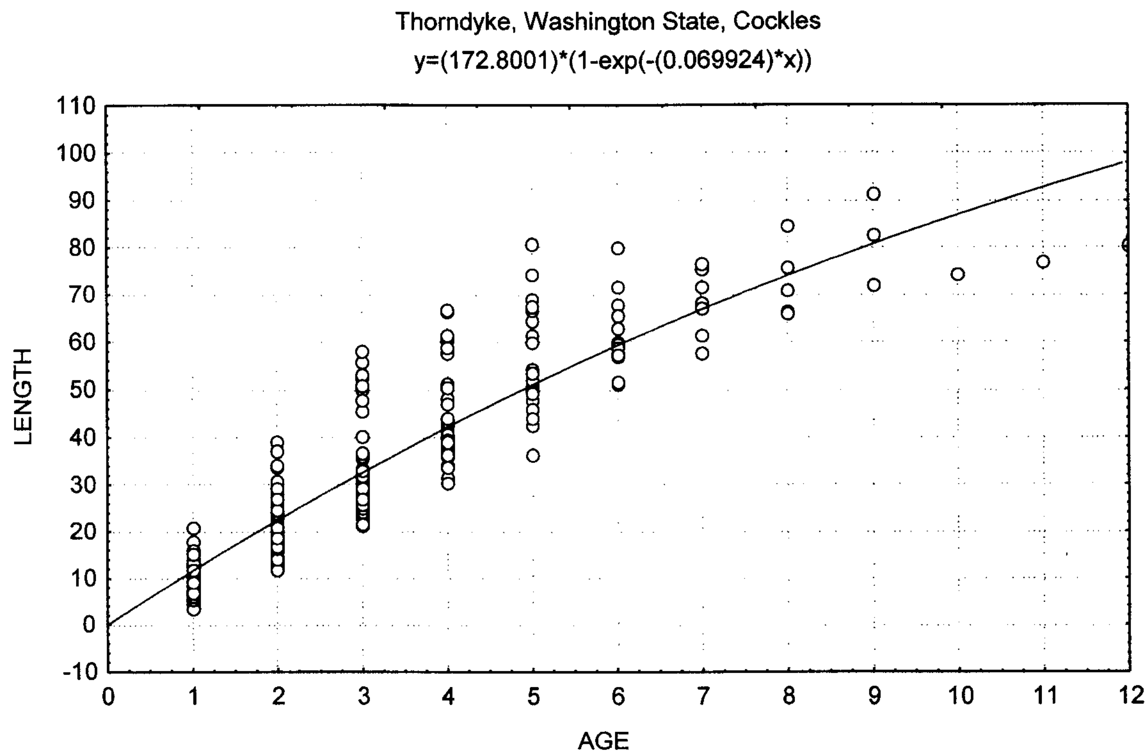


Figure 1. Length at age with von Bertalanffy model predictions for cockles collected from Thorndyke Bay in Washington State.

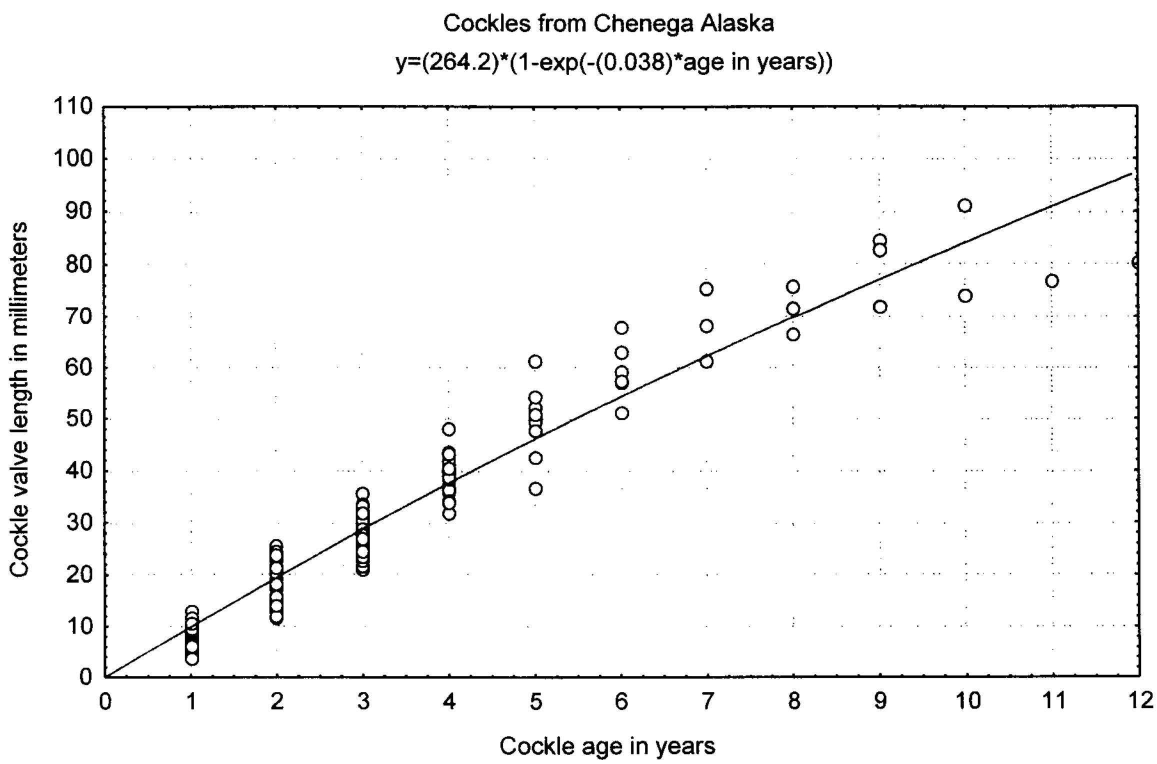


Figure 2. Length at age with von Bertalanffy model predictions for cockles (*Clinocardium nuttallii*) from Chenega, Alaska.

Reproduction of Nuttall's cockle. Robinson and Breese (1982) histologically examined gonadal tissue from cockles (*Clinocardium nuttallii*) collected from Yaquina Bay and Tillamook Bay, Oregon. They observed ripe gonads from March through September and assumed a summer spawning season. Robinson (personal communication) noted that they did spawn cockles in June but could not grow the larvae through metamorphosis. Gallucci and Gallucci (1982) confirmed that spawning could occur from April to November with a proposed peak in July and August. However, these author's discussed the possibility of a minor spawn in April and May, followed by a major spawning period from July to September.
Strathmann ((1987) confirmed a breeding season of April through November with peak reproduction between July and August in this species. The hermaphroditic nature of this species was noted by Strathmann (1987). She added that oocytes are ca. 80 μm in diameter and have jelly coats over 50 μm thick. At 15 °C, first cleavage took place within one hour and early veligers developed within 18 hours. None of the literature (including Strathman, 1987) reported spawning cockles and raising them through metamorphosis.

Materials and methods. Several activities were initiated in an effort to define hatchery, nursery and growout methods for *Clinocardium nuttallii.* This was a cooperative effort between Aquatic Environmental Sciences, Mr. Dick Poole at the Lummi native shellfish hatchery in Washington State and Mr. Ed Jones at the Taylor Resources Hatchery and nursery facility on Dabob Bay, Washington.

Cockle spawning. Cockles were collected from Thorndyke Bay in Washington State from April until October during 1996 and 1997. They were held in marine aquaria at 15 °C overnight. Each cohort contained 20 to 30 cockles with valve lengths greater than 50 mm. Initial spawning attempts were made with the cockles placed in 10 μm filtered and pasteurized seawater maintained at 15 °C. The temperature was raised rapidly by six degrees C through the addition of heated seawater. In the first series of attempts during April 1996, a single animal released a moderate quantity of ova. No sperm were released. Microscopic examination of tissues at the base of the foot revealed mature ova in several individuals – but no sperm.

During the second spawning effort (late August 1996), cockles were placed in clean sand in individual Pyrex dishes and maintained in aquaria at a temperature of 16 °C to mimic the ambient temperature observed in Thorndyke bay at the time of collection. The temperature of the water was rapidly raised to ca. 22 °C. On the first attempt, two males released sperm, which was used in an attempt to stimulate other cockles to spawn. Microscopic examination of the sperm indicated that they were viable. However, no additional animals spawned and no eggs were obtained. On the next day, the experiment was repeated. Sperm were obtained and a small quantity of immature ova that averaged 30 μm in diameter. A dilute sperm suspension was added to the ova in seawater (30 ppt) at 18°C. No cell cleavage was observed. Removal of gonadal tissue from the spawning female revealed what appeared to be mature ova packed in oocytes. However, no mature ova were expelled (at least none were observed). Two hundred milliliters of a dense suspension (2 x 10^6) of phytoplankton (*Chaetoceros calcitrans* and *Thalassiosira pseudonana*) were added to the 15-liter aquaria used in each of these trials after one hour of unsuccessful spawning. The addition of food did not stimulate spawning. Attempts to spawn cockles continued in 1997 at both the Taylor Resources Hatchery on Hood Canal and at

Aquatic Environmental Sciences without success. The injection of 0.9 cc of a 0.2 molar solution of seratonin into the proximal junction of the cockle's foot regularly yielded sperm – but not eggs.

Mr. Dick Poole, hatchery manager at the Lummi native hatchery received approximately 400 cockles, in plastic mesh bags, on April 12, 1998. These were placed in tanks of filtered, 30 o/oo seawater heated to 21°C in preparation for spawning Manila clams. The cockles spawned overnight without further intervention. The trochophore larvae were siphoned into other tanks at a density of ca. 2 larvae/ml for rearing at temperatures between 17 and 23°C. Parameters under which the larvae were raised through metamorphosis are provided in Table (1). The 1998 cohort metamorphosed at 200 to 300 µm on April 25, 1998. The larval stage was reported to have lasted only two weeks. The set larvae were transferred to the Suquamish tribe for planting at 500 microns valve length on April 29, 1998. They were lost (died) while being held overnight in buckets.

Table 1. Spawning and rearing conditions used by the Lummi shellfish hatchery for production of Nuttall's cockle (*Clinocardium nuttallii*) seed.

Parameter	Range	Notes
Spawning season:	Unknown – spawned only from wild stocks collected in April.	
Spawning temperature:	20 to 22°C	Spawn in mass - siphon into other tanks to dilute to 1.85 larvae/ml.
Rearing temperature:	17 to 23°C	Limits not investigated
Salinity:	20 to 30 o/oo	
Food:		
Larvae - up to 120µm.	20,000 to 50,000 cells/ml of a mixed diet containing *Isochrysis galbana, Pavlova lutheri, Chaetoceros calcitrans* and *Skeletonema costatum (3)*	
Larvae – 120 to 220 µm.	<100,000 cells/ml of a mixed diet containing *Isochrysis galbana*, Tahitian *Isochrysis*, *Chaetoceros calcitrans*, *Skeletonema costatum (3)*, *Thalassiosira pseudonana* (clone 3H), *Chaetoceros gracilis* – fed twice daily.	
Signs of metamorphosis:	Foot shows at 200 to 220 microns. Metamorphosed larvae were caught on a 149 µm screen.	

Note: The regimen for feeding twice daily included feeding *Isochrysis* and Tahitian *Isochrysis* in the morning. The remaining species were fed in the afternoon. Phytoplankton cell densities were raised to 20,000 to 50,000 cells/ml in the culture tanks at each feeding.

Nursery and growout phases of cockle production. The following protocol was designed to evaluate the growth and mortality of Nuttall's cockles (*Clinocardium nuttallii*) under a variety of culture conditions. The Lummi hatchery successfully spawned and reared cockles again during the first week of April 1999 and transferred them to Mr. Paul Williams (Suquamish tribe) and Aquatic Environmental Sciences on June 2, 1999. A subsample was taken for length frequency analysis and the cockles placed in an upweller at the Taylor United hatchery.

Approximately 3,000 cockles were seeded into window screen covered trays on June 12, 1999. A subsample of this seed was randomly selected for length-frequency analysis. The remaining seed was retained in the Taylor United shellfish hatchery for outplanting on July 29, 1999. Approximately 9,000 cockle seed were transferred to Aquatic Environmental Sciences for the following trials at Dr. Joth Davis's shellfish culture site in Thorndyke Bay on Hood Canal, Washington. Substrate in this area consists of organically enriched fine and intermediate sands with small amounts of silt and clay (Brooks, unpublished). Nuttall's cockles are abundant throughout Thorndyke Bay.

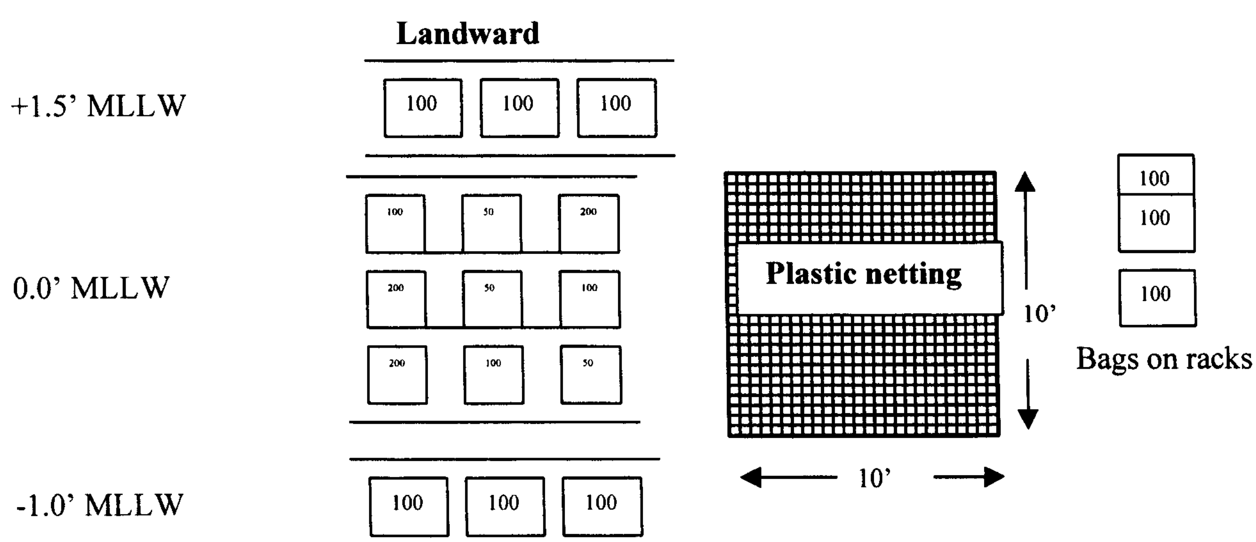
A. Nine cohorts of 100 cockles each were individually measured and planted, in three replicates at the –1.0, 0.0 and +1.5' MLLW tidal levels, in half-Norplex™ bags. The –1.0' level was established at low water (1240) on July 30, 1999. The remaining tidal heights were established using a properly leveled transit and aluminum stadium.

B. Three cohorts each of 50 and 200 cockles were measured and planted in half-Norplex™ bags at the 0.0' MLLW level on July 29, 1999.

C. Six thousand cockles under planted at a density of 60/square foot under plastic netting in Thorndyke Bay at the 0.0' MLLW tide level on July 29, 1999.

Cockles were placed in half Norplex™ bays and one end sealed with a split PVC pipe and electrical ties. The bags were placed in shallow depressions dug into the substrate and filled with sieved sand such that the top one-inch of the bag protruded above the natural level of substrate. All tests, excepting the tidal height test, were conducted at the 0.0' MLLW level. The study layout is provided in Figure (3).

Figure 3. Layout of cockle (*Clinocardium nuttallii*) studies conducted in Thorndyke Bay, Washington State during 1999 and 2000

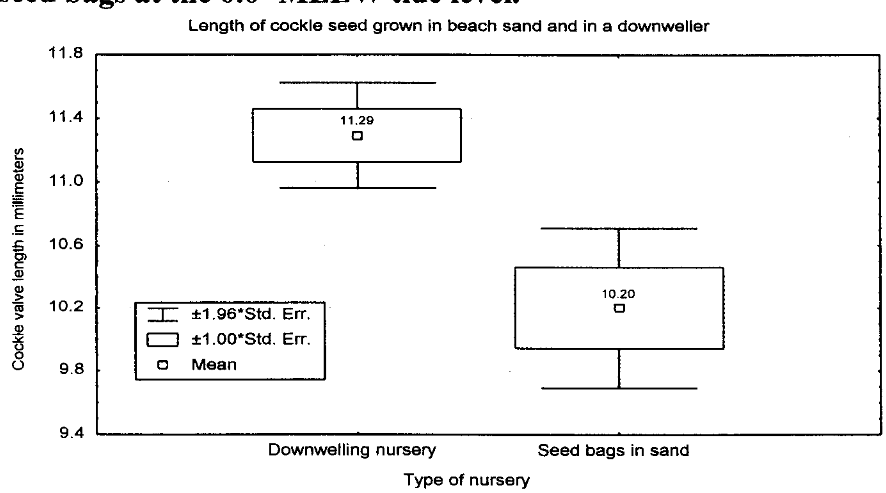


These cultures were sieved and the cockles counted and measured on October 27, 1999. Unfortunately, this portion of the CRRC project was cancelled due to lack of funding in November 1999. All of the cultures were removed except for one of the replicates containing 50 cockles/bag. Cockles in that bag were sampled for a final time on June 14, 2000. The data were entered in a Statistica™ database for evaluation.

Results of cockle nursery and growout experiments. Figure (5) describes the length of all cockles planted in this study as a function of age after setting at the Lummi hatchery. Slow growth occurred at the Lummi hatchery where the cockles were held without adequate food because of commitments to produce clam and oyster seed until June 2, 1999. Initial sampling of the received stocks revealed a mixed stock containing Pacific oyster seed (*Crassostrea gigas*) and cockles (*Clinocardium nuttallii*). A random sample of the seed revealed 164 living and 170 dead cockles together with 129 living and 6 dead Pacific oysters. Cockles in this mixed culture survived at a lower rate (49%) than did the Pacific oysters (96%). This suggests that juvenile *Clinocardium nuttallii* are more fragile and perhaps difficult to maintain in culture than Pacific oysters. The differences may also be because the cockles were treated similarly to Manila clams and optimum culture conditions for this species have not been determined. To the best of the author's knowledge, the Lummi hatchery is the only facility that has successfully reared larvae of this species through metamorphosis in quantity.

Cockle nursery experiments. Cockles grew rapidly from 3.05 mm to 10.75 mm mean valve length during six weeks of nursery. Approximately 1000 juvenile cockles were simultaneously placed in seed bags at the 0.0' MLLW tide level in Thorndyke Bay to compare growth in this nursery method with the hatcheries downwelling system. The mean valve lengths of a subsample of 100 cockles from each culture, measured after 46 days of culture, are provided in Figure (4). A *t-test* with different variance estimates for each culture indicated that the differences were statistically significant at $\alpha = 0.05$ ($t = 3.51$, $p = 0.0005$). The reasons for this difference were not explored.

Figure 4. Comparison of the lengths of 100 cockle seed sampled from Taylor Resources hatchery downwelling nursery system and a beach culture planted in Thorndyke Bay in seed bags at the 0.0' MLLW tide level.



Growth of cockles in Thorndyke Bay. A history of the growth of cockles, as measured by valve lengths, is provided in Figure (5). Cockles grew rapidly following their placement either in the downwelling nursery or in seed bags. The given value for age 103 is a mean of the two nursery treatments. Cockles examined on June 14, 2000, following 319 days of growout had grown from a mean valve length of 10.75 mm to 46.10 mm. Other cockle experiments (Brooks, unpublished) suggest that little growth occurs during the winter months and that most of the growth occurs during the spring of the year following spawning.

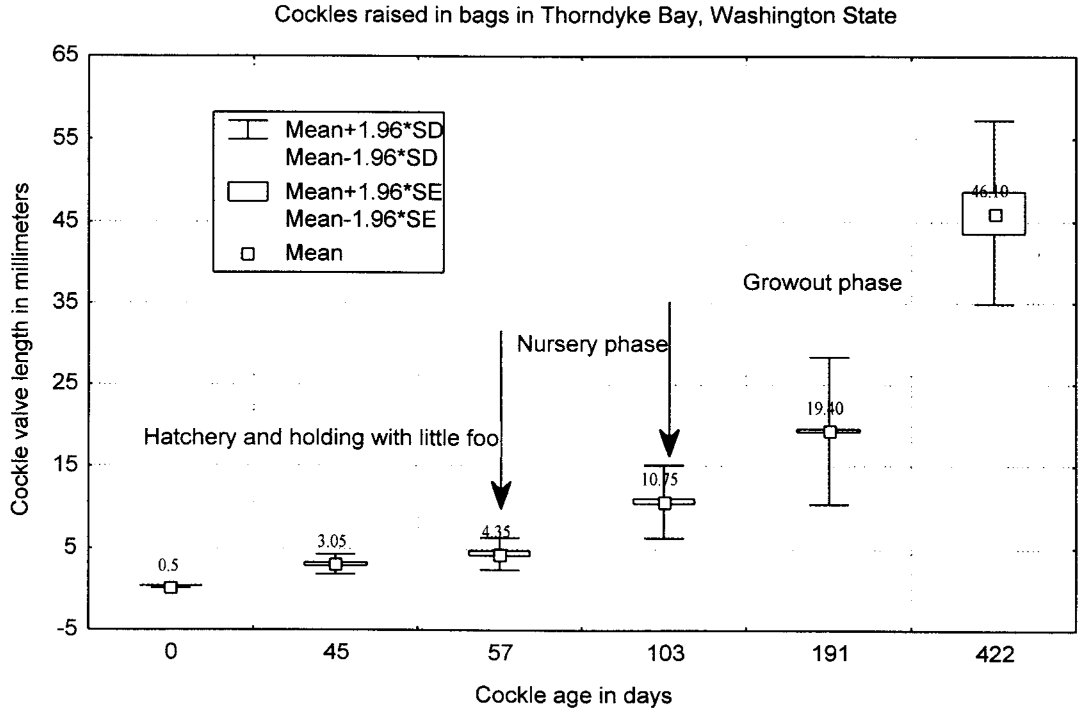


Figure 5. Nuttall's cockle (*Clinocardium nuttallii*) valve lengths as a function of age post setting. The cockles were spawned during the first week in April 1999 and held on minimum rations until June 2, 1999 when they entered Taylor Resources' nursery on Dabob Bay, Washington. The cockles were outplanted to Thorndyke Bay on July 29, 1999 and evaluated in October 1999 and June 2000.

Analysis of variance indicated significant differences in growth as a function of both planting density ($F = 115.9$; $p = 0.00$) and tidal height ($F = 234$; $p = 0.00$) during the first 88 days of growout in Thorndyke Bay. Figure (6) describes valve length statistics as a function of tidal height. Post hoc testing using Scheffe's test indicated that in this experiment, mean cockle length on October 27, 1999 at an age of 191 days was significantly shorter for cockles grown at +1.5' MLLW when compared with those grown at 0.0' MLLW ($p = 0.00$) or at –1.5' MLLW ($p = 0.00$). Significant differences were not detected in cockles grown at the two lower elevations ($p = 0.38$).

Analysis of variance also indicated significant differences ($F = 115.8$; $p = 0.00$) in cockle valve lengths at 191 days of age as a function of planting density. These differences are described in Figure (7). Cockles grown at the lowest density of 50 cockles per half Norplex™ bag had significantly longer ($p= 0.000$ in either case) mean valve lengths (24.55 mm) than those grown at densities of 100/bag (19.75 mm) or 200/bag (19.10 mm). The standard error of the mean in both cultures grown at the higher densities was low enough such that and these differences were also significant (p = 0.045).

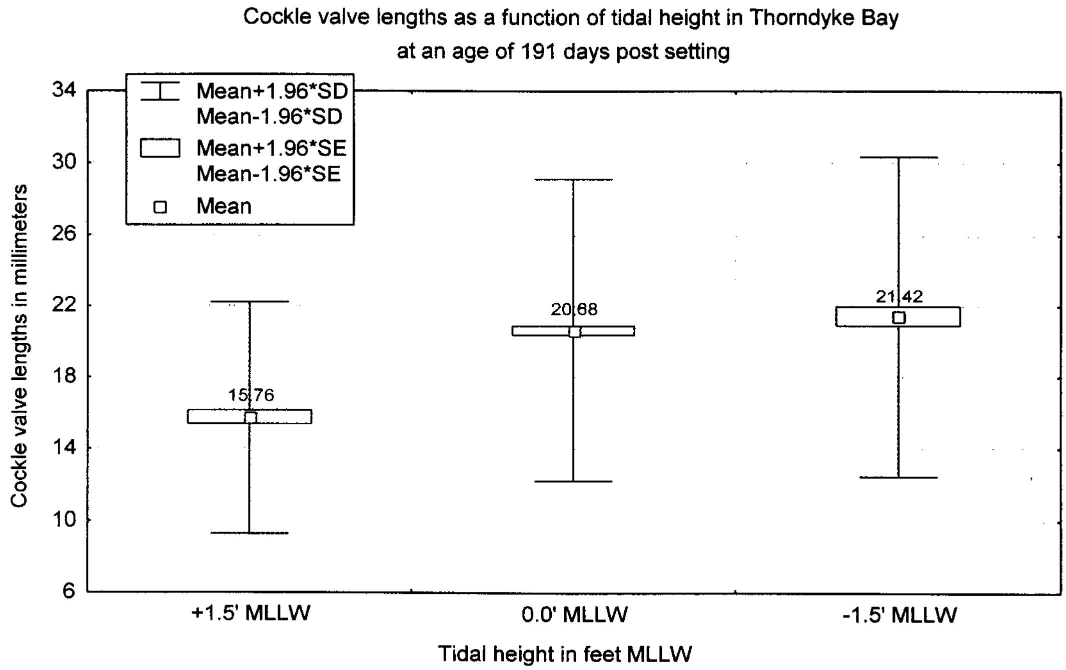


Figure 6. Mean valve lengths for cockles grown to an age of 191 days at three tidal heights in Thorndyke Bay, Washington. Cockles were seeded in three replicates each at a rate of 100 animals per half Norplex™ clam bag.

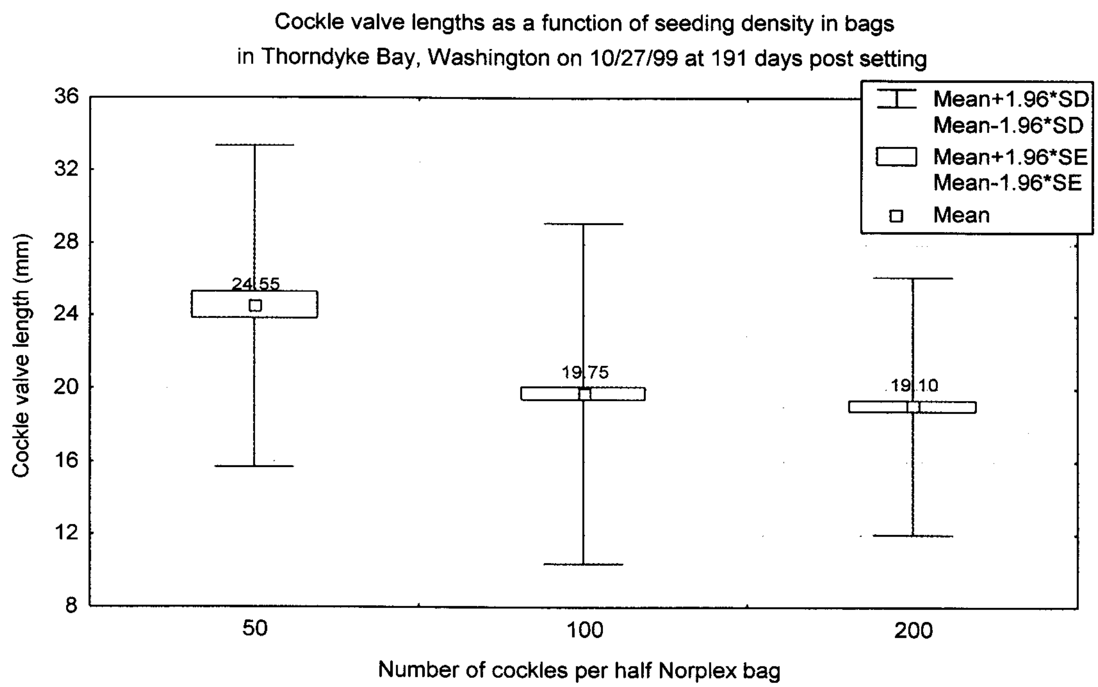


Figure 7. Cockle (*Clinocardium nuttallii*) valve lengths observed following 88 days of growout in Thorndyke Bay (Age = 191 days) as a function of planting density. The differences between each group were significant at $\alpha = 0.05$. Data included three replicates at each density. All replicates were grown at the 0.0' MLLW tide level.

Cockle survival during growout in Thorndyke Bay. The proportion cockles surviving in each replicate on October 27, 1999, following 88 days of growout in the field was transformed using the arcsin(sqrt(proportion)) transformation (Zar, 1984) and subjected to ANOVA. In general, more cockles survived at lower densities and at lower tidal elevations. However, none of the differences were statistically significant at $\alpha = 0.05$. The results are summarized in Figures (8) for density and (8) for tidal elevation.

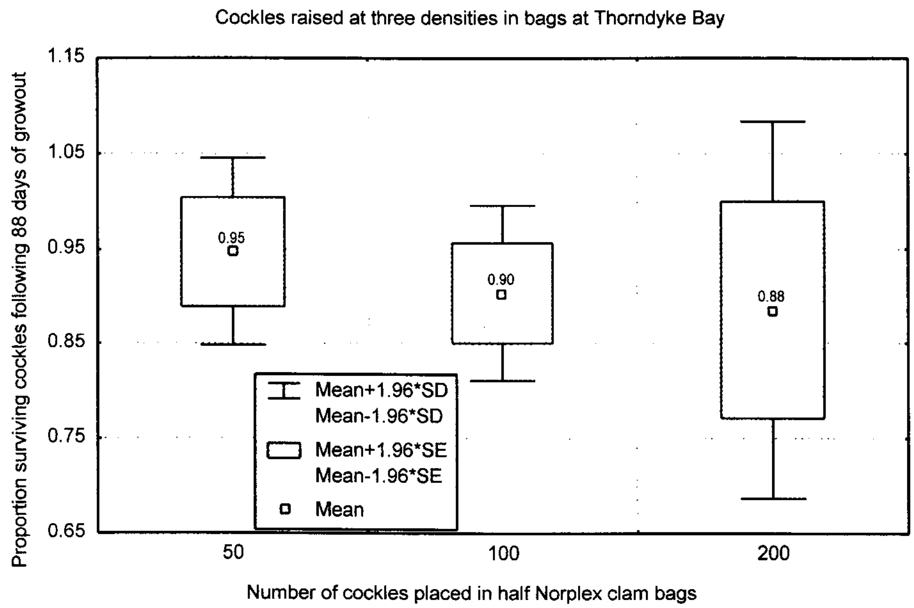


Figure 8. Survival of cockles following 88 days of growout. The bivalves were planted at three densities at the 0.0' MLLW tide level in Thorndyke Bay, Washington. None of the observed differences were statistically significant at $\alpha = 0.05$.

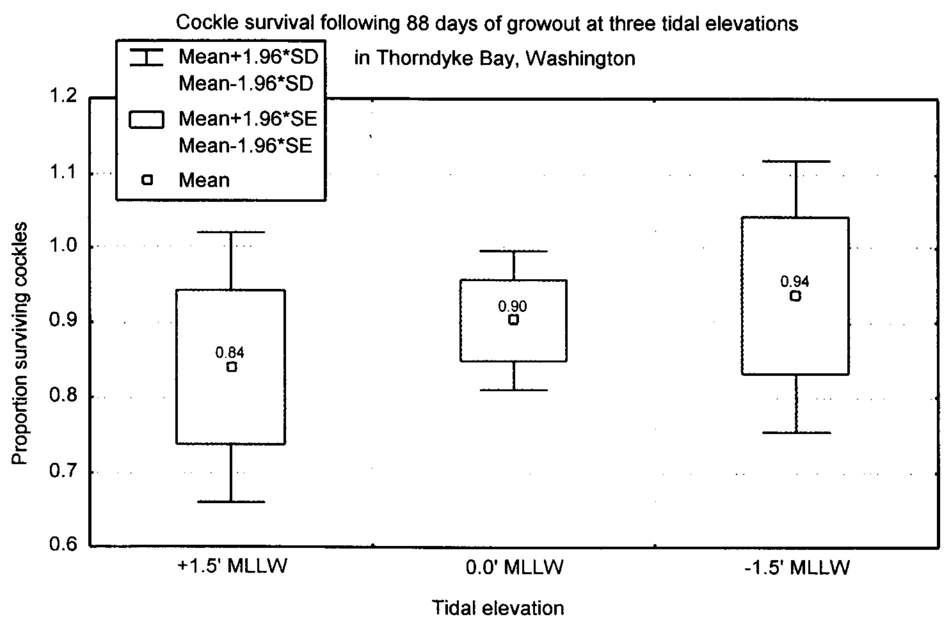


Figure 9. Survival of cockles following 88 days of growout. The bivalves were planted at a density of 100 cockles per half Norplex™ clam bag at three tidal elevations in Thorndyke Bay, Washington. The observed differences were not statistically significant at $\alpha = 0.05$.

Reconciliation of length at age analysis. Gallucci and Gallucci (1982) used the von Bertalanffy growth model to predict a size of 34.3 to 50.3 mm at the end of one year and 65.4 to 76.8 mm at three years of age in Oregon. The results reported here are consistent with their Oregon observations at one year and inconsistent with the predictions made in section 5.1 of this report. Gallucci and Gallucci (1982) noted, "the Pacific cockle's checks or growth lines are known to be unreliable for aging purposes". They opined that apparent "false checks" were a consequence of a spawning period that extends over 2/3 of the year and an existence at the sediment surface, which accentuates the impact of environmental fluctuations. Figure (10) is a photograph of cockles of known age from this study. Two sets of valves are shown for November 27, 1999. The smaller cockles were removed from the highest density culture and the largest cockles are representative of those observed in the 50-cockle/half-bag density. The valve on the right was representative of those evaluated in the 50-cockle/half-bag cohort examined on June 14, 2000. An apparent winter annulus is highlighted.

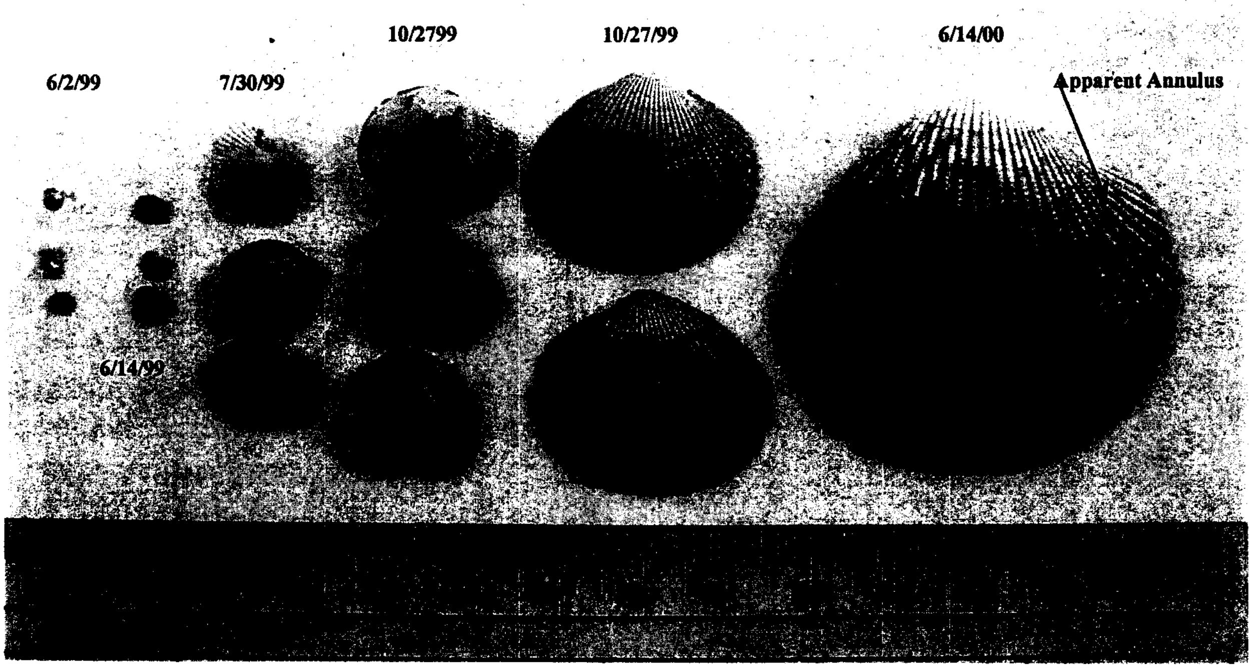


Figure 10. Representative cockles (*Clinocardium nuttallii*) from nursery and growout studies. Cockles were spawned by the Lummi hatchery, nurseried at Taylor Resources and grown in Thorndyke Bay, Washington.

