Exxon Valdez Oil Spill
Restoration Project Annual Report

Clam Restoration Project

Restoration Project 96131
Annual Report

This annual report has been prepared for peer review as part of the *Exxon Valdez* Oil Spill Trustee Council restoration program for the purpose of assessing project progress. Peer review comments have not been addressed in this annual report.

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Clam Restoration Project

Restoration Project 96131
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Study History: The project effort was initiated under Restoration Project 96131, the subject of this annual report. This is the second year of a scheduled five year project.

Abstract: Cost effective procedures for establishing safe, easily accessible subsistence clam populations near Native villages in the oil spill region will be established. The Qutekcak hatchery in Seward will annually provide about 800,000 juvenile littleneck clams and cockles. Historical information, local and agency expertise, and research will be used to identify areas to seed and method. Total seeded area during project will not exceed 5 hectares. Follow-up research on success of seeding will be conducted. Development work will be confined to areas near the Native villages of Eyak, Tatitlek, Nanwalek and Port Graham. Other Native villages in the oil spill region interested in becoming part of the project will only have preliminary beach survey work done.

Key Words: Beach survey, clam growout areas, clam restoration, *Clinocardium nuttalli*, cockles, *Exxon Valdez* oil spill, Eyak, littleneck clam Nanwalek, Port Graham, *Protothaca staminea*, shellfish hatchery, shellfish nursery, Tatitlek.

Project Data: (will be addressed in the final report)

Citation:

Daisy, D., J. Hetrick, K.M. Brooks, and J. Agosti. 1997. Clam restoration project, *Exxon Valdez* Oil Spill Restoration Project Annual Report (Restoration Project 96131), Alaska Department of Fish and Game, Habitat and Restoration Division, Anchorage, Alaska

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Executive Summary

Clams were once a major subsistence resource in the Native communities of Nanwalek and Port Graham in lower Cook Inlet and Tatitlek in Prince William Sound. Local clam populations have been decreasing in recent years and their contribution to the subsistence harvest has been greatly reduced. There are probably 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 many clams were not directly impacted by the oil, 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 goal is to provide the project villages with safe, reliable, easily accessible sources of clams for subsistence use. Project objectives for 1996, the second year of the project, were to continue to improve hatchery production techniques for littleneck clams (*Protothaca staminea*), develop hatchery culture procedures for cockles (*Clinocardium nuttalli*), continue work with the nursery pond near the hatchery as well as experiment with a tidally driven fluidized upwelling nursery system (FLUPSY), growout studies on beaches near the project villages, test predator control coverings on razor clam beaches near Eyak, conduct baseline beach surveys on beaches near the villages of Chenega Bay in Prince William Sound and Ouzinkie on Kodiak Island, and initiate PSP testing of the designated subsistence beaches. The following is a rundown of the activities under each objective.

Hatchery: The Qutekcak Shellfish Hatchery located on the Institute of Marine Science grounds in Seward has been in operation since October 1993. This is a small, temporary facility intended for use until the State of Alaska's Mariculture Technical Center/Hatchery Complex is built. The Qutekcak Hatchery will be leasing the hatchery portion of the State facility. Anticipated occupancy of the new hatchery is May, 1997.

The current hatchery has produced several small batches of littleneck clam and oyster seed however, survival through metamorphosis has been poor. An experienced hatchery manager was brought into the facility in FY 96 to ensure the proper culture procedures were in place and to improve seed production. The hatchery manager did initiate new protocols for the hatchery to improve algal quality and production and increase the survival of shellfish spawn through metamorphosis. Unfortunately these changes did not materially improve spawn survival.

The continued poor results led the hatchery to investigate both the seawater quality and broodstock health and condition. These investigations are ongoing, but initial results indicate that the hatchery has a seawater quality problem. In addition, the quality of littleneck clam female gametes appears to be highly variable over time.

Analysis of heavy metals in the hatchery seawater showed nothing unusual although there may be deficiencies in some trace elements. Trace metal supplementation will be tested in upcoming growth trials. Larvae from various rearing trials have been submitted for histopathological analysis to see if any problems can be found. The results are still pending.

One rearing trial has shown positive results. Larvae spawned in seawater with prolonged (30 minute) activated carbon filtering and fed with algae grown in water with the same filtering survived at much higher levels than other rearing trials. This points to a potential problem with organics in the water as well as a potential cure. Results from the histopathological analyses may shed more light on this.

The cause of the variability in female clam gametogenesis is still being investigated. It could be that as the broodstock becomes more acclimated to the hatchery environment gametogenesis will improve. The hatchery has established a health management program utilizing the services of a shellfish pathology lab. This program should help provide information on any unique gametogenic requirements for the hatchery broodstock as well as information on the cause of poor larval development.

The big unknown here is whether or not the water quality problems will be found in the new facility. The first order of business after moving to the new facility will be to answer this question.

Work under a contract with Aquatic Environmental Sciences, Port Townsend, WA, to develop spawning techniques for the cockle is ongoing. To date the contractor has been unable to produce any fertilized eggs using an array of standard spawning induci Unfortunately, there is nothing in the literature describing successful methods of inducing spawning in this animal. It should be noted that similar difficulties have been experienced in the initial attempts to spawn a variety of shellfish. Work will continue in 1997 using the standard as well as some novel spawning inducing techniques.

The cockle is a popular subsistence species. Its high value warrants additional research to produce a successful method to spawn them.

Nursery Pond: The hatchery utilizes a 1 million liter pond to culture algae for its pre-nursery. The 30m by 37m pond is 5 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 can controlled to allow for adequate flushing yet maintain the ambient air temperature. An air compressor is used to aerate and circulate water in the pond to eliminate stratification and increase phytoplankton production. Fertilizer solutions are added daily to increase the intensity and duration of phytoplankton blooms. Physical parameters of the seawater including temperature, salinity, pH, and redox potential are monitored and water samples are collected at various intervals for nutrient level analysis. Identification of the most abundant phytoplankters as well as secchi disk readings are also made. The food laden pond water is pumped through dense trays of small (1.5-2 mm) bivalve spat.

Phytoplankton production in the seawater pond increased markedly during the summer and fall of 1996 due to flow management and changes in the nutrient medium and its use. A bloom of unusual duration was initiated and maintained for three months while also maintaining a favorable mix of algal species. Centric diatoms such as *Chaetoceros sp., Skeletonema sp. or Thalassiosira sp.* dominated the blooms which also included unknown phytoflagellates. Secchi disk readings averaged one half meter and cell counts ranged up to 250,000 cells per milliliter.

Restricting flow prior to the bloom or during a decline diminished cell flushing while increasing flow during peak periods sustained a longer bloom. This may be due to steady trace nutrient addition and limited pH buffering. Improved fertilization of the pond accounts for most of the increased phytoplankton growth. Switching the nutrient medium from solely an organic nitrogen source (urea) to one composed of dual inorganic nitrogen, phosphate, silicate, and iron salts at appropriate nutrient ratios made the difference. A lower nutrient concentration in the pond water was also used which kept costs low. The nutrient medium needs still further improvement to remedy some apparent trace mineral deficiencies in the local seawater. Carbon dioxide was also limiting as indicated by pH readings above 8.7 and will be added in trials during next summer's blooms. Much of the pond's production potential still has yet to be tapped.

One hundred micron bag filtration of recirculating pond water succeeded in removing only some of the high levels of organic particulate that blocked light penetration and some of the high levels of phytoplankton grazers (i.e. amphipods and copepods) which developed. Better methods will be pursued to reduce these problems. Plumbing the pond-side upwellers so that feces produced by the spat is shunted to the drain should help reduce the particulate levels.

Oyster spat in upwellers recirculated with pond seawater grew well during the three month bloom. A floating upweller was constructed, as planned, during July and immediately put into service. It was designed to be small and light enough so that the IMS crane can lift it out of the pond whenever draining or storage is necessary. Growth of spat in the pond-side upwellers vs. floating upweller were identical so no additional floating upwellers are planned. As production increases land-based upwellers will be added.

<u>Tidal FLUPSY</u>: A tidal fluidized upwelling system (tidal FLUPSY) was designed and constructed to test its potential as a remote nursery system for the EVOS clam project. 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 to remote nursery systems is that the cost of pumping water at a remote location in Alaska make them impractical.

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 which forces large quantities of water (and plankton) to flow through upwelling chambers containing juvenile bivalves.

An aluminum tidal FLUPSY identical in size and dimension to the system described in Baldwin, et al. "Construction and Operation of a Tidal-Powered Upweller Nursery System" 1995, South Carolina Sea Grant Consortium, was built and set up in late August in the Tatitlek Narrows near the village of Tatitlek. Since there was no clam seed available, the unit was seeded with 50,000 oyster seed with an average length of 15 millimeters. The seed were removed for the winter in late November. They grew from 15millimeters to 18 millimeters for a 20% increase in length. Considering that the seed attained this growth during the time that water temperatures were cooling and plankton production was shutting down, that is a satisfactory level of growth.

In FY 97 the tidal FLUPSY will be tested for the entire growing season using both oyster and littleneck clam seed.

Growout Studies: Growout studies of the littleneck clam were initiated on beaches near the Tatitlek, Port Graham and Nanwalek villages. These beaches were identified during the FY 95 beach surveys. About 8,100 clam seed per village were used in three separate tests. The same tests are being conducted at each village. One test 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 foot tide level, the "zero" tide level (mean lower low water) and the +1.5 foot tide level. These clams are being used for detailed growth and mortality studies. The remaining clams were divided into 12 subsamples of about 600 clams each. Six of the subsamples were seeded at the +1.5 foot tide level, three under netted "car cover" and three uncovered. The remaining six subsamples were seeded at the -1.5 foot tide level in a similar arrangement.