The apparent first annulus was well defined in all cockles from this cohort. Approximately 15 cockle valves were sectioned and polished with a 600-grit whetstone. These sections revealed distinct discontinuities in the shell's structure caused by an apparent excursion of the inner lamellar layer through the outer prismatic layer to the shell's surface. These excursions were sometimes rather broad (several millimeters) and colored brown corresponding with the exterior color, which does not generally permeate the white prismatic layer. These apparent annuli, visible in section, always corresponded with significant exterior checks. However, additional exterior checks were not always associated with these discontinuities in the sectioned material. These apparently false exterior checks only occurred during and following the initial annulus. They may be associated with spawning and/or other stressful events as suggested by Gallucci and Gallucci (1982). This study did not last beyond one year and this hypothesis could not be confirmed. However, the weight of evidence strongly supports the hypothesis of Gallucci and Galluci (1982). Based on these results, it is recommended that future cockle ages be determined by sectioning the valves. In this study, that was accomplished very quickly (3 to 5 minutes per animal) by cutting with a 0.89 mm thick carborundum disk of 37.5 mm diameter attached to a Craftsman™ variable speed rotary tool operated at ca. 22,000 rpm. This was followed by light sanding of the edge on 220-grit aluminum oxide sandpaper, finishing on a 600-grit whetstone in water and examination under a stereomicroscope. A typical set of valves from Ouzinke is described in Figure (11) with the apparent true and false annuli marked.

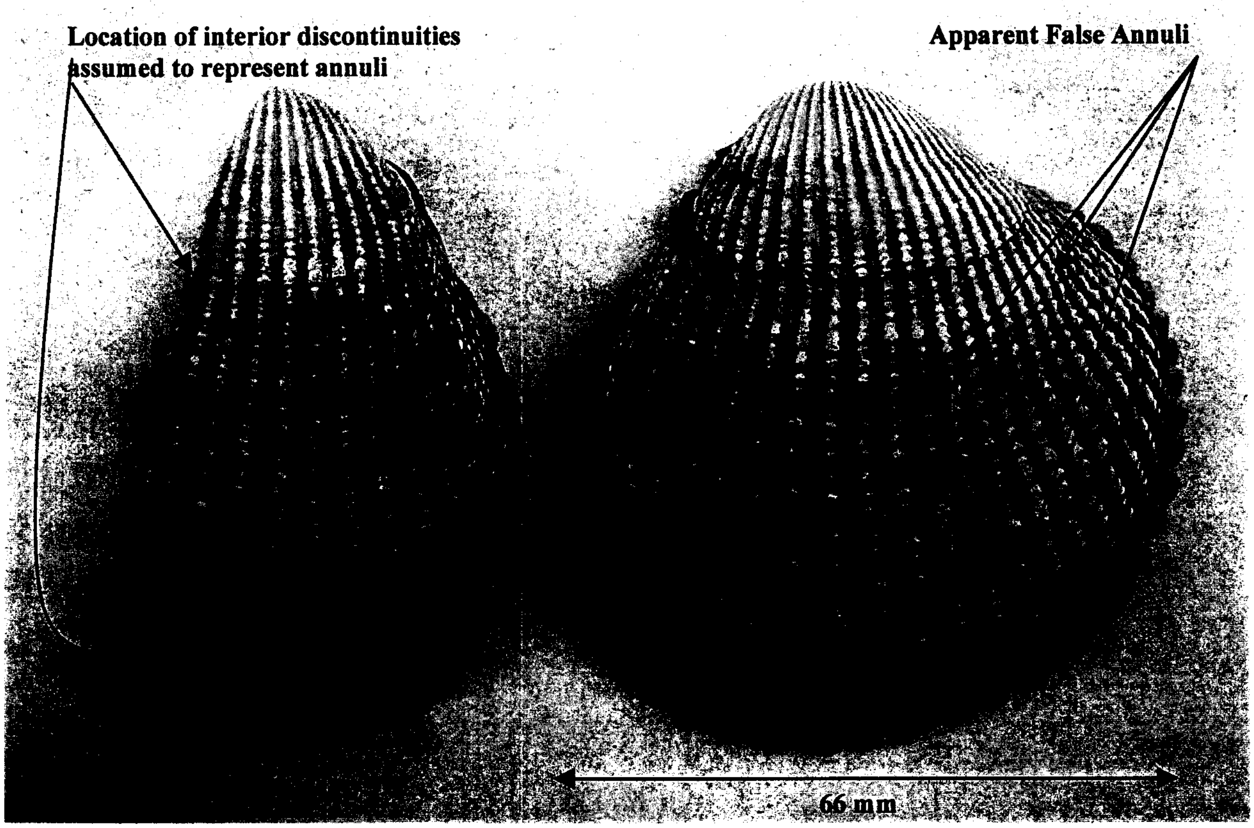


Figure 11. Cockle (*Clinocardium nuttallii*) valves from Ouzinke, Alaska with the annuli identified in sectioned material identified on the left and apparent false annuli on the valve's exterior annotated on the right. The valve length in this cockle was measured at 66 mm and was judged to have lived through two winters.

Cockle study summary. These preliminary studies with Nuttall's cockle (*Clinocardium nuttallii*) suggest the following:

- Nuttall's cockle was spawned and reared through metamorphosis in the Lummi hatchery using the parameters described in Table (1). The stated parameters worked, but additional research is required to determine optimum parameters for hatchery production. Experience suggests that newly set larvae are fragile and subject to high mortality when improperly handled. However, what constitutes "proper handling" was not determined in this study.

- Nuttall's cockle was successfully grown in a commercial nursery to a length of 11 mm in six weeks. The animal grew adequately but more slowly when held in seed bags at the 0.0' MLLW tide level in Thorndyke Bay, Washington for an identical period.

- Cockles were successfully grown to market size in 11 months of field growout. They grew more quickly during the first 88 days of field culture at tidal levels $\leq$ 0.0' and at lower densities within the tested range of 100 to 400 cockles per full Norplex™ clam bag.

- Cockles planted at ca. 600/m^2 under plastic netting dispersed during the first 88 days of culture. That statement is made because cockles were found only within the roots of scattered eelgrass in the plot. Empty cockleshells were not found in the sediments suggesting little or no mortality after burrowing in. They simply disappeared. This suggested that juvenile cockles may be mobile and a series of experiments were designed to monitor their movement using a short-term mark and recapture methodology. These experiments were not initiated because the study was terminated due to lack of funding.

- Statistically significant differences in cockle survival at varying tidal heights and densities were not observed over 88 days of field growout. However, consistent trends indicating higher survival at lower intertidal elevations and lower densities were observed. A continuation of these trends during a 10 to 12 month growout might lead to significant differences. That determination will have to wait for a longer-term study.

- Most importantly, the mean valve length of cockles raised at a density 50/half bag at the 0.0' MLLW tide level reached 46 mm in 11 months. This suggests that cockles, a species preferred by Alaskan natives, could become a viable part of future shellfish enhancement programs. Obviously, the results from Washington State may not be directly applicable to Alaska due to differences in climate. However, these results suggest that further study by the Qutekcak hatchery and CRRC is warranted.

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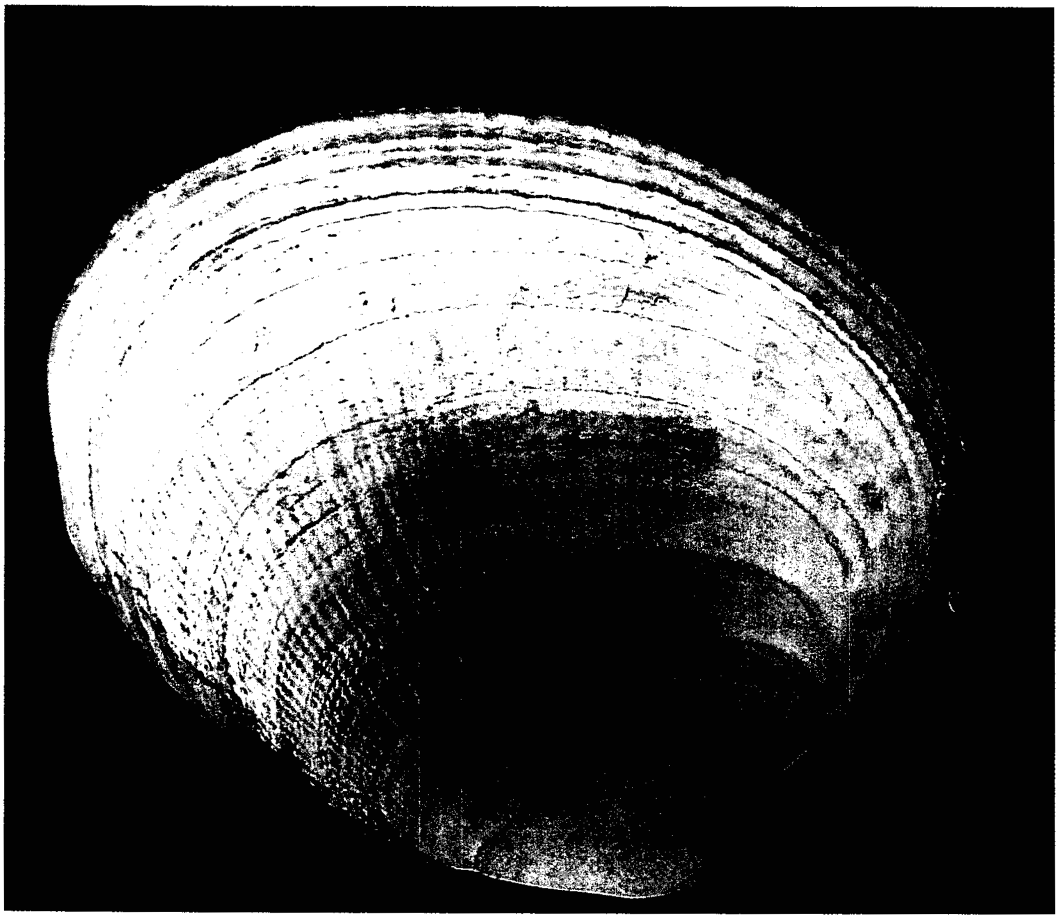
Appendix D

Synopsis of Littleneck Clam (*Protothaca staminea*) Life History, Clam Culture Techniques and Commercial Fisheries Clam Management in Southcentral Alaska



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Synopsis of Littleneck Clam (*Protothaca staminea*) Life History, Clam Culture Techniques and Commercial Fisheries Clam Management in Southcentral Alaska

Table of Contents

List of Figures

List of Tables

Background. The existence of extensive shell middens throughout the North Pacific Coast attests to the historic importance of bivalves in the diet of Native Americans. Clams have provided an important subsistence food resource in the native villages of Tatitlek, Nanwalek and Port Grahams as well as many other villages located within the area affected by the *Exxon Valdez* oil spill. However, clam populations have declined markedly at these villages in the recent past. The reasons for these declines are not well documented – but the loss of a traditional food source is significant to Native Americans. In response to concerns expressed by village elders, the Chugach Regional Resource Commission (CRRC), in cooperation with the Alaska Department of Fish and Game (ADFG), requested and received funding from the *Exxon Valdez* Oil Spill Trustee Council to re-establish populations of clams in areas readily accessible from the villages of Tatitlek, Nanwalek and Port Graham.

Littleneck clam life history. The native littleneck clam (*Protothaca staminea*) occurs in estuaries, bays, sloughs and open coastlines along the Pacific coast of North America from the Aleutian Islands to Baja California (Fitch 1953; Abbott 1974).

Reproduction. Sexual maturity appears to be size, rather than age dependent. It is reached at a valve length of 25 to 35 mm (Quayle, 1943). Reproductive competence is achieved between the second and eighth year of life (Paul and Feder, 1973). In Prince William Sound, Feder, *et al.* (1979) observed limited spawning in late May with a major release of gametes during June. Female *Protothaca staminea* gonads were observed in a spawning phase from early June through September. In contrast, males were in spawning condition throughout most of the year. Fraser (1929) reported limited spawning during January in Departure Bay, British Columbia and he found planktonic larvae (veligers) of this species in February.

Strathmann (1987) noted that larval culture temperatures of 10-15 °C were optimal with some survival to 20 °C. She noted that larvae survive at 32 parts per thousand (o/oo) salinity, but not at 27 o/oo. Spawning appears to be temperature related (Quayle 1943) and an examination of USFWS (1968) suggests that the sea surface temperatures are warming rapidly from less than 8 °C to >10 °C during June and July of each year in South Central Alaska.

Larval clams are planktonic for three to four weeks. Therefore, they may be dispersed over large areas by wind and tides or they may remain in localized areas (Mottet, 1980). Successful recruitment is dependent on a wide range of environmental parameters and it may vary significantly from year to year. Large year classes may be separated by either missing or subdued year classes (Rodnick and Li, 1983). Maximum life span has previously been reported at 13 years (Fitch, 1953; Paul *et al.*, 1976; Rudy and Rudy, 1970). However, ADFG (1995) reported native littleneck clams to 14 years of age.

Littleneck clams grow continuously throughout their lives. However, growth slows as clams age and is dependent on local environmental conditions; including tidal height, currents, food availability, temperature and salinity (Quayle and Bourne 1972; Trowbridge *et al.* 1996).

Distribution as a function of tidal elevation. The native littleneck clam inhabits the intertidal zone from approximately –2.5' to +6.0' MLLW in Prince William Sound, Alaska (Nickerson, 1977). Nickerson (1977) observed peak native littleneck biomass at +1.5' MLLW with reduced biomass above +3.0' or below –1.5' MLLW. Feder and Paul (1973) observed maximum numbers of littleneck clams at tidal heights ranging from +1.4' to –1.7' MLLW with very few clams observed at tidal elevations ≤ 1.9' MLLW. However, Goodwin (1973) reported that this species is infrequently found at subtidal depths in Puget Sound, Washington. Consistent with these reports, Quale (1960) reported that littleneck clams in British Columbia were concentrated at "about the half-tide level". He also noted that they occured in reduced numbers at subtidal depths. This literature suggests that highest densities of native littleneck clams are typically found between –1.7' and +3.0' MLLW.

Substrate preferences. Mottet (1980) provides an excellent review of the interaction between sediment physicochemical characteristics, hydrodynamics and clam habitat preferences. Unfortunately, her treatise does not specifically include the native littleneck clam. Quayle (1941) noted that littleneck clams can be found in a variety of substrates but appeared most typically in mixed substrates of "pebbles and fine mud". In the Pacific Northwest, littleneck clams are seldom encountered in muddy or sandy areas, they prefer loosely packed substrates consisting of a mixture of cobble, gravel, shell, sand and mud (Rutz 1994; Nickerson 1977; Feder and Paul 1973; Strathman 1987). Alexander *et al.* (1993) identified native littleneck clams as a *Substrate Sensitive* species found in sand – silt and clay substrates in San Francisco Bay and Peterson (1980) reported native littleneck clams from muddy and clean sand environments in Magu Lagoon, California. Hughes and Clausen (1980) also reported native littleneck clams from muddy substrates in Newport Bay, California. The literature suggests that while this species inhabits fine-grained sediments in the southern parts of its range, it prefers mixed substrates containing cobble, gravel, sand, silt and clay in Washington, British Columbia and Alaska.

Unfortunately, none of these reports included analyses of important physicochemical characteristics such as sediment grain size distribution, organic content measured as total organic carbon (TOC) or total volatile solids (TVS) and perhaps most importantly, sediment total sulfides ($S^{=}$). Goyette and Brooks (1999) and Brooks (2000a, 2000b) have shown that small changes in these physicochemical parameters have significant effects on infaunal communities – including large and small bivalves. Freese and O'Clair (1987) reported that survival of *Protothaca staminea* was inversely related to sediment concentrations of hydrogen sulfide and ammonia and directly related to pore water dissolved oxygen concentrations. Despite this report, the author (Brooks, unpublished) has observed large (>38 mm valve length) native littleneck clams surviving in anaerobic sediments where their shells become blackened by iron sulfides. Native littleneck clams, like Manila clams, require stable substrates (Toba *et al.* 1992; Quayle and Newkirk 1989). They can be washed out of erosional environments or buried in depositional areas (Peterson, 1985).

Habitat Suitability Index (HIS) for native littleneck clams. Rodnick and Li (1983) developed a Habitat Suitability Index for native littleneck clams. They concluded that littleneck clams prefer a mixed substrate of gravel, sand and mud and that this species burrows to approximately 15 cm. Rodnick and Li (1983) considered tidal elevation an important endpoint and cited Nickerson's (1977) observation that native littleneck recruited in greatest numbers at tidal heights between –1.4' and +1.4' Mean Lower Low Water (MLLW) in Galena Bay, Prince William Sound. This observation is consistent with that of Amos (1966) and Paul *et al.* (1976) who observed maximum clam densities near the 0.0' MLLW tide level.

Rodnick and Li (1983) noted that thermal stress causes death in native littleneck clams at a few degrees below 0°C and above 35°C. Rutz (1994) reported the absence of clams below a freshwater runoff stream in Kosciusko Bay, Southeast Alaska. Brooks (unpublished) has also observed a paucity of native littleneck clams in Puget Sound near small streams. However, the largest commercial harvester of littleneck clams in Washington State (Mr. Reed Gunstone, personal communication) noted that littleneck clams are sometimes found in areas subjected to lowered salinities. He added that their short shelf life following commercial harvest during periods of high freshwater runoff suggests significant stress at reduced salinity. These observations are consistent with those of Quayle and Newkirk (1989) who noted that growth in native littleneck clams is optimum at salinities between 20 and 30 o/oo and that they can tolerate salinities as low as 10 to 12 o/oo for periods up to one month.

Goodwin (1973) observed higher hardshell clam (including native littleneck clams) densities in areas with high maximum current speeds (optimum between 77.1 and 154.3 cm/sec). His data are summarized in Table (1)

Table 1. Relationship between current speed and the biomass of hardshell clams observed in Puget Sound, Washington by Goodwin (1973).

Current Speed (cm/sec)	g/m^2 (butter clams)	G/m^2 (littleneck clams)
0.0 to 25.3	808	252
25.3 to 50.7	671	145
50.7 to 101.3	710	353
> 101.3	1580	646

Marking clams and other bivalves. Numerous methods are available for marking clams and other bivalves with valve lengths greater than ca. 1.5 to 2.0 cm. Marking techniques for aquatic species have been reviewed by Rounsefell (1963) and Mottet (1980).

- **Etching of valves with marks or numbers** (Brooks 1991) used a tungsten carbide tipped etching tool to inscribe numbers into the valves of mussels *Mytilus edulis galloprovincialis* and *Mytilus edulis trossulus* having valve lengths greater than 3.0 cm. This provided an individual mark that lasted for at least three years. Trowbridge *et al.* (1996) notched the margin of native littleneck clams with a valve length of between 1.5 and 3.5 cm and Peterson and Quammen (1982) marked ca. 2.5 cm native littleneck clams by etching the valves' surfaces.

- **Gluing plastic tags on the exterior of valves.** Brooks (1991) marked mussels with 3/16" diameter plastic tags, cut from microscope slide boxes with a paper punch and fixed to the valves with epoxy glue (West System™). These tags lasted for over one year in field growout experiments.

- **Vital stains and paints.** The preceding techniques are not considered appropriate for marking small bivalve seed < 15 mm valve length because of the stress involved and fragility of their valves (Trowbridge *et al.* 1996, Mottet 1980). The most common method for marking juvenile bivalves is staining with a vital stain such as neutral red (Loosanoff and Davis, 1947), alizarin red (Hidu and Hanks, 1968) or by spray painting (Glock and Chew, 1979). Vital stains may be identifiable for several weeks (Rounsefell, 1963) and fluorescent spray paints for up to 15 months. However, all of these marking techniques tend to become eroded and indistinguishable over longer periods.

- **Morphological characteristics of hatchery reared bivalves.** Mottet (1980) noted that hatchery reared seed can frequently be differentiated from natural seed by examining the "early shell". In this instance, seed produced in the Qutekcak hatchery and nursery system displayed a polished appearance prior to outplanting (Figure 2a). In general, the relatively large polished early shell remained a visible mark during much of the study (Figure 2b) – especially when compared with wild clams (Figure 2c). Because these studies started with very small seed and lasted for four years, no effort was made to mark the hatchery seed. It was considered unlikely that paints or dyes would last four years and the seed was too small to mark by etching or affixing tags. In addition, no evidence of natural native littleneck clam recruitment (newly recruited juveniles, living native littleneck clams, or native littleneck clam shells) was observed at the Port Graham study beach in Murphy's Slough and the growth data was not confounded by natural recruitment. The hatchery trait illustrated in Figure (2a) was helpful, but it did not produce an unequivocal mark for identifying hatchery seed. Naturally recruited clams in this study showed a range of early shell morphologies – likely associated with the season of spawning. Seed spawned early in the growing season possibly produced a larger early polished shell, while those spawned late in the season produced the smaller unsculptured early shell illustrated in Figure (2c).

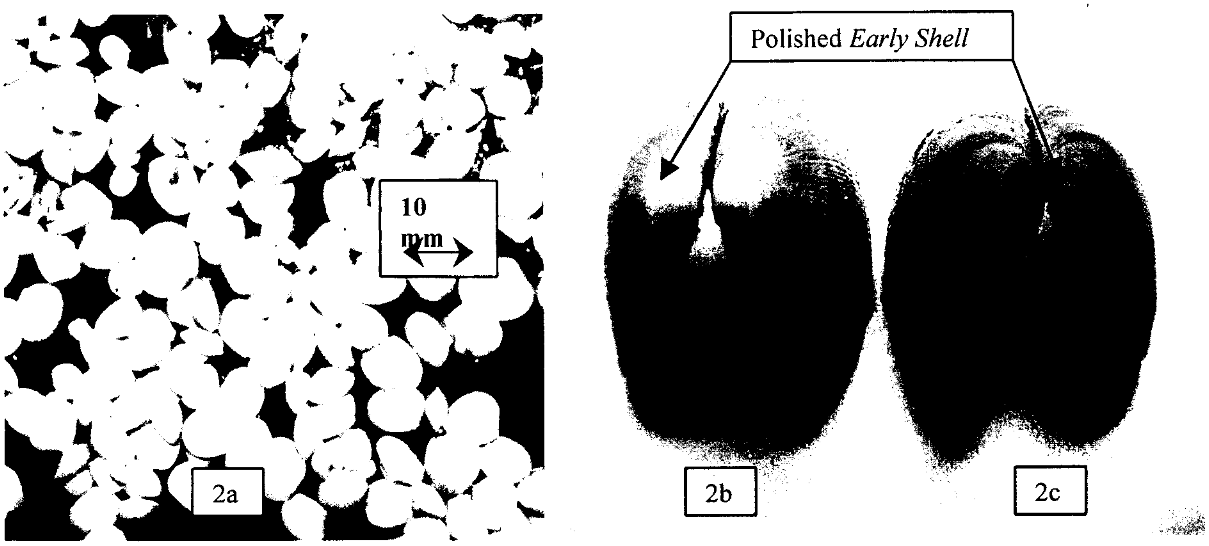

Figure 1a. Hatchery produced native littleneck clam seed ready for planting; 2b. Four-year-old native littleneck clams still showing the polished appearance of the early shell; 2c. Wild native littleneck clam from Tatitlek.

Aging of bivalves. There is a rich literature describing the aging of numerous bivalve species using incremental changes in shell growth. Shell growth in marine bivalves is greatest during the spring and summer in the presence of elevated temperatures and food supplies. Feder and Paul (1973) estimated the age of native littleneck clams by counting prominent discontinuities in the circular valve sculpture. Valve sculpturing associated with growth results from any physiological stress, including unusually low tides, reproductive activity, unsuccessful predation, disease, etc. However, Feder *et al.* (1976) consider annular shell morphology adequately reliable for aging most Prince William Sound clams because of high seasonality of growth on intertidal beaches, which are subject to freezing during low tides in January and February. The greater the seasonal variation in these primary factors, the greater the differences in shell growth will be (Quayle and Bourne 1972). Latitude has a significant effect on both temperature and the length of the growing season. For instance, Harrington (1986) demonstrated that growth rates and the lifespan of *Protothaca sp.* were strongly influenced by temperature and therefore by latitude along the Pacific coast of North America. Of particular importance, he noted that littleneck clams from southern extremes of their range (southern California to Baja) demonstrated rapid initial growth followed by significant decelerations in growth rates (as measured by the width of individual annuli). In contrast, *Protothaca sp.* from the northern portions of their range (Prince William Sound) grew more slowly and at a more constant rate.

Other stresses such as spawning, emersion during low tides, lowered salinity, handling, and storms can also influence shell growth, albeit on a microscopic scale (Crabtree *et al.*, 1980). The analysis of diurnal and seasonal patterns in bivalves shells has been explored in depth by archaeologists. Microscopic examination of daily growth lines in *Mercenaria mercenaria* has shown annual changes in increment line thickness associated with slow winter growth and 14 day cycles of thick and thin daily increments associated with tides (Pannella and MacClintock, 1968). Era (1985) demonstrated that stressful salinities of 12 and 19.5 o/oo reduced daily incremental growth in *Protothaca staminea* to the same degree, as did emersion during semi-diurnal tidal cycles.

Ropes (1884, 1985) described procedures for aging surf clams (*Spisula solidissima*) and Feder *et al.* (1976) aged *Spisula polynyma* in Prince William Sound by identifying winter annuli recorded in the valves. Paul and Feder (1976), Paul *et al.* (1976), Trowbridge *et al.* (1996), Weymouth *et al.* (1931) and Bechtol and Gustafson (1998) described the aging of *Protothaca staminea, Mya arenaria* and *Siliqua patula* in Prince William Sound by counting winter annuli. Paul *et al.* (1976) determined the age of butter clams (*Saxidomus giganteus*) in Prince William Sound using the same techniques. For purposes of the current study, Ham and Irvine (1975) provided a detailed evaluation of various methods for determining daily, seasonal and annual growth increments in native littleneck clams, butter clams (*Saxidomus giganteus*) and Nuttall's cockles (*Clinocardium nuttallii*) from British Columbia.

Despite the well-understood theory of the relationship between bivalve shell growth and the environment, interpretation of the sometimes-complex patterns is equivocal and requires experience. This is particularly true for older individuals because of umbonal erosion and the closer spacing of annuli at ages greater than five to six years (Ropes and Jearld, 1987). Alexander *et al.* (1993) found that shell morphology in the native littleneck clam is habitat dependent – specifically that concentric lamellae are pronounced on individuals living in coarse-grained sediments and less pronounced in individuals from fine-grained sediments along the Pacific Northwest coast. Hughes and Clausen (1980) and Peterson and Ambrose (1985) noted that increments in bivalve shells result from 1) size and age differences, 2) microhabitat differences, 3) migrational behavior and 4) genetic variability. These authors advised caution in interpreting bivalve growth from an analysis of shell structure.

Trowbridge *et al.* (1996) investigated growth recorded in the valves of *Protothaca staminea* in Prince William Sound. The *Executive Summary* in Trowbridge *et al.* (1996) contains contradictory statements regarding the comparative accuracy of sectioning valves or counting external checks. At page xiv, the summary states, "Ages of littleneck clams using the external surface method were younger than those estimated from the sectioned valve method." However, the body of the report and the author's conclusions clearly state that the external method is more accurate and that the sectioning method tends to underestimate the age of native littleneck clams. Trowbridge *et al.* (1996) made several points worth reiterating here:

➢ Annular interruptions in shell growth appeared as deep notches in the outer shell layer, with the interruption extending through the middle shell layer of the valve. The interruptions in incremental growth were typically wide.

➢ Some individual shells present confusing patterns and should be discarded for purposes of determining age at length.

➢ The possibly long protracted spawning season results in significant differences in the first years growth.

➢ They recorded significantly faster growth in 1990 compared with 1991, suggesting that environmental factors important to shellfish growth may vary significantly from year to year.

➢ They concluded that the sectioned valve method under-estimated the age of littleneck clams and that the external surface aging method was more accurate.

Length at age for native littleneck clams in Alaska. Feder and Paul (1973) estimated that it required 8 to 10 years for native littleneck clams to reach a valve length of 30 mm throughout Prince William Sound. Nickerson (1977) estimated that *Protothaca staminea* recruited into a harvestable class size ($\geq$ 38 mm valve length) at an average age of 7.5 years in Prince William Sound, while the butter clam (*Saxidomus giganteus*) required only 5.5 years to reach the same valve length. Rutz (1994) estimated the mean age of recruitment into the class having $\geq$ 38 mm valve length at between 10 and >12 years in Kosciusko Bay, Southeast Alaska. His data suggested that approximately 2% of the littleneck clams reached 38 mm in 7 to 9 years. Bechtol and Gustafson (1998) examined littleneck clam growth at Chugachik Island in Cook Inlet, Alaska and estimated that 0.4% of the clams attained a valve length of 38 mm at age 5. In their study of natural populations, 83.4% of the native littleneck clams reached harvest size of 38 mm at ages of 7 to 8 years. Most recently, Figure (21) in the Trowbridge *et al.* (1996) report suggested a maximum valve length of 36 to 37 mm in native littleneck clams that were $\geq$ 9 years old. These reports are summarized in Table (2).

Table 2. Reported age of native littleneck clams (*Protothaca staminea*) at which they recruit to a legal harvest size of 38 mm in Prince William Sound, Alaska.

Author	Mean age to reach 38 mm valve length
Feder and Paul (1973)	8 to 10 years
Nickerson (1977)	7.5 years
Rutz (1994)	10 to >12 years
Bechtol and Gustafson (1998)	5 to 8 years
Trowbridge *et al.* (1996)	$\geq$ 9 years

Bivalve predators. Sea otters (*Enhydra lutris*) are well-recognized predators on crab, sea urchins and bivalve mollusks, including *Saxidomus giganteus* and *Protothaca staminea* (Kvitek and Oliver 1992; Kvitek *et al.* 1993; Doroff and DeGange 1994). *Saxidomus giganteus* was reported as the most frequent otter prey item (Kvitek and Oliver 1992; Kvitek *et al.* 1993; Doroff and DeGange (1994). Recent sea otter predation is evidenced by excavations in the substrate and broken bivalve shells. No reports describing interaction between sea otters and intensive or extensive aquaculture were identified in the literature.

Other predators include crabs (Pearson *et al.* 1981; Pearson *et al.* 1981), white-winged scoters (Sanger and Jones 1992), fish (Peterson and Quammen, 1982) and gastropods – particularly in the family Naticidae (Kent 1981; Peitso *et al.* 1994; Quayle and Newkirk 1989). Starfish, particularly *Pycnopodia helianthoides* and *Evasterias troschellii* prey on littleneck clams (Toba *et al.* 1992). All of these predators are reported to take small and large littleneck clams up to their maximum size. Pearson *et al.* (1979) determined that Dungeness crabs can locate buried native littleneck clams by detecting clam extracts in the water. Boulding and Hay (1984) observed that predation by *Cancer productus* on *Protothaca staminea* increased with increasing clam density. This may have implications for the intensive culture of native littleneck clams in areas where crab predation is a problem. Both *Cancer productus* and *Cancer magister* are capable of tearing through light plastic netting used to protect clams from large gastropods and starfish.

Bivalve culture. Native littleneck clams have not previously been used for intensive commercial culture or for subsistence enhancement in the Pacific Northwest because hatchery reared seed has not been available. However, numerous publications discuss the intensive and extensive cultivation of Manila clams in the Pacific Northwest (Quayle and Newkirk, 1989; Toba *et al.* 1992; Mottet 1980; Magoon and Vining 1981).

Successful enhancement begins with good site selection. Toba *et al.* (1992) discuss several factors important for extensive or intensive clam culture. The following parameters were discussed with village elders during the study site selection process:

- Sufficient area at an appropriate tide level (-1.5 to + 2.5' MLLW for native littleneck clams);

- Appropriate substrate composition containing a mixture of gravel, sand, ground shell and mud with enough organic matter (> ca. 1% TVS) to bind the sediments;

- Exposure. Sediments become unstable and may move excessively when exposed to high wind and wave conditions. The fine sediment that holds gravel and sand together washes away, leaving a loose matrix of gravel and sand. As the beach shifts, small clams are either washed out of the substrate or buried under new accumulations. Clam cultivation in high-energy sites requires some form of intervention to stabilize the substrate.

- Log damage. The potential for storm damage and catastrophic loss must be assessed. This is particularly important for intensive cultures where the investment in time and money can be high. Knowledge gained from local elders was considered invaluable in choosing enhancement sites. An understanding of storm tracks, fetch, upland vegetation, the presence of logs, debris, and beach slope and composition can be used in assessing this factor. Intensive cultures should not be placed in areas subject to excessive log damage.

- Oxygen availability in sediments. Native littleneck clams survive in anaerobic sediments. However, in optimum conditions, the depth of the redox potential discontinuity

(RPD) should be at least 2 cm and preferably greater than seven to ten centimeters. A deep RPD suggests adequate pore water movement, which is desired during low tides, particularly during winter to reduce the potential for freezing.

- Temperature. Beach substrates can freeze during nighttime winter low tides in the Pacific Northwest (Bower, *et al.* 1986) causing significant mortality. This suggests that Alaskan clam culture should not be attempted high intertidal elevations – particularly in the winter.

- Salinity. Areas heavily influenced by freshwater should be avoided for two reasons. First, native littleneck clams do not thrive in areas subject to prolonged periods with salinities less than 20 o/oo and second, streams tend to meander across intertidal areas. As the streams meander, they create new channels that wash away shallow infauna, including clams.

- Primary production. Native littleneck clams feed primarily on living phytoplankton and detritus that is part of the seston. The intensity and extent of enhancement projects must consider the availability of food. This may be particularly important in Alaska where primary productivity is limited by short summer growing seasons. Brooks (2000c) has brought together the literature necessary to determine carrying capacities for coastal embayments. The methodologies are not restricted to specific environments and could be applied in Alaska for estimating bivalve carrying capacity in small to medium size embayments.

- Longshore currents. Goodwin (1973) observed increased clam biomass in areas with strong currents. These currents bring food over the shellfish bed. However, as pointed out by Toba *et al.* (1992) and Nosho and Chew (1972), strong longshore currents can also redistribute clam seed, significantly reducing their density.

- Predation. Areas where predators congregate, particularly scoter ducks, should be avoided. As previously noted, the potential interaction between sea otters and intensive clam culture has not been investigated.

- Water Quality. The water quality of areas near human habitation should be carefully evaluated prior to enhancing shellfish stocks. Leaking septic systems and industrial pollution can contaminate shellfish making them unfit for human consumption. Growing area certification in accordance with the National Shellfish Sanitation Program Part I (NSSP, 1995) should be accomplished during initial culture trials and an *Approved Harvest Classification* determined prior to undertaking any significant enhancement effort.

- Paralytic shellfish poisoning (PSP). Neurotoxins synthesized by some dynoflagellates, like *Alexandrium catanella*, are concentrated in the tissues of bivalves, particularly butter clams. Intensive shellfish enhancement should not be undertaken in areas where blooms of toxic phytoplankton have been frequently observed. In addition, areas from which shellfish are harvested for human consumption should be frequently tested for PSP. Kvitek *et al.* (1993) hypothesized that high concentrations of brevetoxins in butter clams may exclude sea otters from some areas of Southeast Alaska.

- Human resources available to tend intensive shellfish cultures should be determined. Some techniques require a significant investment in time and energy. These techniques should be reserved for easily accessible beaches of optimum substrate composition.

In addition, different villages may partition their time differently. In some, the intensive culture of shellfish may be a rewarding and appropriate activity. In others, village members may have outside jobs with little time to devote to caring for intensive shellfish cultures. Enhancement methods must recognize village needs and desires - they must "fit" with the village's lifestyle. Recommendation of specific enhancement techniques should only follow a careful determination of the villages needs and desires.

➢ Assessment of natural recruitment. Natural recruitment depends on many factors as discussed by Mottet (1980). Native littleneck clams can be absent for a number of reasons including failure to recruit new cohorts because of local hydrodynamics. Predation on new recruits and beach instability can chronically reduce or eliminate young clams from an area. The point is that the absence of clams does not mean that a beach is unsuitable for cultivating native littleneck clams. However, artificial seeding is expensive and an assessment of clam recruitment should be undertaken irrespective of the presence of adults. This can only be accomplished by sieving sediments on small (1 mm) sieves and examining the retained material under a microscope or magnifying glass. All clams retained on 1.0 mm screens should be accounted for in surveys. Alternatively, some areas may have excellent growth but they may not sustain harvests because of limited or sporadic recruitment. The frequency of successful recruitment can be assessed by evaluating age frequency histograms. However, this requires that the clams be carefully aged and valve lengths measured.

Clam culture techniques. Manila clam culture techniques used in the Pacific Northwest are reviewed in depth by Toba *et al.* (1992), Mottet (1980) and Magoon and Vining (1981). Taylor (1989) provides interesting insight into growout techniques used by commercial clam producers in the Pacific Northwest. The following increasingly intensive culture methods are commonly used for Manila clams in the Pacific Northwest.

Predator control. Where natural recruitment is sufficient, beaches can be enhanced by simple predator control measures such as trapping crabs and picking or trapping starfish and predatory gastropods (Quayle and Newkirk 1989).

Supplemental seeding. Supplemental seed can be added to beaches holding clams, but where recruitment is either too low or sporadic to sustain desired harvest levels.

Substrate modification. Beaches not meeting the physicochemical attributes described in Section 1.5 can still be used for shellfish culture. However, they often require modification and/or protection in order to warrant the expense of planting clams. Substrates that are too soft and muddy to support optimal clam growth can be modified by the addition of gravel and/or crushed shell (Toba *et al.* 1992).

Plastic netting described in Figure 3a excludes many predators and can help stabilize substrates on beaches subject to excessive sediment movement. Netting does not exclude all predators. For instance, some gastropods can burrow under the nets and numerous predators can recruit through the mesh at a young age and prey on small clams. Miller (1982) and Anderson *et al.* (1982) have reported the effectiveness of lightweight plastic netting for improving survival of Manila clams. For instance, at the end of two years, Anderson *et al.* (1982) reported 57 percent survival under ¼" x ½" netting compared with only 1% survival for unprotected Manila clams seeded at three to four mm valve length in Filucy Bay, Washington. Similar increases in survival were observed at three other test sites. Very low survival (4 to 6%) was reported at two sites regardless the protection. Toba recommended ¼" mesh for small seed averaging 3 to 4 mm valve length and ½" mesh for planting 6 to 8 mm seed. Netting typically comes in 17-foot wide rolls. The rolls are cut into 100' lengths for ease of handling. Netting can be secured by burrying the edges approximately 6" deep around the perimeter or by sewing a leadline around the perimeter and stapling the leadline to the substrate using rebar bent in a "J" shape.

The use of plastic clam bags is described in (Figure 3b). Rogers (1989) and Toba *et al* (1992) discuss the culture of Manila clams in plastic cages. These cages are available in several sizes with different mesh openings designed for different stages of culture. In protected environments, the cages can simply be set into the substrate as shown in Figure (3b). In exposed environments the cages are attached to polypropylene lines running down the rows using electrical ties or to ½" steel rebar. Tying the cages together in this fashion helps to stabilize the culture reducing the potential for loss of individual cages and reducing the degree of sediment movement within the culture area. Toba *et al.* (1992) reported clam survival of 51 to 79 percent during a 17-month growout in Puget Sound. The bags measured 32" x 18" x 4" deep. Survival was not a function of density at between 300 and 1,500 clams per bag (75 to 375 clams/square foot). However, clam growth was highest at the lowest density (13.1 grams/clam) and decreased linearly as density increased to 6.8 grams/clam at 1,500 clams/bag. Toba *et al.* (1992) recommend a density of 500 – 700 Manila clams/bag, equivalent to 125 to 175 clams/sf.

3a **3b**

Figure 3a) One-half inch square plastic netting being used to protect a goeduck (*Panopea abrupta*) culture and 3b) Manila clams being cultured in plastic cages. Both cultures are in Thorndyke Bay, Washington State.

Environmental effects associated with bivalve culture. The intensive culture of any animal brings with it environmental changes. Brooks (1993, 1995) and Dumbauld *et al.* (2001, In press) documented a more diverse and abundant invertebrate community in cultivated Pacific oyster beds than was found in adjacent eelgrass meadows that had been displaced by oyster culture. Brooks (2000a, 2000b and 2000c) has documented the environmental response to salmon aquaculture and the raft culture of mussels. Organic loading from intensive aquaculture can exceed the assimilative capacity of local sediments causing reduced oxygen tension and increased concentrations of total sediment sulfide, causing significant changes in the infaunal and epifaunal community. However, as shown by Brooks (2000a), these effects are generally ephemeral and invertebrate communities return to normal within a period of weeks to perhaps two years during fallow periods. Newman and Cooke (1998) discussed the environmental response to the addition of gravel and/or crushed shell to fine substrates to improve the potential for littleneck clam and/or oyster cultivation in the Pacific Northwest.

Kaiser *et al.* (1996) studied the environmental response to intertidal Manila clam culture under plastic netting in England. They found that infaunal abundance was greater within the netted culture than at reference sites. A similar number of species (20-22) was observed in all areas. Harvesting of the clams by suction dredge resulted in a significant reduction of infauna. However, seven months later, no differences between the cultured plots and reference areas were found. Kaiser *et al.* (1996) did not observe statistically significant ($\alpha = 0.05$) differences in total volatile solids (TVS), percent silt/clay or photosynthetic pigments (chlorophyll α) in sediments collected under netted cultures and when compared with those from reference areas.

In follow-up studies, Spencer *et al.* (1996) compared physicochemical and biological response in netted plots with and without clams and unnetted control areas. They observed a significant, but small increase in organic content from 2.42% to 3.37% on netted plots when compared with unnetted controls. They also observed a four fold increase in the accumulation of new sediments under the netted plots when compared with the controls. The green algae *Enteromorpha sp.* settled on the nets resulting in an increase in the number of littorine snails. Deposit feeding polychaetes like *Ampharete acutifrons* and *Pygospio elegans* dominated the netted areas. In general, the authors concluded that the netting increased both the sedimentation rate and productivity of the cultivated areas. At the end of the 30-month growout cycle, Spencer *et al.* (1997) observed that increased sedimentation had elevated the beach profile by 10 cm under the netting. Clam survival was poor (500 clams/m^2 seeded and an average of only 26 clams/m^2 harvested or 5.2% survival). At the end of the culture cycle, 236 times as many herbivorous snails (*Littorina littorea*) were observed on the netted plots when compared with the controls. The number of species was significantly higher on the netted clam ground when compared with the controls (8:5) and total abundance was nearly three times higher within the clam culture than at controls (31.9:11.2/0.018 m^2 quadrat). Shannon's and Simpson's indices were also higher in the cultured plots when compared with the controls. At the end of the culture period, Spencer *et al.* (1997) concluded that the observed biological responses indicated that organic enrichment occurred within the net-covered areas. The degree of enrichment did not exceed the assimilative capacity of the sediments and the abundance of infaunal and epifaunal increased in cultured areas.

Spencer *et al.* (1998) continued their study by examining the biological and physicochemical response to suction dredge harvesting of the netted plots. They found that suction dredging significantly reduced both the abundance and diversity of infauna. However, the harvested area remediated quickly and no differences between the cultivated and control plots were observed 12 months after harvesting. Similar effects were reported for cage culture of Manila clams in the citations provided by Spencer *et al.* (1997). This review suggests that the intensive culture of bivalves under netting (or in cages) may result in the following effects:

- Increased sedimentation rates – particularly silt and clay;
- Increased organic content in sediments;
- Increases in the abundance of some infauna – particularly deposit feeding annelids;
- Increases in the number of taxa;

- Decreases in all of the metrics following removal of the nets and harvesting of the clams;
- A return to reference physicochemical and biological conditions within a relatively short period of weeks to perhaps a year.

Commercial clam harvest management in Alaska. The Alaska Department of Fish and Game (ADFG, 1995) conducted clam surveys for native littleneck clams (*Protothaca staminea*) in Kachemak Bay in the Southern District of the Cook Inlet Management Area. The purpose of this study was to examine the affects of commercial harvests from Department of Environmental Conservation certified beaches. This ADFG study did not examine small clams ($< \approx 15$ mm) in the 1992 - 1994 surveys. Therefore, ratios of sublegal to legal size clams were skewed toward the legal clams. They observed clams from age three to age 14 and found that minimum legal size (38 mm valve length) was achieved in *Protothaca staminea* between the ages of 5 and 10 years. They concluded that growth was variable and slow.

In addition, ADFG (1995) concluded that recruitment was sporadic and that native littleneck clam populations were characterized by generally low to moderate recruitment with periodically strong year classes. The study did not examine intersite length-frequency or age-frequency distributions to determine if strong year classes occurred during the same years on all beaches in Kachemak Bay, suggesting that strong recruitment was a function of generally favorable environmental conditions - or if strong year classes were present on only a few beaches in any one year - suggesting that variable wind and current patterns, or other stochastic processes, may concentrate shellfish larvae at different beaches in different years. ADFG (1995) did find significant quantities of shellfish on all beaches in Kachemak Bay and their estimates of the number of legal and sublegal (>15 mm) size clams per square meter are provided in Table (3).

Table 3. Numbers per square meter of legal (≥38 mm valve length) and sublegal (<38 mm valve length) clams (*Protothaca staminea*) observed on five beaches in Kachemak Bay by the Alaska Department of Fish and Game in 1994.

Beach (year)	# legal size clams	# sub-legal size clams
Chugachik (1994)	36.4	42.8
Jakolof Bay East (1993)	19.0	1.3
Jakolof Bay West (1993)	17.9	10.5
Tutka (1993)	13.6	4.8
Halibut Cove (1994)	77.5	96.5
Sadie Cove (1993)	27.6	35.2

Other findings of interest in the ADFG (1995) report include the following:

- *Protothaca staminea* were generally found buried in sediment to depths of 25 to 31 cm. However, clams were found at unspecified depths greater than this.

- The biomass of clams at the most heavily harvested beaches (Chugachik and Jakolof) was slowly declining.

- Clam growth was highly variable and clams reached minimum harvest size (≥ 38 mm) at between 5 and 10 years of age.

ADFG (1995) examined several years of data at sampled beaches and compared changes in available biomass of legal size clams with department harvest records. The results are summarized in Table (4). This information suggests that, while beach response to harvest is variable, the beaches examined in their study could not sustain harvests greater than perhaps 10 to 15% per year. This seems reasonable when the median age to recruitment into the legal size population averaged 7.5 years. The ADFG (1995) data suggests that an adequate management plan will be essential to the development of a sustainable subsistence shellfish resource anywhere in Alaska.

Table 4. Changes observed in ADFG estimates of the biomass (reported in pounds) of legal size clams found on five beaches in Kachemak Bay between 1990 and 1994.

Beach	Year (biomass)	Year (biomass)	Percent Harvest	% Biomass Change
Chugachik	1992 (249,929)	1994 (131,485)	10.8% ('92); 20.5% ('94)	-47.4%
Jakolof	1992 (110,025)	1993 (108,227)	16.9% ('92); 12.0% ('93)	-1.6%
Sadie Cove	1993 (95,506)	1994 (135,467)	none reported	+41.8%

Summary. The review provided herein discusses only the growout phase of clam production. In the Pacific Northwest, native littleneck clams prefer intertidal environments with mixed substrates containing gravel, sand and mud. They prefer salinities greater than 20 o/oo but can survive lower salinity for periods of up to a month. Their survival and growth depends on temperature, food availability, substrate stability, and predator avoidance. Crabs, gastropods, ducks, sea otters and fish all prey on native littleneck clams. Native littleneck clam abundance depends on larval recruitment and the foregoing environmental constraints. Some of these constraints, like substrate composition and stability, recruitment of juveniles and predator control, can be artificially ameliorated. Other constraints, such as hydrodynamics and food availability are beyond the control of humans and become critical aspects of site selection and management planning.

Bivalve cultivation in the Pacific Northwest is a mature industry with well-developed practices for the hatchery production, nursery, and growout of Pacific oysters, Manila clams and geoducks. These technologies, developed over the last 30 years, have enabled shellfish growers in British Columbia, Washington State and Oregon to meet the ever-increasing public demand for bivalve mollusks. Similar technologies have not been developed for native littleneck clams because they grow more slowly, do not open as reliably on steaming, and have a shorter shelf life. However, the similarities in habitat needs between Manila clams and native littleneck clams suggests that culture techniques developed for the former may also prove useful in enhancing subsistence harvests at native villages in Alaska.

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Alaskan Native Village Shellfish Enhancement Program

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Traditionally, Alaskan Indian Villages moved from one site to another. As subsistence food sources were used up in one place, the Village would move on to another location where time and nature had replenished fish, shellfish and other resources that people need. Villages are no longer able to move freely from one place to another. That means that the fish, shellfish and timber available to a Village must be used very carefully so that there is plenty for our children, grandchildren and all of the future generations that follow us. This is a tough job, it means that we need to understand clams and cockles, how they live, how fast they grow, and how many we can take to meet today's needs and still have plenty for tomorrow.

In nature, juvenile clams are spawned in one place and drift for several weeks before they get big enough to settle to the bottom and dig into the gravel with their foot. Most of the clam larvae die before they get that big and usually only a few clams survive to replenish our beaches. Some years, when tides and currents are good, more clams will settle on the beach. When the weather is cold and tides and currents are no good, the Village's beach may not get any new clams. Even after the juvenile clams set on a beach, there are lots of other animals that depend on them for food. Gulls, crabs, ducks, fish, starfish, otters and snails all eat clams. Everywhere we have been in South Central Alaska, we have seen lots of holes dug by sea otters - and everywhere we have seen these sea otter holes, we haven't found any big clams.

In other parts of the world, people have learned how to raise clam seed in hatcheries and nurseries. Clams and oysters swim around in the water when they are juveniles. Just like a butterfly, they metamorphose into an adult after three or four weeks. After the little clams settle on the bottom of the tanks, they are moved to what is called a FLUPSY or floating upwell nursery system where they grow very fast.

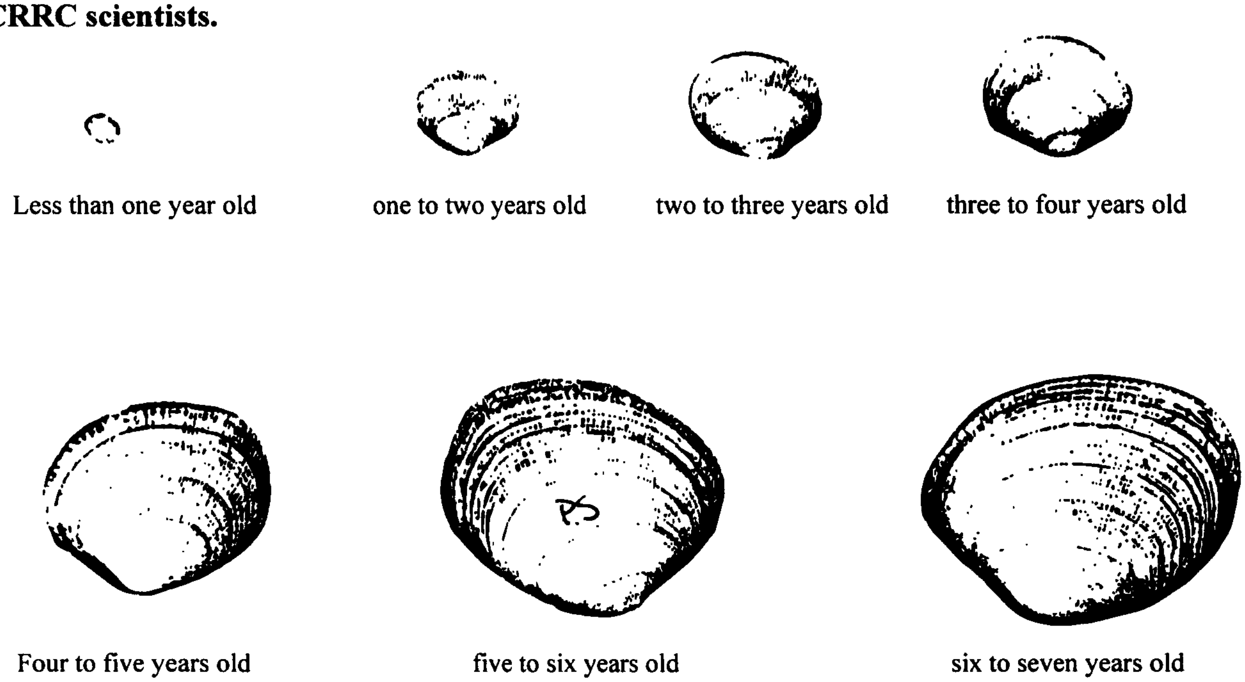
Clam growers have also developed techniques for protecting clams and oysters from predators - especially starfish, ducks, snails and crabs. There aren't a lot of sea otters in other parts of the world and they haven't been a problem for most people. One of the challenges facing Alaskan Villages is how to keep sea otters from eating your clams and oysters. We're going to try putting nets over the clams to see if that hides them from the otters. But Villagers must work hard to scare the otters away from the clam beaches.

In 1995, the Chugach Regional Resource Council (CRRC) started a shellfish enhancement program at the Villages of Port Graham, Nanwalek and Tatitlek. In 1996, the program is being expanded to include the Villages of Ouzinkie and Chenega Bay. More than 8,000 clams will be planted at Port Graham, Nanwalek and Tatitlek this year. These Villages will carefully watch and measure these clams to see how fast they grow and how many survive. This is important because it will tell us how many clams we can harvest if we take really good care of them. We have brought you some books to read about growing clams and oysters.

What have we learned about clams at Port Graham, Nanwalek and Tatitlek. In 1995, we looked at shellfish beaches near these villages. We found basically the same conditions at each beach. There weren't enough juvenile clams being caught on the beaches to supply village needs. It takes about six years for a littleneck clam to reach 1.5", which is a minimum size for

harvesting. We weighed the parts of the clams you eat and found that clams less than 1.5" in length didn't have much meat. You need to let the clams grow at least this big. So your beaches don't get very many new clams and the ones that do collect there take about six years to get big enough to eat. That's a long time. Figure 1 shows the actual size of clams when they're one to six years old on your beaches.

Figure 1. Photographs of littleneck clams that are one to six years old. These are typical of the clams dug up on beaches at Tatitlek, Nanwalek and Port Graham in 1995 by CRRC scientists.



We did find many small mussels in some places. These are high on the beach where starfish can't get to them. When they live up high on the beach, they don't get covered with water for very long each day and don't get a lot to eat. So they're small. If we put them in nets to protect them, and hang them from a float, everyone will be surprised at how fast they grow - and how good they taste.

Predators. We found lots of starfish and many holes made by sea otters. There were almost no butter clams and very few littleneck clams and we didn't find hardly any clams big enough to eat- only empty and broken clamshells. Before Villages can grow many clams, you need to control the starfish and protect your clams from the sea otters.

How good are the beaches? On the plus side, we found some really good beaches that could grow lots of clams. Some of the beaches have lots of big rocks on them. These rocks need to be moved out of the way. The gravel is deep and lots of water flows through it. Currents at most beaches were fast enough to bring lots of food for the clams to eat.

Summary.

1. We didn't find many clams large enough to harvest.
2. Not many juvenile clams set on these beaches.
3. The bigger clams are being eaten by starfish, snails and sea otters
4. Cockles seem to grow fast
5. There's lots of mussel seed high on some beaches
6. The beaches are good and could grow lots of clams

What can we do to grow more clams for Villagers? In years past, several people have tried to raise native littleneck clams in hatcheries. Everyone failed. But in 1994, the Qutekcak hatchery in Seward figured out how to grow these tricky clams. They have raised about 25,000 clams that we will use for seed in 1996. In another two years, with a new hatchery, Qutekcak should be able to raise millions of juvenile clams for Alaskan Villages.

To raise clams in a hatchery, adults are brought in and conditioned for spawning by holding them in slightly warm water for several weeks. This causes the clams to make eggs and sperm. When they're ready to spawn, the hatchery personnel quickly raise the temperature by 5 or 6 degrees centigrade. Then they may add some food. This encourages the clams to release their eggs and sperm into the water where they are fertilized. The eggs develop into swimming *Trochophore* larvae in about 12 hours. They become "D" hinge larvae in about two days and then spend the next several weeks swimming in the water as *Veliger* larvae. These stages are shown in Figure 3. It is important to know that for the first three weeks or so, clams live in the water, like fish. They are swept all over the place by currents. The clams that set on your beach may have been spawned a hundred miles away. In the hatchery, they're all kept in tanks and fed single celled algae that are too small to see with your naked eye. Raising enough algae is the hardest part for a hatchery.

When the clams get ready to settle out of the water and dig into the bottom, they metamorphose and lose the *Velum* in favor of a strong foot for digging, and siphons and gills for collecting food. After metamorphosis, clams and oysters need more algae than can be grown in a hatchery.

As soon as the clams and oysters are about three millimeters long, they are placed outdoors in what's called a floating upwell nursery system. This FLUPSY is designed to force lots of water up through millions of little clams or oysters. The shellfish filter most of the food out of the water. If the FLUPSY is put in the right place, where there's lots of good food in the water, the little shellfish can grow to over a centimeter in six weeks or so. It can take over a year to grow that much on your beach. If we leave these clams in the FLUPSY for a whole season, they can get up to over 20 mm. It can take several years to grow that large on your beach. Using this system, we believe we can cut at least one, and maybe two years off the time it takes to grow clams on your beaches. It will still take 4 or 5 years before these clams are ready to eat. And each year you'll have to plant a new crop - from now until forever. Figure 4 is a picture of the FLUPSY that CRRC is building to help provide Villages with more clams and oysters.

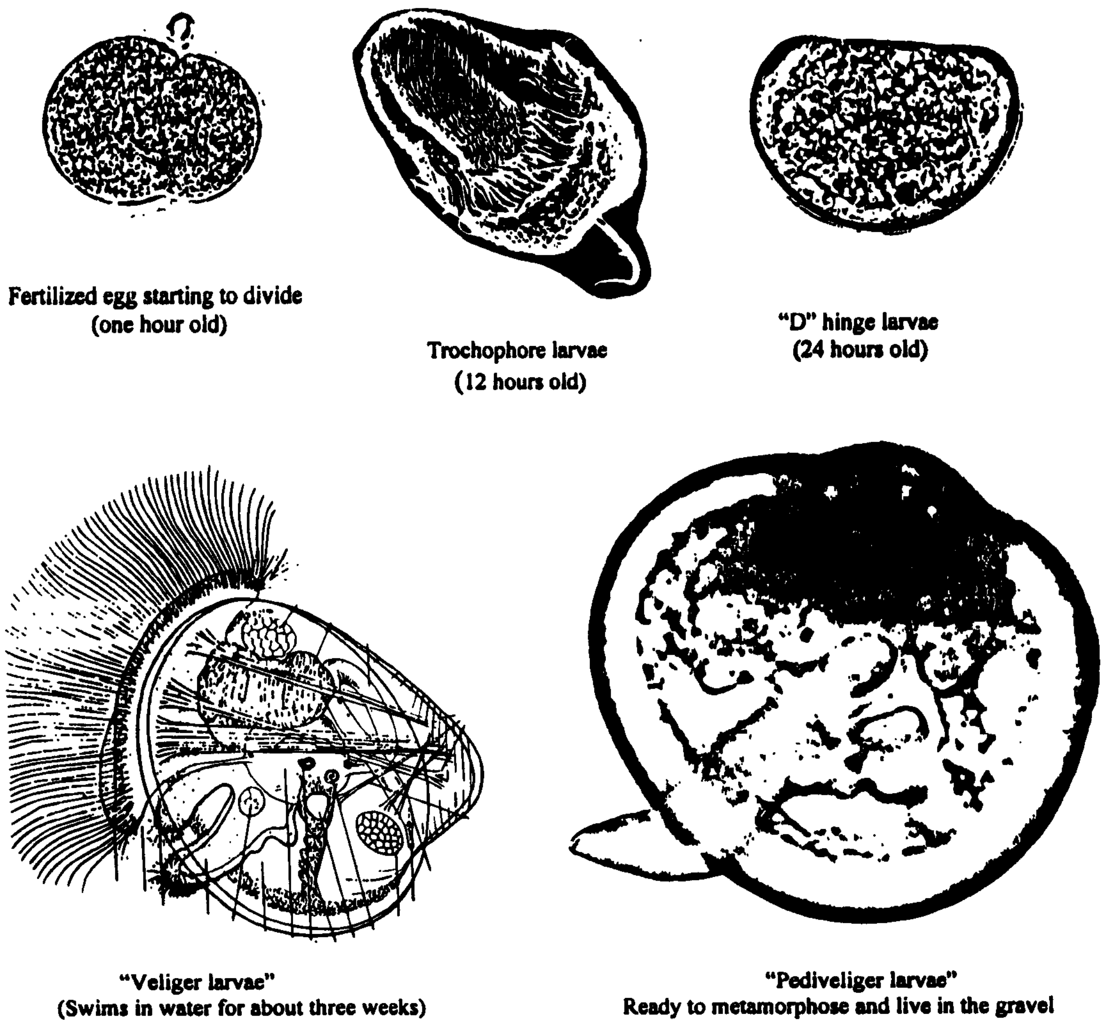
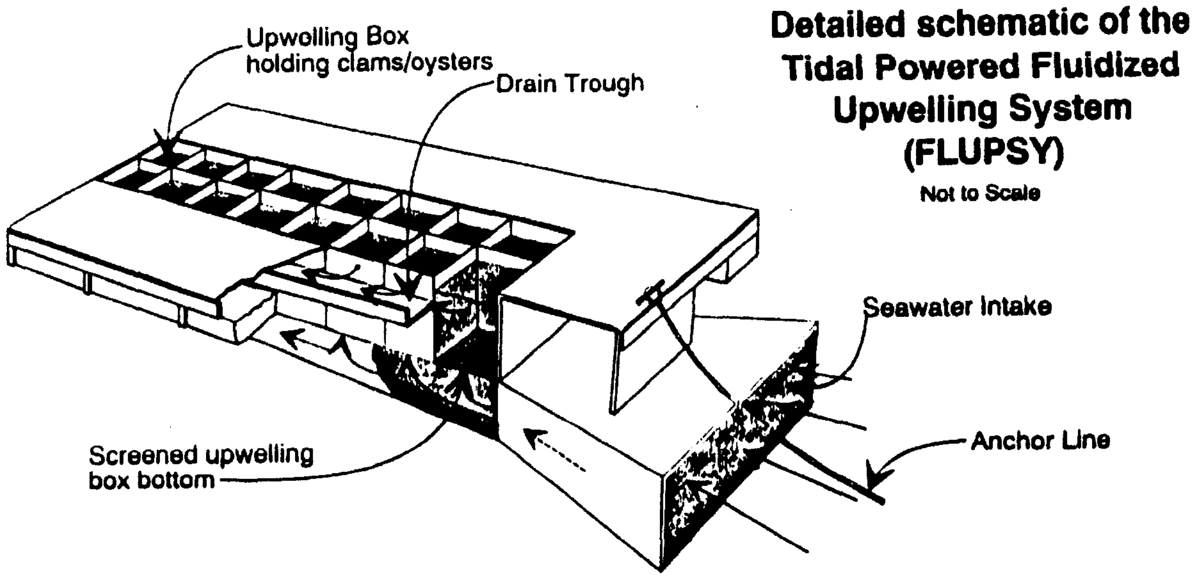


Figure 3. How little clams and oysters grow.



Tidal current forces seawater entering the intake to move through the screened bottoms of the upwelling boxes, out the upwelling box drain holes and into the drain trough. The level of the drain trough is slightly above sea level. Construction materials forTidal FLUPSY are uncertain.

Figure 4. Drawing of the CRRC FLUPSY that will be used to quickly raise juvenile clams and oysters from 3 millimeters to over 12 mm.

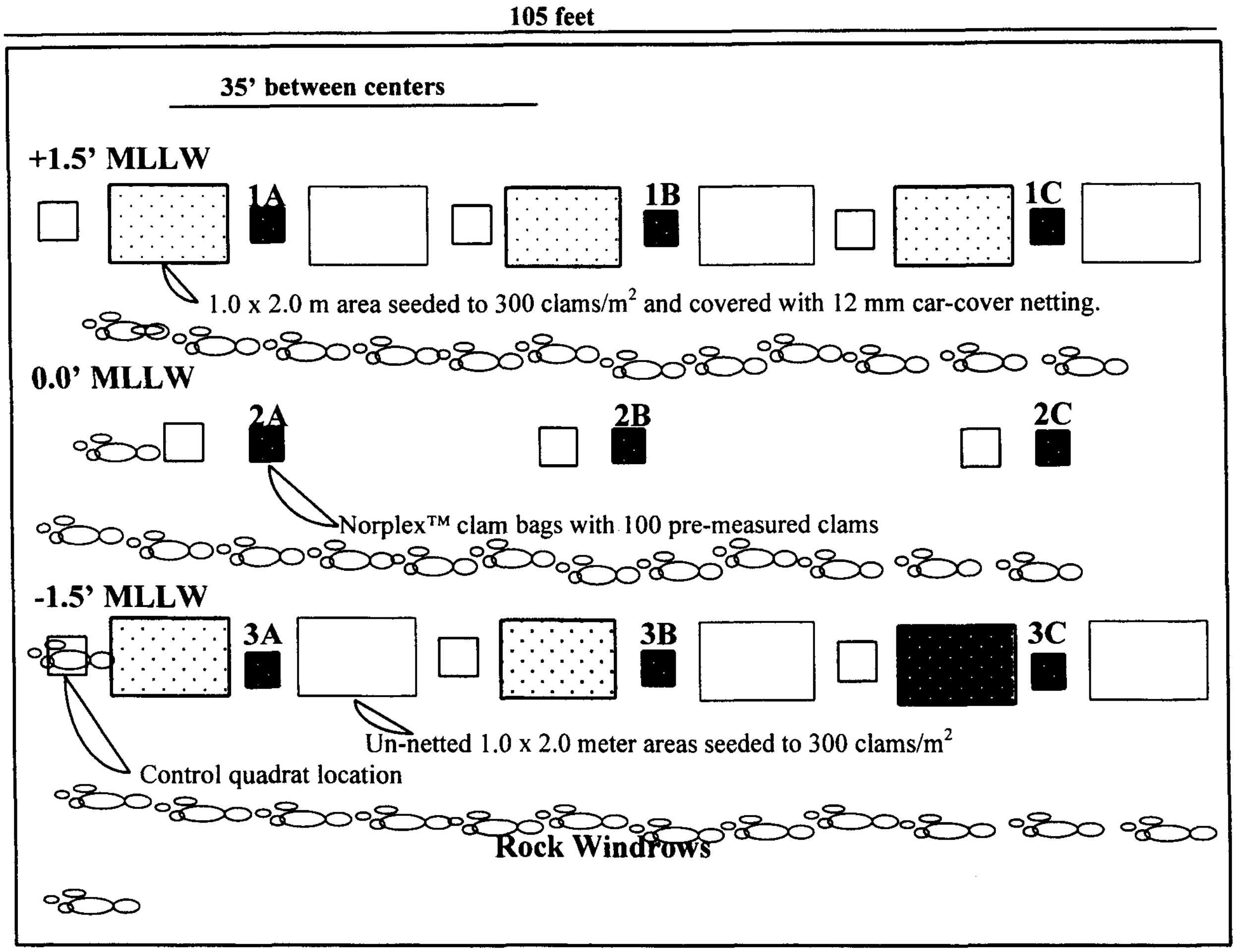
Village shellfish enhancement in 1996. Thanks to the hard work at the Qutekcak hatchery, we have about 25,000 strong little clams to plant in 1996. We're going to use about 8,000 of them at Port Graham, Nanwalek and Tatitlek to study how fast these clams grow and how many survive with and without efforts to keep predators like starfish, crabs, gulls and sea otters away.

The first thing we need to do is to prepare the beach. We'll do this by moving all the big rocks into rows below each row of test spots. We'll try to remove all of the rocks bigger than your fist. That will make planting the seed, covering it with mesh, and monitoring the clam's growth much easier. If we didn't move the rocks, they would tear up the plastic netting we put down. In addition, the windrow of rocks helps to create eddy currents which encourages wild baby clams to settle there.

The studies that we'll start this year are designed to give us the most knowledge from the work we do. We're going to plant clams at three different elevations on the beach. Some of the clams will be in bags where we can keep track of them. We'll count and measure these clams every three months. That kind of information will allow us to predict how fast clams grow on your beach - and how many will survive if we keep the predators away.

Growing clams in bags is really hard work. There are easier ways. Lots of clams are grown under plastic nets in British Columbia, Washington, Oregon and California. We don't know if the light plastic nets will disguise the clams from sea otters or not - we hope so. We've going to put 600 clams under each net. We will put six nets on your beach. We won't bother these clams until next summer when we'll see how their doing. In addition, next to each netted group of clams, we'll put 600 clams into the beach without any protection. Maybe just adding juvenile clams will provide plenty of shellfish for the village - we don't know. The general layout of each study is provided in Figure 5.

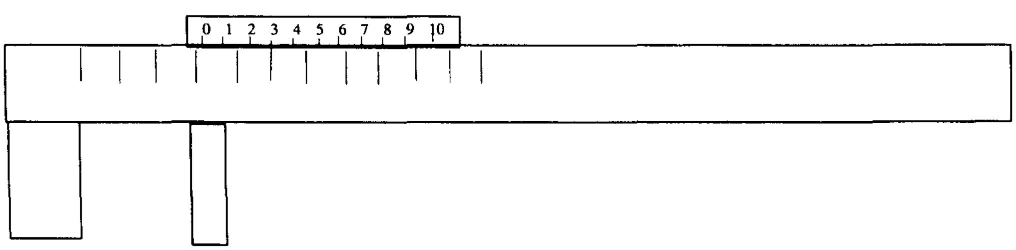
Figure 5. Study design for clam enhancement studies at previously surveyed beaches at the villages of Tatitlek, Nanwalek and Port Graham.



How will we start? The first thing were going to have to do is learn to use these vernier calipers. Then we'll measure nine groups of 100 clams each and three groups of 100 mussels each. These will be put in small mesh bags and labeled. That way we know how big the clams and mussels are when we start the study.

Vernier calipers are easy to use. You read the millimeter scale under the zero mark on the sliding scale. To read the 1/10s of millimeters you find the mark on the top scale that lines up with a line on the bottom scale. The number on the sliding scale is the tenths of a millimeter. This is described in Figure 6 where the calipers are measuring 3.3 millimeters.

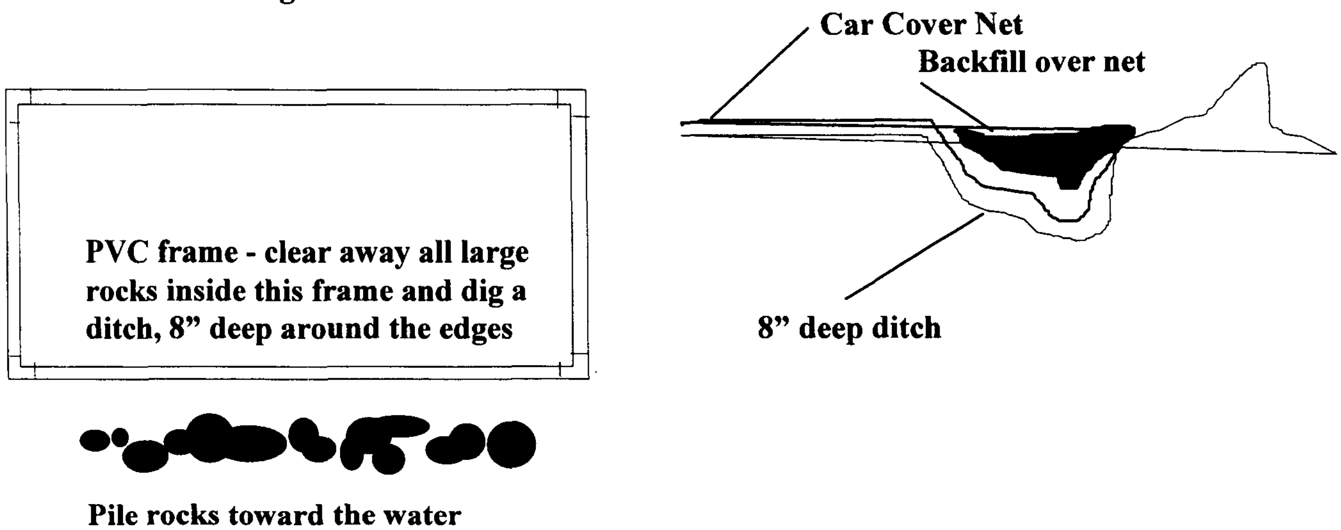
Figure 6. Vernier calipers measuring something that is 3.3 millimeters long.



Measuring clams and mussels. I have brought a bag of lima beans. Each of you can take turns and measure 10 lima beans. I'll come around and make sure you're doing it right. Now lets measure 100 clams out of these bags and enter their lengths on this data sheet. Place the clams into these bags after you finish measuring 100 good clams. Well keep the clams moist and cool while we work. When we finish measuring the clams, we'll measure three samples of 100 mussels for the lantern net experiment. Then well take a break and put them all in the water.