Clams in the clam bags are being measured every three months for growth and mortality. The netted and unnetted treatments will be examined annually during the summer for the presence and type of predators. A small subsample will be removed, measured and immediately returned. The sediment sampling initiated during the FY 95 surveys will be continued.

The growout study objective is to determine if clams in seeded beaches will reach harvest size in a short enough time frame and in reasonable enough numbers to make a seeding program worthwhile. This initial lot of clams was placed on the beaches in July. It is too early to tell much from the sampling that has been conducted to date, however, growth to date is good and overwinter survival has been excellent. A more in-depth analysis of the situation can be made after the 1997 growing season.

Eyak Razor Clam Studies: FY 96 was the first year of an effort to restore razor clam populations near the village of Eyak for subsistence use. A literature search, interviews with tribal members and beach surveys were conducted to determine the best approach.

Initially, it was believed that there were some number of sub-legal (too small for legal harvest) clams on nearby beaches which would grow to harvestable size if predation could be reduced. However, this turned out not to be the case as very few clams of any size were found during the beach surveys. The clams that were found were placed in a 4 meter by 3 meter predator control study area and covered with 12 millimeter mesh netting. The netting was torn off during a severe winter storm so no information from this study was collected.

Future work on razor clams under this project will continue with local beach surveys, observations on gamete development, spawning activity and recruitment, predator control and growth and mortality studies and exploring the possibility of seeding local beaches with either hatchery produced razor clam seed or seed collected from the wild.

Baseline Beach Surveys: Baseline shellfish surveys were conducted at traditional harvest beaches near the Ouzinkie and Chenega Bay villages to develop an understanding of the existing shellfish resources and the potential for enhancement. In addition, the survey was designed to provide an insight into the preferred environments and recruitment of valuable clam species as well as their growth and age at recruitment to harvest size. These surveys were conducted between June 29 and July 2, 1996. It is hoped that these initial surveys will allow for the rapid development of a clam enhancement program for these villages if the growout studies indicate that enhancement is feasible.

Using local knowledge a single beach area was identified for each village. A beach assessment, substrate characterization, gross water analysis and shellfish population estimates were collected for each beach area. Neither beach area had significant populations of clams, however, the Chenega Bay site was rated as "good" and the Ouzinkie site was rated as "excellent" as areas suitable for littleneck clam and cockle enhancement.

PSP Testing: Because of the lack of shellfish in the study areas no PSP sampling was conducted in 1996. Some sampling will be conducted in 1997. Mussels were placed in the study areas when the clams were seeded in 1996. The main intent was to use them for PSP studies. Unfortunately, none of these mussels survived.

If the 1997 growth and mortality analyses show promise for clam enhancement, a PSP program will need to be initiated. There should be sufficient clams under enhancement after 1997 to warrant initiating a sampling program.

Introduction

The purpose of this project is to develop cost effective procedures for establishing managed populations of clams in areas that are readily accessible from Native villages in the oil spill region. These clams will be used as a source for subsistence food to replace the natural clam resource that has been lost, damaged or depleted. The villages of Port Graham, Nanwalek, Tatitlek and Eyak will take part in the development process.

Clams were once an important subsistence food in the Native villages. 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. 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 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 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 re-establish local clam populations as a subsistence resource for the Native 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.

This program was initiated in FY 95 as a demonstration project. The first year objectives were to decide what species of clams will be used for the project, determine the potential of the Qutekcak Shellfish Hatchery to produce seed for the project and develop the system for identifying the growout areas near the villages of Port Graham/Nanwalek and Tatitlek.

After consultation with the Native villagers, experts in clam production techniques and a literature search, littleneck clams (*Protothaca staminea*) and cockles (*Clinocardium nuttalli*) were selected as the species that will be used in the restoration effort. The butter clam *(Saxidomus giganteus)*, a popular species with the Native villagers, was rejected because of its slow growth characteristics and propensity to retain the Paralytic Shellfish Poison toxin for extended periods.

Littleneck clam broodsource for both Port Graham/Nanwalek and Tatitlek have been cleared for use in the Qutekcak Shellfish Hatchery in Seward. A Nanwalek/Port Graham source of cockle broodstock has also been cleared for hatchery use, but clearance for a Tatitlek cockle broodstock is being withheld pending further analysis by the state fish pathologist.

As part of the study 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 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. Beach surveys were then conducted near Port Graham, Nanwalek and Tatitlek. Several sites were identified as suitable for use in this project.

The hatchery produced several small batches of littleneck clam seed. However, survival through metamorphosis was poor. An experienced shellfish hatchery manager was brought into the hatchery to ensure that the proper culture procedures were in place and to improve larval health and survival. There appears to be a seawater quality problem in the hatchery. Whether this is caused by something in the hatchery, i.e. the plumbing system, or something in the water supply is uncertain. A heavy duty activated carbon filtering system has been installed which seems to be clearing the problem up.

There is also a problem with female gamete viability in the littleneck clam broodstock during most of the year. It is unknown whether this is something that the hatchery is causing or if it is an artifact of the behavior of the species in the wild. A health management program is being initiated in the hatchery to help resolve this problem as well as help with improving larval survival rates.

Dr. Ken Brooks of Aquatic Environmental Sciences in Washington state has been contracted to develop the protocols for the hatchery/nursery production of cockles. A tidally driven fluidized upwelling nursery system (tidal FLUPSY) was set up near Tatitlek to test its potential for nursery production. Test plots on beaches near Tatitlek, Nanwalek and Port Graham have been seeded with littleneck clams for growth, mortality and predator control studies, and predator control coverings are being tested on razor clam beaches near Eyak. Baseline beach surveys were conducted on beaches near the villages of Chenega Bay in Prince William Sound and Ouzinkie on Kodiak Island.

The project anticipates moving into the new hatchery facility now being built by the state sometime in May, 1997. The hatchery will be leased and operated by the Qutekcak Native Tribe who will contract with the project to conduct the hatchery and nursery work. This new facility will greatly enhance operations and allow the project to increase production as well as expand into cockles. The facility will have increased algae production capabilities which, in addition to permitting increased seed production, will allow the project to expand investigations on pre- nursery production at the hatchery. The shellfish hatchery manager brought into the hatchery in FY 96 will remain on staff for at least the duration of this project to complete and equip the new hatchery bringing it online as soon as possible, continue training the hatchery staff and ensure that proper operational procedures are in place and functioning. The first order of business will be to insure that the process seawater is of sufficient quality.

Because very little culture or enhancement work has been done previously with littleneck clams or cockles, this project is breaking a lot of new ground. This is perhaps good news from the standpoint of contributing to the knowledge pool, but it is slowing the project down. The hatchery, nursery and growout procedures that are being developed for this project must be adapted from previous work on other species. The growout work will first require the development of a data base on growth and mortality for both species to help determine the best enhancement approach.

Objectives

1. Hatchery Processes- Develop reliable, cost effective hatchery techniques for the littleneck clam (*Protothaca staminea*) and the cockle (*Clinocardium nutalli*). Produce a 5mm seed in the hatchery within 19 weeks after spawning.

2. Nursery- Develop cost effective, reliable techniques to grow 5mm hatchery seed to an out-planting size of 10mm - 15mm within 12 weeks.

3. Growout - Describe current local clam populations through interviews and resource assessments. Locate sites, develop reliable, cost effective growout techniques, and evaluate the efficacy of proposed methods. Develop permanent subsistence beaches.

4. Safety Testing - Set up a program for testing clams from the subsistence beaches for the presence of paralytic shellfish poisoning (PSP).

Methods

Hatchery: The Qutekcak Shellfish Hatchery located on the Institute of Marine Science grounds in Seward has been in operation since October 1993. During this time the hatchery was designed and assembled and has evolved into a small pilot-scale operation. The staff has successfully set larvae of the Pacific oyster (*Crossastrea gigas*) and raised them to 15 mm for the aquatic farm industry. In addition, the hatchery has successfully conditioned, spawned, set and raised the native littleneck (*Protothaca staminea*) to 10mm. As part of this project the hatchery will also attempt to produce cockle (*Clinocardium nutalli*) seed.

Although a great deal had been accomplished at the hatchery, operations and procedures needed to become more reliable and efficient for the hatchery program to succeed over the long term. Total survival and production were low. To address this problem an experienced shellfish culturist with twelve years of practical hatchery experience was brought on as hatchery manager(see attached resume). He will remain on staff for the duration of this project at least and will be responsible for developing operational procedures and policies, finishing and equipping the new hatchery, training staff and making hatchery operations more successful and efficient.

In FY 96 extensive larval deformity and mortality in both littleneck clams and oysters, plus inconsistent algal growth despite many quality controls, were experienced. In addition a large percentage of broodstock clams also failed to undergo gametogenesis. It was thought that these problems could be caused by poor seawater quality and water analyses were conducted to try to determine the cause. Histology work was also conducted on the broodstock and larvae. In addition, several tests in treating the seawater were conducted to see if spawning losses could be alleviated or reduced.

The testing and histology work are still ongoing. It appears however, that an extensive activated carbon filtering system will greatly reduce, spawning losses. A rudimentary carbon filtering system has been installed in the existing hatchery. If the new hatchery also has the same seawater problems an extensive carbon filtering system will be installed there.

The present small facility was intended to operate for a limited period of time until a new and permanent hatchery could be built. Construction on the new facility began in April, 1996 with a now anticipated completion date of early May, 1997. The new facility will be owned by the state and leased to the Qutekcak Native Tribe. It is anticipated that the project will move into the new facility as soon as it is ready for occupancy.

With all the activities planned for the hatchery this year it was not reasonable to attempt to develop cockle seedstock there as well. However, postponing cockle seedstock development would set the project back too far. In order to keep cockle development on schedule, Dr. Ken Brooks of Aquatic Environmental Sciences in Port Townsend, Washington was contracted to develop the techniques and procedures for producing cockle seedstock. This technology will then be transferred into the hatchery.

Nursery: Algal 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 can controlled to allow for adequate flushing yet maintain the ambient air temperature. An air pump can be used to bubble and circulate water in the pond for adequate mixing and prohibit stratification. Water temperature and salinity along with nitrogen, phosphorous and silica levels can be checked on a regular basis.

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 can be manipulated to produce 250,000 cells/ml for feeding the shellfish.

Although the nursery pond has produced 10+ mm seed, the results have been erratic. It is unclear at this point whether or not the pond can produce seedstock in an reliable and cost efficient manner. Staff from the Institute of Marine Science along with the hatchery staff (including the hatchery technician) will work on the pond to see if production can be improved.

Remote Nursery Systems: 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 to remote nursery systems is that the cost of pumping water at a remote location in Alaska made them impractical.

Recently, work conducted under the South Carolina Sea Grant program lead to the development of a tidally driven remote nursery system. This system, called a Tidally Driven Floating Upwelling System (tidal FLUPSY) uses the strength of tidal currents to force sea water, with its accompanying load of phytoplankton, through cages containing small clams. The system appears to work quite well and is easy to maintain. Because the system is driven by a natural energy source readily available in Alaska, it appears to have great promise here.

A prototype FLUPSY was built and tested in Tatitlek Narrows where it was subjected to various tidal current speeds in areas that offer fairly good protection from the weather.

Growout: Baseline Data: Baseline surveys of tidelands near the villages of Chenega Bay and Ouzinkie were conducted last summer. The survey was undertaken to develop an understanding of existing shellfish resources near the villages and their potential for enhancement. If this project proves viable information from these surveys will allow clam enhancement activities to be initiated within a short period of time.

Growout Techniques: Seeding Intertidal Areas: In 1995 a series of baseline surveys were 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 selected. The Nanwalek beach is representative of moderate energy beaches, the Tatitlek beach is representative of open gravel beaches with good tidal exchange and the Port Graham beach is representative of protected areas. The Port Graham and Nanwalek beaches are located within two miles of one another and were tended by the same crew.

The intent of the beach growout work is to establish similar growth and mortality, and predator control studies on each of the three beaches and compare the results. This information will be used to determine the kind of clam production, for each of the two species, that can be expected from each beach type, and what predator control measures seem to work best on each beach.

The seeding study involved the placement of littleneck clam seed clams (10 mm to 15 mm valve length) in a replicate, blocked design which will examine growth and mortality as a function of tidal height and in the presence or absence of protective predator exclusion devices. A uniform seeding density of 30 seed clams per square foot was utilized.

Growth and mortality of Caged Clams: One hundred seed clams were placed in "Norplex™" clam bags for a detailed growth and mortality study. The valve lengths of all clams placed in there bags were measured to the nearest 0.01 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 can be used as the mean lengths of the clams seeded into other parts of the study.

Clam bag ends were secured with electrical ties on one end and a 1" piece of split PVC pipe on the other end. Each bag received a shovelfull of sieved (1/2" sieve) gravel. Bags were then nestled into the substrate to a minimum depth of 6". The top surfaces of each bag extended a minimum of 1" above the substrate. Each bag was secured to a piece of 1/2" rebar driven into the substrate to a minimum depth of 18" or when hitting bedrock. Identical study lay-outs were used at all three Villages.

Bags are being retrieved at three month intervals and all contents removed from the bags. The number of surviving clams, and the number of empty clam shells, are determined. The valve length of each clam is measured and recorded. Fouling organisms are removed from the bags and clams replaced in the bags with a shovelfull of sieved (1/2") gravel. Clam bags are then carefully nestled back in the sediment.

Clam enhancement evaluation: A minimum of 4 feet is required between each treatment block. This will provide access without disturbing adjacent plots. Car-cover netting was precut to a dimension of 7'x 5'. It was secured in a trench an all four aides of each 1.0 meter by 2.0 meter plot. Each plot was marked with four pieces of PVC pipe driven into the substrate at each corner. Each piece of PVC pipe had the plot number written on it (i.e. A +1.5). After all plots were seeded, the tidal elevation of the center of each plot or bag was measured against a known tidal elevation. Sediment samples were taken adjacent to each set of netted, un-netted and bagged samples for analysis of total volatile solids and sediment grain size. In addition to treatment samples, control stations are sampled annually and processed in a similar manner.

Seeding: All large (>10.0 cm diameter) rock and cobble was removed from the area to be seeded. The area was the dug to remove all clams larger than 1.0 cm. The valve length of clams removed were measured and recorded. Three random samples of seed for each beach were weighed and counted to obtain an average weight per clam. A total clam weight equivalent to 600 clams were seeded into each 1.0 x 2.0 meter area as the tide floods. Clams were seeded through the car cover netting.

Maintenance: Village culturists were set up to monitor these studies on a weekly basis, or as tidal conditions permit. All rips in the netting are being repaired and all predators removed.

Badly damaged nets are being replaced.

Data recording: Clams in the enhancement evaluation will be examined annually during the 1997, 1998 and 1999 field work. Clam plots will be evaluated by noting the presence of predators, and covering the netted plots and collecting three randomly selected 0.1 M^2 samples from each plot. The clams in the samples will be counted, measured in-situ and immediately replaced at a shallow depth with the substrate taken from the quadrat. New netting will then be installed.

A sediment sample was collected from the top four inches of the substrate at randomly selected stations along each of the orthogonal transacts. The RPD was measured at each of these points and a second sediment sample retained for total volatile solids analysis. The substrate was be characterized to include the following:

A. Substrate color
B. Presence of attached macroalgae
C. Presence of predators
D. Evidence of excessive littoral drift or log damage
E. Oily sheen
F. Odor (hydrogen sulfide, ammonia or petroleum)
G. Suitability for specific culture techniques.
H. A photographic record of the site will be made to include at least 20 pictures describing the general area, shoreline, fetch, and substrate type.
I. A small drogue will be placed in the water on arrival and its progress along the shoreline monitored during the period of study to assess currents.
J. A transit will be used to measure the elevation of the water height at a specific time and of each sample station on the transects run orthogonal to the beach.
K. Water temperature, dissolved oxygen and salinity will be measured. A 500 ml water sample will be retained for total suspended solids and total volatile solids analysis.
L. At a minimum, each beach survey will include:
   1. 12 shellfish samples
   2. 4 sediment samples (50 gm each) for sediment grains size analysis
   3. 4 sediment samples for Total Volatile Solids analysis.
   4. One 500 ml water sample

Sediment grain size was determined using the sieve and pipette method. Sediments greater than 1 cm will be pooled. Additional sieves sizes included 2 mm, 1 mm, 500 μm, 125 μm, 63 μm. Silt (>3.9 μm) and clay (<3.9 μm) were differentiated using the pipette method.

Sediment Total Volatile Solids were determined by drying a sediment sample at 103 ± 2° C until no further weight reduction was observed and then the sample was ashed at 550° C until no further weight loss is recorded.

Water Total Suspended Solids and Total Volatile Solids. A 0.45 μm glass filter was ashed at 550° C and weighed. A 350 ml sample of thoroughly mixed water is suction filtered and the residue dried at 103 ± 2° C to determine TSS. Total volatile solids was determined following ashing of the sample at 550° C.

Razor Clam Predator Control: The razor clam project was started at the request of Eyak tribal members who during 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 Cordova 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 (Figures 1 and 2).

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 II.