Seeding Clams under car cover. In addition to understanding how clams grow and survive on your beach, we want to know if we can keep predators away by simply covering the clams with light netting. This works in other parts of the world to keep out crabs, snails and starfish. We don't know if it will hide the clams from sea otters. They could certainly rip through the net if they wanted to. We won't measure the clams under these nets. But we do need to bury the edges of the nets to hold them down. The way we do this is shown in Figure 6.

Figure 6. Burying car cover netting to keep out predators. Clams will be seeded through the net on an incoming tide.



Seeding clams in bags. After we've cleared away the rocks and gotten the nets in place we'll be ready to start seeding the clams. First we take the clams out of the bags. Then we put a shovel full of beach sand and gravel into the bag after removing all rocks larger than about 1" diameter. When the sand and gravel are in the bag, we'll sprinkle the clams on top and close the bag using the PVC pipe. Make sure the PVC pipe is secure using an electrical tie. Next, dig a small depression in the beach where the bag goes. It should be about three inches deep and as big as the bag. Nestle the bag down in the hole and tie it to the steel stake that will be driven into the beach next to the spot. Check to make sure the label on the bag matches the label on the stake and that both are the same as the diagram in Figure 5.

Monitoring the clams. Measure the air temperature and water temperature with a thermometer. If you have a salinometer, measure the salinity of the sea water. Note any unusual conditions. Ripped nets or loose bags should be repaired as soon as possible. Do not dig up the clams planted under the net or the experiment will be spoiled. We'll count and measure the clams in these bags every three months. The approximate dates are:

a. September 26 through September 30, 1996.
b. December 20 through December 29, 1996
   or if missed, then January 16 through January 25, 1997
c. March 15, through March 24, 1997

Clam measurements. Retrieve all of the clam bags on a low tide. Keep them in the water near high tide and replace them on the next low tide. Be careful not to walk on the areas planted with baby clams. Your steps will kill them.

a. Gently shake each clam bag under the water to remove as much mud and sand as possible. This will make retrieving the clams easier. Do this gently or you'll break the little clams.

b. Cut the electrical tie that holds the PVC pipe in place and slide the pipe off.

c. Gently dump the remaining contents of the bag into a five gallon bucket.

d. Put a couple of handfuls of sand and gravel from the bucket on a tray and carefully sort through to remove all of the clams you can find. Place these in a ziploc bag temporarily. Its really good for two people to do this. The second person tries to find any clams that the first person missed. You have two sets of calipers - so you can have at least two teams working on this project.

e. Once all of the clams have been sorted out of the gravel, count the clams and then measure the length (longest part) of each clam and enter the length on the data sheet. If new clams crawl into the cage, measure them and simply list their lengths in the notes section. Use a separate data sheet for each clam bag. There are nine bags and you should have nine data sheets when you finish. You should have 100 clams. Some of them may die and so you'll only have an empty shell. If there's a crab in the bag, even a little one, he may break up the shells. Just try real hard to find every clam.

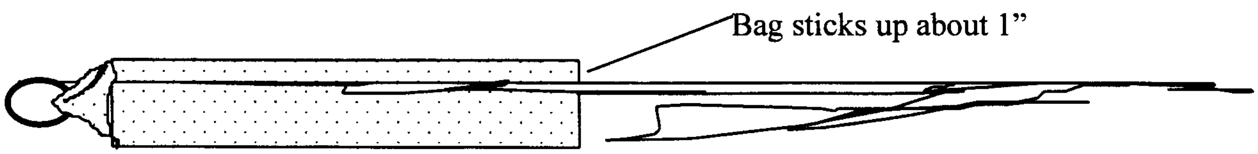
f. Count any empty clam shells you find in the bags and make a note of the number on the data sheet.

g. Note any predators in the bags like small crabs or snails. Note any tears or damage to the bags. If the bags get damages, replace them. You have some spares.

h. Place a shovel full of small sand and gravel in the bag and then gently put the clams back in. Place the bags in the water until the next day when they can be put back in their proper position. Don't leave the bags high and dry. Keep the bags right side up. The right side is the side you sprinkled the clams onto.

i. Slide the PVC closure over the opening of the bag and secure it with an electrical tie. Make sure the label is still on the bag.

j. Gently nestle the bag back into its pocket in the beach next to the correct stake and tie the bag to the stake with a piece of nylon cord, or an electrical tie. The bag should have the clean side up. The side that was up before is probably fouled with algae and barnacles. Put the fouled side down in the hole. Make sure the right bag goes back in the right spot. Check the label on the bag with the label on the stake. If they get mixed up, it will spoil the experiment. About one inch of the top of the bag should be above the beach.



k. Take careful notes describing any problems or predators on the beach. Check the parts of the beach that have nets over the clams and make sure the net hasn't been damaged. If it has, then repair the hole with nylon line or replace the net with a spare one. Even a small hole will let a crab or snail get in. One or two crabs can eat all of the clams in a year.

l. Make a copy of the data sheets for the Village's records. Mail or FAX the original data sheets to Dr. Brooks at (360) 732 -4464

Dr. Kenn Brooks
Pacific Rim Mariculture
644 Old Eaglemount Road
Port Townsend, WA 98368

You can retrieve all of the clam bags on one tide. If you don't get them all measured and back into their proper location on the same tide, anchor them together as low in the intertidal as possible and put them in their right spot on the next tide. It will take about 20 minutes to count and measure each bag of clams. That's about three hours of work to do the whole study.

The clam seed that we are planting is large. However, it will take another four or five years before these clams get big enough to eat. We'll watch them and measure them for this whole time. Nobody has done this before in Alaska and everyone is going to learn a lot about clam growth and survival. If the clams are doing well in this study, we'll probably plant a lot more of them at each of these villages in 1997. That way clams will be ready to eat every year in the future.

Seeding mussels. When we talked to Villagers' about mussels in 1995, they weren't enthusiastic. However, mussels are delicious and considered a delicacy all over the world. The best part about mussels is that they really grow fast. In Washington State, mussel seed planted in the early spring can be harvested in eight or ten months. You can grow 40,000 pounds of mussels on a 40' x 80' raft in about 15 months. That's about 320 pounds of mussels per person per year for a village with 100 people. There are other advantages to mussels. You can put predator nets around a mussel raft. These nets really help keep sea otters, fish and ducks out. In addition, because mussels are grown on rafts, you don't have to worry about sharing your shellfish with the public - as you do on the beach. A good recipe is included for steamed mussels and we hope you will try them.

In the mussel study, we'll find out how mussels survive and grow in nets hung in deep water. They will be protected from predators by one of these lantern nets. Each net has five compartments. We'll put 100 mussels in each one of the top three spaces after we've measured them. We'll put several hundred mussels in each of the bottom two tiers. We should be able to eat these when we come back in 1997!

We'll measure the mussels every three months when we measure the clams. Mussels are easier because we'll grown them from floats. That way we don't have to wait for a low tide. Mussels are very delicate creatures. They tend to clump together using their byssal threads. If you pull these clumps apart, you'll injure them and they may die. It's much better to cut the clumps apart using scissors. Keep the mussels moist and in the shade while you work with them. When you measure a mussel, measure the longest part of the shell. After the 100 mussels are measured, put them back in the same space that you took them from in the lantern net. Work with one level in the lantern net at a time. That way you won't get the mussels mixed up. When all of the mussels are in the lantern net, sew it up with the colored thread. You don't need to tie knots in the end of the thread, just weave it into the net. Hang the lantern nets from a buoy or raft or float. Keep the top of the net about a meter below the surface.

Monitoring the mussels. We'll count and measure these mussels every three months. Use these data sheets to write down all the lengths. After you finish measuring the mussels, make a copy for the Village's records and mail or fax the original to Dr. Brooks. Make sure you get the right group of mussels back into the right place in the lantern net. If the nets become fouled with algae, barnacles and other creatures, use a new net and let the old one dry in the sun.

Cockle culture. We didn't find very many cockles in 1995. The otters and starfish probably got them because they don't dig deep. The cockleshells we found told us that they grow fast in Alaska. In Washington State, they grow big enough to eat in one or two years. Up here it may take three or four years. That's faster than the clams will grow!

Cockles spawn later in the summer and they have been difficult to raise in the hatchery. We're going to try and spawn cockles in Pacific Rim Mariculture's laboratory in Port Townsend, Washington later this year. We keep watching the cockles, but so far they aren't fat enough to make many eggs. We hope they do better when we get home. We'll let CRRC know as soon as we find some that can spawn.

You told us in 1995 that you like cockles and we're really going to try and make cockle seed available to you. Keep your fingers crossed and maybe we can solve this tough problem. If you have any ideas, let us know.

Taking care of your beaches and managing your shellfish harvests. Its too early in these studies to make good recommendations for managing the Village's shellfish resources. We can do a much better job after we find out how fast the clams grow and how much success we have at keeping the sea otters, crabs, ducks, starfish and snails away. However, we do know that a good management plan will include the following:

1. Predator control. Keep snails, sea otters, crabs and starfish off your beach.

2. Be thoughtful clam diggers. Dig all of the clams from a small area. Fill in all of the holes. It is best to dig clams in a series of parallel trenches. That way the sediment is constantly being put back in the trench. If you don't fill in the holes, baby clams will be washed away from the piles of sand and gravel and the clams under the piles will be buried and will die.

3. Break the beach up into at least six parts and only dig one section each year. Leave the rest of the beach alone for as long as possible.

4. When clam seed becomes available, treat the seed with respect and prepare the beach carefully. Seed areas of the beach that have been recently harvested and then leave that area alone.

5. Monitor your beaches each spring for natural sets of new clams. When nature gives you lots of new little clams, you may not need to add seed from the hatchery.

6. Don't harvest small clams. Wait for them to get to at least 1.5" before you keep them.

How many clams can the Village grow? This is a hard question to answer until our studies give us good knowledge. Based on what we know about the length of time it takes for littleneck clams to grow in Alaska, it seems reasonable to predict that 3,600 pounds of clams can be grown on each acre of beach that is enhanced each year. That's about 36 pounds of clams per acre per Villager in a village of 100 people. It may take several acres of carefully maintained beach to provide all of the clam subsistence needs of a small village.

Shellfish sanitation. We need to talk about shellfish sanitation. Clams, oysters and mussels are really good food. However, they filter lots of water and can collect any contaminants that occur in the water. There are several things that villagers' should be careful about:

Bacterial certification. The best shellfish beaches are those that are close to the Village because they're easy to get to. That means all Villages must have good septic systems or a good sewage system. Even a small amount of raw sewage can pollute a lot of water. If you don't have good sanitation, the shellfish can concentrate bacteria and viruses from the water and spread disease among the Villagers. The state of Alaska has a program to monitor shellfish growing waters. You should participate in this program by sending water samples to the state for analysis. The laboratory will determine how many fecal coliform bacteria there are in the water. If there are too many bacteria in the water, the state will advise you that it is unsafe to eat the shellfish. That will protect the villagers from becoming sick.

Paralytic Shellfish Poisoning (PSP). Certain single celled phytoplankton that naturally occurs in the water can cause serious disease and even death. These dynoflagellates contain a toxin, which is concentrated by shellfish when they filter out the phytoplankton. When a human being eats the contaminated shellfish, the toxin affects your nervous system. First signs are a numbing and tingling in your lips, nose and ear lobes. That's followed by nausea, vomiting, and pain in your chest and arms. In serious cases, you stop breathing and if medical attention is not available, you may die.

The State of Alaska has a program to monitor for PSP. If you are part of this program, the state will analyze shellfish samples that you send to them. When the level of toxin in the shellfish reaches a level of concern, the state will advise you that it is no longer safe to eat your shellfish. It takes several weeks or months for shellfish to purge the toxin from their tissues and PSP outbreaks come and go. Beaches are seldom closed permanently because of PSP.

Alaskan Shellfish Enhancement Protocol Summary

The Qutekcak hatchery should randomly divide the clams into three groups of 8,100 clams each. Separate the clams in two size classes (< 12.5 mm and > 12.5 mm). Package each of the three groups separately. The three groups should be divided into six bags with about 1350 clams in each bag. Label the bags 1-1, 1-2, 1-3, 1-4, 1-5, 1-6, 2-1, 2-2 etc. We will randomly choose bags for each test site at each village. Plan on picking up all of the clams at once. They should be in coolers with a small amount of ice if it is warm out. It's probably easiest to pick up all of the clams at once. The clams will be kept in water while at each village and will be held moist (not in water) during transit from one village to another.
During the workshop, to be given the day before beach enhancement, we will instruct Villagers in the use of micrometers. We will then break up into teams of two. Each team will measure 100 clams, record the data, and place them in a small mesh net that will already be labeled. These will be combined in a larger clam bag and placed back in the water. In addition, 12 samples of 600 clams each will be counted out and placed in similar, small mesh nets, combined in a larger net and placed in the water. In addition, we will demonstrate the use of lantern nets and measure 300 mussels and place 100 of them in each of three lantern net tiers. Each tier will have its own plexiglass label. At each village, we will,

1. Lay out the beach
2. Draw a map of the beach (survey each plot)
3. Remove all shellfish from each car cover plot
4. Remove all rock larger than two inches diameter (possibly 3") and pile on the down slope side of the plot.
5. Dig a trench (8" deep) around each plot. Cast the spoils to the outside. (use red wire flags to outline each one meter by two meter plot). Bring nine pieces of rebar (two feet long) to each beach. Have a ring (1/2" washer) welded to the top. (will need a total of 27 of these). A plexiglass tag will be wired into each ring along with the clam bag for the growth and mortality study.

2 foot long piece of rebar. A total of 27 of these are required.

6. Rake the surface of each carcover plot to provide a smooth surface. Stretch the precut carcover over the plot and bury the edges with the spoils.
7. Lay out the position of each bag and drive in a piece of rebar at this site. Place a bag at each site. Put a shovel full of substrate, with all rock greater than 1" diameter removed, into each bag.
8. When all of this has been accomplished, we will add the prelabeled clams. An inside label (write in the rain) will follow each bag. Each bag will also have an outside, plexiglass label and the PVC pipe closure will be labeled.

9. When the tide comes in, we will gently sprinkle the clams on each plot 10 to 15 minutes before the tide reaches the plot.

10. Following the planting, we will demonstrate how to sieve the seed from the bags and measure and replace them (use the bags as a sieve). Emphasize that they are fragile. Show how to make the closures secure. Provide 100 electrical ties per village (300 ties total). Provide 2 cafeteria trays per village (6 total). Provide 2 hand trowels per village (6 total). Provide three extra bags and closures per village. Provide 50 data sheets per village (150 total on write in the rain paper). Provide 6 data sheet covers with appropriate information on write in the rain paper. Ask if each village has a FAX machine. Otherwise, provide four self-addressed envelops for each village. Emphasize the need to turn the bags over after each measurement. Emphasize the need to brush off the tops of the bags if they become heavily fouled between quarterly sampling. Emphasize the need not to walk on the clam cultures.

11. At each Village, we will leave the following:

   a. 12 clam bags with PVC closures and labels (AES will ship to Jeff in June)
   b. 2 Vernier calipers (AES will ship to Jeff in June)
   c. one hand trowel (AES will ship to Jeff in June)
   d. two lantern nets (Jeff Hetrick will provide)
   e. nine pieces of rebar, 2 feet long with rings welded onto the top. (Jeff Hetrick)
   f. 100 electrical ties (AES will ship to Jeff in June)
   g. two cafeteria trays (AES will ship to Jeff in June)
   h. 50 clam data sheets (AES will ship to Jeff in June)
   i. 12 mussel data sheets (AES will ship to Jeff in June)
   j. 2 data control sheets (AES will ship to Jeff in June)
   k. 6 data cover sheets (AES will ship to Jeff in June)
   l. 2 clam rakes (AES will ship to Jeff in June)
   m. 1 hard bristle brush (AES will ship to Jeff in June)
   n. 12 pieces of Carcover. (AES will ship to Jeff in June)
   Each one measures 5' x 9'. Will need 6 tags for Carcover.

12. Lengths should be measured during the following low tide series (Seward District).

   a. September 26 through September 30, 1996.
   b. December 20 through December 29, 1996
      or if missed, then January 16 through January 25, 1997
   c. March 15, through March 24, 1997

Instructions for Taking Clam and Mussel data at
Tatitlek, Port Graham and Nanwalek

In is very important that the clams and mussels be measured and counted very carefully as close to the dates below as possible. The following steps will make this as easy as possible:

Schedule. The mussels and clams in the lantern nets and small square clam bags should be measured as close to the following dates as possible. You can retrieve the nine bags on one low tide, measure them and then replace them on the next low tide. Keep them in the water when not actually measuring their lengths.

1. September 26 through September 30, 1996.
2. December 20 through December 29, 1996
   or if missed, then January 16 through January 25, 1997
3. March 15, through March 24, 1997

General. Measure the air temperature and water temperature with a thermometer. If you have a salinometer, measure the salinity of the seawater. Note any unusual conditions. Ripped nets or loose bags should be fixed as soon as possible. Don't dig up the clams planted under the predator netting or the experiment will be spoiled.

Clam measurements. Retrieve all of the clam bags on a low tide. Keep them in the water near high tide and replace them on the next low tide. Be careful not to walk on the areas planted with baby clams. Your steps will kill them.

a. Gently shake each clam bag under the water to remove as much sand and mud as possible. This will make finding the clams easier.

b. Cut the electrical tie that holds the PVC pipe in place and slide the pipe off.

c. Gently dump the remaining contents of the bag into a five-gallon bucket.

d. Put a couple of handfuls of sand and gravel from the bucket on a cafeteria tray and carefully sort through to remove all of the clams you can find. Place these in a Ziploc™ bag temporarily. It is really good for two people to do this. The second person tries to find any clams the first person missed. You have two sets of calipers - so you can have at least two teams working on this project.

e. Once all of the clams have been sorted out of the gravel; count the clams and then measure the length (longest part) of each clam and enter the length on the data sheet. If new clams crawl into the cage, measure them and list their lengths in the notes section. New clams will be much smaller than the seed we're using. Use a separate data sheet for each clam bag. There are nine bags and you should have nine data sheets when you finish.

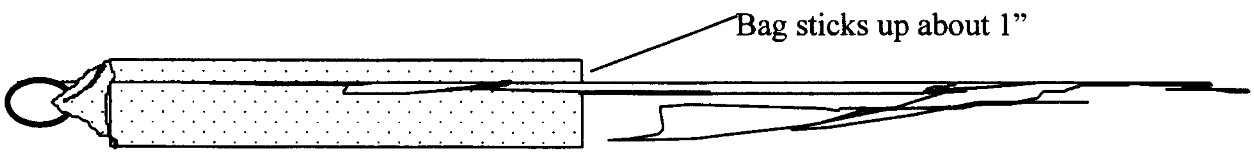
f. Count any empty clamshells you find in the bags and make a note of the number on the data sheet.

g. Note any predators in the bags like small crabs or snails. Note any tears or damage to the bags.

h. Place a shovel full of sieved (1/4") sand and gravel in the bag and then gently put the clams back in. Put the fouled side of the bag down and sprinkle the clams on the clean side of the bag. Place the bags in the water until the next day when they can be put back in their proper position. Don't leave the bags high and dry.

i. Slide the PVC closure over the opening of the bag and secure it with an electrical tie.

j. Gently nestle the bag back into its pocket next to the right stake and tie the bag to the stake with a piece of nylon cord. The bag should have the clean side up. The side that was up before is probably fouled with algae and barnacles. Put the fouled side down in the hole. Make sure the right bag goes back in the right spot. Check the label on the bag with the label on the stake. If they get mixed up, it will spoil the experiment. About one inch of the top of the bag should be above the beach.



l. Take careful notes describing any problems or predators on the beach. Check the parts of the beach that are covered with car cover to make sure the net hasn't been damaged. If it has, then repair the hole with nylon line or replace the net with a spare one. Even a small hole will let a crab or snail get in. One or two crabs can eat all of the clams in a year.

m. Make a copy of the data sheets for the Village's records. Mail or FAX the original data sheets to Dr. Brooks at (360) 732 -4464

Dr. Kenn Brooks
Pacific Rim Mariculture
644 Old Eaglemount Road
Port Townsend, WA 98368

Clam Data Sheet

Village________________________________ Date: ______________________
Culturists: ___________________ ____________________ ________________
Tidal height (in feet) __________ at (time) _____________
Air temperature __________Water temperature ____________Salinity ____________

1. ____________	26. ____________	51. ____________	76. ____________
2. ____________	27. ____________	52. ____________	77. ____________
3. ____________	28. ____________	53. ____________	78. ____________
4. ____________	29. ____________	54. ____________	79. ____________
5. ____________	30. ____________	55. ____________	80. ____________
6. ____________	31. ____________	56. ____________	81. ____________
7. ____________	32. ____________	57. ____________	82. ____________
8. ____________	33. ____________	58. ____________	83. ____________
9. ____________	34. ____________	59. ____________	84. ____________
10.____________	35. ____________	60. ____________	85. ____________
11.____________	36. ____________	61. ____________	86. ____________
12.____________	37. ____________	62. ____________	87. ____________
13.____________	38. ____________	63. ____________	88. ____________
14.____________	39. ____________	64. ____________	89. ____________
15.____________	40. ____________	65. ____________	90. ____________
16.____________	41. ____________	66. ____________	91. ____________
17.____________	42. ____________	67. ____________	92. ____________
18.____________	43. ____________	68. ____________	93. ____________
19.____________	44. ____________	69. ____________	94. ____________
20.____________	45. ____________	70. ____________	95. ____________
21.____________	46. ____________	71. ____________	96. ____________
22.____________	47. ____________	72. ____________	97. ____________
23.____________	48. ____________	73. ____________	98. ____________
24.____________	49. ____________	74. ____________	99. ____________
25.____________	50. ____________	75. ____________	100. ____________

Notes:

Mussel measurements. Unweave the closing string on the lantern nets, one tier at a time. Finish measuring the mussels in one tier before you untie the next tier. Do this on a cloudy day or in the shade. Don't allow the mussels to dry out while you're measuring them.

a. Carefully remove the mass of mussels from inside the lantern net.

b. Place the mussels in a bucket and carefully cut the mass apart with a pair of scissors. You will injure the mussels if you pull them apart.

c. Wash the mussels gently in seawater.

d. Measure each mussel using the calipers provided.

e. Record each measurement on the data sheet provided. Use a separate data sheet for each of the top three tiers in the lantern net.

f. Replace the mussels in the proper tier of your spare lantern net. And sew the opening closed. Make sure the tier is properly labeled.

g. Do each of the next two tiers in the same way. The last two tiers don't need to be measured. Just transfer the mussels to the bottom tiers of the new lantern net.

h. Make a copy of the filled out data sheet for Village records. Mail or FAX the data sheets to Dr. Brooks at (360) 732 -4464

Dr. Kenn Brooks
Pacific Rim Mariculture
644 Old Eaglemount Road
Port Townsend, WA 98368

Mussel Data Sheet

Village________________ Tier Number__________ Date: ________________________

Culturists: ____________________ ____________________ ____________________

Air temperature __________ Water temperature ____________ Salinity ______________

1. ______________	26. ______________	51. ______________	76. ______________
2. ______________	27. ______________	52. ______________	77. ______________
3. ______________	28. ______________	53. ______________	78. ______________
4. ______________	29. ______________	54. ______________	79. ______________
5. ______________	30. ______________	55. ______________	80. ______________
6. ______________	31. ______________	56. ______________	81. ______________
7. ______________	32. ______________	57. ______________	82. ______________
8. ______________	33. ______________	58. ______________	83. ______________
9. ______________	34. ______________	59. ______________	84. ______________
10. ______________	35. ______________	60. ______________	85. ______________
11. ______________	36. ______________	61. ______________	86. ______________
12. ______________	37. ______________	62. ______________	87. ______________
13. ______________	38. ______________	63. ______________	88. ______________
14. ______________	39. ______________	64. ______________	89. ______________
15. ______________	40. ______________	65. ______________	90. ______________
16. ______________	41. ______________	66. ______________	91. ______________
17. ______________	42. ______________	67. ______________	92. ______________
18. ______________	43. ______________	68. ______________	93. ______________
19. ______________	44. ______________	69. ______________	94. ______________
20. ______________	45. ______________	70. ______________	95. ______________
21. ______________	46. ______________	71. ______________	96. ______________
22. ______________	47. ______________	72. ______________	97. ______________
23. ______________	48. ______________	73. ______________	98. ______________
24. ______________	49. ______________	74. ______________	99. ______________
25. ______________	50. ______________	75. ______________	100. ______________

Notes:

FAX or mail this data cover sheet with the 12 data sheets that have clam or mussel lengths on them to:

Dr. Kenn Brooks
Pacific Rim Mariculture
644 Old Eaglemount Road
Port Townsend, WA 98368

Phone Number: (360) 732-4464
FAX Number (360) 732-4464 (same number)

Village ________________________
Contact person ____________________
Telephone number _________________
Survey date: _____________________
Low tide: _______________________
Time of low tide: _________________
Air temperature: __________________
Water temperature: ________________

Survey Plot Number (initial that each data sheet is included)

Clam surveys

Bag Number	Number of clams found	Comments:
1A______	__________________	
1B______	__________________	
1C______	__________________	
2A______	__________________	
2B______	__________________	
2C______	__________________	
3A______	__________________	
3B______	__________________	
3C______	__________________	

Mussel surveys	Number of mussels found
M1______	__________________
M2______	__________________
M3______	__________________

Signature of contact person: ____________________________________

1999 Survey and Enhancement Protocols for the Tatitlek, Nanwalek and Port Graham Village Shellfish Restoration Program EVOS DPD Project #95131

1.0 Introduction. The purpose of this project is to establish populations of clams in areas that are readily accessible from the villages of Tatitlek, Nanwalek and Port Graham. These clams will be used as a source for subsistence food to replace the natural clam resource that has been lost or depleted. There are numerous techniques that can be used to enhance shellfish populations, particularly clam populations. This project began in 1995 with an inventory of intertidal bivalves at beaches chosen by the technical team from candidates proposed by the elders at each village. The results of those inventories are documented in Brooks (1995b). Approximately 24,000 native littleneck clam seed were planted in three replicated treatments (three replicates/treatment) in 1996 at Tatitlek, Nanwalek (Passage Island) and Port Graham (Murphy's Slough). The treatments were:

- 600 clams were seeded into a ground that had been prepared by removal of large rock (>5 cm diameter), cultivating to a depth of 10 to 15 cm, and raking the surface smooth. The density of these clams was 300 m^2. These prepared plots were then covered with Carcover™ mesh to restrict entry of small to medium size predators.

- 600 additional clams were seeded into three replicated plots prepared as described above, but without the installation of Carcover™ netting.

- Lastly, an unmanaged control area was identified adjacent to each set of treatments.

- Replicates of three cages containing 100 premeasured clams were placed at the –1.5', 0.0' and +1.5' (MLLW) tide levels. The other treatments were replicated only at the –1.5' and +1.5' (MLLW) tide levels.

- Baseline values of sediment grain size and total volatile solids were determined for each plot.

The 100 premeasured clams (9 bags at each village) were retrieved, counted and measured once each quarter, except at Passage Island where winter weather precluded some measurements. Other treatments were left undisturbed until 1998 when they were randomly sampled.

2.0. 1998 Monitoring and enhancement. All treatments were monitored between April 24 and April 26, 1998. Data analysis and the 1998 report are being delayed until native littleneck clams at Port Graham can be counted and measured.

Mr. Jeff Hetrick made the appropriate decision to not disturb the clams during January 1999 when extremely cold weather was encountered during a planned field trip. In Washington State, significant die-off of native littleneck clams is frequently observed after winter temperatures drop to <20 °F during nighttime low tides. The clams are observed to come to the surface where they die. No cause and effect relationship between low ambient temperatures and the observed mortality has been established (the epizootics have not been investigated). However, the phenomenon is regularly observed. The near record low temperatures observed during a period of low tides in South Central Alaska during January and February 1999 may have been very stressful to intertidal shellfish and significant mortality in the field studies would not be a surprise. This weather will certainly test the ability of clams cultured in the mid intertidal, in cages, to withstand low temperatures during nighttime low tides.

It is hoped that the necessary fieldwork can be completed during the first daylight tides in late March 1999. A preliminary assessment suggests that survival and growth under Carcover was good through April of 1998, and few native littleneck clams were retrieved from areas seeded in 1996 but not protected.

Preliminary native littleneck clam growth in the paddle wheel Flupsy suggests that 3 to 5 mm clam seed can be grown to a plantable size of 8 to 10 mm in four to five months.

Replicated (three replicates) studies were initiated at Tatitlek and Port Graham to evaluated density effects on clams grown in bags during 1998. First results from these density studies will not be available until late in 1999.

3.0.Evaluation of a model for the use of native littleneck clam seed to enhance subsistence resources. Based on the data obtained to date by the CRRC study team, it is anticipated that hatchery stock, averaging 3 to 5 mm will be available in March of each year. The 1998 Flupsy data from Tatitlek suggests that native little neck clams can be nurseried to a plantable size of 6 to 10 mm by August of the same year. This would allow for beach preparation during low tides in July, followed by planting during the last daylight low tides in August and/or September. This scenario would take advantage of the observed rapid growth in Flupsy's while avoiding holding the clams over winter.

This model will be used to accomplish the first major planting of native littleneck clams at Tatitlek and Port Graham in 1999. Approximately 2,000,000 native littleneck clams will be planted, using a variety of methods, during the 1999 field season. The Villages of Port Graham and Tatitlek now have two years of limited experience in clam culture using Carcover and bags. Mr. Jeff Hetrick will interview Village Elders at these villages to determine the type of subsistence culture preferred by the Villagers. Culture options are listed below. In 1999, a mix of these approaches will be undertaken. The proportion of the available seed allotted to each approach will depend, in large part, on input from Village Elders.

- ⇒ Culture in clam bags (from planting to harvest)
- ⇒ Culture under Carcover (from planting until harvest)
- ⇒ Initial culture under Carcover for one year, followed by removal of the Carcover protection (and the need to maintain the cover).
- ⇒ Initial culture in bags for one year, followed by distribution to small, traditional beaches where the clams would be seeded into areas that have been prepared by removing predators and cultivating to a depth of approximately three inches. This would not be accomplished until 2,000 and will require additional permits.

Based on discussions with Dr. Spies and Dr. Peterson and a January conference call between the study participants, the following activities are recommended for 1999: Protocols are presented in the temporal order in which the activities should occur.

3.1. Qutekcak Hatchery - March 1999. For the entire 2,000,000 clams, remove six random clam samples of 2.0 ml each (approximately 100 clams in each sample). These samples should be placed in 10 ml HDPE vials (supplied by AES) and filled with 5 ml of 60% isopropyl alcohol. Federal Express confirmed that anything with a flash point greater than 141 °F is **not** considered a dangerous good. Dr. Brooks will ship sample bottles, filled with the appropriate amount of 60% alcohol to Jeff Hetrick in March (assuming these protocols are accepted). Isopropyl alcohol will not dissolve the valves and will provide for long holding times so that the clams can be transported and shipped inexpensively. The bottles will be prelabeled when shipped by AES with the code described below. The example code is for a sample taken on March 23, 1999 at the Qutekcak Hatchery. It was the fourth replicate in a total of six. The samples should be shipped to AES, wrapped in cotton, bubble wrap, etc. and placed in doubled Ziploc™ bags. Cooling is not required and the samples can be shipped in any sturdy box via 2nd day air or priority mail.

DATE:Location:Replicate **Example: 3/23/99:Qutekcak:(4)**

3.1.1. AES will determine the number of clams per unit volume (milliliter) and will measure the valve lengths of each clam in each sample and will determine the proportion of clams living. This will provide an assessment of the initial distribution of valve lengths in the entire cohort. (600 clams sacrificed)

3.1.2. The Qutekcak Hatchery will place the 225,000 clams (~4.9 liters) in the pond nursery system in cohorts of 46,000 clams (1.0 liters) each. Half of these will be out-planted to Port Graham and/or Tatitlek in April or May of 1999 and half in August 1999. Hatchery personnel should document the configuration of the nursery system used in the ponds (clam density, upwell, downwell, etc.) and provide that information to Dr. Brooks.

3.1.3. At monthly intervals (April, May, June, July and August), the Qutekcak Hatchery will randomly remove six each two milliliter samples of clams and then ship them to AES for length and volume measurement. (This requires the sacrifice of 60 ml or ~2,760 clams).

3.1.4. The remainder of the 1,775,000 clams will be shipped to Tatitlek in the care of Mr. Jeff Hetrick for distribution into available Flupsies.

a) **Flupsy evaluation – March 1999.** Mr. Hetrick will place a total of 20.25 liters (~ 1,000,000 clams) in half of the bins in each of the two tidal Flupsys located in Tatitlek. The undesignated bins are available for oyster seed. The number of clams is approximate and is based on an initial mean valve length of 4 mm. The distribution of the seed is described in Figure (2).

b) It may be possible to temporarily relocate the paddlewheel Flupsy to Tatitlek. If so, then it is recommended that the remainder of the 1998-99 hatchery production available to the grow-out studies be placed in the Paddle Wheel Flupsy. If this were accomplished in Tatitlek, it would allow a direct comparison between growth in the Tidal and the Paddle Wheel Flupsies. For that reason, the distribution of clams in Flupsy (A) is repeated for the Paddle Wheel Flupsy (C).

(~69,000 clams or 1.5 liters of seed) (0.4 cm deep) **BIN (1)**	Bins are 24" x 24" x 18" deep. **BIN (2)**	(~138,000 clams or 3.0 liters) (0.8 cm deep) **BIN (3)**	(~115,000 clams Or 2.5 liters) (0.67 cm deep) **BIN (4)**	**BIN (5)**
Inlet End **BIN (6)**	(~92,000 clams or 2.0 liters of seed) (0.54 cm deep) **BIN (7)**	**BIN (8)**	**BIN (9)**	(161,000 clams or 3.5 liters) (0.94 cm deep) **BIN (10)**

a) Tidal Powered Flupsy (A) receives a total of 437,000 (9.5 liters) native littleneck clams

(34,500 clams or 0.75 liters of seed) (0.36 cm deep) **BIN (1)**	(46,000 clams or 1.00 liters of seed) (0.48 cm deep) **BIN (2)**	**BIN (3)**	Bins are 18" x 18" x 18" deep. **BIN (4)**	(57,500 clams or 1.25 liters of seed) (0.6 cm deep) **BIN (5)**	**BIN (6)**
Inlet End **BIN (7)**	**BIN (8)**	(138,000 clams or 3.5 liters of seed) (1.44 cm deep) **BIN (9)**	(69,000 clams or 1.5 liters of seed) (0.72 cm deep) **BIN (10)**	**BIN (11)**	(92,000 clams or 2.0 liters of seed) (0.96 cm deep) **BIN (12)**

b). Paddlewheel Flupsy (B) currently available at Tatitlek (if available) will receive the remainder of the clams available from the hatchery (~759,000 clams or 16.5 liters).

(~69,000 clams or 1.5 liters of seed) (0.4 cm deep) **BIN (1)**	Bins are 24" x 24" x 18" deep. **BIN (2)**	(~138,000 clams or 3.0 liters) (0.8 cm deep) **BIN (3)**	(~115,000 clams or 2.5 liters) (0.67 cm deep) **BIN (4)**	**BIN (5)**
Inlet End **BIN (6)**	(~92,000 clams or 2.0 liters of seed) (0.54 cm deep) **BIN (7)**	(~184,000 clams or 4.0 liters) (1.08 cm deep) **BIN (8)**	**BIN (9)**	(161,000 clams or 3.5 liters) (0.94 cm deep) **BIN (10)**

c) Tidal Powered Flupsy (C) receives 437,000 (9.5 liters) native littleneck clams

Figure 2. Distribution of 3 to 5 mm native littleneck clam seed in two tidal and one powered paddlewheel Flupsy to be located in Tatitlek, Alaska.

One additional bin is designated for use, at a higher density, for the Paddlewheel Flupsy because it has sustained water flows, and is more productive (if managed properly), when compared to the Tidal Flupsy. If the paddlewheel Flupsy is not available, then the 775,000 seed will be held in the nursery ponds until additional tidal Flupsy space is available or until planted in Port Graham.

Tidal Powered Flupsy (A) receives a total of 575,500 (10.75 liters) native littleneck clams

Floating Upwell Systems (Flupsys) have been used to achieve very fast growth of juvenile clams and oysters held at very high densities in some areas of Puget Sound and elsewhere. The Flupsy works by moving large volumes of water through dense shellfish cultures creating a *fluidized bed* of shellfish in which each individual is separated from its neighbor by flowing water. If the flow rate is too slow, the shellfish will settle into a more dense pack with little flow around each individual. If the flow rate is too high, turbulence can result and/or channels may form in the shellfish bed. In either case, some individuals will be exposed to very fast velocities and others to velocities that are too low. The feed available is proportional to the water velocity.

If water flows maintain the bivalves in a *fluidized bed*, growth will be determined by the concentration and quality of food in the water. Water that is rich in phytoplankton and detritus of the proper size can support fast growth in shellfish held at significant (10 to 20 centimeters) depth in the bins. The shellfish bed will become deeper as the clams grow, if the depth becomes too great for the amount of food in the water, then clams located near the bottom of the culture will filter most of the food out and clams located near the top surface of the water will have insufficient food for optimum growth. The water exiting the top of the bins should contain food at a concentration of at least a few thousand particles per ml under optimum conditions.

The point that needs to be made is that efficient Flupsy operation requires nearly constant monitoring and fine-tuning of the bivalve density and water flow (in powered paddle-wheel Flupsys). The better the management – the better the results.

This design will require that Jeff Hetrick measure the depth (in mm) of the clams in each bin at monthly intervals. The depth will be recorded at six locations onto datasheets provided by AES. The actual volume could better be obtained by placing all shellfish from each bin in a graduated cylinder and measuring them volumetrically. However, this would result in the monthly homogenization of the sample and a random redistribution of the clams back into the bin. That technique will eventually result in more uniform growth of the shellfish. However, during this study, it would be informative to evaluate clam growth as a function of depth in the fluidized bed.

3.1.1. July, 1999 Flupsy preparation. The vertical mixing of clams in a fluidized bed is unknown. If there is significant vertical redistribution of clams, then the culture will continually be mixed and no effect associated with vertical position would be observed. However, it there is minimal vertical mixing of the culture, then position related differences in growth will depend on the depth of the culture and the availability of phytoplankton in the seawater. The vertical mixing of these cultures will be examined during the July and August field trips in the following manner. In July, Mr. Hetrick will remove approximately 500 clams from each of three bins in Tidal Flupsys A and C (a total of 3000 clams). Each cohort will be labeled and kept distinct because it must go back into the same bin from which it was taken. He will then blot dry each cohort and lightly spray paint them with fast drying, non-toxic, fluorescent paint. After the paint dries, the clams will be washed several times in ambient seawater to remove any residual solvent or paint particles and then sprinkled gently and evenly on top of the existing cultures in the bin from which they were removed. A small cohort of 50 clams will be caged and placed in one bin to evaluate the mark's retention and marked clam survival.

During the annual monitoring, to be conducted in August, 1999, the vertical distribution of these painted clams will be determined in each of the six bins by sampling at successive two to five millimeter depths and counting the proportion of painted and unpainted clams observed at each depth.

3.1.2. Monthly Flupsy monitoring. In this study, the density of shellfish, judged by the depth of the shellfish in each bin, is initially varied incrementally over a range from 0.36 cm to 1.44 cm. It is recommended that shellfish in each bin be evaluated for growth on a monthly basis starting in April 1999 (April, May, June, July and August). It is recommended that Mr. Hetrick collect three clam samples of 2.0 ml each from each of the Flupsy bins, in each of the three individual Flupsys and ship these to AES at monthly intervals. The three replicates should be collected from three vertical positions in the culture (top, middle and bottom). There are 17 bins used in this study and this will require the sacrifice of 3 replicates x 17 bins x 2.0 ml/replicate or 102 ml of clam seed on each of 5 sample days. A total of 510 ml of clam seed will therefore be sacrificed in this effort. Even at the initial clam density of 46 clams/ml, this represents 23,460 clams or 1.2 percent of the stock.

These samples should be placed in 10 ml HDPE vials (supplied by AES) and filled with 2 ml of clams and 5 ml of 60% isopropyl alcohol. The bottles will be prelabeled when shipped from AES with the code described below. In the example, the clams were collected on May 8, 1999 from Tidal Flupsy (A), Bin Number (4) and the sample was from the top of the culture. Use the initial M for middle of culture and B for bottom of culture.

DATE:Flupsy(Bin Number):Vertical Position. Example: 5/08/99:A(4)T

3.1.3. Data analysis. The experimental design will use regression analysis to evaluate the dependent variables (incremental increase in mean valve length and/or mean incremental increases in clam volume) against the independent variables (shellfish depth, Flupsy type (paddle wheel or tidal), and Flupsy location (two tidal Flupsies in different areas at Tatitlek). The regression approach will allow for the examination of a larger range of shellfish densities than would a replicated (ANOVA) approach. Chi-square analysis can be used to evaluate differences between type Flupsy and location.

3.2. Direct planting of seed held in the Qutekcak Hatchery until April or May of 1999. This study element will allow CRRC to compare the growth and survival of native littleneck clam seed that is grown in Flupsys to a valve length of eight to ten mm and then planted with three to five mm seed planted directly out of the hatchery.

In early April or May, the Village of Port Graham, with the assistance of Mr. Hetrick, will prepare six plots, each measuring three meters on a side at Murphy's Slough during the first daylight tides in march or April of 1999. The study layout is described in Figure (3). Clams will be planted at densities of 300, 450 and 600 per square meter in the 9 plots as described below. Plots will be centered on the 0.0' MLLW elevation defined in the existing shellfish studies. Half of the plots will be covered with Carcover having a leadline sewn into the perimeter and held in place on the beach using eight rebar "J" hooks. Carcover remaining from the 1998 field studies should be available for this exercise. If not then a new roll of Carcover should be obtained. Additional leadline and "J" hooks will be required.

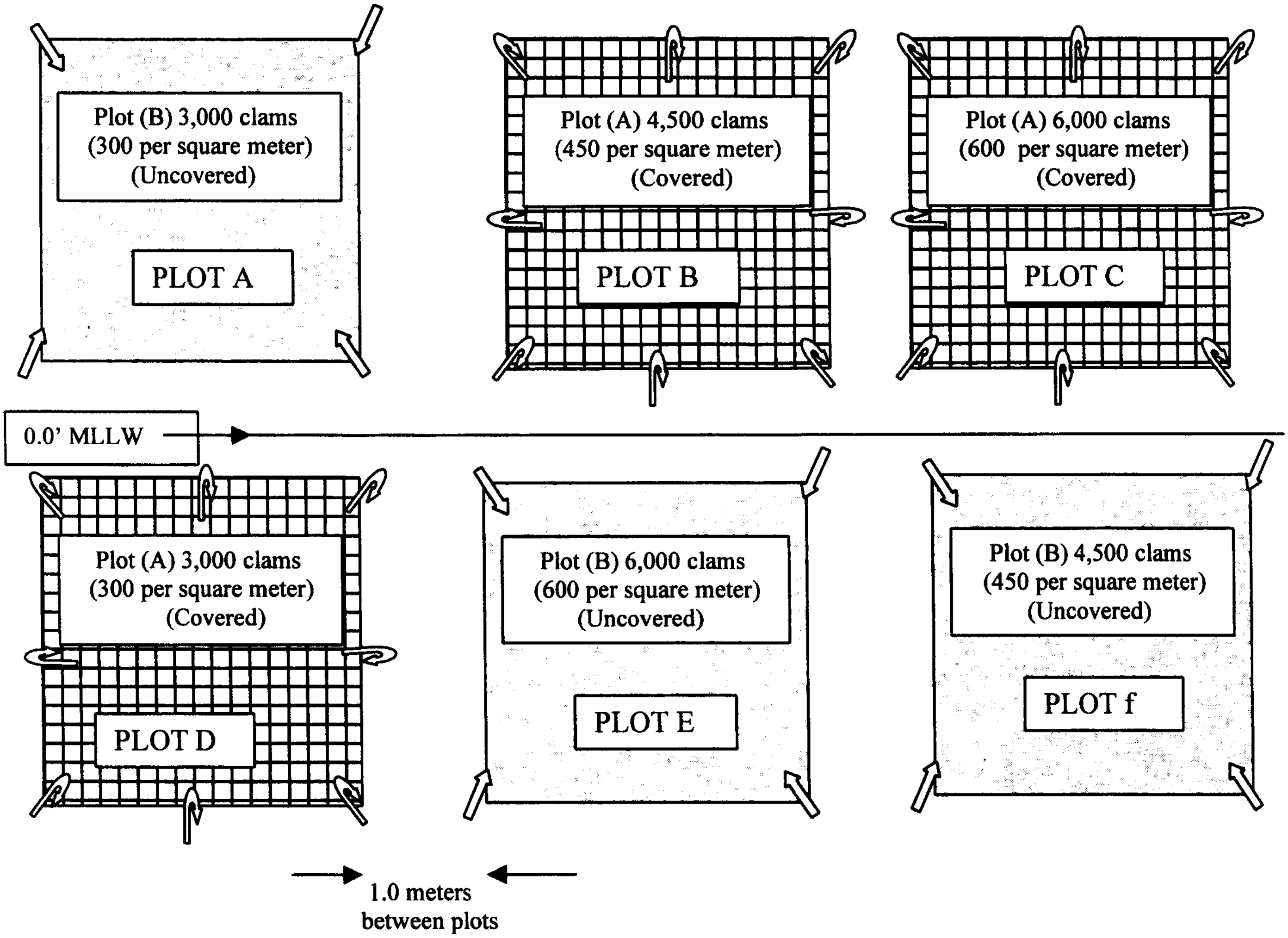


Figure 3. Study layout for the planting of 30,000 native littleneck clam seed (3 to 5 mm valve length) directly from the Qutekcak Hatchery nursery ponds into a growout site. The planting will occur in early April or May of 1999.

The approximate volumes, assuming 4 mm seed in March-April of 1999 will be 65 ml for 3,000 clams, 98 ml for 4,500 clams and 130 ml for 6,000 clams. A total of 30,000 seed (~650 ml) should be measured out of the stocks retained at the Qutekcak Hatchery for this part of the study. Three randomly selected subsamples containing 2 ml of seed each should be removed. These should be preserved in 60 percent isopropyl alcohol and sent to AES for measurement (linear and volumetric), determination of the proportion living clams at the time of collection, and archival.

The seed will be evenly sprinkled on the prepared plots as the incoming tide covers them. These plots will be randomly sampled during the Annual Monitoring in August 1999 using protocols developed in 1998 and repeated below. Port Graham (Murphy's Slough) was chosen as the primary site for this study because the substrate is easily prepared and because Mr. Hetrick will likely have to visit there to sample the 1996 growth and mortality study in late March 1999. Time and resources permitting, this experiment should be replicated at Tatitlek where there appears to be significantly more starfish predation and where the coarse sediments present a different set of environmental conditions. If similar studies are established at both sites, it will take a total of ~60,000 seed.

3.3. August 8 through 14, 1999 annual monitoring. Low tides are forecast for Seldovia (Port Graham/Nanwalek) and Cordova (Tatitlek) during the period August 8 through August 15, 1999. The following schedule is proposed:

Sunday, August 8, 1999 – Dr. Brooks flies into Anchorage. Brooks and Hetrick proceed to Tatitlek in the afternoon. Discuss alternate growout areas with Steve Totemoff and Gary Komkoff (others?)

Monday, August 9, 1999 - Tatitlek (-1.5' @ 0632)

Tuesday, August 10, 1999 - Tatitlek (-2.2' @ 0719)

Wednesday, August 11, 1999 – Tatitlek – fly to Port Graham after the morning tide (-2.5' @ 0802). Retrieve all material from Passage Island on the evening tide(0.4' at 2124 hrs)

Thursday, August 12, 1999 - Port Graham (-4.0' @ 0953 & 0.0' @2208)

Friday, August 13, 1999 - Port Graham (-3.3' @ 1032 & 0.1' @ 2250)

Saturday – August 14, 1999 - Depart Port Graham for Anchorage after the morning tide (-2.2' at 1110). Dr. Brooks departs for Washington State in the late afternoon or evening.

3.3.1. Clam growth and mortality studies. Clams grown in bags will be counted and measured and areas in which clams were seeded and protected with Carcover will be randomly sampled (see 1998 protocols and Section 3.6.4) as will areas seeded, but not protected and unseeded control areas.

3.3.2. Sediment physicochemical parameters were evaluated in 1996, 1997 and 1998. These evaluations will not be repeated in 1999. Physicochemical parameters will be evaluated at new beaches proposed for future enhancement.

3.3.3. Density study monitoring. Native littleneck clams were seeded in three replicates at three densities (3 x 3 matrix) in bags at Port Graham and Tatitlek in 1998. Their growth and survival will be evaluated in 1999 to assess density effects.

3.3.4. Passage Island. Clams remaining in Passage Island studies will be released and all study equipment removed from the site following 1999 monitoring.

3.4. Initiation of new enhancement efforts. Two million native littleneck seed clams are anticipated to be available from the Qutekcak Hatchery in March of 1999. Assuming 80% survival of the 1,775,000 clams placed in Flupsys, approximately 1,420,000 native littleneck clams with a valve length of between eight and ten millimeters should be available for planting in August 1999. It is unknown whether or not funding will be found to continue these studies beyond 1999. The following recommendation will allow for the additional examination of growth and survival as a function of tidal height and clam density along with a determination of the value of the use of Carcover as protection for juvenile clams. If additional funding is not provided, then based on our experience to date, the following recommendations will provide the Villages of Tatitlek and Port Graham with an excellent opportunity for increased subsistence harvest of native littleneck clams at some point in the future (likely four to five years after planting). This will represent the first large-scale enhancement effort in this project.

3.4.1. Evaluation of additional growout sites near the Village of Nanwalek. Passage Island has proven too remote to be useful as a study site. Villagers have previously discussed Dogfish Bay as a potential alternate. This potential site should be evaluated in 1999. Its suitability will be documented and recommendations made with respect to the need for permits to enhance this area (if warranted). It is recommended that remaining native littleneck clam cultures located at Passage Island site be evaluated in 1999 and then released. All of the study equipment (bags, Carcover netting and rebar stakes) should then be collected and properly disposed of in an upland waste disposal facility at Port Graham. Additional subsistence shellfish enhancement is not recommended at Nanwalek until a more suitable beach can be identified and appropriate permits obtained.

3.4.2. Evaluation of additional growout sites near the Village of Tatitlek. The beach currently being used at Tatitlek has proven suitable for shellfish studies and the Villagers have done a remarkably good job of supporting the scientific effort with careful fieldwork. However, the size of the beach and its very coarse texture, limits its value to significantly increase subsistence shellfish harvests. One half day should be spent at Tatitlek with tribal elders familiar with local beaches in an effort to identify additional areas for enhancement. Given that those areas exist, permits should be sought and the village's opportunities expanded. However, the beach currently being studied will be further enhanced using existing permits. Additional culture sites (within the permitted study area) at Tatitlek will also be evaluated in consultation with tribal elders. Suitable sites will be planted in 1999.

3.4.3. Clam enhancement in Port Graham (Murphy's Slough). Because of the ease of planting, and large area available, it is recommended that 1,000,000 of the available seed be planted in Murphy's Slough (Port Graham). The remaining 420,000 will be planted in Tatitlek. Low tides of –4.0 feet are predicted for the mornings of August 11 and 12, 1999. This will enable the crews to plant shellfish as low as -2.5 feet (MLLW) in Plot A (see Figure (4)).

3.4.3.1. Enhancement layout. Assuming an optimum density of 35 clams per square foot, planting 1,000,000 seed will require the preparation of 28,571.42 square feet or about 0.7 acres of ground. The proposal is described in Figure (4).

3.4.3.2. Preparation of Carcover. Lead line should be woven into 100' long sections of Carcover prior to arrival. This protocol requires a total of 900 lineal feet (9 sections of 100' each) of Carcover and approximately 2,000' of lead line. In addition, 18" long pieces of rebar, bent into a "J" shape should be available to stake the lead line down at 20 foot intervals (100 pieces total). Lastly, 14 steel stakes (used for concrete forming) should be available to mark the ends of each culture. Dr. Brooks will bring the etched Plexiglas tags and electrical ties.

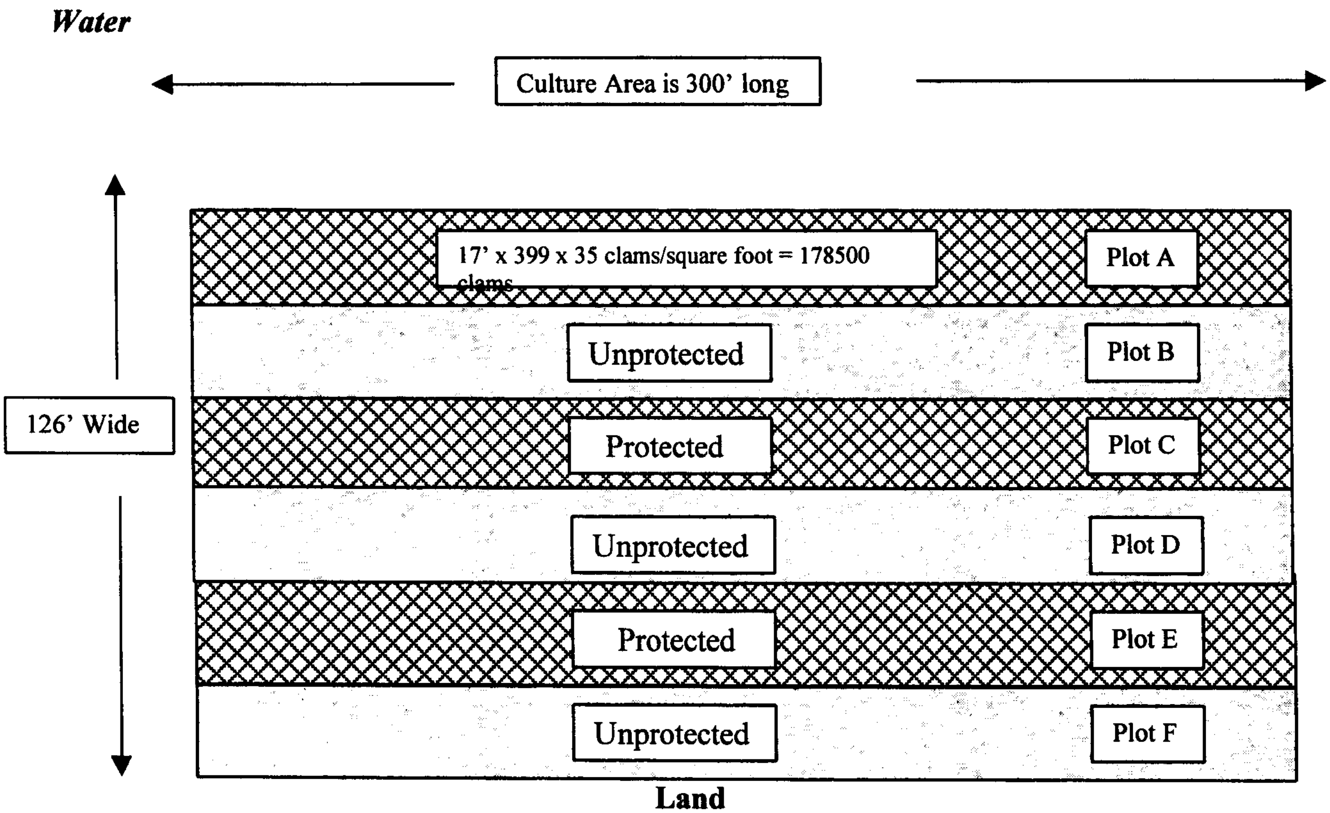


Figure 4. Proposed layout for seeding 1,000,000 juvenile native littleneck clams at Murphy's Slough near the Village of Port Graham, Alaska.

3.4.3.3. Beach preparation. Beach preparation will occur on August 12, 1999 under the supervision of the CRRC study team. Preparing 0.7 acres of beach for shellfish seeding will require a crew of at least twelve Villagers equipped with clam forks and rakes. The crew should arrive on the beach at least 3 hours prior to the low tide (by 0700 hrs). The intertidal area at Murphy's Slough that is being planted is composed of ground shell, sand and small (pea) gravel. Beach preparation will involve removing large woody debris, any mats of loose organic material and all large rocks and/or cobbles > four to six inches in diameter. All predators (gastropods, crabs and starfish) should be removed from the area to be seeded. The substrate should then loosened using rakes and clam forks. These items should be procured in early summer.

If a total area of 28,600 square feet is to be prepared by ten clam culturists', then each person will have to cultivate a total area of 2,800 square feet (a square with 53' sides). This is considered possible in the intertidal at Murphy's Slough. It would not be possible on beaches like those found at Passage Island and Tatitlek. Once an individual plot is prepared, the remaining two Village culturists' will roll out the Carcover and stake it down. The CRRC study team will lay out the plots and mark them.

3.4.3.4. Transportation and handling of clam seed. Assuming the clams are 8-mm valve length in August, there will be an average of approximately 7 clams per ml or 7,000 clams per liter. One million clams will occupy 142.9 liters or close to 40 gallons. These should be transported moist in coolers with sufficient ice or phase change gel packs to maintain the temperature at ca. 6 to 8 degrees centigrade until they can be placed back in the water at Port Graham. The clams should be taken out of the Flupsies as close to departure from Tatitlek as possible and placed in 72, fine meshed, shellfish sacks. Each sack will contain about two liters of clam seed. As soon as the clams arrive in Port Graham, they should be placed in ambient seawater water not warmer than 12 °C. The volume of 1,000,000 clams should not be underestimated!

3.4.3.5. Planting of native littleneck clam seed at Port Graham. Clams will be seeded at a density of ca. 35/square foot. Each of the plots (A through F) described in Figure (4) can be divided into thirds by observing the ends of the 100' sections of Carcover™. Each of these 100' x 17' sections will receive four (4) sacks or eight liters of seed. The seed will be sprinkled evenly over the ground on an incoming tide walking backward up the beach. Three people (one for each 100' long section) will seed each of the prepared Plots.

3.4.4. Clam enhancement at Tatitlek. Substrates on the current study beach at Tatitlek are very coarse with a high proportion of cobble and rock. Large areas, like those being planted in Murphy's Slough do not exist at the Tatitlek study beach. The following proposal is made in light of these physical constraints.

3.4.4.1. Identification of enhancement areas. The CRRC study team will work with Steve Totemoff to identify suitable enhancement areas between the tidal heights of –2.0' and +1.5' MLLW. Rows of hundreds of *Pycnopodia helianthoides* have been present at tidal elevations below –2.0' on every field trip to Tatitlek. These voracious starfish have been observed with whole clams in their gut. They would quickly consume small clams available in the upper substrate horizon. Enhancement areas will be identified with red wire flags by the CRRC study team upon arrival. Groups of these small areas will be assigned to each Village Culturists for preparation and seeding. One person will be responsible for all work in one set of enhancement areas. The largest areas, to be covered with Carcover or seeded with clams in bags, will be identified first and Village Clam Culturists can begin preparing those beaches within hours of arrival.

Enhancement areas at Tatitlek will be seeded at higher density than at Port Graham. This is consistent with the evidence of higher predation (primarily *Pycnopodia*) at Tatitlek and the increased beach instability resulting in additional loss of clams due to substrate movement. Approximately 90 ml of clam seed will be planted in each square meter giving a density of ca. 63 clams per square foot. Paper cups, marked at a depth representing 90 ml will be prepared upon arrival. At this density, the 420,000 clams available for seeding will require suitable substrate covering 6,667 square feet. The anticipated extent of the various types of enhancement techniques appropriate to Tatitlek are summarized below:

- Ten 17' x 17' areas covered with Carcover = 2,890 sf.
- Clams in Norplex Bags (250 bags) with 700 clams/bag = equivalent to 2778 sq. ft.
- Scattered small plots prepared but unprotected – 50 covering a total of 1000 sq. ft.

It should be emphasized the identifying this much suitable ground on the beach at Tatitlek will be difficult. Preparing the ground will be hard work. The presence of the Flupsys at Tatitlek ameliorates these concerns because shellfish can be held in the Flupsys until beach preparation is complete. The CRRC study team can help Village Culturists get started in August. If the work is not completed during the annual monitoring event, the people of Tatitlek can continue to prepare suitable areas and seed them during additional low tides in August and September.

3.4.4.2. Culture team. Intensive shellfish enhancement will be more labor intensive at Tatitlek. A crew of at least 14 should be available for two days. Each person should be provided with a clam fork, bucket and rake.

3.4.4.3. Clam bag preparation. Clam bags will come folded flat. They must be shaped and one end cut, folded and stapled with hog rings to form a rectangular bag. The other end should be pre-cut to facilitate closure during planting in the field. The preparation of 250 bags will take one person at least two days.

3.4.4.4. Preparation of enhancement areas for seeding. Where possible, rock and cobble (> three or four inches in diameter) should be removed from the enhancement area to form a small berm on the water's side. The remaining substrate should be loosened with a rake and leveled. Each area found suitable for enhancement will be staked with a coded tag for identification. The location of each area identified during the August field trip will be mapped for future reference.

In some areas, small sections (perhaps a square meter in extent) will be raked, predators removed from the adjacent intertidal and the seed simply sprinkled on top of the prepared substrate on the incoming tide. No protection will be provided in these small plots.

3.4.4.5. Installation of Carcover. Patches that are as large as five meters by five meters will be covered with previously prepared Carcover nets. Each net will measure 17' square and will have a lead line sewn in prior to arrival. Ten of these nets should be prepared in anticipation of the August enhancement effort.

Carcover should be stretched out over the prepared ground and staked with eight rebar "J" stakes (one in each corner and one in the middle of each side). Carcover must be maintained in order to be effective. Ten replacement nets should be left at Tatitlek. When one is damaged, it should be replaced with a new one. The lead line can be salvaged and used to construct new nets. The damaged netting should be properly disposed of at an upland landfill site.

3.4.4.6. Seeding of clams. Clams will be seeded on the incoming tide at densities of ca. 63 clams per square foot (90 ml of clams per square meter). Clams will be measured out in paper cups with an appropriate volume of clams calculated for each enhancement patch based on its size. 700 clams (100 ml) will be placed in each Norplex™ bag after two to four shovels-full of sediment are placed inside and the bag is nestled into its depression. The bags will then be secured with hog rings and attached to rebar using UV resistant electrical ties.

3.4.4.7. Native littleneck clam growth in sandy substrates. Current studies are evaluating the growth and mortality of native littleneck clams as a function of tidal height and of substrate type (more coarse at Tatitlek and less coarse at Port Graham). There is a sandy beach at Tatitlek, adjacent to existing studies. Much of this sandy area is covered with eelgrass (*Zoostera marina*). However, in previous years, exposed areas of sand, of sufficient size to support a native littleneck growth and mortality study, were observed. A limited evaluation will be undertaken in this area during 1999. This would expand the study to provide a better understanding of native littleneck growth in sandy substrates as well as in mixed ground shell, sand and small gravel substrates (Port Graham) and sand-gravel-cobble substrates at the original Tatitlek beach. The clam density experiment described in the 1998 protocols will be duplicated in exposed sandy areas of the beach at Tatitlek.

This study is designed to examine clam density effects on native littleneck clams grown in one-half Norplex clam cages. Optimum clam density has been estimated from data for Manila clams presented in Toba *et al.* (1992). This study will examine three replicates of native littleneck clams grown in sandy substrates at Tatitlek at each of the following densities.

200 clams per half Norplex™ bag
350 clams per half Norplex™ bag
450 clams per half Norplex™ bag

All replicates will be planted in an area 20' wide centered along the 0.0' MLLW station along the sandy beach located northwest of the existing study area in Tatitlek. The layout is described in Figure (5).

The study will be initiated by randomly selecting four replicate two-ml samples of seed designated for this study. These samples will be placed in 10 ml vials with 5 ml of 60% isopropyl alcohol for valve length and seed volume. The following code will be used to identify these samples:

DATE:TD(1) through DATE:TD(4)

This will provide an assessment of the initial size of the seed used in this study. The culture team will then remove three replicates of 200 clams from the seed supply. These will be counted out in cafeteria trays. Care should be taken to insure that clam selection is random. Don't select especially large clams or small clams. Clams should be taken with a paper cup from the supply.

This process is repeated by randomly selecting three replicates of 350 clams from the supply and three replicates of 450 clams. After being counted, all clams for a particular replicate should be placed in a Ziploc™ bag with a paper towel moistened in seawater and appropriately coded Plexiglas tags. These bags should be stored in a refrigerator until the clams are planted. Each replicate should be provided with a tag numbered as described in Figure (5). It is important that we place the bags randomly as shown in Figure (5) and that we know exactly where each replicate went in the study. The tags should be made up as the clams are counted and measured. Place both tags in the Ziploc™ bag while the clams are being stored (need 36 plastic tags and 126 electrical ties).

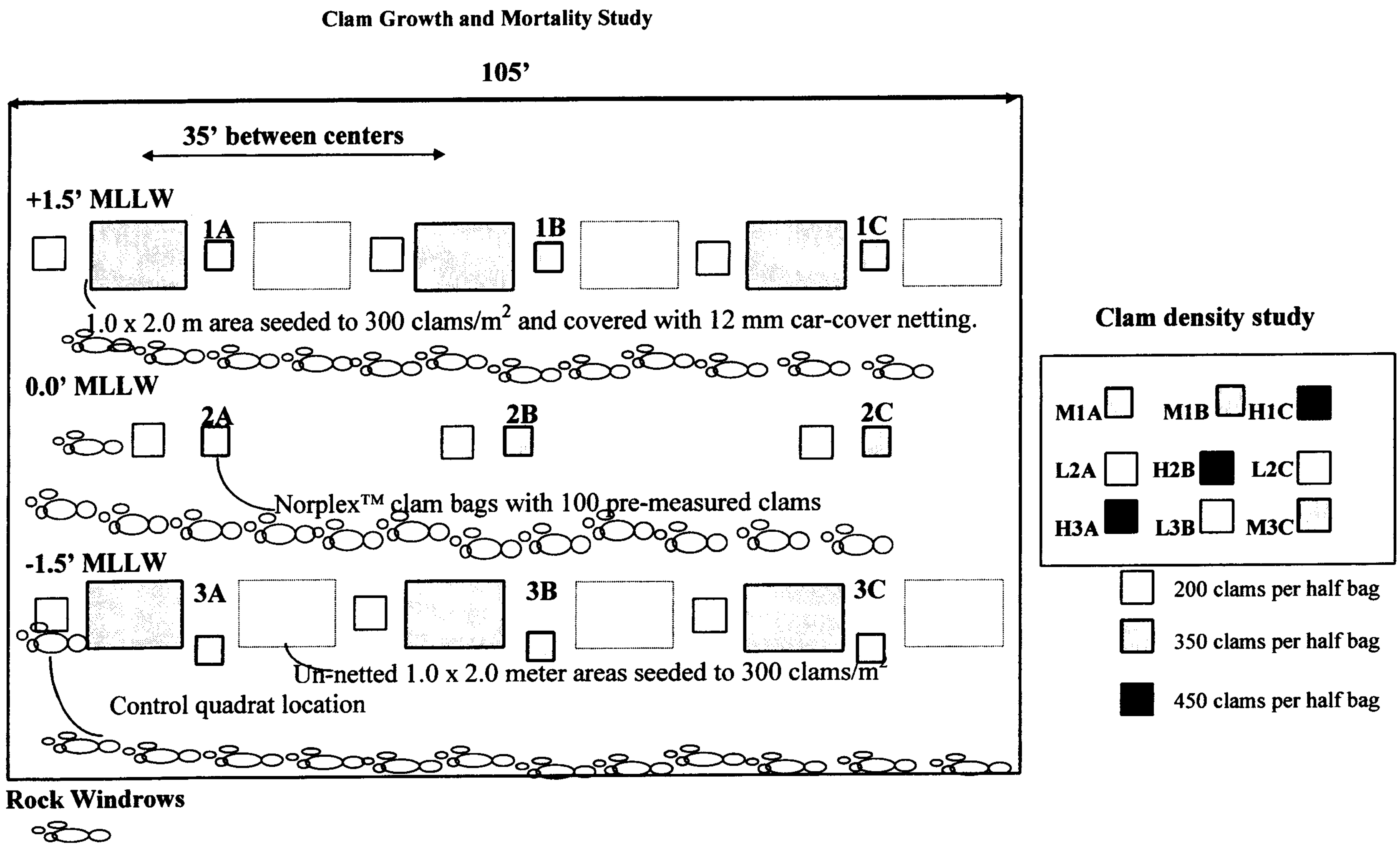


Figure 5. Study design for clam enhancement studies at previously surveyed beaches at the village of Tatitlek. A replicated density study is being added in 1998. It is shown to the right of the existing study site in this figure. It could be placed either right or left of the existing sites at the 0.0' MLLW tidal level. Leave a minimum of 10 feet between the existing study area and the density study.

In the field, one tag should be placed inside the Norplex™ bag before it is sealed with a split PVC pipe and electrical ties. The other tag should be fixed to the outside of the bag with an electrical tie. The bags should be tied to the rebar provided by CRRC.

The area in which these clams will be cultured should be cultivated and shallow depressions dug to receive the bags. One or two shovelfulls of sand should be placed in each bag. Exclude any obvious predators or other juvenile clams. When the tide approaches the lower portion of the study area, sprinkle the clams for the appropriate bag over the top of the substrate; slide the split PVC closure over the end of the bag, insuring that there is no entry for small crabs; and secure the PVC closure to the bag with two stout electrical ties. These bags should be secured to long pieces of ½" rebar using electrical ties.

Once the bags are in place, nestle them into the substrate with a gentle rocking motion and shovel more sediment around the outside to help hold them in place. The top of the bags should lie about one inch above the beach. The rest of the bag should be buried.

3.4.4.8. Evaluation of the vertical movement of clams in the Tatitlek Flupsies. Six cohorts of 500 clams each were marked and sprinkled on top of the clam cultures in thee bins of Tidal Flupsy (A) and Paddlewheel Flupsy (C) during July, 1999. Three samples will be collected from each of these six bins during August 1999. The samples will be collected from the top third, middle third and lower third of the cultures in each bin. The number of marked clams in each third, in each bin will be determined. In addition, two-ml samples of seed clams will be removed from the lower, mid and upper thirds of the cultures in each Flupsy bin. These will be placed in 10 ml vials with 5 ml of 60% alcohol and returned to AES for length and volume analysis.

3.5. Monitoring of 1996 growth and mortality studies.

3.5.1. The Village Shellfish Culture Teams should retrieve the nine clam bags used in the growth and mortality study before arrival of the CRRC study team. They will separate the clams from the substrate and measure and record the valve length of each surviving clam. A single sediment sample will be retrieved from each treatment replicate (prepared & covered, prepared & uncovered, and control) at the –1.5 and +1.5 MLLW elevations. This will give three replicates at each tidal height for each treatment and control. In addition, three sediment samples will be retrieved from the newly prepared ground. Twenty-one (21) sediment samples will be collected at each Village. The depth of the RPD will be determined and the presence of H_2S evaluated organoleptically. These samples will be analyzed for Sediment Grain Size and Total Volatile Solids.

3.5.2. Additional observations will include the following:

- Fouling of Carcover™ nets and bags
- Presence of predators in the study area
- Evidence of excessive littoral drift or log damage
- Odor (hydrogen sulfide, ammonia or petroleum)
- Evidence of sea otter activity in the area.

3.5.3. Three water samples will be collected in 500 ml autoclaved bottles at each Village. The water samples will be analyzed for fecal coliform bacteria, salinity, TSS and TVS at Aquatic Environmental Sciences. In addition, the temperature of the water will be determined on both flood and ebb tides. Requires nine water bottles.

3.5.4. Assuming sufficient time is available, three random sediment samples will be collected from each of the treatments established in 1996. Three samples are preferred. However, there are 18 sites to be sampled at each village in this part of the effort. Two replicates result in 36 samples and 3 replicates in 54 samples. The sampling design is a systematic random sample. Sample points will be established using the PVC fixture described in Figure (6). Two sets of these fixtures, whose outside dimension is one meter by two meters, were left with CRRC in 1998. These should be inventoried. If they cannot be located, new quadrats will be provided. The grid is approximately 7 7/8 inches square and will accommodate a six-inch diameter quadrat. A piece of colored survey tape will be tied to the lower left-hand corner of each grid designated for sampling. The coffee can quadrat will be placed within the grid with its perimeter touching the lower and left strings of the grid section located above and to the right of the survey tape. The upper right hand corner of the quadrat will have a piece of duct tape secured to the pipe for orientation. This will require 152 bags for the collection of the sediment contents within the sampling quadrats (6" coffee cans).

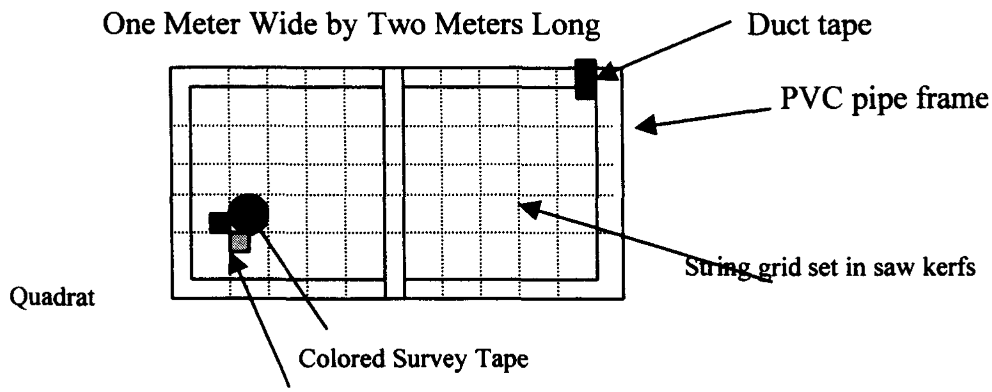


Figure 6. Sample location fixture used to determine the location of samples within each treatment.