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

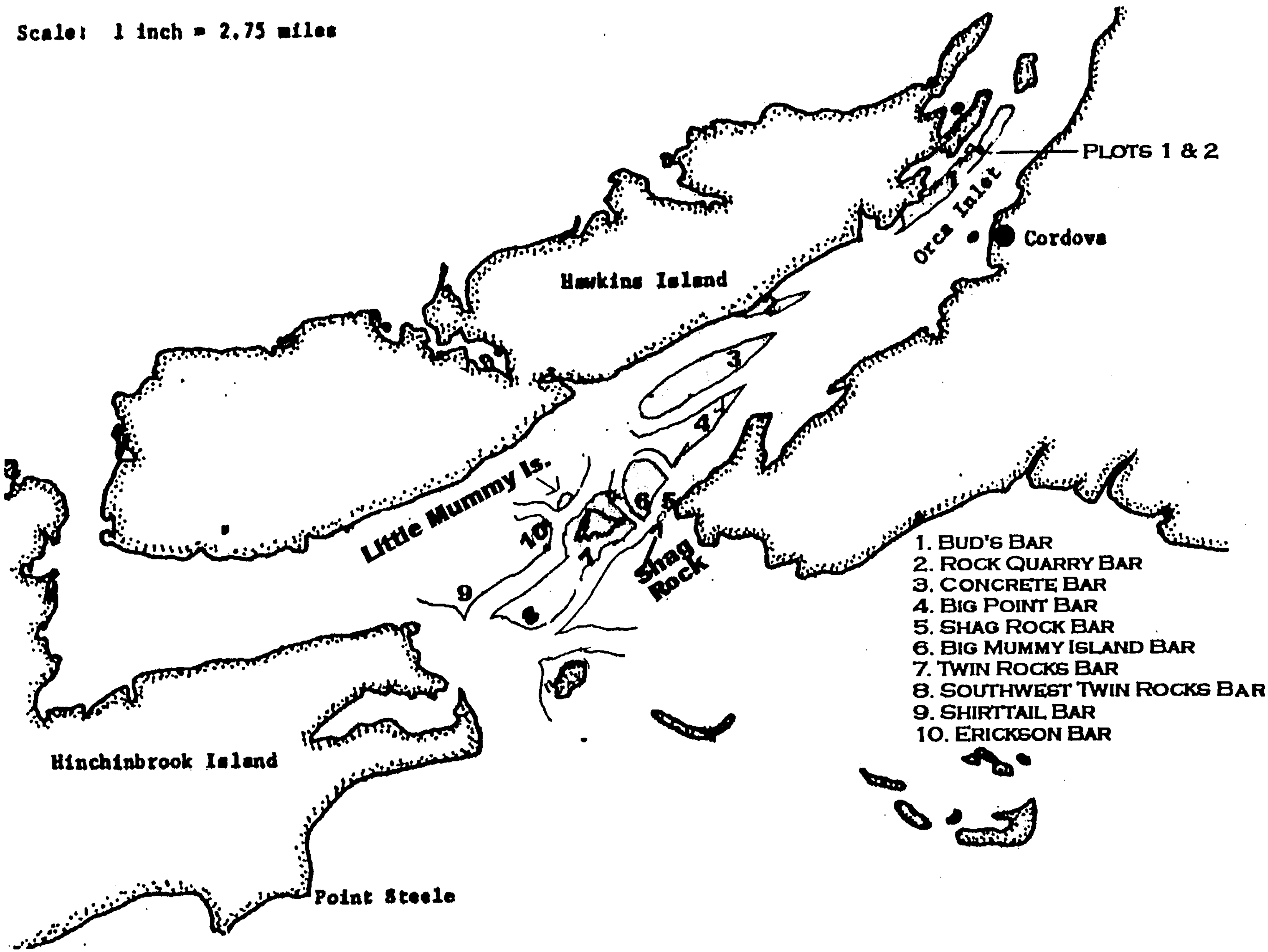

Figure 1. Study beach locations.

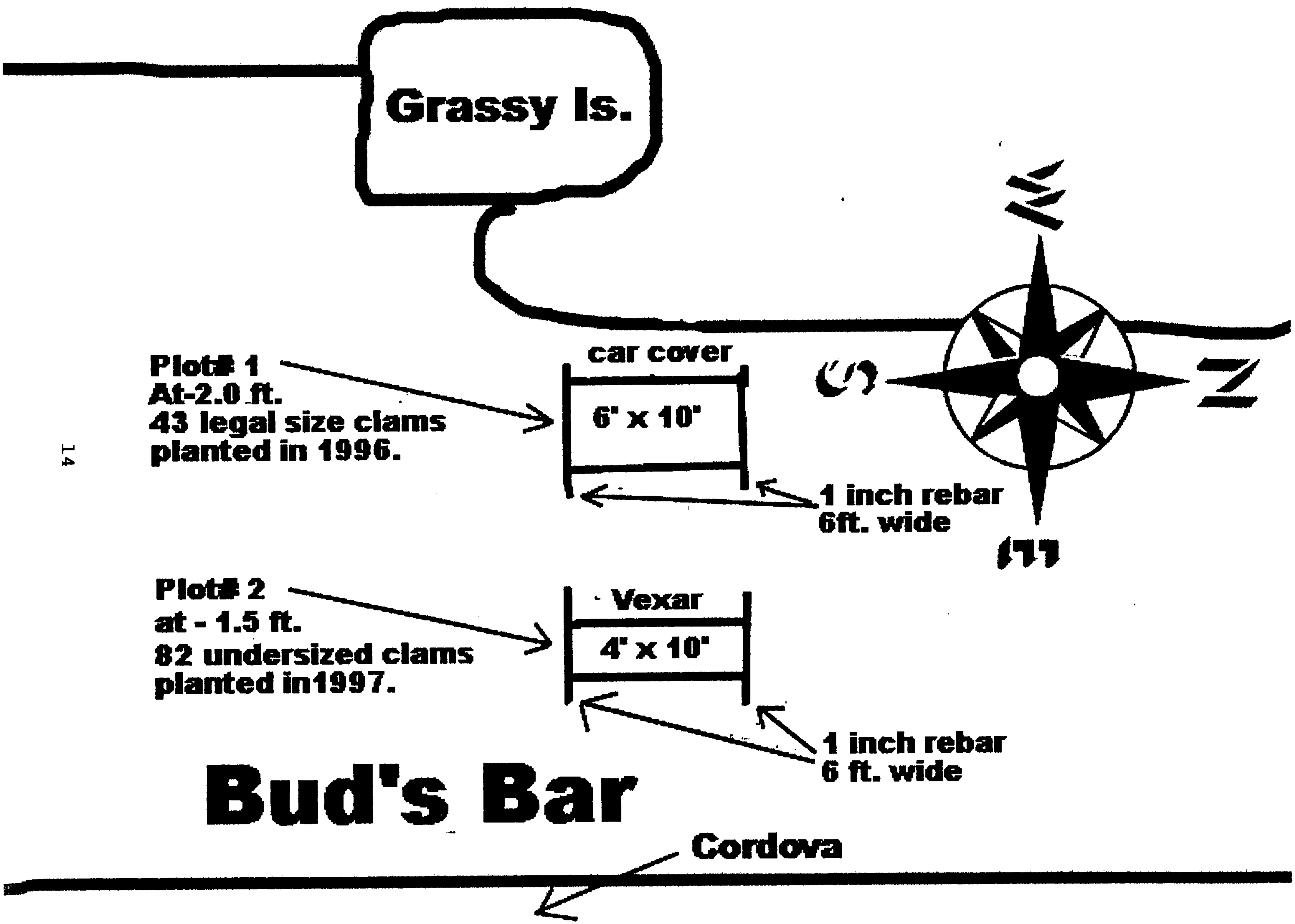

Figure 2. Sampling layout.

.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 II.

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".

PSP Testing: A PSP testing program is needed for the subsistence beaches at Nanwalek and Port Graham. The testing on the commercial beaches at Tatitlek will be sufficient to cover the subsistence beaches. In the early stages of the project it was felt that mussels cultured near the subsistence beaches could be used to test for the presence of the PSP toxin. Mussels were chosen because they are easily obtainable and grow well. Consequently a sock of mussel spat was placed at each of the study site at the same time the clams seed was planted.

Results

Hatchery: A new bivalve hatchery expert assumed management of the shellfish hatchery on June 10, 1996 with the responsibility to improve production success and reliability, train staff and prepare for the move into the new hatchery to be completed in fall/winter among others. Controlled broodstock conditioning was immediately initiated within the hatchery after observing a large percentage of immature gonads among the available clam broodstock maintained in natural conditions in the seawater pond.

Algae cultures had to be replaced due to complete contamination and equipment had to be purchased or fabricated to support axenic stock culture propagation. The new algal starts acclimated slowly to our hatchery environment during the next four to six months. Much attention was directed to improving algae culture quality and density which grew less consistently than desired during this period. Steps taken included:

- purchase of axenic algal starts and the maintenance of axenicity through sterile transfer methods and verification with a sterility test medium
- growing denser, healthier, and more consistent microalgae cultures through finer (one micron) filtration, activated carbon adsorption, and carbon dioxide sparging of the seawater, as well as more scrupulous cleanliness at all steps

- augmenting the commercial nutrient medium with additional micro-nutrients
- acquisition of more nutrient-rich strains of microalgae to replace other strains
- sterile filtration of the air supply to carboy algal cultures
- daily bacterial pathogen testing of algal and larval cultures on TCBS medium

Algae production gradually increased and improved as these extensive changes were incorporated but occasionally cultures still failed to grow at all or grew poorly despite careful identical treatment. Failing cultures always grew heavily bacterized. Fluctuating seawater chemistry, perhaps pulses of contamination, are suspected. Seawater samples from these cultures are being collected for analyses.

Spawning trials began during the second week of indoor conditioning. Clam broodstock underwent the first controlled mass spawning at three weeks. Hatchery staff induced three more mass spawnings of clam broodstock by the end of September. Far more veliger larvae developed from these spawns than rearing capacity permitted in the small pilot-scale hatchery and the larvae survived from 12 to 27 days. Larvae from the first spawn were accidentally killed on day four by staff unfamiliar with new techniques. The next spawn occurred eight days later. However, a very high rate of ongoing deformity and subsequent rapid mortality of the larvae in two of the three subsequent spawns prevented any seed production during FY 96.