Sediment is removed using a large spoon to a depth of approximately 7.5 cm. The contents will be placed in prelabeled Ziploc™ bags, which have an inside label that follows the sample through processing. Sediments will be sifted in saltwater on ¼" sieves to remove fine material and all clams greater than ¼ retrieved and replaced in the Ziploc Bag. These clams will be stored on ice and shipped to aquatic environmental sciences for analysis.

Carcover™ netting should be replaced over all sampled plots. If the netting was torn during removal, new netting should be installed (CRRC will provide) and the old netting properly disposed of.

3.5.5. Photography and disposition of the data. Appropriate photo documentation will be made of all study activities during the August 1999 field trip using a 35 mm camera.

4.0. Future semiannual monitoring. The various study components initiated since 1996 as part of this CRRC effort should be monitored for at least another two years or until the essential variables in the enhancement (Flupsy, growout, density, etc.) are documented through one production period. Ideally, the various studies should be monitored twice a year (once during the spring and again during the fall). No change in the existing protocols for these activities is recommended at this time.

5.0. Summary. These proposed protocols will accomplish the following.

5.1. Monitor the growth and survival of clams planted at tidal elevations of –1.5', 0.0', and +1.5' during 1996.

5.2. Evaluate the survival and growth of clams planted at various densities in bags during 1998.

5.3. Evaluate changes in sediment physicochemical properties under a variety of culture techniques.

5.4. Evaluate the nursery phase of this enhancement project by:

5.4.1. Comparing the growth and survival of clams nurseried in paddlewheel and tidal Flupsys with those planted directly into Port Graham at valve lengths of 3 to 5 mm.

5.4.2. Comparing the growth of clams held in ponds managed for optimum algal growth at the Qutekcak Hatchery with those nurseried in Flupsys from March until August.

5.4.3. Compare the growth and survival of juvenile clams in tidally driven Flupsys with growth in a paddlewheel Flupsy.

5.4.4. Compare the growth and survival of juvenile clams grown in tidally driven and paddlewheel Flupsys at a variety of clam densities.

5.4.5. Compare the growth and survival of juvenile clams grown in two separate areas near Tatitlek to tidally driven Flupsys.

5.4.6. Evaluate the vertical mixing of seed clams in tidally driven and paddlewheel Flupsys.

5.4.7. Determine the optimum density (depth of the culture) of clams in Flupsys by examining differences in clam growth rates (and/or survival) as a function of depth in the culture.

5.5. Initiate a study to examine the survival and growth of native littleneck clams in very sandy substrates. This will expand the studies evaluation of *beach type* to include very coarse sediments (Tatitlek and Passage Island); small gravel – sand – crushed shell beaches (Port Graham); and sandy beaches (Tatitlek). This study element will require continued surveillance for at least one more year (2,000) at Tatitlek to produce useable data.

5.6. Collect additional data on the bacteriological quality of ambient seawater in the vicinity of the three study areas and on the physicochemical characteristics of that water (TSS, TVS, turbidity, salinity, temperature and dissolved oxygen)

Nanwalek/Port Graham/Tatitlek Clam Restoration

ENVIRONMENTAL
ASSESSMENT

October
1995

DRAFT

COVER SHEET

Proposed action: The Chugach Regional Resources Commission (CRRC) and Native Villages of Nanwalek, Port Graham, and Tatitlek propose to stock littleneck clams and Pacific cockles in beaches that are readily accessible from the three villages. These bivalves would be used as a source of subsistence food to replace the natural clam resources that have been lost or severely depleted.

Type of statement: Environmental Assessment

Lead Agency: National Oceanic and Atmospheric Administration (NOAA)

Cooperating Agencies: Alaska Department of Fish and Game (ADF&G)

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Abstract: This Environmental Assessment documents the analysis of three alternatives. These are: ***Alternative A, Proposed Action*** - plant littleneck clams and Pacific cockles on beaches near the villages of Nanwalek, Port Graham, and Tatitlek for subsistence use; the No ***Action Alternative*** - do nothing to restore or improve the subsistence lifestyle of the villages; and ***Alternative C, Reduced Stocking*** - reduce the scope of the project and plant fewer littleneck clams and Pacific cockles.

Project Duration: The planting of seed on the selected beaches would be initiated May 1996 and would continue through November 1999. Harvest of the planted clams would commence in 2001 and continue through 2004. Environmental studies, including collection of broodstock for pathological evaluation, beach surveys, permitting and other preliminary activities were initiated in June 1995 under the authority of a NEPA categorical exclusion granted by the NOAA.

Contents

List of Tables

List of Figures

Chapter 1. Purpose of and Need for Action

1.1 Introduction to the Area Considered for the Proposed Action

Three remote, coastal Alaska villages (Nanwalek, Port Graham and Tatitlek) would be affected by the proposed project. All three villages predate contact with Europeans in the late Seventeenth Century. Tatitlek is located on the coast of northeastern Prince William Sound about 25 air miles southeast of Valdez (Figure 1.1) Nanwalek and Port Graham are located about four miles apart near the southwest tip of the Kenai Peninsula in lower Cook Inlet, roughly 25 miles southwest of Homer and 15 miles from Seldovia. (Figure 1.3) The three communities are accessible only by boat or small airplane.

Some primary characteristics of the villages include: small populations - (1992) Nanwalek 161, Port Graham 161, and Tatitlek 108; largely Native populations - (1992) Nanwalek 90%, Port Graham 84%, and Tatitlek 95%; low per capita incomes - (1991) Nanwalek $6,646, Port Graham $8,807, and Tatitlek $8,141; and heavy dependence upon subsistence foods - (total wild resource harvests in pounds per capita, 1991) Nanwalek 259 lbs., Port Graham 280 lbs., and Tatitlek 344 lbs.[1]

1.1.1 Physical Features

Much of the land around Tatitlek is part of the Chugach National Forest, managed by the U.S. Forest Service, and state and federal park and refuge lands cover much of the lower Kenai Peninsula near Port Graham and Nanwalek. Alaska Native Claims Settlement Act Corporations control inholdings by all three villages. The uplands are typically undeveloped wilderness and the climate is maritime with extensive rainfall.

Shores of the area around Tatitlek are irregular and dominated by fjords. From the shore, the terrain rises rapidly into steep mountains with peaks in the 2,500-4,000 ft. range. Coastal hemlocks and Sitka spruce dominate lower areas, and alpine tundra covers the higher elevations. There also are extensive muskeg wetlands where the ground is perpetually soggy or frozen.

The area surrounding Port Graham and Nanwalek are characterized by somewhat smaller (1,500-3,000 ft.) peaks with gentler slopes. Nanwalek is located on a narrow band of land at the mouth of the English Bay River, and Port Graham is located to the east of Nanwalek in a very protected bay. While the climate for the two neighboring communities is maritime, precipitation is approximately 60 inches or about half of the usual precipitation for the Gulf of Alaska.

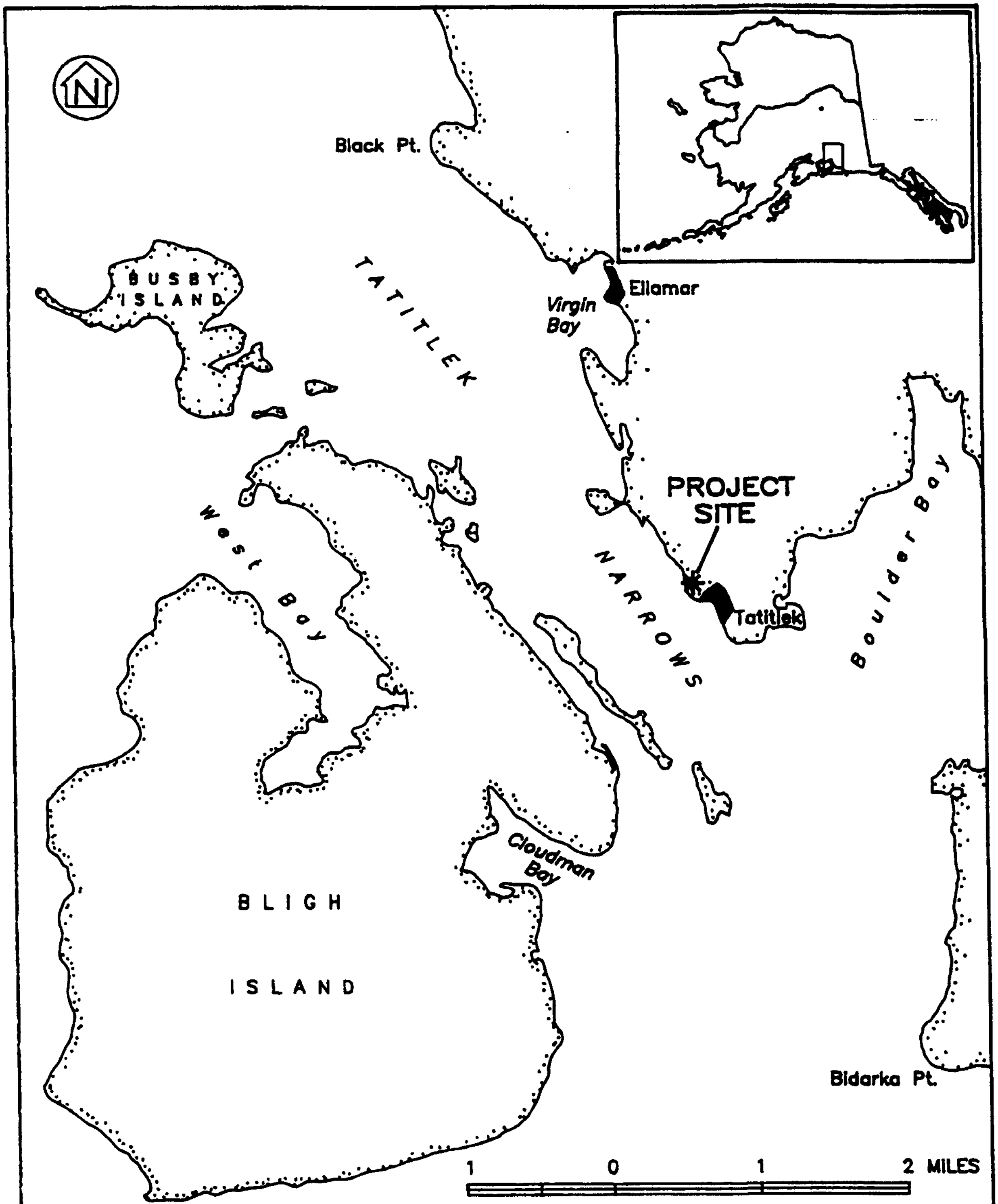
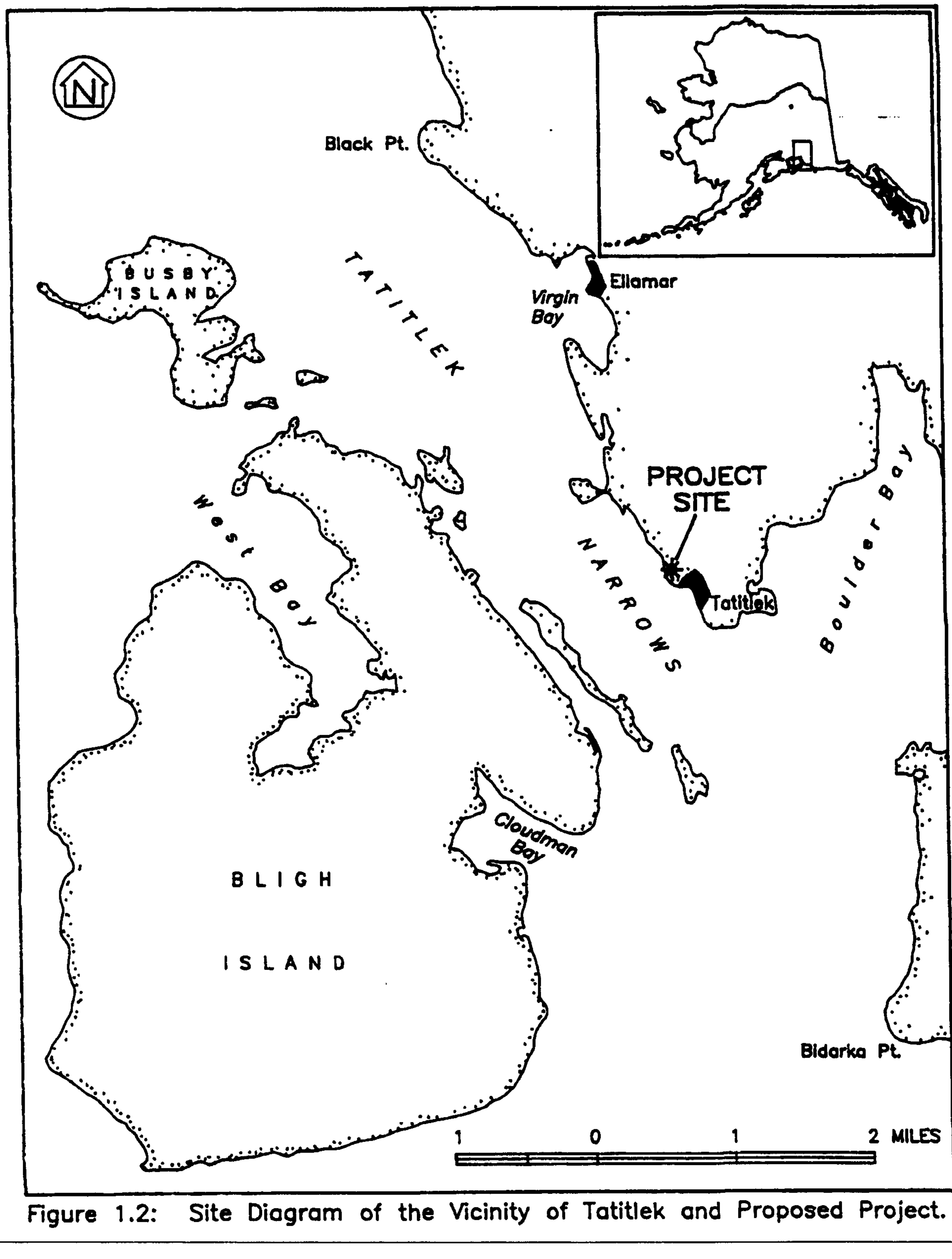


Figure 1.2: Site Diagram of the Vicinity of Tatitlek and Proposed Project.



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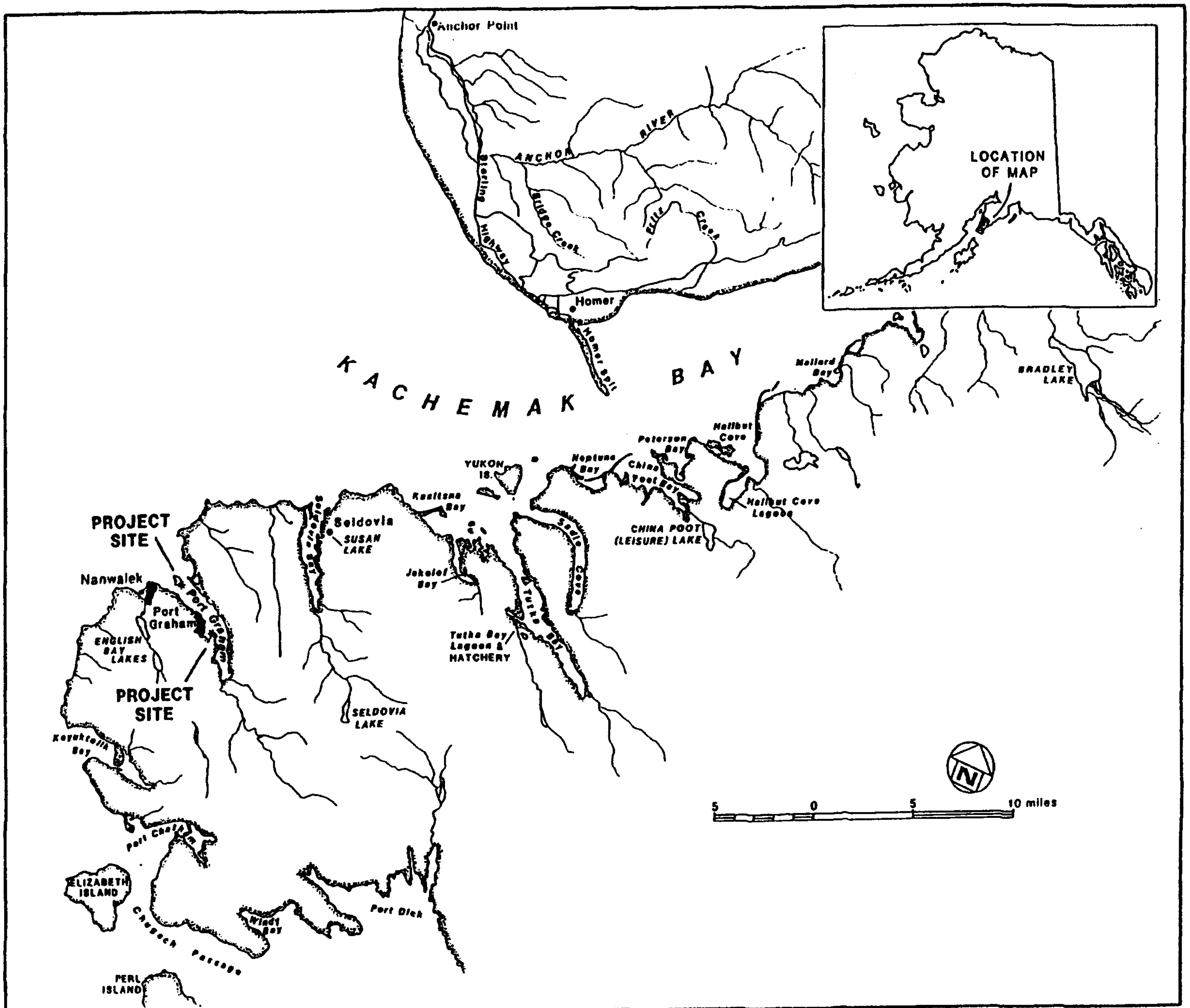

Figure 1.3: Location of Nanwalek and Port Graham in Kachemak Bay.

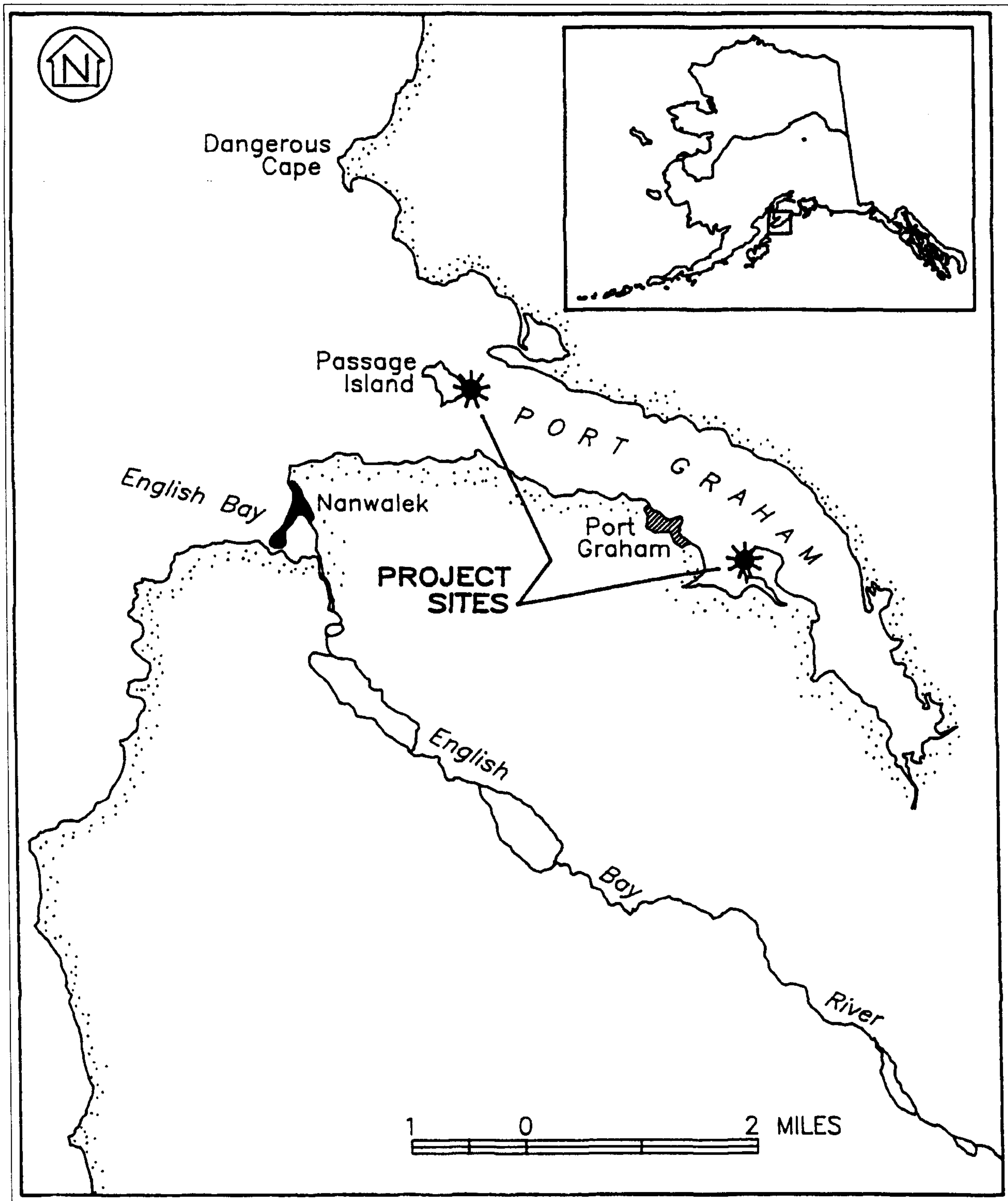

Figure 1.4: Site Diagram of Nanwalek/Port Graham and Proposed Project.

The target beaches near Nanwalek, Port Graham and Tatitlek are excellent clam habitats, containing numerous cobbles to boulder-size rocks and substrate that are ideal for littleneck clams. The Port Graham and Tatitlek beaches also contain the muddy substrate preferred by Pacific cockles. Initial site surveys revealed significant numbers of juvenile clams at Tatitlek, moderate numbers at the Nanwalek site, and none at the Port Graham beaches; none of the beaches surveyed contained a harvestable shellfish population. A preliminary investigation of the three areas showed that each could be enhanced by seeding, reducing predation and developing an effective management plan. Appendix A.

1.1.2 Subsistence Resources

Members of all three communities are heavily engaged in subsistence gathering of marine shellfish, finfish and plants. (Table 1.1)'

Table 1.1: Nanwalek, Port Graham & Tatitlek Per Capita Subsistence Harvests (lbs.), 1991

	Nanwalek	Port Graham	Tatitlek
Salmon	125.6	132.6	148
Other Finfish	82.7	99.7	89
Land Mammals	3.1	3.3	40.4
Marine Mammals	6.4	14.7	46.3
Birds & Eggs	3.8	1.8	7.2
Marine Invertebrates	24.4	21.6	6.6
Wild Plants	12.8	6.8	6.8
Total Subsistence Harvests	258.8	280.5	344.3

1.1.3 Social Features

The residents of all three communities follow a mixed, subsistence-based economy and way of life. Seasonal cash employment and commercial fishing supplement large harvests of wild fish, game and wild plants for local use. Subsistence hunting, fishing and gathering play a central role in the expression of social and cultural values, community viability and stability. Harvesting and processing groups are generally made of extended families. Subsistence foods often are distributed along kinship lines.'

Historically, clams have been an important source of food in coastal Native villages, but clam populations in areas reasonably accessible to the villages have declined to very low levels. The factors that led to these resource declines include increasingly heavy sea otter predation, human over-harvest and the 1989 *F.xcon Valdez oil spill.'*

Table 1.2 shows that per capita harvest of marine invertebrates in Tatitlek rose dramatically during 1989, and sharply declined in subsequent years following the *Exxon Valdez oil* spill. When it became clear the oil spill was headed toward Tatitlek, villagers harvested all the clams and other shellfish possible before the beaches were fouled. While Port Graham residents harvested fewer marine invertebrates in the year of the oil spill, harvests increased slightly in subsequent years. Villagers have overcome local depletion of shellfish resources by banding together and traveling by larger vessels to distant locations where invertebrates are more plentiful. This has increased the cost and time involved in subsistence harvests and has resulted in increased competition for resources with other users.` Anecdotal evidence suggests that subsistence harvesting patterns in Nanwalek have followed the Port Graham post-oil spill pattern.

Table 1.2: Nanwalek, Port Graham and Tatitlek Per Capita Harvests of Wild Marine Invertebrates in Pounds'

	1987	1989	1990/91	1991192	1992193	1993/94
Nanwalek	19.5	16	16.7	24.4	24.8	23.3
Port Graham	16.6	8.6	14.5	21.6	23.9	16
Tatitlek	16.7	45.9	0.8	1.9	6.6	9.6

With declines of traditional subsistence resources, the community may be expected to increase its reliance upon commercially obtained foods. Increased reliance on purchased and processed foods would mean less shared harvesting and processing activity within the community, between fishing and hunting partners, and between generations. If this occurs for extended periods, knowledge of hunting and fishing practices and traditions would decline as well. It would be expected that children not accustomed to eating wild foods would adopt tastes for foods from commercially available sources.

Nanwalek was known as English Bay until recently when the name was changed back to the original Alutiiq name which means "place with a lagoon." Recognized as one of the oldest villages in the North Pacific, Nanwalek was occupied by the Russian fur traders and renamed Fort Alexandrovsk in 1785 and was maintained as a Russian outpost until the U.S. purchase in 1867. The name English Bay was incorrectly applied to the village by U.S. Geological Survey map makers after a nickname for a nearby bay.[5]

The Alutiiq name for Port Graham is "Paaluwik" which means "where the people are sad." The name comes from the longing of early residents for their original villages in Prince William Sound and the Kenai Peninsula. The Russians began mining a huge coal vein in 1855, and a settlement eventually known as Coal Village grew into the third largest Russian-American Settlement. At peak production, the mine employed 130 persons and produced 30-35 tons of coal per day. Later the village became a trading center, port and cannery site.[6]

Tatitlek predates European contact and was one of the four Prince William Sound villages occupied by the Chugach people throughout the contact period. Most Tatitlek residents are of Chugach Eskimo descent. Historically, the cash economy of the village was based upon the fur trade, mining and commercial fishing. The Ellamar copper mine operated at Tatitlek between 1902 and 1930.'

All three villages are unincorporated communities governed by traditional tribal councils.

1.1.4 Economic Features

There are very few paid jobs available in the three villages. There are only a few limited entry permits in the villages and average per capita incomes are very low. (Table 1.3)' The increased reliance on purchasing processed food means the number of local residents seeking employment has been rising. Many young people have opted to leave the villages to seek employment in urban centers.

Table 1.3: Some Economic Features of Nanwalek, Port Graham, Tatitlek

	Nanwalek	Port Graham	Tatitlek
Per Capita Income	$6,646	$8,807	$8,141
Average Number of Months Employed (Employed Adults)	6.63	8.08	8.05
Percentage of Adults, Employed Year-Round	14%	42%	24%

1.2 Purpose of and Need for *Action*

Subsistence harvesting patterns in the three villages were disrupted by the 1989 *Exxon* Valdez oil spill. Bligh Reef, where the *Exxon Valdez* went aground, is about five miles from Tatitlek and many of the community's traditional subsistence harvesting areas were heavily oiled. Villagers in Nanwalek and Port Graham report chemicals used in oil spill clean up activities staged in the area apparently killed many mussels and clams.

A 1993 study by the Alaska Department of Fish and Game shows that littleneck clam tissues and sediments in these areas were exposed to oil from the spill.' The study also found that growth rates of clams in Prince William Sound were decreased or were depressed as a result of this exposure.

Other reasons that littleneck clam and Pacific cockle resources near the villages are far below historic levels include heavy predation by a growing sea otter population, changes in beach configurations from the 1964 earthquake, and an unregulated human harvest in areas of growing populations. There is virtually no verifiable historic data available on littleneck clam and Pacific cockle populations in the affected areas since these resources are not managed.

Depletion of the littleneck clam and Pacific cockle resources has reduced the importance of bivalves in the subsistence diets of local residents, and has led to an increased dependence upon other resources in the area, many of which were adversely affected by the *Exxon Valdea oil spill.* The purpose of this project is to help restore littleneck clam and Pacific cockle resources on beaches readily accessible to the three villages for subsistence harvests.

The Qutekcak Shellfish Hatchery was originally started by the Qutekcak Native Tribe in Seward to provide a source of Pacific oyster seed for shellfish farms in Prince William Sound and Cook Inlet. In 1994, Qutekcak became the first hatchery ever to successfully reproduce littleneck clam stocks, opening up the potential for addressing the declining littleneck clam and Pacific cockle resources.

1.3 Other EISs/EAs that Influence the Scope of this EA

None.

1.4 Decisions to be Made and Other Agencies Involved in this NEPA Analysis

Three alternatives are presented for analysis in this Environmental Assessment. Based on these analyses the decision maker, the National Oceanic and Atmospheric Administration (NOAA) will select one of the following alternatives:

Alternative A (proposed action), Plant a Mix of 800, 000 Juvenile Littleneck Clams and Pacific Cockles Per Year for Four Years on a

total of 2.5 Acres of Beach.

Alternative B, No Action

Alternative* C *Plant a Mix of 200,000, Juvenile Littleneck Clams and Pacific Cockles Per Year for Four Years on 12 Acres of Beach

1.5 Scoping Summary

The National Oceanic and Atmospheric Administration (NOAA) is the lead federal agency assigned to review this Environmental Assessment (EA) and make a decision based on the analysis. The Alaska Department of Fish and Game (ADF&G) is the cooperating State Agency assisting in writing the EA. Staff of the Chugach Regional Resources Commission (CRRC) were the primary author of this EA and worked closely with ADF&G throughout the writing of the document.

During the scoping process, ADF&G coordinated review of the EA with the following agencies: NOAH; the Habitat, Subsistence and Commercial Fisheries and Development Divisions of ADF&G; the village governments and Native Corporations of Nanwalek, Port Graham and Tatitlek; Qutekcak Shellfish Hatchery; Alaska Departments of Environmental Conservation (DEC), Natural Resources and Transportation; U.S. Fish and Wildlife Service; U.S. Coast Guard; U.S. Army Corps of Engineers; U.S. Environmental

Protection Agency; Kenai Peninsula Borough; Prince William Sound Aquaculture Corporation; Cordova District Fisheries Union; City of Cordova; Chugach Corporation; Native Village of Chenega; and the Upper Cook Inlet Development Foundation.

The proposed federal Fiscal Year (FY) 1996 project was reviewed by the ***Exxon Valdez*** Trustee Council (TC) in 1994. The TC recommended NEPA requirements be complied with prior to seeking funding for planting clams in FFY 1996. State of Alaska members of the TC are the Attorney General, and the Commissioners of ADF&G and DEC. Federal agency members are representatives of the US Departments of the Interior and Agriculture and NOAA.

If the ***Alternative A (Proposed Action)*** and funding are approved by the TC and National Environmental Policy Act (NEPA) compliance is satisfied, CRRC would begin planting littleneck clams and Pacific cockles in 1996.

1.6 Permits, Licenses, Authorizations Necessary to Implement the Project

Existing and new permits, licenses, authorizations needed to implement *Alternative A (Proposed Action)* or *Alternative C (Reduced Stocking)* are listed in Table 1.4.

Table 1.4: Qutekcak Shellfish Hatchery - Existing Permits

Regulated Activity	Permit Required	Governing Agency	Duration
Operate Shellfish Hatchery (Permitted species: Pacific oysters, littleneck clams, butter clams, macrocystis kelp, blue mussels, purple hinged rock scallops, Pacific cockles)	Shellfish Hatchery Permit # DFG-92-1 HA-SC	ADF&G	Dec. 31, 1995
Acquire, Transport and Hold Littleneck Clam Stocks	Aquatic Stock Acquisition Permit # DFG-92-17-AS-SC	ADF&G	Dec. 31, 1995

Table 1.4 (cont.): ADF&G/CRRC - Existing Permits

Regulated Activity	Permit Required	Governing Agency	Duration
Sampling native shellfish at beaches targeted for seedin	Scientific-Educational	ADF&G	Annual Renewal

Table 1.4 (cont.): Qutekcak Shellfish Hatchery - New Operational Permits Required

Regulated Activity	Permit Required	Governing Agency	Duration
Acquire, Transport and Hold Pacific Cockle Stocks	Aquatic Stock Acquisition Permit	ADF&G	Open-ended

Table 1.4 (cont.): ADF&G/CRRC - New Operational Permits Required

Regulated Activity	Permit Required	Governing Agency	Duration
General Authority to Plant Littleneck Clams and Pacific Cockles	Fish Resource Permit	ADF&G	FY 1996-2004
Tidelands Usage (floating clam tray, longline clam culture)	Tidelands Permit	Alaska Department of Natural Resources, Div. of Lands	FY 1996-99
General Authority for Project	Coastal Consistency Determination	Office of the Governor, Division of Governmental Coordination	FY 1996-2004
Transport Juvenile Littleneck Clams and Pacific Cockles to Nanwalek, Port Graham & Tatitlek	Shellfish Transport Permits (six separate permits)	ADF&G	FY 1996-2004

1.7 Key Issues

The following issues, identified during the scoping process, were determined to be key issues under NEPA guidelines [40 *CFR §1508.27]*.

- **Subsistence Shellfish Harvests**: How would the project affect subsistence harvests of littleneck clams and Pacific cockles in Nanwalek, Port Graham and Tatitlek?

- **Predator Management**: How to protect the littleneck clams and Pacific cockles from being eaten by starfish, crabs and sea otters without harming the predators or other native marine life?

Allocation: Since the planted littleneck clams and Pacific cockles would become common property resources, would the introduction of hatchery stocks create allocation conflicts between subsistence, personal use or commercial users of bivalve resources in the area?

Navigation/Access/Project Activity: Would project activities have an adverse impact upon navigation, access across beaches, or activities of other potential users of the growout sites?

Protection of Public Health: Would the planted bivalve shellfish be suitable for human consumption?

1.8 Description of Issues Considered but Eliminated from Detailed Study

Several issues were considered but dropped from detailed analysis following initial analysis.

Would spawning littleneck clams and Pacific cockles from planted hatchery stocks adversely impact the gene pool of native bivalve stocks? The "working policy" on shellfish genetics developed by ADF&G in 1994 provides for movement of stocks of shellfish within delineated geographic regions. The Southcentral region encompasses Prince William Sound, Cook Inlet and Kodiak, thus the littleneck clam and Pacific cockle broodstock of the Qutekcak Shellfish Hatchery could be utilized at all three villages. The prevailing scientific view is clam larvae are carried by tidal currents over very large areas before settlement and that intermixing of gene pools is the rule rather than the exception.' Therefore, this project is not expected to alter any natural patterns of genetic mixing.

Would the manipulation of substrate to prepare plots for littleneck clam and Pacific cockles production unduly impact other resources? When a substrate of a plot is compacted, making it difficult for a juvenile clam to burrow, the plots of beach would be prepared by the loosening of the top two or three inches of substrate with rakes or forks to make it easier for the juvenile clams to embed themselves. This may disturb some benthic organisms (worms, snails, small crabs and fishes), but the impacts would be small in comparison to harvest methods employed throughout the region by subsistence, personal use and commercial diggers.'

Would the introduction of hatchery stocks adversely affect the food supply of native bivalves? Littleneck clams and cockles feed upon phytoplankton filtered from the water column. The waters adjacent to the three villages are exceptionally rich and this microscopic resource generally is very abundant. The relatively small number of clams and cockles planted at each location is not expected to have a measurable impact upon the food supply for native bivalves. There may be some competition among the planted shellfish for the food supply during the periods of low abundance (ie., the winter months).'

Would the byproducts and metabolites of littleneck clam and Pacific cockle production affect the surrounding environment? The biomass of byproducts produced by the planted littleneck clams and Pacific cockles would be very small and the nature of the waste would be identical to substances already in the environment from invertebrates already found in the targeted areas. No impact is anticipated from the byproducts and metabolites.

Chapter 2. Alternatives

2.1 Introduction

This chapter describes the alternatives and summarizes the environmental consequences of the *Proposed Action* and two *Alternatives* to the planting of a maximum of 800,000 seed littleneck clams and Pacific cockles per year for four years on beaches near the villages of Nanwalek, Port Graham and Tatitlek. The reason for this project is to stock beaches traditionally used for subsistence shellfish harvests to replace natural clam resources which have been lost or severely depleted.

2.2.1 Description *of Alternative A, Proposed Action*

Working under contract to ADF&G, the Chugach Regional Resources Commission (CRRC) would initiate a subsistence littleneck clam and Pacific cockle stocking program on selected beaches readily accessible to the Native Villages of Nanwalek, Port Graham and Tatitlek. These beaches would be stocked with littleneck clams and Pacific cockles to replace natural bivalve resources that have been lost or severely depleted.

Hatchery techniques for the littleneck clam *(Protothaca staminea)* pioneered by the Qutekcak Shellfish Hatchery would be improved, and culture techniques for Pacific cockles *(Chnocardium nuttalli)* would be developed. Qutekcak Shellfish Hatchery would focus on production of a 5 mm seed stock in the hatchery within 19 weeks after spawning. Broodstock for the littleneck clam stocks already have been obtained from beaches adjacent to Tatitlek and are in use at the hatchery. Adult Pacific cockles would be gathered from sites near the target villages and examined at the ADF&G pathology lab for diseases or parasites of transport significance before spawning and broodstock production can be initiated on the new species.

CRRC and Qutekcak Shellfish Hatchery would develop nursery techniques to grow the 5 mm seedstock to outplanting size (10 mm - 15 mm) within 12 weeks. A variety of substrates and nursery systems would be tested.

CRRC and the three individual villages would identify target beaches that would be most suitable for subsistence clam culture (appendix A). CRRC would use crews from the three villages to survey the selected beaches using a systematic random sampling method (stratified where appropriate) and plan developed by Aquatic Environmental Sciences and reviewed by the ADF&G. The surveys would gather information on benthic organisms in target plots using a random sampling method developed in cooperation with ADF&G. Information on substrate composition would be gathered through the graduated sieve method. (This analysis involves washing substrate through a series of progressively finer mesh sieves, allowing researchers to determine content of substrate types such as mud, sand and gravel.) Actual beaches would be selected on the basis of accessibility to the villages and suitability of the area for growing clams.

A total of 2.5 acres of beach would be seeded with littleneck clams and Pacific cockles at the three villages. Qutekcak Shellfish Hatchery would provide a mixture of 800,000 juvenile littleneck clams and cockles per year from FY 1996 - FY 1999 for the bivalve restoration project, or a total of 3,200,000 seed shellfish. If the predator nets are effective and average survival rates are applied, the plantings would produce an estimated 20,000 pounds of littleneck clams and Pacific cockles per year or a total of 80,000 pounds over the life of the project. The littleneck clams and Pacific cockles are expected to reach harvestable size in roughly five to six years from time of planting.

Table 2.1: Sample Planting and Harvesting Plan for Each Village

Year	Number of Plots" Planted	Area Planted in Square Feet	Number of Seed Planted	Harvest in Pounds
1996	14	7,000	280,000	0
1997	13	6,500	260,000	0
1998	14	7,000	280,000	0
1999	13	6,500	260,000	0
2000	0	0	0	0
2001	0	0	0	7,000
2002	0	0	0	6,500
2003	0	0	0	7,000
2004	0	0	0	6,500
Totals	54	27,000	1,080,000	27,000

Thirteen or fourteen individual plots of 10 feet by 50 feet would be prepared and seeded at each of the three villages each year from FY 1996-1999 (See Table 2.1). Together, the project would involve a total of 54 plots at each of the three villages, or a total of 162. The planted areas would cover 81,000 $ft.^2$ or 1.86 acres of beach; with spacing between plots, the total affected area would be roughly 2.5 acres. Successful sites would be expanded by adding additional plots, and those with poor results would be scaled back. The plots would be prepared for planting by removing logs, debris and obstacles, and, if necessary, the top 2-3 inches of substrate would be loosened with rakes or forks to prepare for seeding. The plots would be seeded at a maximum density of 45 littleneck clams per square foot; Pacific cockles would be planted at about 35 per square foot. Each 10 x 50 feet plot would be seeded with roughly 20,000 juvenile shellfish.

Predation by crab, starfish, seabirds and sea otters would be controlled with the use of predator netting (light, high-strength extruded plastic) which would be stretched across the entire plot and securely anchored. The ground cover would be trenched six inches around the perimeter to dissuade crabs and other animals which do not burrow deeply. To validate the need for predator netting and test the impact of the netting on clam growth, a prepared beach area adjacent to the covered plot would be seeded but not protected. The potential for enhancement by simply adding predator netting would be tested by covering a prepared, unseeded area adjacent to the first two areas.

The field teams of trained local workers would visit the sites regularly during low tides (at least twice monthly) to check on the plots. Access to the sites would be by skiff at low tide and project staging areas would be at existing community docks and buildings. Samples of the planted littleneck clams and Pacific cockles would be collected on a regular basis for measurements of size and weight increases. Shellfish samples would be collected monthly from the planted beaches at Port Graham and Nanwalek for paralytic shellfish poisoning (PSP) tests by the Alaska Department of Environmental Conservation's laboratory in Palmer. The PSP test results would be used to build a solid baseline of information on the toxin prior to harvests of the planted littleneck clams and Pacific cockles. Shellfish samples also would be tested for residual chemicals and hydrocarbons resulting from the *Exxon Valdez oil* spill and clean-up activities. Project personnel also would collect water samples at Port Graham and Nanwalek for analysis by the ADEC laboratory for presence of fecal coliform. (PSP and water quality at Tatitlek has been conducted independently of this project, over the past several years, to comply with health regulations governing its established oyster farming operation.)

Alternative littleneck clam and Pacific cockle culture techniques would be tested in Tatitlek and Port Graham, including hanging trays and floating racks. Hanging culture would involve the suspension of stackable plastic trays from longlines. Some trays would be filled with natural or artificial substrate, and other trays would be left empty of substrate. This approach might be most suitable for cockles which live at or near the surface of the substrate. The floating racks would consist of plywood boxes with Styrofoam floatation and anchored in deep water. Clams and cockles would be planted in natural substrate in the boxes. Clams and cockles raised in the trays and racks would be transferred to beach plots at the conclusion of the project for common property harvests.

At the conclusion of the project, a long-term subsistence beach management plan would be drafted in concert with the appropriate state agencies and in compliance with regulations and policies of the Alaska Board of Fisheries. The plans would include permitting procedures, reseeding schedules, procedures for expanding to different areas, testing for PSP, and harvesting schedules. The plan also would include provisions for scheduling common property harvests when the predator nets would be removed to provide ready access.

2.2.2 Description of *Alternative B, No Action*

Analysis of a No *Action, Alternative B* is a procedural requirement of NEPA [*40 CFR §1502.14(d) and §1508.25(b)(1)]*. It provides an important alternative to the *Proposed Action* and action alternatives and provides baseline information for use in assessing each of the action alternatives, including the *Proposed* Action and their anticipated impacts. With this No *Action Alternative,* no littleneck clams or Pacific cockles would be planted and subsistence shellfish harvests at Nanwalek, Port Graham and Tatitlek would remain poor. Residents of the three communities would continue to utilize other subsistence resources, some of which were damaged by the *Exxon Valdez oil spill.* The other subsistence resources include, but are not limited to, herring and herring spawn, seals, octopi, ducks, mussels and salmon. Continued use of these animals may inhibit their recovery from the oil spill.

2.2.3 Description of *Alternative C, Reduced Stocking*

Alternative B is similar in most respects to the *Proposed Action* except that only 200,000 juvenile littleneck clams and Pacific cockles per year, or 800,000 total bivalve shellfish, would be planted at the three participating villages. The smaller number of clams would reduce the total affected area from 2.5 acres to 1.2 acres. The smaller amount of seed shellfish also would reduce the amount of littleneck clams and Pacific cockles produced annually from 20,000 pounds to 5,000 pounds. This level of production would amount too less than 12 pounds of shellfish annually for each of the be filled with natural or artificial substrate, and other trays would be left empty of substrate. This approach might be most suitable for cockles which live at or near the surface of the substrate. The floating racks would consist of plywood boxes with Styrofoam floatation and anchored in deep water. Clams and cockles would be planted in natural substrate in the boxes. Clams and cockles raised in the trays and racks would be transferred to beach plots at the conclusion of the project for common property harvests.

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430residents of the three communities. Residents of Nanwalek, Port Graham and Tatitlek would continue to rely primarily upon other subsistence resources, some of which were damaged by the *Exxon* Valdez oil spill. The other subsistence resources include, but are not limited to, herring and herring spawn, seals, octopi, ducks, mussels and salmon. Continued use of these animals may inhibit their recovery from the oil spill.

2.3 Description of Alternatives Considered but Eliminated from Detailed Study

One additional alternative was considered in the scoping process and after a cursory review it was eliminated from further detailed study. The *alternative* was *establishment of a village store.* Under this option, alternative food sources such as meat from farm animals would be distributed to replace subsistence shellfish harvests. This alternative was eliminated from further study because of the cultural and sociological importance of continuing subsistence harvesting activities and lifestyles in the Native villages of the Chugach region. Residents of the three communities have voiced strong support for restoration of traditional shellfish resources and continuation of their subsistence lifestyle. In addition, the *Exxon Valdez* Trustee Council previously rejected a similar proposal to fund a community store because of the legality of using restoration funds for this purpose. For these reasons, this alternative was not studied further.

2.4 A Comparison of Environmental Consequences

The planting of juvenile littleneck clams and Pacific cockles on beaches near Nanwalek, Port Graham and Tatitlek would result in the use of 2.5 acres of beach to produce an estimated 20,000 pounds of shellfish per year for subsistence harvests. Availability of these shellfish for subsistence harvests would reduce harvest rates on other depleted native bivalve populations and other natural resources adversely affected by the *Exxon Valdez oil* spill.

Predator nets are expected to have a minor visual impact because they blend into the beaches. No problems are anticipated with accidental ensnarement of birds, sea otters or marine creatures."[°] The nets also would not interfere with any natural sources of food for the predators, although the nets would limit their access to the planted sites. Indeed, the project would provide additional sources of nutrition for predators from the seed planted in adjacent uncovered plots used for controls.

While the planted littleneck clams and Pacific cockles would become common property resources, the remote locations of the three villages would tend to depress non-local harvests of the subsistence beds and minimize the potential for creation of allocation conflicts. The best commercial clam beds are located much closer to the more urban areas of Cook Inlet and recreational clam diggers concentrate on even more accessible beaches.

The development of the beds for stocking would not create impediments to navigation or access to beaches. The floating tray and longline would be located to minimize impacts; siting of the equipment would be subject to multi-agency and public review under the Coastal Consistency process. The project would provide baseline information on paralytic shellfish poisoning (PSP) in Port Graham and Nanwalek and would provide new protections for subsistence shellfish users. The beaches selected for the project would be tested for pollution from the adjacent villages. Samples of shellfish would be tested during the project for residual contaminants from the *Exxon Valdez* oil spill and clean up.

Table 2.2: ***Summary of KEYISSUES VS. ALTERNATIVES***

	Alternative A, Proposed Action, Stocking of 800,000 Juvenile Littleneck Clams and Pacific' Cockles Per Year for Four Years	**Alternative B, No Action**	**Alternative C, Stock 200,000 'Littleneck Clams and Pacific Cockles Per Year for Four Years**
Subsistence	20,000 pounds of littleneck clams and Pacific cockles available for subsistence users in Nanwalek, Port Graham & Tatitlek per year for four years.	No restoration of shellfish resources. Littleneck clam and Pacific cockle stocks would remain depleted. Other species impacted.	5,000 pounds of littleneck clams and cockles available for subsistence users in Nanwalek, Port Graham & Tatitlek per year for four years.

Table 2.2(cont.): Summary of *KEYISSUES VS.*

	Alternative A	Alternative B	Alternative C
Predator Management	The netting is a proven predator control in clam culture in other regions. It does not entrap birds or other creatures. Light colored plastic mesh has low visual impact.	No impact.	Similar to *Proposed Action,* but the area covered by predator nets would be reduced.
Allocations	The number of shellfish available on target beaches after the enhancement efforts would not be large enough to attract recreational or commercial diggers to these remote locations.	No impact.	Similar to *Proposed Action,* but smaller potential for allocation conflicts because of smaller number of clams involved.
Navigation/Access/ Project Activity	(a) 10 x 50 ft. beds would not obstruct beach access. No impact upon navigation. (b) Test clam culture tray and longline would be located for minimal impact on navigation.	No impact.	Similar to *Proposed Action,* but potential for impacts is smaller because of reduced scope.
Protection of Public Health	Testing for paralytic shellfish poisoning would be initiated and shellfish would be tested for lingering contaminants from *Exxon Valdez oil spill* and clean up activities. Water quality also would be tested.	Lack of testing would mean less protection for shellfish harvesters in the villages.	Similar to *Proposed* Action.

While the planted littleneck clams and Pacific cockles would become common property resources, the remote locations of the three villages would tend to depress non-local harvests of the subsistence beds and minimize the potential for creation of allocation conflicts. The best commercial clam beds are located much closer to the more urban areas of Cook Inlet and recreational clam diggers concentrate on even more accessible beaches.

The development of the beds for stocking would not create impediments to navigation or access to beaches. The floating tray and longline would be located to minimize impacts; siting of the equipment would be subject to multi-agency and public review under the Coastal Consistency process.

The project would provide baseline information on paralytic shellfish poisoning (PSP) in Port Graham and Nanwalek and would provide new protections for subsistence shellfish users. The beaches selected for the project would be tested for pollution from the adjacent villages. Samples of shellfish would be tested during the project for residual contaminants from the *Exxon Valdez* oil spill and clean up.

Table 2.2: Summary of KEY ISSUES VS *ALTERNATIVES*

	Alternative A, Proposed Action, Stocking of 800,000 Juvenile Littleneck Clams and Pacific Cockles Per Year for Four Years	**Alternative B, No Action**	**Alternative C, Stock 200,000 Littleneck Clams and' Pacific Cockles Per Year for Four Years**
Subsistence	20,000 pounds of littleneck clams and Pacific cockles available for subsistence users in Nanwalek, Port Graham & Tatitlek per year for four years.	No restoration of shellfish resources. Littleneck clam and Pacific cockle stocks would remain depleted. Other species impacted.	5,000 pounds of littleneck clams and cockles available for subsistence users in Nanwalek, Port Graham & Tatitlek per year for four years.

Chapter 3. Environmental Effects

3.1 Introduction

This chapter compares the alternatives and describes-the probable consequences of each alternative on the identified issues.

3.2 Effects of Alternative A, Proposed Action

Subsistence Shellfish Harvests: The planting of 800,000 juvenile littleneck clams and Pacific cockles per year in the beds located adjacent to the three villages would result in an annual subsistence clam harvest of 20,000 pounds. Over the four-year funding of the project, an estimated 80,000 pounds of clams for subsistence consumption would be produced. Data gathered in a study of the impacts of the *Exxon Valdez* oil spill on clams suggests that littleneck clams reach harvestable size in eight years in Prince William Sound? Growth rates generally accelerate under the controlled conditions employed in the project, and it is estimated the clams may be available for subsistence harvest beginning in *2001* or *2002 (5-6* years from introduction).

Predator Management: Starfish, crab, sea birds, sea otters and fish prey heavily upon juvenile clams and can destroy a crop of seed clams within a few days.' Shellfish farmers throughout the Pacific Northwest and East Coast have been able to protect young clams with the use of plastic netting. The effectiveness of this lightweight netting upon sea otters is unknown and it may be necessary to use a heavier netting material to prevent predation by these larger and stronger animals on the adult clams or cockles. Clam farmers in other regions with extensive experience with the use of predator nets say they have encountered no problems with animals or fishes becoming entangled in the netting.' The nets are colored to blend into the surrounding beach, so visual impacts would be slight.

Allocations: The planted littleneck clams and Pacific cockles would be considered common property resources open for harvest by any subsistence or recreational diggers. Commercial operators would have to receive a harvest quota and permits from ADF&G before harvesting these new stocks. The allocation issue is minimized because of the relatively small number of littleneck clams and Pacific cockles involved in the project. Roughly, each village would be allocated approximately *267,000* juvenile clams and cockles per year, which at average survival rates would translate to *6,700* pounds of littleneck clams and Pacific cockles per year. This amount of clams probably is not sufficient to attract commercial diggers in Kachemak Bay to the Nanwalek or Port Graham beaches, particularly considering the large resource of littleneck clams in upper

Kachemak Bay (Figure 1.3) close to Homer available to commercial diggers. Kachemak Bay is the area in the state with a management plan for commercial harvests of littleneck clams, and only very restricted digging is allowed in Prince William Sound and other areas. There is no commercial fishery open in Alaska for Pacific cockles. It appears unlikely that this enhancement project would attract commercial interest. Likewise, it appears unlikely that many recreational or personal use clam diggers would travel to any of the enhanced beaches because of the remoteness of the areas. Since the native clam stocks near the three villages are so depleted, recreational and personal use clam diggers target on other areas more accessible to the "urban" ports. The management plan drafted at the conclusion of the project would include provisions for conducting common property harvests on the planted littleneck clams and Pacific cockles when predator nets are removed.

Navigation/Access/Project Activity: The project would involve the introduction of littleneck clams and Pacific cockles in prepared "beds." These "beds" are not raised like beds in a garden, but would consist of a 10 x 50 ft. plot of beach covered with plastic netting. The netting is strong enough to sustain a person walking on it without tearing and animals do not become entangled."° Consequently, the "beds" do not create obstructions to access to the beaches by humans or animals. The project also would involve the deployment of several test pieces of gear, including a floating rack and small surface longline. The floating rack would be constructed of plywood and Styrofoam floatation, and would resemble a raft or small dock. Suspended from a 50-ft. longline would be trays filled with substrate from nearby beaches. The longline would resemble an oyster or mussel growout line which consists of a length of rope strung between two anchored buoys; units of gear are suspended from the lines and floats are added at each unit of gear to provide buoyancy. The longline and floating rack would be located to minimize interference with access and navigation. Location of the longline and floating rack would be subject to the Coastal Consistency Determination process administered by the Division of Governmental Coordination and the tidelands permitting process administered by the Department of Natural Resources. In addition, since this project would involve local residents helping with site locations, the navigational problems would be minimized because the navigators would help select the sites. In summary, impacts of the project equipment on access and navigation should be minimal.

Protection of Public Health: The Alaska Department of Environmental Conservation presently monitors only a few miles of beaches statewide for safety of bivalve shellfish for personal use and subsistence harvests. These beaches, located between Kenai and Homer, are sampled monthly for paralytic shellfish poisoning (PSP) from spring through the early fall. While there has been no PSP sampling of bivalves in the Port Graham and Nanwalek areas, extensive sampling of clams, oysters and mussels in Kachemak Bay and Cook Inlet have shown that the general area is very safe from PSP. The project would involve regular monthly sampling of shellfish from the target beaches in Port Graham and Nanwalek to establish a baseline for PSP in the area. Tatitlek has been submitting samples of oysters for PSP testing for several years and the ongoing oyster farming operation would provide the necessary data. Tatitlek area waters also are tested regularly for water quality because of the oyster farm. The project would involve water quality testing in Port Graham and Nanwalek to ensure the bivalves are grown in water safe for human consumption. In addition, the project would involve the testing of bivalves for residual hydrocarbons and chemicals resulting from the *Exxon Valdez* oil spill. Studies and monitoring programs initiated in the wake of the 1989 *Exxon Yaldez* oil spill have shown the presence of hydrocarbons in the flesh of invertebrates in Prince William Sound and lower Cook Inlet.'," The level of hydrocarbons found in invertebrates taken from beaches near Tatitlek, Port Graham and Nanwalek during more recent tests are at levels considered safe by public health agencies.''," This project would include the testing of invertebrates taken from the target beaches for the presence of hydrocarbons, chemicals or other residuals from the *Exxon Valdez* oil spill or other sources.

3.3 Effects of Alternative B, No Action

Subsistence Shellfish Harvests: If the beaches near Nanwalek, Port Graham and Tatitlek are not seeded with clams and cockles, there would be no increase in subsistence shellfish harvests. This may lead to increased use of other species, some identified as injured by the *Exxon Valdez* oil spill. Other subsistence resources include but are not limited to herring and herring spawn, seals, octopi, ducks, mussels and salmon. Continued use of these animals inhibits their recovery from the oil spill. Also, the traditional subsistence life style would be difficult to achieve.

Predator Management: Not applicable.

Allocations: Not applicable.

Navigation/Access/Project Activity: Not applicable.

Protection of Public Health: Without the testing under the project, subsistence users of bivalve shellfish at Port Graham and Nanwalek would not receive the protections the sampling for PSP, water quality and residual hydrocarbons and chemicals would provide.

3.4 Effects of Alternative C, Reduced Stocking

This alternative would reduce the number of littleneck clams and Pacific cockles stocked in prepared plots on beaches near the three villages. The total amount of intertidal area affected by the plantings would be cut back from 2.5 acres to 1.2 acres.

***Subsistence Shellfish Harvests**:* The reduction in number of juvenile clams and cockles planted would reduce the benefits to subsistence users accordingly. This alternative would produce roughly 5,000 pounds of clams and Pacific cockles per year, or 20,000 pounds total. When spread evenly throughout the three villages, this option would produce 12 pounds per person per year versus 48 pounds under the proposed action.

***Predator Management**:* Impacts from the full-scale project would be minor, and the scaled back version negligible.

Allocations: The small number of clams and cockles produced under this alternative at each site would not be large enough to attract commercial or recreational diggers to any of the villages involved.

***Navigation/Acces&/Project Activity**:* Impact of the planting operations on navigation and access would be minimal. The impacts from the longline and floating racks would be identical to *Alternative A, Proposed Action.*

Protection of Public Health: The same testing program provided under *Alternative A, Proposed Action* would be undertaken under a scaled back project.

3.5 Unavoidable Adverse Effects

No unavoidable adverse effects are expected to result from the *Proposed Action.*

3.6 Relationship of Short Term Uses and Long Term Productivity

The relationship between short-term uses of the environment and the maintenance and/or enhancement of long-term productivity is complex. Short-term uses generally occur on an annual basis. Long-term productivity generally refers to the ocean's capability to produce a continuous supply of resources and values for future generations. For purposes of this analysis the duration of all of the action alternatives would be a maximum of nine to ten years. Under any of the action alternatives, the long-term productivity of the ocean and its resources would be protected from unacceptable impacts by full compliance with the Permits, Licenses, and Entitlements listed in Table 1.4.

3.7 Irreversible and Irretrievable Commitments of Resources

Irreversible Commitments are those that cannot be reversed, except perhaps in the extreme long run. *Irreversible* applies primarily to nonrenewable resources such as minerals but it may also refer to extinction of a species. *Irretrievable Commitments* are those that are lost for a period of time. It applies to the loss of production, harvest, or use of natural resources. There would be no *Irreversible or Irretrievable Commitments.*

3.8 Any Other Disclosures

An expansion of the project into three additional villages (Eyak, Chenega Bay and Ouzinkie) is under consideration. This expansion would be in response to the high degree of interest which has been expressed by local residents and tribal leaders. If this expansion is approved, it would result in fewer shellfish being planted at each site, since the Qutekcak hatchery production would not be increased. Consequently, each of the six villages would be allocated approximately 136,000 juvenile littleneck clams and Pacific cockles per year, or half of what each village would receive under the present project. The number of plots per village would also be reduced, and the total area utilized for the project would remain at approximately 2.5 acres. If the expansion is approved, by the *Exxon Valdez* Trustee Council and an addendum to this Environmental Assessment may be issued.

3.9 Endangered Species

No endangered species would be impacted by the project.

Chapter 4. List of Preparers/Primary Reviewers

Name	Agency	Contribution	Degrees	Years Ea erience
Jeff Hetrick (preparer)	CRRC	Primary Investigator	BS- Biological Sciences MBA	15
Rodger P Painter (Preparer)	CRRC	Investigator	BA-Journalism	17 Years Fisheries Consultant
Dan Moore (reviewer)	ADF&G	Fisheries, Editor, Team Leader	BS- Fish & Wildlife Management	17
Rita Miraglia (reviewer)	ADF&G	Subsistence	BA-Anthropology MA-Anthropology	8
Bill Hauser (reviewer)	ADF&G	Fisheries, Editor	BS-Zoology MS-Fish & Wildlife Management PhD- Zoology	22

Chapter 5. Public Involvement

5.1 Individuals and Organizations Contacted in Regards to this Project

Name	Organization
Bill Hauser	Alaska Department of Fish and Game (ADF&G)
Joe Sullivan	ADF&G
James Brady	ADF&G
Rita Miraglia	ADF&G
Jim Cochran	ADF&G
Jim Seeb	ADF&G
Don McKay	ADF&G
Kelly Hepler	ADF&G
Janetta Pritchard	Alaska Department of Natural Resources (ADNR)
Chris Titus	ADNR
Larry Bullis	ADNR
Tim Smith	ADNR
Judith Bittner	ADNR
Elaine Pistoresi	Alaska Department of Environmental Conservation (ADEC)
Michael Ostasz	ADEC
Mike Tinker	Alaska Department of Transportation and Public Facilities (DOT)
Carol Jo Sanner	DOT
Kathy Chorostecki	National Oceanic and Atmospheric Administration (NOAA)
Nancy Briscoe	NOAA
Heather Dean	U.S. Environmental Protection Agency
Duane Harp	U.S. Forest Service (USFS)
Ray Thompson	USFS
David McGillivary	U.S. Fish & Wildlife Service
Victoria Taylor	U.S. Army Corps of Engineers
Commander	U.S. Coast Guard
Gary Kompkoff	Native Village of Tatitlek
Charles Totemoff	Chenega Village Corporation
Mary Gordaoff	Tatitlek Village Corporation
Larry Evanoff	Native Village of Chenega
Don Emmal	English Bay Native Corporation
Patrick Norman	Port Graham Native Corporation

Mark Stahl	Chugach Alaska Corporation
Vincent Kvasnikoff	Nanwalek Village Council
Eleanor McMullen	Port Graham Village Council
Harriet Wegner	Kenai Peninsula Borough
Don Gilman	Kenai Peninsula Mayor
Tamara Smid	Upper Cook Inlet Development Foundation
George Kesney	City of Cordova
Mary McBurney	Cordova District Fishermen's United Eyak
Eyak Corporation	
Nancy Lethcoe	At Large
Larry Smith	At Large
Howard Ferren	Prince William Sound Aquaculture Association (PWSAC)
Sandra Shubert	Exxon Valdez Oil Spill (EVOS)
Eric Meyers	EVOS
David Daisy	Chugach Regional Resources Commission

5.2 Summary of Comments Received During the Scoping Process

Public Health

Locate plots to avoid sources of pollution from the village.

Develop a baseline of information for paralytic shellfish poisoning.

Predator Management

Would the netting/plastic screening pose any potential risks to local flora/fauna, e.g. snaring?

Allocations

Allocative management plans should be developed before this is done, not after. It is presumptively allocative to begin with because it allocates public beach and resource to a specific user group.

Substrate Manipulation

The environmental impact statement should be very precise in addressing the likely outcome of habitat manipulation at the expense of native organisms. Substrate manipulation on a public intertidal area is a bad idea unless it can be proven in the literature that long term risk is minimal.

Genetics

Are there data from other bivalve culture projects that show a possible detriment to the wild stock gene pool?

General

Are there any environmental impacts to be expected at beaches intended for grow-out, e.g. effects on local flora/fauna, predator-prey relationships?

Basically, I'd like to know whose decision it was that the littleneck clam, a species that may not be natural to most of the so-called restoration area, has a priority over the indigenous predators of bivalves, including the natural prey species that may be transplaced by the stocking?

Glossary

ADF&G:	Alaska Department of Fish and Game
alternative:	A potential action.
CRRC:	Chugach Regional Resources Commission. A private nonprofit organization which assists Native villages in the Chugach region, Prince William Sound and lower Cook Inlet.
DEC:	Alaska Department of Environmental Conservation.
EA:	Environmental Assessment.
effect:	The impact or consequence of an alternative, or potential action, on the physical, biological, social, or economic resources within the affected area.
floating rack:	A small floating structure constructed of untreated wood and Styrofoam floatation in which juvenile littleneck clams and Pacific cockles would be suspended on plastic mesh.
issue:	Concern about effects, whether direct or indirect, on a physical, biological, social, or economic resource.
limited entry permit	Permit required to harvest salmon commercially or to participate as a harvester in other lucrative commercial fisheries such as Prince William Sound herring. The permits may be purchased at varying market values.
longline:	A line or rope strung between two or more buoys secured by anchors from which nets or trays of littleneck clams or cockles will be suspended.
NEPA:	National Environmental Policy Act.
NOAA:	National Oceanic and Atmospheric Administration.
PSP:	Paralytic shellfish poisoning. A toxin caused by a microscopic dynoflagellate which can accumulate in their bodies during the filter feeding process

scoping:	The range of actions, alternatives, and impacts to be considered in an environmental impact statement (CEQ §1508.25).
TC	*Exxon Valdez* Trustee Council

Bibliography/Personal Communications

1. Fall, James and Charles Utermohle. "An Investigation of the Sociocultural Consequences of Outer Continental Shelf Development in Alaska." 1993. Alaska Department of Fish and Game. P. 597-639.

2. Wolfe, Robert J. and Robert J. Walker. "Subsistence Economies in Alaska: Productivity, Geography and Development Impacts." 1987. Arctic Anthropology 24(2): 56-81.

3. Trowbridge, Charles. "Effects of Hydrocarbons on Bivalves." 1993. Alaska Department of Fish and Game.

4. Rita Miraglia, anthropologist, Alaska Department of Fish and Game, Division of Subsistence. (Personal communication.)

5. McClintock Land Survey & Planning Company. "Community Profile: English Bay." 1989. Produced for the Kenai Peninsula Borough.

6. McClintock Land Survey & Planning Company. "Community Profile: Port Graham." 1989. Produced for the Kenai Peninsula Borough.

7. RaLonde, Raymond. "Shellfish Aquaculture in Alaska and the Potential of Interaction with Wild Species" 1995.

8. Dr. Kenn Brooks, Pacific Rim Mariculture, a Washington-based researcher. (Personal communication.)

9. Dr. Ted Cooney, oceanographic researcher, School of Fisheries and Oceanography, University of Alaska Fairbanks. (Personal communication)

10. Paul Taylor of Taylor United, the largest clam aquaculture company in the U.S.. (Personal communication.)

11. Test results of sampling stations from the ADF&G Subsistence Division 1989, 1990, 1991, 1993 and 1994 studies and the *F=on* Valdez/NOAA study.

Appendices

Aquatic Environmental Sciences
644 Old Eaglemount Road Port
Townsend, WA 98368 (206) 732-
4464

September 2, 1995

Jeff Hetrick Box 7
Moose Pass, Alaska 99631

Dear Jeff,

We have received all of the samples collected during our August 25 through August 29, 1995 field trip to Nanwalek, Port Graham and Tatitlek. The collecting effort was ambitious - however, with hard work and 18 hour days we accomplished everything that was planned. No deviations from the study protocols were required. The following people comprised the survey crew:

Dr. Kenn Brooks (lead scientist)
Mr. Jeff Hetrick (project coordinator)
Mr. Dan Moore (ADFG)
Mr. Roger Painter (shellfish grower)
Mr. Andrew Brooks (technician) Mr.
Jeff Joseph (technician)
Mr. Dale Bowers (Nanwalek Village) Mr.
Pat Norman (Port Graham Village) Mr.
Gary Kompkoff (Tatitlek Village) Mr.
Steve Totemoff (Tatitlek Village)

Homer (Alaska Department of Fish and Game (ADFG)). Our meeting on August 25, 1995 with Al Kimker and Richard Kresler was interesting and informative. The information we collect should complement their 1994 report assessing commercial clam populations in Kachemak Bay. In addition, our description of growth and recruitment should be valuable to ADFG's efforts to manage intertidal hardshell clam populations. Obviously, we need to closely coordinate our efforts with their office.

Nanwalek (Passage Island). This site, in the mouth of Port Graham, contained a small beach (approximately 18,200 square feet or 0.42 acres) which contained numerous cobble to boulder size rocks and substrate that is ideal for native littleneck clams *(Protothaca staminea).* Our village contact, Mr. Dale Bowers was knowledgeable and enthusiastic. He suggested that there are several traditional clam harvest areas in the immediate vicinity that currently do not have healthy clam populations. However, he agreed that Passage Island was the preferred site.

We collected a total of 18 shellfish, 9 sediment and three water samples at this site. Each shellfish sample contains all of the clams within a 0.1 mete? quadrat. We dug the quadrats to approximately 10 inches depth because we found clams deeper than anticipated. These samples were sieved on • " screens and all clams were picked from the retained substrate. Sediment passing the • " screen was then sieved on a one millimeter screen. All of this small material was placed in sample bags and small clams are being retrieved in our lab under magnification.

Our evaluation will take several months. However, we did find moderate numbers of small native littleneck clams at the -0.9 to +1.0 Mean Lower Low Water (MLLW) tide level on Passage Island. Very few harvestable clams (>1.5 inches valve length) were observed.

Moderate currents were observed at this site providing a good source of food for clams or oysters. However, growth appears to be slow and a preliminary examination suggests that five to eight years will be required to raise native littleneck clams exceeding 1.5" in valve length. Examination of growth rings on dead cockle valves in this bay suggests that they grow much faster. However, very few living cockles *(Clinocardium nuttalli)* were observed - none of them were large enough to harvest.

Numerous round holes, presumably dug by sea otters, were observed on the beach. This, together with the lack of large clams, suggests that otter predation is an important factor effecting clam harvests.

This is a high energy beach which will require special consideration when enhancing native littleneck populations. Because of the rocky nature of the beach, it would not be suitable for cockles.

A mussel sample (Mytilus *edulis* trossulus) was collected at Passage Island. The mussels were shucked at Aquatic Environmental Sciences and forwarded to Alaska

Port Graham appears well protected with numerous suitable culture sites. We originally intended on sampling Duncan Slough. However, a preliminary examination on the evening of August 25, 1995 found few clams and no littleneck clams. Based on several hundred test digs at Duncan Slough, we decided to switch our efforts to Murphy Slough. These sites are discussed separately below:

Port Graham (Duncan Slough). This slough contains an extensive area of stable substrate at approximately -2.0 to + 2.0 (MLLW) and was reported to contain large quantities of butter *(Saxidomus giganteus)* and littleneck clams in the past. The substrate appears very stable with sufficient fines and volatile solids to support either cockles or littleneck clams. However, the substrate includes a large amount of angular gravel (1" minus) that packs too tightly for good clam recruitment. No littleneck clams were observed at this site which did contain a few small horse clams (Tresus *capax)* and *Macoma nasuta.* Duncan Slough would be an excellent candidate for enhancement because of the expanse and composition of stable substrate at an ideal tidal height. There are ways to overcome the compact substrate. I believe this is an excellent site. Salmon hatchery workers noted that ice forms in Duncan Slough during cold winters. This will require additional consideration.

Port Graham (Murphy Slough) is an area of approximately five acres lying east of Duncan Slough. There is an area suitable for either cockle or native littleneck clam enhancement lying between the braided stream channels on the west and an area of anaerobic sediments on the east. This area covers approximately one acre and contains excellent substrate from every aspect.

A total of nine shellfish samples were collected at Murphy Slough. Protocols were identical to those previously discussed. In addition, nine sediment and three water samples were collected at this site. Only low numbers of small clams were observed in each quadrat. It appears that clams are failing to recruit in both Duncan and Murphy Sloughs. In fact, with the exception of Passage Island, there was no evidence of successful recruitment of cockles, littleneck clams or butter clams on Port Graham beaches. The only clams found in moderate abundance were small (2"±) horse clams *(Tresus* cf. capax).

Many round holes have recently been dug in these beaches suggesting sea otter predation. Empty, broken butter and horse clam shells were visible in the vicinity of these holes.

Like Duncan Slough, Murphy Slough has traditionally produced hardshell clams. However, it appears that recruitment is failing on both of these beaches. We will be able to quantify recruitment over the last few years during analysis of the samples collected on this trip. Either beach appears, at first look, to be an excellent candidate for enhancement.

A clam sample was obtained from a beach further east of Murphy Slough for PSP analysis. These clams were shucked at AES and forwarded to DEC in Palmer. We completed our work in Port Graham in the afternoon and flew to Tatitlek where we examined potential shellfish beds until dark.

Tatitlek. Work at Tatitlek began at 0600 to meet a 0848, -0.9' MLLW tide. The potential clam producing area is immediately adjacent to the village and measures 200 feet wide by 350 feet long. It is bounded on the north by sand and mud substrates covered with eel grass (apparently *Zoostera japonica)* and on the south by hard rock substrates. The area to be enhanced contains excellent substrate for native littlenecks - it would not be suitable for cockles. However, cockles could be enhanced on the sandy substrates covered with eel grass.