Deformities, indicative of seawater quality problems, typically consisted of incomplete, abnormally-shaped trochophores with vestigial, misshapen shell valves that would develop no further and quickly die; D-stage veligers with misshapen valves showing bent hinge lines and notched, checked, or curled shell margins; and veligers with incomplete or misshapen vela. Larvae from subsequent rearing trials have been preserved and submitted for histopathological examination. Results are still pending. During future periods of larval deformation more samples will be collected for histopathological analyses as part of an overall hatchery health management program. A very few larvae (< 0.5%) survived the larval stage in the fourth spawn and were placed into a downwelling setting system. About 20% of these survived metamorphosis and began to feed again but were unable to deposit new shell growth during the next four weeks and eventually died.

The inconsistent growth and quality of the algal food further complicated these rearing trials because high quality algal cultures were not always available. Unfavorably bacterized cultures fed to larvae did cause periods of mortality in addition to the mortality caused directly by the apparent seawater toxicity. Unfortunately, real time information on levels of bacterial pathogens in algal cultures or larval tanks is not available because the results of bacterial tests lag two days after the day of testing due to a plate incubation period. Cultures are inspected under the microscope before feeding to larvae to avoid using poor cultures.

To investigate the possibility that our clam broodstock were producing non-viable gametes a series of Pacific oyster spawns began one week after the last clam larval cultures. Oyster broodstock had completed gametogenesis under natural conditions in the seawater pond and spawned immediately upon warming. The first group of larvae never successfully developed to D stage larvae. No food is added during this pre-feeding period to avoid complications. All the trochophores were incompletely formed or abnormal and the pre-D larvae produced tiny, irregular and misshapen valves. Very few of these deformed larvae survived to day three. One tank with 3 μM EDTA added to detoxify any heavy metals present in the seawater, showed much higher survival at day three though still with larvae heavily deformed.

Two more oyster spawn groups were reared in various tanks to test EDTA-treated vs. untreated seawater collected one mile away, seawater in another IMS laboratory (Hood) pumped from a deeper intake, and treated seawater minus the usual UV irradiation from our hatchery. All untreated seawater groups suffered almost total deformation and arrested development before the D-veliger stage in contrast to treated, distant seawater and Hood laboratory seawater that produced mostly normal D veligers by day two. This dramatic initial improvement was subsequently lost even in these larval groups due to ongoing, heavy deformity and mortality over the next seven to eleven days. Veligers grew very little despite some visible feeding. Eliminating UV irradiation of hatchery water did not improve larval survival. After this trial the hatchery seawater supply was transferred to the deeper intake/pump system.

In view of the deformation of both clam and oyster larvae and the beneficial effect of EDTA, both clues suggesting heavy metal toxicity or deficiency, samples of filtered laboratory seawater and seawater collected with a Nansen bottle near the 70m deep IMS intake were analyzed for twelve heavy metals. The results are attached. None of the concentrations exceed typical coastal seawater concentrations with eleven of the twelve about 1 ppb or less. Zinc measured 9.5 ppb at the intake. Selenium an essential trace element, may be deficient at less than 0.3 ppb. Strontium an essential trace element not analyzed by us, has also been measured at potentially deficient levels in our seawater and has been shown to deform larval shells when deficient. Trace metal supplementation will be tested in upcoming growth trials.

Table 1. Metals in Seawater from Samples Collected from Qutekcak Shellfish Hatchery on October 17, 1996 and Analyzed by Battelle Marine Science Laboratories, Sequim, WA.

Metal	Units	Seawater Intake	Filtered	Blank	Detection Limit
Ag	μg/L	0.0350	0.0454	0.0110	0.01
As	μg/L	1.21	1.17	<0.1	0.1
Cd	μg/L	0.0411	0.0403	<0.01	0.01
Cr	μg/L	0.218	0.191	0.0683	0.03
Cu	μg/L	0.439	0.425	0.0367	0.03
Hg	μg/L	0.000434	0.000677	0.000327	0.000055
Mn	μg/L	1.20	1.35	1.43	0.1
Ni	μg/L	0.416	0.441	0.0367	0.03
Pb	μg/L	0.0487	0.0176	0.0124	0.01
Se	μg/L	<0.3	<0.3	<0.3	0.3
Sn	μg/L	1.55	1.65	2.59	0.1
Zn	μg/L	9.55	2.29	2.12	0.2

Thirty broodstock clams were submitted to a certified pathologist for a complete tissue examination after consistently proving unable to spawn despite three to six months of conditioning at 14° C with a diet proven to be replete and nutritious for six other bivalve species in Northwest hatcheries. Results were significant. Fifteen of the sixteen females were completely gemetogenically inactive with a small number of abnormal eggs in ovarian follicles. All males were very ripe with normal sperm cells and why they resisted spawning remains to be answered. Total spawn-resistant individuals represented about one half to two thirds of our total clam broodstock. A health management program will also provide information on the unique gametogenic requirements of these northerly Littleneck clam populations. Lowering the conditioning temperature to 10° C (unusually low in NW experience) may be important for supporting gametogenesis in such individuals.

A recent littleneck clam spawn was placed in hatchery water that is subjected to an extended (30 minute) exposure in an activated carbon filter and fed with algae grown in water with similar activated carbon filtering. The larvae are now beginning to set. Survival to this point has been much higher than any other group reared in the hatchery to date. This indicates a potential problem with organics in the water. Results from the histopathological analysis may shed more light on this.

Twenty five thousand clam spat were shipped from the hatchery in June for planting on village beaches. They ranged in size from one third to two centimeters long with individuals from two year classes. A significant number of these clam spat had died during the previous winter due to inadequate holding methods. Most clam spat were held in gravel filled trays suspended in the seawater pond.

Nursery: Algal Production Pond: Phytoplankton production in the seawater pond increased markedly during the summer and fall of 1996 due to flow management and changes in the nutrient medium and its use. A bloom of unusual duration was initiated and maintained for three months while also maintaining a favorable mix of algal species. Centric diatoms such as *Chaetoceros sp., Skeletonema sp.* or *Thalassiosira sp.* dominated the blooms which also included unknown phytoflagellates. Secchi disk readings averaged one half meter and cell counts ranged up to 250,000 cells per milliliter.

Restricting flow prior to the bloom or during a decline diminished cell flushing while increasing flow during peak periods sustained a longer bloom. This may be due to steady trace nutrient addition and limited pH buffering. Improved fertilization of the pond accounts for most of the increased phytoplankton growth. Switching the nutrient medium from solely an organic nitrogen source (urea) to one composed of dual inorganic nitrogen, phosphate, silicate, and iron salts at appropriate nutrient ratios made the difference. A lower nutrient concentration in the pond water was also used which kept costs low. The nutrient medium needs still further improvement to remedy some apparent trace mineral deficiencies in the local seawater. Carbon dioxide was also limiting as indicated by pH readings above 8.7 and will be added in trials during next summers blooms. Much of the pond's production potential still has yet to be tapped.

One hundred micron bag filtration of recirculating pond water succeeded in removing only some of the high levels of organic particulates that blocked light penetration and some of the high levels of phytoplankton grazers (i.e. amphipods and copepods) which developed. Better methods will be pursued to reduce these problems. Plumbing the pond-side upwellers so that feces produced by the spat is shunted to the drain should help reduce the particulate levels.

Oyster spat in upwellers recirculated with pond seawater grew well during the three month bloom. A floating upweller was constructed, as planned, during July and immediately put into service. It was designed to be small and light enough so that the IMS crane can lift it out of the pond whenever draining or storage is necessary. The eight bay upweller can maintain about 400,000 one centimeter long spat in a fluidized bed. A set of twenty four inch square fiberglass trays and another optional set of round plastic trays are screened at their base with 1.25 mm mesh on which the spat rest. A submersible electric recirculation pump draws about 50 gpm up through the trays of spat. Algal and invertebrate fouling of the floating upweller and the entire pond was remarkably light apparently due to the very low levels of larvae at the 70 m intake depth and due to the shallow penetration of sunlight (0. 5 m secchi depth). Growth of spat in the pond-side upwellers vs. floating upweller were identical so no additional floating upwellers are planned. As production increases land-based upwellers will be added.

Remote Nursery Systems: The tidal FLUPSY was seeded with 50,000 oyster seed as a trial operation in August. At the time no surplus littleneck clams were available. Seeding oysters offered an opportunity to test the unit. The oysters grew very well through November putting on an average of 3mm in length. The oysters were seeded at 15mm and were removed for the winter at a mean of 18mm.

The tidal FLUPSY sustained damage to the intake during a storm in November. High winds and seas tore a hole in the intake flume, separating it from the main unit. The tidal FLUPSY was taken to the beach and secured above the tide line. The intake flume will be re-welded and made more stout before the 1997 growing season.

Growout: Results of the baseline beach surveys at Chenega Bay and Ouzinkie, the littleneck clam enhancement studies at Tatitlek, Port Graham and Nanwalek, and the attempt to develop hatchery culture techniques for the cockle can be found in the report by Dr. Kenneth M. Brooks, "Part I: Baseline shellfish survey of tidelands near the Alaskan Villages of Ouzinkie and Chenega; Part II: Native littleneck clam (*Protothaca staminea*) enhancement studies at the villages of Nanwalek, Port Graham and Tatitlek; Part III: Literature Search and Development of Spawning Techniques for the Basket Cockle (*Clinocardium nutalli*)", April 13, 1997, located in Appendix I.

Razor Clam Predator Control: Results of the razor clam predator control project can be found in the report by Jeff Hetrick, "Results of Razor Clam Survey for the Village of Eyak", April 1997, located in Appendix II.

PSP Testing: The mussel spat that was set out in the vicinity of each of the test beaches with the intent of using them for PSP sampling, did not survive the winter.

Discussion

Hatchery: Bringing in a seasoned hatchery technician to run the Qutekcak Shellfish hatchery has made a marked difference in the quality and professionalism of the hatchery operations. Perhaps nothing illustrates this better than the manner in which the hatchery seawater quality problem was addressed. The water quality problem is still not resolved. It is also uncertain if this problem will be present in the new facility and to what degree. What is certain is that the methodical approach to this problem now being taken will likely result in a satisfactory resolution.

The new State hatchery facility, scheduled to be operated by the Qutekcak Native Tribe beginning in May, 1997, will greatly expand production capabilities. If a subsistence clam enhancement program in the oil spill region proves feasible the new hatchery will be able to supply the needed seedstock.

Developing the techniques for spawning cockles is proving more elusive than was originally thought it would be. However, cockles are a very popular subsistence shellfish. They are worth the additional effort it will apparently take to develop the procedures for producing hatchery seed.

Nursery: Phytoplankton production in the hatchery nursery pond was made much more efficient in 1996 due to better flow management and an improved nutrient medium. The intent is to use the pond solely for plankton production which will be fed to seed in land based upwellers.

The tidal FLUPSY looks promising. A better understanding of the production that could be expected from them will be available after the 1997 when the FLUPSY will be in use for the entire growing season. It apparent from the 1996 season the these units cannot be left on station during the winter.

Growout: The growth and mortality and the predator control studies for littleneck clams are going well. The study plans are well laid out and the village crews are doing a good job following them. Winter sampling has proven difficult and may be greatly reduced in the future unless there appears to be a compelling need for them.

There are insufficient data at this point to draw any conclusions on how well littleneck clams will fare under beach culture, what the mortality rate will be, or how well predation control measures will work. The results to date look promising. A more definitive appraisal can probably be made after the 1997 growing season.

The razor clam studies near Eyak are more problematical. There are not numbers of undersize razor clams on the beaches near the village as was originally thought. In additional to implementing predator control measures to give the clams a chance to grow to harvest size it will be necessary to relocate clams from more distant, less accessible areas to these beaches.

The beaches near Eyak that are being used in this study appear ideal for razor clams according to the limited amount of literature that exists on the subject. Why there are hardly any razor clams of any size there now is a question that will need to be addressed.

PSP Sampling: If a subsistence clam enhancement program appears feasible a PSP testing program will be needed. Growing mussels near the subsistence clam beaches for PSP testing cannot be relied upon. It now appears that the best approach will be to use some of the clams for testing. By the 1998 season there should be enough clams from the 1996 planting to begin a testing program. There is no need to initiate a sampling program until then.

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Conclusions

The Clam Restoration Project remains on track in spite of some significant problems that have cropped up along the way. The 1997 growing season is shaping up to be a major milestone in the project. The Qutekcak Shellfish Hatchery will relocate to the new State hatchery/mariculture technical center. The water quality problem, if there is one in the new facility, will have to be resolved one way or another. Hatchery culture techniques for the cockle will hopefully be developed. The tidal FLUPSY will get a thorough testing. Enough information will be collected from the littleneck clam growout studies to indicate whether or not a subsistence clam enhancement program is feasible. A direction for the Eyak razor clam studies will be established.

In 1996 the project established the approach it will be taking to develop a long term clam restoration program in the oil spill region. Information gathered in 1997 will give the first solid indications on whether or not this approach is reasonable and worthwhile.

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Appendix I. Project Report: Part I: Baseline Shellfish survey of tidelands near the Alaskan Villages of Ouzinkie and Chenega; Part II: Native littleneck clam (Protothaca staminea) enhancement studies at the villages of Nanwalek, Port Graham and Tatitlek; Part III: Literature Search and Development of Spawning Techniques for the Basket Cockle (Clinocardium nutalli).

Project Title

Part I: Baseline shellfish survey of tidelands near the Alaskan Villages of Ouzinke and Chenega

Part II: Native littleneck clam (Protothaca staminea) enhancement studies at the villages of Nanwalek, Port Graham and Tatitlek

Part III: Literature Search and Development of Spawning Techniques for the Basket Cockle (Clinocardium Nutallii)

Chugach Regional Resources Commission Shellfish Enhancement Program
Exxon Valdez Oil Spill Trustee Council
Project Number 95131

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April 13, 1997

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Part I: Baseline shellfish survey of tidelands near the Alaskan Villages of Ouzinke and Chenega

Introduction. This baseline survey of shellfish populations at traditional harvest beaches near the Alaskan villages of Ouzinke and Chenega was undertaken to develop an understanding of existing shellfish resources and their potential for enhancement. In addition, this survey was designed to provide insight into the preferred environments and recruitment of valuable clam species as well as their growth and age at recruitment to harvest size. The surveys were completed between June 29, 1996 and July 2, 1996. The results of those surveys are documented in this report.

Background. Historically, clams have provided an important subsistence food source in the Native villages of Ouzinke and Chenega as well as many other villages located within the area affected by the Exxon Valdez oil spill. The village of Ouzinke lies north of Kodiac Island and is outside the area directly effected by the *Exxon Valdez* oil spill. However, according to Ouzinke Village residents, clam populations have declined in the vicinity of this village in the recent past, just as it has at villages affected by the spill. The reasons for these declines are not well documented - but the loss of traditional shellfish resources has been significant for Alaskan Villages. In response to concerns expressed by Village elders, the Chugach Regional Resource Commission (CRRC), in cooperation with the Alaska Department of Fish and Game, requested and received a grant from the *Exxon Valdez* Oil Spill Trustee Council to re-establish populations of clams in areas that are readily accessible from the villages of Tatitlek, Nanwalek and Port Graham (EVOS Project 95131) and to assess clam resources in the vicinity of Ouzinke and Chenega.

Intertidal populations of native little neck clams (*Protothaca staminea*), butter clams (*Saxidomus giganteus*) and cockles (*Clinocardium nuttallii*) have not been intensively managed by either federal or state agencies in the past. Consequently there is little information regarding the life history and population dynamics of these species in cold Alaskan waters.

Littleneck clam life history. The littleneck clam (*Protothaca staminea*), occurs in estuaries, bays, sloughs and open coastlines along the Pacific coast of North America. It primarily inhabits the intertidal zone from approximately -2' MLLW to +3' MLLW. However, it is infrequently found at subtidal depths. It ranges from the Aleutian Islands to Socorro Island, Mexico (Fitch, 1953).

Reproduction. Sexual maturity appears to be size, rather than age dependent and 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 or early June with a major release of gametes between June and July. 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. Spawning appears to be temperature related (Quayle 1943) and an examination of USFWS (1968) suggests that South Central Alaskan sea surface temperatures warm rapidly, from less than 8 °C, to >10 °C, during June or July of each year.

Larval clams are planktonic for three to four weeks. Therefore, they are dispersed over large areas by wind and tidally driven currents. Successful recruitment is dependent on a wide range of environmental parameters and varies significantly from year to year. Large year classes are 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) reports native littleneck clams to 14 years of age. Littleneck clams grow continuously throughout their lives. However, growth slows as the clams age and is highly dependent on local environmental conditions; including tidal height, currents, food availability, temperature and salinity. (Qualyle and Bourne, 1972). Feder and Paul (1973) reported that *Protothaca staminea* rarely reaches a valve length greater than 55 mm in Prince William Sound. Maximum valve length in Washington State appears to be approximately 68 mm (Brooks, unpublished data). In highly productive areas of Puget Sound, native littleneck clams can reach 38 mm valve length in 3 years.

Feder and Paul (1973) examined growth of littleneck clams and estimated intertidal populations in Prince William Sound. They sieved sediments on ¼" screens and counted only those clams with valve lengths > 30 mm, which represented the legal size at that time. The lack of length data makes comparison of their data with this study difficult. Feder and Paul (1973) provided a photograph describing the suspected annuli used to age littleneck clams. However, they did not verify that these checks were, in fact, annuli. Feder and Paul (1973) observed maximum clam (> 30 mm valve length) densities between –1.5' and +1.5' MLLW. The density of native littleneck clams > 30 mm valve length varied between 68 and 92 per square meter or 7 to 9 per square foot. Growth increments reported by Feder and Paul (1973) varied between 1.1 and 6.0 mm and they estimated that eight to ten years was required to reach a minimum size of 30 mm. Rutz (1994) examined native littleneck clams in Kosciusko Bay, Southeast Alaska. He reported native littleneck clams to substrate depths of 15 cm at mean densities of 40 to 142 clams/m^2 for clams > 38 mm valve length. Rutz (1994) estimated that it takes 10 to 13 years to reach the minimum harvest size of 38 mm. For Kachemak Bay, Alaska, ADFG (1995) reports a minimum time of five years to reach the minimum legal size of 38 mm.

In Washington State, the manila clam (*Tapes japonica*) is the favored aquaculture species because of a longer shelf life, reliable opening on cooking and ease of seed production. Little work has been devoted to the hatchery production of native littleneck clam seed because of problems encountered in carrying the clams through metamorphosis. In 1994, the Qutekcak Native Tribe, with the assistance of Mr. Jeff Hetrick, was able to successfully spawn and raise small quantities of native littleneck clam seed at their Seward hatchery. These successes were repeated in 1995. This is a significant development in making enhancement of depleted clam resources in Alaska a reality. No additional clams were produced at the Seward hatchery in 1996, but work continues to refine the hatchery practices and nursery techniques are being developed.