We collected a total of 35 shellfish samples, 10 sediment samples and three water samples at this site. The extent of this survey was such that we barely finished as the tide swept in on a considerable current. However, Gary Kompkoff and Steve Totemoff provided a skiff in which our samples and gear were loaded for transport to the village.

This site contains significant numbers of small littleneck clams. We have finished examining the fine portion of the substrate on about half the samples and there are numerous small (< 0.5 inch), and recently set (< 1/8") clams in samples from -0.9 to + 2.0 feet (MLLW). In addition, we found clams as high as approximately +3.0' MLLW at this site. This is higher than expected in Alaska. We did not find many harvest size clams (>1.5").

Numerous sea stars (cf. *Pycnopodia helianthoides)* were observed along-with obvious (presumably) otter digs on this beach. Because of the large number of predators, three randomly selected quadrats, each measuring 10'x 10' square were examined for starfish, burrowing shrimp and otter digs. The results suggest starfish densities of one per 18 square feet. Otter digs averaged one per 50 square feet.

Strong currents and ideal substrate suggest that this beach at Tatitlek should produce a significant quantity of shellfish for the village. In addition, there is a potential to re-establish a cockle population in the protected eel grass bed. However, either enhancement will require measures to reduce predation by starfish and sea otters.

Summary. Sample evaluation will require several weeks for completion. A final report should be completed by the end of the year. That report will be detailed and contain specific recommendations for beach enhancement and village management. However, a preliminary evaluation of these beaches suggests the following:

a. None of the beaches surveyed in this study contain a harvestable shellfish population. Based on interviews with long time salmon hatchery workers and village members, each of these beaches used to produce clams. They can again.

b. Each of the beaches surveyed can be enhanced by seeding, reducing predation, and developing an effective management plan specific to each beach and village. Such a plan must be based on the biology and population dynamics of the species and beaches in question. Each beach has its special problem and can be enhanced for specific shellfish species using specific techniques. The technology for employing these techniques has been developed and implemented successfully elsewhere.

c. The next step will be to test the forthcoming enhancement methods at each site. That will require native littleneck seed in 1996 and subsequent years. I anticipate a need for approximately 40 to 50,000 clams (6 to 8 millimeters shell length) in 1996 and perhaps three times that number in 1996. After 1996, clam enhancement projects will be able to use as many clams as the Qutekcak hatchery can produce (ten million per year). That effort will also require completion of one or more floating upwell systems (FLUPSYs) to be placed in productive bays as nurseries to grow seed from 1.0 to 3.0mm to 6 to 8mm.

This preliminary report is intended to provide you with information upon which to base decisions over the next few months. This is an exciting project. The enthusiasm of village members and their desire to once again harvest shellfish was refreshing. If I can be of assistance, or answer questions before the final report is complete, please call me at (360) 732-4464.

Sincerely,

Dr. Kenneth M. Brooks

President, AES

Exxon Valdez Oil Spill Trustee Council
FY 95 Detailed Project Description

Project Title:	Nanwalek/Port Graham/Tatitlek Clam Restoration
Project Number:	95131
Lead Trustee Agency:	Alaska Department of Fish & Game
Cooperating Agencies:	Chugach Regional Resources Commission Native Villages of Tatitlek, Nanwalek and Port Graham
Project Start-up/Completion Dates:	March 1, 1995 - February 28, 2001
Expected Project Duration:	Five Years
Cost of Project FY 95:	$208.3
Cost of Project FY 96:	$327.1
Cost of Project FY 97 and beyond:	$995.0
Geographic Area:	Port Graham/Nanwalek and Tatitlek areas

Project Leaders:

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A. INTRODUCTION

The purpose of this project is to establish populations of clams in areas that are readily accessible from the villages of Tatitlek, Nanwalek and Port Graham. These clams will be used as a source for subsistence food to replace the natural clam resource that has been lost or depleted.

Clams were once an important subsistence food in the Native villages of Tatitlek, Nanwalek and Port Graham as well as most other Native villages in the *Exxon Valdez* oil spill area. Clam populations in areas that are reasonably accessible to Tatitlek, Port Graham and Nanwalek have decreased to very low levels in recent years. Consequently, the role of clams in the subsistence diet in these villages has been greatly reduced. And, with a few exceptions, the role of clams in the subsistence diet of most Native villages in the oil spill area is a lot less than it was historically.

There are likely a number reasons why local clam populations are currently at low levels. Since clams are basically an unmanaged resource in the oil spill area, there are no quantifiable data available that could point to the actual circumstances that lead to the sharp reduction in these clam populations. However, there are events that likely played a major role. These include changes in beach configurations resulting from the 1964 earthquake, increasingly heavy sea otter predation, human over-harvest and the *Exxon Valdez* oil spill.

The oil spill impacted the wild clam populations and their importance as a subsistence food in two ways. First, many clam beds suffered from direct oiling. The impact of the oil on the clam beds in Windy Bay, for instance, destroyed one of the more important clam beds in the lower Kenai Peninsula. With the current timber harvesting operations soon to provide road access from Port Graham and Nanwalek to the Windy Bay area, the loss of the clam resource there had a major impact on these villages. Second, even though many clams weren't killed from the oil, they have a tendency to accumulate and concentrate the toxic contaminants from non-lethal amounts of oil. This has badly eroded the confidence of the villagers in the healthfulness of the remaining wild clam populations as a subsistence food.

In order to reestablish local clam populations as a subsistence resource for the Tatitlek, Nanwalek and Port Graham villages a program needs to be developed to enhance the depleted stocks and the replace damaged ones. Over the past ten years the nursery systems and field growout technologies have sufficiently evolved to make clam enhancement and reseeding efforts feasible. This technology can be readily applied to increasing the clam resource near the villages to determine which applications would be best suited for the task at hand.

One of the main problems with clam enhancement in Alaska has been the availability of a sufficient supply of seedstock. Because of the potential for transporting disease into the state, seed stock for all other bivalve shellfish species except oysters must be obtained from in-state sources. Collecting seed from wild spawn is a relatively easy task with mussels, but nearly impossible to do with other species of interest such as clams and scallops. To resolve this problem the Qutekcak Native Tribe of Seward is developing a shellfish hatchery that is working to develop the technology for producing clam seedstock and is currently working on the littleneck clam (*Protothaca staminea)*. This clam has never before been produced in a hatchery. However, the hatchery staff was able to bring small batches of littleneck clams through the most critical stages of development and it seems certain that the techniques for successfully producing littleneck clam seedstock in the hatchery can be developed. In addition to littleneck clams the hatchery has plans to do seedstock development work on cockles (*Clinocardium nuttalli*) and is considering butter clams (*Saxidomus giganteus*). The Qutekcak hatchery is very interested in becoming involved in a program that revitalizes the clam resources near Native villages.

With an Alaskan shellfish hatchery and nursery complex able and willing to produce seedstock for this program and the growout technology well understood, the time is right to begin the process of restoring the clam resources near Native villages in the oil spill area.

B. PROJECT DESCRIPTION

The proposed project will be a cooperative effort between ADFG and the Chugach Regional Resource Commission (CRRC). Participants are outlined in personnel section and appendices.

1. Resources and/or Associated Services

Local shellfish populations, especially clams have been severely reduced as a subsistence food source for Native villages. Part of the reduced use is a loss of confidence in the safety of consuming shellfish as a result of the Exxon Valdez Oil Spill. In addition, local shellfish populations have been greatly reduced as result of hydrocarbon toxicity, sea otter predation, human overharvest and beach changes from the 1964 earthquake.

2. Relation to Other Damage Assessment/Restoration Work

The project (95131) will complement Fish/Shellfish Study 13 <u>Effects of Hydrocarbons on Bivalves</u> conducted under State/Federal Natural Resource Damage Assessment. That project studied shellfish populations throughout the oil impacted area and conducted growth and mortality studies, collected age and size information and examined reciprocal transplants from oiled and control beaches. It was determined that littleneck clam populations were adversely affected through increased mortality and reduced growth rates.

The Clam Restoration Project (95131) will provide future resources for subsistence harvest and will be valuable for Projects 95279(Subsistence Restoration Projects Food Safety) and 95052 (Community Interaction/ Traditional Knowledge) to develop harvest plans. Information from 95052 can be used in the community survey, population assessment described in Objective 3.

3. Objectives

Objective 1. Hatchery Processes- Develop and improve hatchery techniques for the littleneck clam (*Protothaca staminea*), the cockle (*Clinocardium nutalli*) and, if hatchery resources allow, the butter clam (*Saxidomus gigantus*).

Objective 2. Nursery- Develop techniques to grow 1mm-2mm seed from the hatchery to an outplanting size of 10mm - 15mm. Review needs and possible alternatives of substrate for nursery and growout.

Objective 3. Growout - describe current populations through interviews and resource assessments. Locate sites and develop growout techniques and evaluate the efficacy of proposed methods. Develop a permanent subsistence beach.

4. Methods

SECTION 1. HATCHERY

The Qutekcak Shellfish Hatchery has been in operation since October 1993. During this time the hatchery was designed and assembled and has evolved into a production scale operation. The staff has successfully set larvae of the Pacific oyster *Crossastrea gigas* and raised them to 15mm for the aquatic farm industry. In addition, the hatchery has successfully conditioned, spawned, set and raised the native littleneck *Protothaca staminea* to 10mm and will attempt to overwinter the clams both in the hatchery and on local beaches. This project will also attempt to develop broodstock and produce cockle *Clinocardium nutalli* seed, and, if possible, butter clam *Clinocardium nutalli* seed.

The systems and techniques that will be used to produce seed for growout under this project are outlined below.

A. Water system

The water source for Qutekcak Shellfish Hatchery is from a 60 meter deep intake which brings up nutrient rich seawater void of many organisms and is well suited for shellfish culture. The hatchery has two head tanks with electric heaters, an on demand heater, bag filters, 2mm and 10mm cartridge filters and ultraviolet light for additional disinfection. Water from shellfish held in quarantine is chlorinated before discharge into Resurrection Bay.

B. Algae

Hatchery production of larval and juvenile bivalves requires a reliable supply of high quality algae. The Qutekcak Shellfish Hatchery (QSH) cultures four species: *Chaetoceros calcitrans, Thalassiosira psuedonana, Tetraselmis suecica and Tahitian isochrysis.*

The techniques for raising these species are well documented. Algae is cultured in three phases 1) stock cultures, 2) 20 liter carboys, and 3) 200 liter Kalwal tanks.

Water for stock cultures and for inoculating carboys is sterilized in a microwave for several minutes. Stock cultures are maintained under strict conditions and are handled only under a laboratory hood. The seawater is inoculated with nutrients such as nitrogen, phosphorous, vitamins and trace minerals. Light intensity and wavelengths are controlled for each species to manipulate growth depending on the need for each. The pH is adjusted with carbon dioxide to maintain the optimum range of 7.8 to 8.4.

Algae cultures go through three phases of growth; lag phase, exponential phase and stationary phase. Algae in the exponential phase is of the highest quality for inoculating additional algae cultures and for clam nutrition.

QSH uses batch culture techniques for producing algae. 20 liter carboys are used to inoculate 200 liter Kalwal tanks for production feeding. Water used for the Kalwal tanks is chlorinated (2-5ppm) for 24 hours and deactivated with sodium thiosulfate. Generally, it takes 4-6 days for a culture to reach its maximum density and several more days to harvest the culture for feed. Several species are always in production to insure all nutrient requirements are met for the juvenile shellfish under culture.

The hatchery staff also keeps several liters of preserved *Chaetacerous* on hand to supplement feeding of setting larvae and as a back up in case cultures become contaminated.

C. Broodstock Conditioning

The gonadal development of shellfish can be controlled by adjusting feeding rates and temperatures. When properly conditioned, shellfish can be induced to spawn by manipulating the temperature.

At QSH broodstock are conditioned in static 60 liter tanks. Water temperature is controlled through aquarium heaters and changed daily. During the spawning season the clams are held at 16° C - 18° C. During the winter months the temperature is lowered to 8° C - 10° C. Broodstock are held in family units of ten in mesh bags which help keep pressure on the hinges. Families are marked to record the spawning history and track the development of the progeny. Broodstock are fed daily to maintain body weight and when ready to spawn are fed to saturation. Prior to the spawning cycle temperatures are raised to accelerate gametogenesis. Gamete development is tracked by dissecting broodstock to assess development. Gamete quality has been the most important factor at QSH in determining the success at setting.

D. Spawning and Larvae Culture

Spawning episodes have occurred at regular cycles throughout the production year. To induce spawning, clams are removed from the broodstock tanks and allowed to dry for several hours. They are then placed in water baths at 22° C -24° C. Hatchery personnel watch for the appearance of spawn in the spawning tank. This process is often repeated several times until the clams are induced to spawn.

When the shellfish have finished spawning the water is filtered and the fertilized eggs placed in larval culture tanks. Notations are made identifying the families and if possible the individuals involved in spawning.

The larvae are fed several times a day at 50,000 cells/ml. The development of the larvae are tracked daily. After almost four weeks of development, the larvae reach 240 microns and are ready to set.

E. Setting

The setting process is slow with littleneck clams. One of the most important variables for successful setting appears to be the time in which the clams are placed from the larvae tanks to the setting system. When the majority of the larvae are sessile and appear to be pedal feeding they are transferred to the airlift system on the downwelling mode. Ground oyster shell sifted at 150mm is placed on a 120mm nitex screen. Up to 2 million larvae are placed on the 1500cm^2 screen in a 130 liter airlift system. The clams are fed 70,000 cells/ml three times daily and finish the setting process in approximately seven days.

F. Primary Culture

The airlift system is also used for primary culture to raise the clams to 2+mm. The flow is alternated between the upwell and downwell mode. Although the clams feed better on the downwell mode, elimination of metabolites are flushed during the upwell cycle. Clams are fed to saturation by feeding enough algae so that the clams "clear" the water within two hours. The amount of feed needed increases to 150,000 cells/ml.

G. Secondary Culture

After almost six weeks of culture the clams are sorted through screens. Those that are 2mm or greater are transferred to a Heath Tray incubation system. The vertical incubator allows water to flow through a stack of ten trays of shellfish. The water is recirculated through the stack to maintain water temperature and changed daily to remove metabolites. Feed is added to a headbox and the clams are fed to saturation. 200,000 clams require up to 40 liters of algae at densities of 3 million cells/ ml.

Growth rates of the clams are highly variable requiring constant sorting to insure that smaller clams are not out competed by their cohorts. Size groups are maintained in different trays of the heath systems.

H. Hatchery Production Summary

A. Broodstock Conditioning	8 weeks
B. Spawning- Larvae culture	4 weeks
C. Setting	1 week
D. Primary Culture to 2mm	6 weeks
E. Secondary Culture to 5mm	8 weeks

The hatchery production schedule has been determined from 1994 data. Hatchery personnel believe the time the clams spend in the primary and secondary systems can be reduced significantly if more feed were available. The 1995 production plan calls for tripling the algae capacity.

SECTION 2. NURSERY SYSTEM

A. Algae Production Pond

The QSH utilizes a 1 million liter pond to culture algae for its nursery. The 10m by 10m pond is 3 meters at it's deepest point. Raw seawater from a 60 meter deep intake is pumped into the pond to bring in nutrient rich water. The flow is controlled to allow for adequate flushing yet maintain the ambient air temperature. An air pump is used to bubble and circulate water in the pond for adequate mixing and prohibit stratification. Water temperature and salinity are monitored daily and nitrogen phosphorous and silica levels checked weekly. The pond is fertilized daily in an attempt to keep nitrate levels at 3.0 ppm to 3.5 ppm and phosphate at 1.2 ppm to 1.5 ppm. Equally important is to keep the ratio at 7N:P.

The flora of the pond changes seasonally with *Chatecerous* dominating in the early months of the summer and pennate diatoms taking over after July. Natural cell densities of Resurrection Bay are 5,000 cells/ml while the pond is manipulated to produce 250,000 cells/ml for feeding the shellfish.

Two 8,000 liter tanks have been installed at the nursery complex to produce mass volumes of axenic cultures outdoors. Preliminary results in 1994 were encouraging and these tanks may be an additional source of large volumes of algae.

B. Nursery Phase

Clams from the hatchery that are 5mm or greater are transferred to shallow raceways adjacent to the pond. Water is pumped into the raceways and flows passively through the clam upwell tanks. The clams are seeded at 50 cm^2 initially on 1mm vexar screen. The screens are cleaned and the clams stirred several times a week. Experimentation is ongoing to determine which system and substrate perform the best.

Many species of clams require substrate to support their hinges when they reach a certain size. To date, this has not been noticed in the native littlenecks, however this will be closely observed and if necessary substrate both natural and artificial will need to be employed.

SECTION 3. GROWOUT

A. Baseline Data

1. Historical Information

It will be necessary to do baseline research on the local beaches prior to planting the clams for growout. Local residents, especially elders, will be canvassed to gather information on old and existing beaches near the villages. An individual, most likely a team leader, from each village will be selected to be the focal point for collecting information.

Staff at the University of Alaska, biologists from ADFG and project leaders from pertinent EVOS research projects will be interviewed and a literature search conducted to see what information is available on species composition and local abundance of shellfish. This will include work conducted by EVOS funded project Fish/Shellfish 13.

2. Field Surveys

Three person field survey crews will be selected and trained from each of the villages of Tatitlek and Port Graham/Nanwalek. ADFG will assist with the sampling design and statistical analysis.

1. For each area surveyed the following information will be gathered:

   a. type and abundance of benthic organism both mobile and sedentary will be gathered using the random plot sampling method.

   b. Composition of substrate will be evaluated using the graduated sieve method.

2. From the surveys an estimate will be made on the abundance of clams that are currently in the area and a profile developed of what constitutes a good clam growing area such as substrate composition, exposure, slope, tide height and other factors.

B. Growout Techniques

Several methods for growout will be tested and analyzed. These include seeding candidate intertidal areas, adapted hanging culture techniques and tray culture. Seeding and hanging culture methods will be explored to determine how suitable they would be in developing clam resources for subsistence use. Although tray culture may prove to be a viable method for producing harvestable quantities of clams, it initially will be used to evaluate various substrate compositions to determine which mixtures are best for seeding clams.

1. Seeding Intertidal Areas

Seeding beaches is the most common and probably least expensive method for developing a clam resource. For developing a subsistence clam resource near the Native villages beach seeding appears to the most reasonable approach.

Because of the predation problems clams encounter, from starfish and crabs on seed to sea otters on large sized clams, protecting seeded beds against predators is a must. The nylon or plastic screening that has been developed for this purpose should be satisfactory. The following steps will be followed for seeding and monitoring intertidal areas:

1. Locate areas for clam seeding
   a. Two criteria will be used to locate intertidal areas for seeding.
      i. Ease of access- Location must be easily accessible from the villages in most weather. Areas that can be accessed by walking from the village would be the best, but easy boat access is acceptable.

      ii. Good chance of successful seeding- Profile developed from abundance surveys will be used to identify potential beaches.

2. Obtain permits for seeding selected intertidal areas

3. Prepare intertidal area for seeding.
   a. Individual plots will be 10 feet by 50 feet. A plot this size should produce approximately 5,000 harvestable clams. Initially there will be one plot installed in each area. Successful sites will eventually be expanded. The following steps will be taken in seeding an area:
      i. Removal of logs and other debris and obstacles.

      ii. Rake the area to prepare the ground for seed.

   b. The process of baking the first few inches of the substrate in growout areas to remove unwanted organisms, yet retain the natural chemistry is a technique that may have application here. The project will conduct tests of this process to determine its ease of application, level of success and cost/benefit ratio.

4. Seeding
   a. The prepared area will be seeded at a density of 75, 10mm+ clams per square foot.
5. Predator control
   a. Predator netting, ("car cover") will be placed on top of the clams and securely anchored. The cover is usually trenched 6 inches or more around the perimeter to dissuade crabs and other animals which cannot burrow too deep. The mesh of the car cover can be changed as the clams increase in size.

6. Inspection/Sampling
   a. The growout sites will be inspected weekly by the field teams to insure that the area remains as designed.

   b. Clam samples will be collected monthly and be measured for length and weight increases. Water and substrate temperatures will also be collected.

c. Local shellfish will be analyzed for Paralytic Shellfish Poisoning (PSP) on a regular basis as recommended by the Alaska Department of Environmental Conservation.

2. Hanging Culture Techniques

Hanging culture involves growing bivalve shellfish in a subtidal area in culture gear suspended from a floating longline. Hanging culture is commonly used for growing oysters, mussels and scallops. It is rarely used for extended clam culture but may work well for species such as cockles whose natural habitat is at or near the substrate surface. It may also be possible to adapt hanging culture to work with burrowing clams.

Hanging culture methods could be useful from a subsistence standpoint for two reasons. First, hanging culture would make it possible to locate a source of clams within easy reach from a village regardless of local beach conditions, and second, if an oil spill or some other catastrophic pollution arises, the hanging culture operation can be moved to a safe location or even brought to shore and stored in a moist environment. The disadvantage of the hanging culture method is that it would require more equipment and maintenance than beach culture methods.

Types of Hanging Culture

a. Floating Racks   Floating racks are made of plywood with Styrofoam floatation. Gravel/rock substrate is placed in the plywood boxes and tidal flush and water movement provide feed for the clams.

b. Hanging Trays   Stackable plastic trays are suspended from a longline and the clams feed from the water column. Trays can be filled with natural or artificial substrate or left without substrate.

Location of Suitable Sites

a. Both Tatitlek and Port Graham/Nanwalek areas already have hanging culture sites for commercial oyster culture operations (Tatitlek's are fully permitted; Port Graham has a site suitability permit). These sites will be used to locate hanging culture experiments with clams.

b. The permits at both Tatitlek and Port Graham will need to be altered to allow for hanging culture experiments with clams.

Growout Tests

a. The growout methods used will be evaluated on survival, growth rate as determined by weight and length measurements and ease and expense of culture. Methods may be altered or abandoned appropriate.

3. Alternative Growout Methods

Other growout methods that are now being introduced will be tested here. An example of this is the biodegradable cone. Growout trays will be used to test the efficacy of different mixtures and types of substrate. Growout trays (2ft x 2ft) containing different substrate mixtures, but in all other ways the same, will be set up side-by-side on a beach and seeded at the same density. Differences in growth and survival will be measured.

C. Subsistence Beaches

Near the completion of the project, after sites are identified and techniques developed, a long-term management plans will be drawn up in concert with appropriate state resource management agencies and in compliance with regulations and policies of the Alaska Board of Fisheries. The plans will include permitting procedures, reseeding schedules, procedures for expanding to new areas and harvesting schedules for each species as appropriate.

The purpose of the plans is to help ensure that the beaches are managed in a manner that will sustain production over the long term.

5. Location

The hatchery and nursery work will be carried out at the Qutekcak Shellfish Hatchery/Nursery in Seward. Growout operations and sampling will occur in the area around the village of Tatitlek in Prince William Sound and in the Port Graham/Nanwalek area in Lower Cook Inlet. Pathology work will be conducted in Anchorage and Juneau. PSP sampling will occur at the DEC lab in Palmer. Data Analysis and project oversight will be conducted at CRRC offices in Anchorage and Moose Pass.

6. Technical support

Technical support for pathology, genetic, biometric services and project oversight will be provided by DFG.

7. Contracts

This will be a cooperative project conducted jointly by the Alaska Department of Fish and Game (ADFG), Chugach Regional Resource Commission (CRRC), and Qutekcak Native Tribe. Contractual services will be required for project review and oversight.

C. SCHEDULE

Schedule of activities for Tatitlek/Port Graham/Nanwalek Clam Restoration project (FY 1995 - 2000)

Date	Activity
2/95 - 3/95	identify and certify broostock for use in hatchery
3/95 - 4/95	collect broodstock and transport to hatchery
4/95 - 6/95	develop techniques to mature and spawn broodstock
5/95 - 3/96	develop techniques for producing 5 mm seed
12/95 - 4/96	transfer 5 mm seed to nursery
4/1/96	submit annual project report for FY 95
12/95 - 6/96	develop techniques for producing 10 mm to 15 mm seed for growout
2/95 - 4/95	collect information on past and current location, history, abundance, etc., of clam beds near Tatitlek, Port Graham and Nanwalek
2/95 - 4/95	obtain permits to sample areas near villages for current clam abundance and identification of intertidal areas for seeding
5/95 - 9/95	sample areas near villages for current clam abundance and identification of intertidal areas for seeding
8/95 - 4/96	identify areas for seeding experiments; obtain permits - also obtain permits for hanging culture tests at Port Graham.
5/96 - 11/96	initiate beach seeding and hanging culture experiments; set up monitoring schedule
12/96 - 2/97	seek permits for additional beach work
3/96 - 9/96	continue with broodstock collection, maturation and spawning
6/96 - 4/97	continue and expand seed production in hatchery and nursery
8/96 - 4/97	conduct artificial substrate experiments in nursery
4/1/97	submit annual project report for FY 96

4/97 - 9/97	initiate growth tests using various substrate mixtures in trays on intertidal beaches
4/97 - 9/97	initiate tests on other beach growout strategies
4/97 - 11/97	continue beach seeding and hanging culture experiments
12/97 - 3/98	analyze growout data; adjust testing as necessary
4/1/98	submit annual project report for FY 97
2/98 - 2/99	continue with hatchery and nursery seed production; refine production techniques
3/98 - 11/98	continue with beach and hanging culture growout development
1/98 - 4/98	begin to identify and obtain permits for permanent subsistence clam growout sites
4/98 - 11/98	seed in permanent growout sites; develop harvest management plan
4/1/99	submit annual project report for FY 98
2/99 - 2/00	continue with hatchery and nursery seed production; continue to refine production techniques
1/99 - 5/99	complete identification of permanent subsistence growout sites; obtain permits
4/99 - 10/99	complete seeding of permanent growout sites; expand harvest management plan
4/99 - 11/99	continue with tray, hanging culture and substrate mixtures growout tests
4/1/00	submit annual project report for FY 99

D. EXISTING AGENCY PROGRAMS

The framework for enhancing aquatic organisms is in place for salmonids in Alaska and will be the basis for similar activities with shellfish. Since the framework is not in place for private enhancement work, ADFG will have to be the lead agency and supervisor of this through contractual arrangements with CRRC.

ADF&G presently, provides oversight for the Hatchery and Nursery System through its Mariculture Coordinator (James O. Cochran). Shellfish Transport Permits are reviewed by all Departments of ADFG and rely on recommendations of the Pathology Section (Dr. Ted Meyers) and Genetics Section (Dr. Jim Seeb).

Review of efforts involving beach alteration or manipulation will involve interagency cooperation from ADFG, ADNR, and local upland owners. The framework for this activity is outlined in the Alaska Coastal Management Plan (ACMP) with a consistency review.

PSP samples will be analyzed by the DEC Palmer Lab (Dick Barret)

A final harvest management plan will be developed in concert with the Regional Shellfish Biologist.

E. ENVIRONMENTAL COMPLIANCE/PERMIT/ COORDINATION STATUS

The project will require an Environmental Assessment as part of the National Environmental Protection Act. (NEPA). This work will be initiated in year one of the project and be completed before any enhancement work is attempted. The lead agency is the National Oceanic and Atmospheric Administration (NOAA) under the Department of Commerce represented by Mr. Byron Morris.

Permits for operating the Shellfish Hatchery and Nursery are issued by ADFG and are current through 1996. Broodstock certification is complete for Tatitlek broodstock and will be requested for Port Graham/Nanwalek. DFG will oversee all transport permits.

Growout sites and activities will be coordinated by the Department of Governmental Coordination (DGC) and the Alaska Coastal Management Program review process. Initial work will be conducted under site suitability permits issued by DNR and DFG.

Long-term transport and seeding permits will be issued by DFG and DNR.

F. PERFORMANCE MONITORING

The performance of each objective outlined in the project description will be reviewed at the completion of each task outlined in the schedule in Part C. An annual report will be submitted by April 1 of each year and be reviewed prior to a DPD for a succeeding year and continuation of the project.

G. COORDINATION OF INTEGRATED RESEARCH EFFORT

The Clam restoration Project (95131) will require little coordination with other FY 95 projects. Interagency coordination will be necessary for the permitting and review process as discussed in Part D.

Previous work done and techniques utilized in the State/Federal Resource Damage Assessment project Fish/Shellfish Study 13 **Effects of Hydrocarbons on Bivalves** will be used as baseline data for beach assessment methods.

H. PUBLIC PROCESS

The project was developed through review of the impact assessment on the Exxon Valdez Oil Spill (EVOS) by the Chugach Regional Resource Commission (CRRC) in native villages in the Chugach region. Local villages requested assistance in reestablishing confidence in the subsistence harvesting of local Littleneck and Butter Clam populations. The CRRC board of directors endorsed the clam enhancement project at its 1994 annual meeting.

The project has gone through thorough public review as a result of the Exxon Valdez Oil Spill project proposal review process. Additional comment will be sought from local villages upon the completion of the Detailed Project Description. The ACMP process will allow the general public to comment of specific activities.

The residents of Tatitlek and Port Graham/Nanwalek will be interviewed on local knowledge of clam and shellfish resources.

I. PERSONNEL QUALIFICATIONS

PATRICIA BROWN SCHWALENBERG
6450 Andover Drive
Anchorage, Alaska 99516
907 345-2187

Employment:
June 1994 to Present: Executive Director Chugach Regional Resource Commission. Responsible for Natural Resource and Fisheries development for the seven native villages in the Chugach region. This includes administering office staff, village projects in mariculture and fisheries and protecting and enhancing subsistence opportunities.

October 92 to June 1994: Office Manager Bering Sea Commercial Fisheries Development Foundation. Responsibilities included maintaining all management systems for the organization including financial, personnel, property and central filing. Responsible for financial management and accountability of all grants of the Foundation payroll, taxes and financial statements, organizing and overseeing Foundation public relations.

October 1987 to June 1992 Society Administrator /Public Relations Director. Native American Fish and Wildlife Society. Assisted in the establishment and development of a national office for the Native American Fish and Wildlife Society. Implemented personnel policies and procedures, property management policies, record and financial management systems. Implemented strategies to obtain goals and objectives of the society.

Education:

Business Administration University of Alaska-Anchorage (ongoing).
Certification of Completion. 1977 Humboldt Institute

DAVID DAISY
3936 Westwood Drive

Anchorage, Alaska 99517
(907) 243-8544

Employment:
October, 1987-Present: Fisheries consultant with emphasis on aquaculture. Contractor to Chugach Regional Resource Commission developing salmonid hatcheries at Port Graham and Nanwalek and oyster mariculture operations at Tatitlek and Chenega Bay. Oversight and management of these projects involves grant writing and financial and activity reporting to granting agencies.

February, 1979 to October, 1987: Regional Program Manager, Region II, Fisheries Rehabilitation, Enhancement and Development (FRED) Division, Alaska Department of Fish & Game. Under general supervision of the FRED Director, responsible for the planning, development, operation and control of the State's salmonid enhancement and rehabilitation program in Region II which encompasses all of Alaska except Southeast.

November, 1977 to February, 1979: Regional Project Manager: Cook Inlet - Prince William Sound, Fisheries Rehabilitation, Enhancement and Development (FRED) Division, Alaska Department of Fish & Game. Under supervision of the Regional Program Manager responsible for the implementation and control of salmon enhancement research and development projects in the Prince William Sound and Cook Inlet areas. Assisted the Regional Program Manager in hatchery development planning.

April, 1968 to February, 1979: Management Biologist, Commercial Fisheries Division, Alaska Department of Fish and Game. Ketchikan, Cook Inlet and Upper Cook Inlet. Oversaw various management projects (weirs, counting towers, fisheries sampling) determined and set fishing periods for herring and salmon and responsible for meeting escapement and recruitment goals.

Education:
B.S. Fisheries, University of Massachusetts, Amherst, 1965.

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Employment:
1987- Present: Hatchery Manager Cook Inlet Aquaculture Association. Manage Trail Lakes Hatchery which produces 12 million sockeye salmon fry and 2 million sockeye salmon smolts annually.

1988-Present: Consultant for Shellfish Culture. Clients include:
Chugach Regional Resource Commission- develop oyster farms at Chenega Bay and Tatitlek. Included permitting, farm design, training and marketing.
Qutekcak Native Tribe- Design and develop first shellfish hatchery in Alaska.

1983-1987 Assistant Manager. Alaska Department of Fish and Game.
Assistant manager at Main Bay (Chum and Sockeye Salmon) and Cannery Creek (Pink Salmon) Hatcheries in Prince William Sound.

Education:
M.B.A. California Coast University- Thesis under review
B.S. Biological Sciences. University of Maryland, 1980

J. BUDGET

The following is a budget summary for the Nanwalek/Port Graham/Tatitlek Clam Restoration project for FY 95 through FY 99. Budgets for FY 96 and beyond may change as results from the first year are applied and as other villages, such as Chenega Bay, are added to the project.

Line Item	Estimated Cost				
	FY 95	FY 96	FY 97	FY 98	FY 99
Personnel	$21.5	$66.4	$68.7	$71.1	$73.6
Travel	$4.2	$7.2	$7.4	$7.9	$8.0
Contractual	$135.0	$103.0	$106.5	$110.3	$114.2
Commodities	$5.5	$27.0	$28.0	$28.9	$30.0
Equipment	$21.0	$15.0	$15.0	$15.0	$15.0
Indirect	$21.1	$26.2	$27.1	$28.1	$29.0
Totals	$ 208.3	$ 244.8	$ 252.7	$ 261.3	$ 269.8

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Appendix C

April 29, 1994

Mr. Jeff Hetrick
President, ASGA
P.O. Box 7
Moose Pass, AK 99631

Dear Jeff:

Thank you for taking the time to bring your thoughts regarding the proposed shellfish genetics policy to my attention. I appreciate that you would like to see the policy developed rapidly. You must understand, however, that the little knowledge there is available upon which to base such a policy is incomplete and complex (in contrast with information available on Pacific salmon, for example).

My staff has virtually no data on the population genetics of bivalves in Alaska. In addition, the published data on bivalves from other areas is in disagreement. Many studies do suggest that unique stocks of shellfish subdivide along short sections of beach. If a genetics policy was written to protect wild stocks without gaining more knowledge of the structure of Alaskan stocks, then that policy would likely end up being very restrictive. We are faced with a tough-to-reconcile dichotomy: We want to restrict transfers in order to protect wild stocks, yet we want to promote a policy that will facilitate the development of mariculture.

Superimposed over this dichotomy is the fact that I have limited staff assigned to genetics policy issues. As important as the finfish and shellfish genetics policies are, I am not willing to redirect them on the three-month schedule you suggest in your letter.

Let me relay the progress we have made and the direction I see the shellfish portion of the policy going. I fully understand the frustrations you and the industry must feel in not knowing what the final policy will be.

First, after the one meeting that you had with Mr. Jim Cochran and Dr. Jim Seeb last year, we did bring the University of Alaska Fairbanks (UAF) Marine Advisory Program into genetics policy discussions. Staff has spoken with and met with Mr. Ray RaLonde a number of times. Dr. Seeb met with Mr. RaLonde and reviewed his theories on larval drift which were presented to an international panel of mariculturists in Homer last August. Mr.

Ralonde's paper, Shellfish Aquaculture in Alaska and the Potential of Interaction with Wild Species, was well received, and he has recently submitted a final draft for review through the Sea Grant process.

We are enthused about--this document because, depending on the reviews, it appears to offer important insight upon which to base a *meaningful* genetics policy. I encourage you to ask Mr: RaLonde for a copy.

Based upon this preliminary *information,* staff believe it will be possible to divide the state into three regions, corresponding to our management regions I (Southeast), II (Prince William Sound to Cook Inlet), and IV (Kodiak and the Aleutians), for genetics and mariculture purposes using Mr. RaLonde's larval drift model. Transports between regions for purpose of release will be prohibited. Transports within a region will be approved on a caseby-case basis following appropriate staff review. Transports within regions, like the one you describe in paragraph two of your letter, will be approved within the guidelines of hatchery quarantine, though two transport permits will still be required. one permit allows acquisition and transport of a stock to the hatchery. The second allows transport of a given number of progeny from that stock to a specific location. This second permit covers a new generation and allows the department to review specific management, pathology, and genetic *concerns* after the species has been through the hatchery phase.

The point is that we are using the above guidelines for shellfish transport recommendations right now, and you can see where your projects fit within the framework the department is constructing. We are waiting for the peer review of Mr. RaLonde's paper, and if that is acceptable, plan to use it for the basis of a shellfish genetics policy. An operational Maricultu%re Technical Center is still years away with possible operation in 1996. Whereas the process for developing a shellfish policy seems arduous, I believe such a completed policy will be in place when needed by the industry.

If you have additional questions or concerns please contact Mr. RaLonde about his paper and Dr. Seeb for his interpretation of this paper. Dr. Seeb can be reached at the department's Anchorage office at 333 Raspberry Road, or at 267-2385. Please let me know if I can be of further assistance.

Sincerely,

Carl L. Rosier Commissioner

bcc: Bob Burkett
Jim Cochran
Jeff Koenings
Ray RaLonde
Jim Seeb

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