Habitat characterization. Littleneck clams are most abundant in substrates containing a mixture of sediment grain sizes. Goodwin (1973) found highest littleneck clam densities in substrates consisting of broken shell. Sand, pea gravel, gravel, and rocky substrates all contained moderately high numbers of clams. Substrates consisting of primarily mud are unsuitable for native littleneck clams.

Quayle (1960) states that littleneck clams in British Columbia are concentrated at "about the half-tide level," but notes that they occur in reduced numbers at subtidal depths. Amos (1966) reported highest littleneck clam densities between -3.0' and +4.0' (MLLW). Goodwin (1973) found significant quantities of native littleneck clams at subtidal depths in Puget Sound. However, there was a general decrease in the observed biomass of both littleneck and butter clams with depth and very few clams of either species were found at depths greater than 30 feet. In addition to water depth, Goodwin (1973) documented a positive correlation between current speed and littleneck and butter clam standing crops. The information in Table (1) is taken from Goodwin (1973).

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

Current Speed (cm-sec^{-1})	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

Rodnick and Li (1983) developed a Habitat Suitability Index (HIS) Model for the littleneck clam (*Protothaca staminea*). They concluded that littleneck clams prefer a mixed substrate of gravel, sand and mud and that this species burrows to approximately 15 cm. Other habitat factors considered important to native littleneck clams included currents (optimum 77.1 to 154.3 cm/sec) and tidal level (optimum -0.75 m to + 1.0 m or -2.46 ft. to +3.28 ft). Rodnick and Li (1983) cite Nickerson's (1977) observation that native littleneck clams enjoyed greatest recruitment at tidal heights between -0.43m and +0.43 m on three beaches in Galena Bay, Prince William Sound. This observation is consistent with that of Amos (1966) and Paul *et al.* (1976) who concluded that maximum clam densities are recorded near the 0.0' tide level. Lastly, Rodnick and Li (1983) note that thermal stress causes death at a few degrees below 0°C and above 35°C.

Intensive culture of intertidal bivalves places additional constraints on several environmental parameters. These techniques generally require finer substrates with few cobbles (> 2 to 3 inches diameter) than is optimum for feral populations of *Protothaca staminea.* Suitable beaches must be stable, and fines (silt and clay) should comprise approximately 5 to 10 percent of the matrix. Total Volatile Solids (organic material) should represent at least one percent of the sediment dry weight. Areas where only sand and gravel are found, or where there is evidence of significant sediment transport, require that clams be contained within cages. Otherwise they will either be washed out of the sediment or smothered.

Native littleneck clams will grow adequately 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 prevent freezing.

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 can be invaluable. 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 log damage, high winds or excessive sediment transport.

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.

All clams (>2 mm) should be accounted for in surveys. Some areas may have excellent growth but limited recruitment because of current patterns or other factors. Recruitment can be assessed by evaluating length frequency and age frequency histograms. However, this requires that the clams be carefully aged, wet tissues weighed, and valve lengths measured.

Commercial clam harvest management. 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:legal clams are 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 are 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 surveyed 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 2.

Table 2. 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:

a. *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.

b. The biomass of clams at the most heavily harvested beaches (Chugachik and Jakolof) is slowly declining as shown in Table 3.

c. Clam growth was highly variable and clams reached minimum harvest size (≥ 38 mm) at ages between 5 and ten years.

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 3. 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 is 7.5 years. Adding a natural annual mortality of even 2% per year means that a maximum sustainable yield would be on the order of 11% per year.

Table 3. 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%

ADFG (1995) data suggests that an adequate management plan will be essential to the development of a sustainable subsistence shellfish resource anywhere in Alaska. In addition, the available information suggests that a significant time lag, at least four to five years, will occur before seed planted on intertidal beaches reaches a minimum legal size.

Materials and methods

Survey site selection and development of an understanding of village goals, desires and resources. Mr. Jeff Hetrick (EVOS Project 95131 project team member) conducted interviews with tribal elders prior to undertaking the 1996 surveys. Based on these interviews, the following specific beaches were identified for survey in 1996.

Village	**Beach Name**	**Latitude**	**Longitude**
Chenega	Crab Bay	60° 04.24' N	147° 59.80' W
Ouzinke	Un-named	57° 48.12' N	152° 30.05' W

Upon arrival, Village goals and desires were discussed with tribal elders and others with local knowledge of shellfish resources. Specific questions included the following:

1. Reasons for choosing the sites to be sampled.
2. Traditional village use of shellfish and sources of supply
3. Accessibility of each site for tending of intensively grown shellfish resources
4. Resources (Villager time, boats, etc.) available to the project.
5. Review recent shellfish harvests at the beach to be surveyed
6. Village understanding of the current condition of local shellfish resources
7. Village understanding of the reasons that shellfish are no longer abundant
8. Investigation of alternate beaches for survey
9. Village preferences for mussels, cockles, native littleneck clams, butter clams, horse clams and soft-shell clams (*Mya truncata*).
10. Traditional predator control measures used by the Village.

Tides and weather. These surveys were undertaken in late June and early July during a period of low tides. The weather at Ouzinke was windy, but warm with scattered clouds. The weather at Chenega was cold, wet and windy. Conditions were such that the actual predicted tides were likely close to the predicted tides shown in Table 4.

Table 4. Predicted low tides during intertidal surveys conducted at Chenega and Ouzinke, Alaska on June 29 and July 2, 1996.

Beach	Date	Survey Time	Low Tide Time	Height of the Low Tide
Chenega	06/29/96	0500 - 0930	0655	-1.6' MLLW
Ouzinke	07/02/96	0630 - 1100	0942	-2.6' MLLW

Little environmental documentation describing the surveyed areas was obtained. Monthly Mean Sea Surface Temperatures, published by the U.S. Department of the Interior for years 1949 to 1962 (USFWS, 1968) suggest that mean low water temperatures of 4° to 5° C occur in this area from December through March of each year. Low tides, which occur at night in December and January in this region certainly exacerbate the low temperature stress experienced by intertidal fauna. Mean high temperatures of 12° to almost 15° C occur in July and August.

Beach assessment. The slope and extent of areas with potential for clam production were determined during each survey. This was accomplished by placing a properly leveled transit at the lowest point inundated at low tide. The elevation of each sample station was then determined relative to this reference point. The height, above Mean Lower Low Water (MLLW), was calculated assuming that the actual low tide equaled the predicted low tide. In view of the benign weather, this seems a reasonable assumption.

Substrate characterization. Three to eight 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.

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). Complete grain size analysis data are provided in Appendix 1. In addition, the following qualitative substrate characteristics were noted:

A. Substrate color
B. Presence of attached macroalgae
C. Evidence of excessive littoral drift or log damage
D. Oily sheen or odors of hydrogen sulfide, ammonia or petroleum.

Sediment Total Volatile Solids. 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 ashed at 550 °C until no further weight loss was recorded. Total Volatile Solids were calculated as the difference between the dried and ashed weights. Details of the results are provided in Appendix 2b.

Water Total Suspended Solids (TSS) and Total Volatile Solids (TVS). Three 500 ml water samples were collected at each sample beach. 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. A 0.45 µm glass filter was ashed at 550°C and weighed. A 350 ml sample of thoroughly mixed water was suction filtered and the residue dried at 103 ± 2 °C to determine TSS. Total volatile solids were determined following ashing of the sample at 550 °C. The purpose of these samples is to evaluate food availability and suspended solids in the water on the day of the survey. High turbidity associated with glacier outwash, low salinity associated with fresh water inputs, or very low TVS would indicate that the site was unacceptable. These point in time analyses do not provide an assessment of the year round suitability or productivity of a beach. In other words they may eliminate a beach from consideration, but they do not assess the long term potential of a beach to support intensive or extensive culture. Details of this analysis are presented in Appendix 2a.

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 just prior to each set of measurements.

Current speeds were measured by placing a drogue in the water and measuring its movement as a function of time. These point estimates of current speed are of minimal value but they do provide an indication of minimum current speeds within an hour of slack tide.

Shellfish population estimates. Each survey began with a series of test digs to define the highest beach level at which clams were found and to stratify the beach by substrate type, where appropriate. This information formed the basis of a systematic random survey, beginning at the highest elevation on the beach at which clams were found. The number of transects, and the number of samples per transect, were determined based on the area of the beach and the time available for collecting samples. 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 transect placed at the random distance from the margin of the productive beach. Additional transects were started at the specified intervals. Each transect was run normal 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 was taken at a random distance (between zero and the calculated sample interval) from the highest point at which clams were observed. Additional samples were taken at the specified interval. Red wire flags were labeled with the sample station designation and placed in the substrate at the appropriate point by the survey crew. These flags followed each sample until sieving and picking of clams was complete.

Individual samples were collected with the aid of 3/32" thick aluminum plate quadrats that cover 0.1 m^2. The quadrats are pushed down into the sample hole during excavation. This prevents sloughing of the sides and provides a precise sample size. Each sample was dug to a depth at which no additional clams were obtained.

Sample processing. 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 picking location. All samples were sieved on 6.4 and 1.0 mm sieves. All clams, and whole clam shells, were removed from each of these sieves and placed in pre-labeled, one gallon, ZIPLOCK™ bags. Where juvenile clams (< 6 mm valve length) were observed, 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 Aquatic Environmental Sciences for processing

Wet tissues in clams with valve lengths greater than ca. 15 mm were shucked, weighed, dried at 90 °C, and a dry tissue condition factor (1000*Dry tissue weight)/$\text{Length}^{2.1}$) determined. Additional age-length data was obtained from whole native littleneck and butter clam shells collected at Ouzinke.

Aging of clams. All clams in each sample were aged using the external shell check techniques described by Feder and Paul (1973), weighed, and their valve length measured to the nearest 0.1 mm. Trowbridge *et al.* (1996) suggest that aging clams based on disturbances observed in sectioned valves underestimates the age by one year. They concluded that the external method used in this study was more accurate. Ongoing growth and mortality studies to be described in Part II of this report will help resolve this issue, because the age of the caged clams is known. Clams were placed on preprinted acetate data sheets and photocopied. Measurements made from the photocopied data sheets were not significantly different from those made with calipers (paired sample *t*-test, $\alpha = 0.05$, N = 36). No correction factor was necessary or applied to the lengths taken from the photocopied data sheets. All clam shells were numbered and have been archived in storage bags, by sample code, for future reference. Until the correlation between known age and external checks is verified in the caged growth and mortality study, these techniques will remain hypothetical as discussed in Trowbridge *et al.* (1996).

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, it is hypothesized that discontinuities associated with wintertime cold temperatures and reduced feed availability result in significant checks commonly referred to as annuli. The distinctiveness of these annuli generally increases with geographical latitude due to increasing reductions in solar insulation during winter as one proceeds north. To the best of my knowledge, long-term studies using caged littleneck clams of known age have not been done. This is the only way to accurately verify this commonly used technique.

Trowbridge *et al.* (1996) compared age data determined by counting external shell checks with that developed from an examination of sectioned valves. The *Executive Summary* in Trowbridge *et al.* (1996) contains contradictory statements regarding the comparison. At page xiv, the summary reports that "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 following statements in the summary suggest that in fact, the external check method reveals a first annulus that was not observed in the sectioned valves. Therefore, the external method results in ages that are older, by one year, than the sectioning method. Trowbridge *et al.* (1996) examined this issue and concluded that the external method was more accurate.

No previous literature was obtained describing the aging of either *Saxidomus giganteus* or *Clinocardium nuttallii* using the external check method. However, there is a very prominent check, which appears to be an annulus, laid down in both of these species. *Clinocardium nuttallii* is a relatively short lived and fast growing species. Within the assumptions made in using the external check method of aging, this species is relatively easy.

Saxidomus giganteus is a long lived species. As predicted by the von Bertalanfy equation, the length (and height) of this species increases slowly at older ages, while the depth of the valve continues to increase. The result is that annuli in older clams become very closely spaced and difficult to read (similar to the scales in fish). In addition, the valves of this clam become increasingly worn as they age, making the identification of external sculpture difficult. One of the valves from these older clams was sectioned and read under a dissecting microscope. This method suggested an age of 21 years. However, the budget for this project did not allow for this method to be used routinely. Because of the difficulty in reading larger butter clam valves, these were not included in the data base when computing regression coefficients for the von Bertalanfy equation.

It should be re-emphasized that this aging technique has not been verified in any of these species. The current study will provide verification for littleneck clams for as many years as the study lasts. The Villages involved in this study may want to set aside a portion of the clams used in this study and maintain them for up to ten years in bags. That would provide a useful verification study.

Data Analysis. Data was entered into a STATISTICA™ database. All discrete data was log transformed. Proportional data was transformed by calculating the Arc Sine of the square root of the proportion. An α of 0.05 was used in all statistical testing and 95% confidence limits on the mean are reported where appropriate. Non linear regression analysis was used to define regression coefficients for the von Bertalanfy 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) has seen use modeling fish growth as a function of age based on annuli interpreted from otoliths. 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 (1995), the residuals in each analysis were examined for homoscedasticity and tested for normality using both the Kolmogorov-Smirnov and Chisquared goodness of fit tests. Residuals were distributed in a manner not significantly different from a normal distribution in every case at $\alpha = 0.05$.

Results

Village of Chenega

Village desires. Steve Ward, Gail Evanoff, Vern Totemoff, Meadow Christensen, Kean and Donia participated in the shellfish survey. Village residents stated a preference for cockles, butter and native littleneck clams. They noted that traditional shellfish resources had been depleted for unknown reasons. The Village has adequate boat and human resources and there some interest in participating in this study. Village residents expressed interest in having more shellfish to eat. The presence of a CRRC floating shellfish upweller at this site may stimulate additional interest.

Beach characterization. The beach surveyed in 1996 is accessible from the village by either boat or four wheel drive via an overland route. The beach is depicted in Figure 1. The total area of the bay is approximately 40 acres. However, an un-named stream enters from the north. Numerous, abandoned stream channels were observed running across a broad expanse of intertidal. These channels suggest that much of the area is unsuitable for clam culture because of the periodic scouring effect of the stream. The bay contains a patchy distribution of eel grass (*Zoostera marina*) at tidal levels below ca. –2.0' MLLW. Numerous holes, attributed to sea otters by village residents, were observed. Starfish (*Pycnopodia helianthoides*) and drills (*Nucella lamellosa*) were present, but in low numbers. The area surveyed measured approximately 115' wide by 236' deep. It lies behind a berm, which is currently carrying the stream well to the east. It appeared to be relatively stable and there was no evidence of recent stream erosion. The bay's substrate is generally composed of broken shale and is fairly compact. The survey 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. Preliminary sampling supported the author's visual assessment that the chosen area contained the highest abundance of shellfish in this bay.

As described in Figure 1, 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 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.

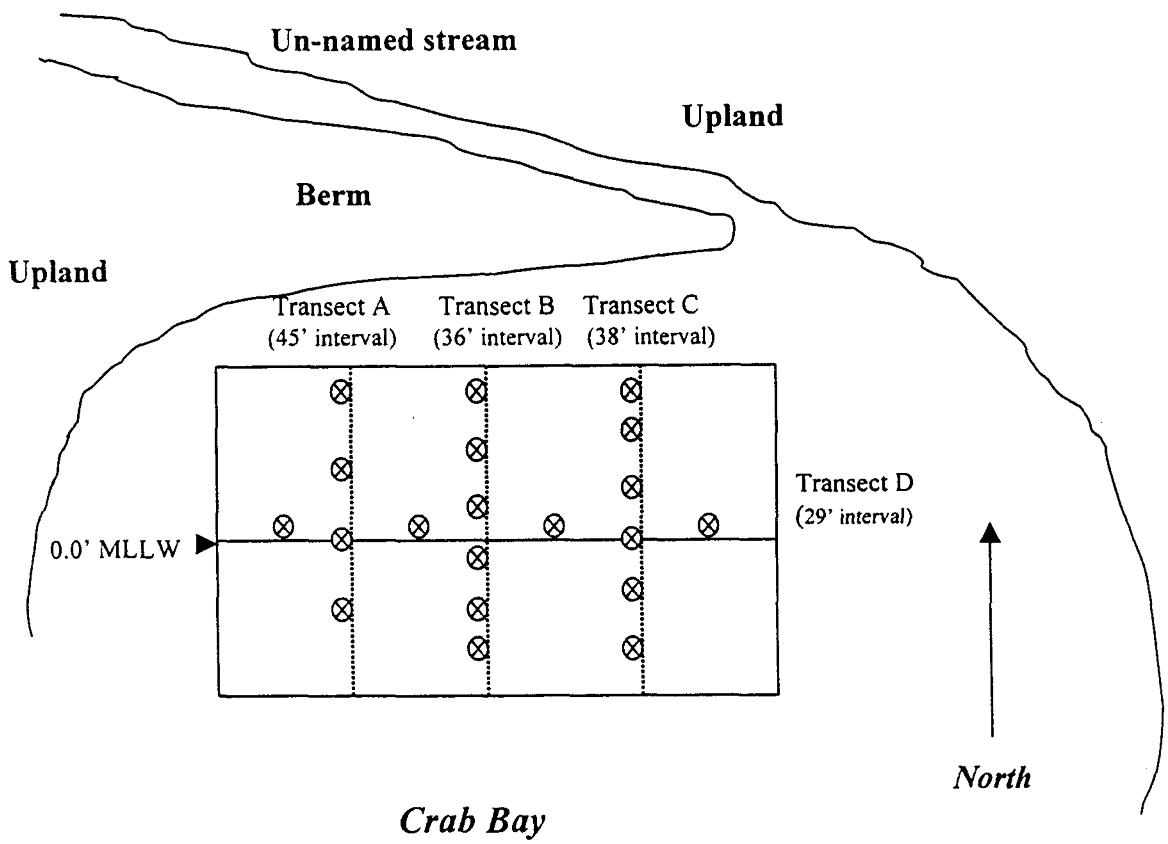


Figure 1. Schematic diagram of the Village of Chenega shellfish beach on Crab Bay. The beach has surveyed on June 29, 1996.

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. Sediments contained adequate oxygen. 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. The results of these analyses are presented in Appendix 1. Chenega clam beach sediments were 57.5 $\pm$ 8.3% (mean $\pm$ 95% CI) gravel, 33.6 $\pm$ 8.5% sand and 8.5 $\pm$ 2.6% silt and clay. Sediment Total Volatile Solids content is presented in Appendix 2. The Chenega clam beach contained an average of 2.8 $\pm$ 0.8 percent volatile solids. These physical characteristics are typical of substrates supporting either littleneck or butter clams.

Water Column Characterization. Water conditions at Chenega on the day of the survey were adequate for shellfish culture. Water temperature was 13.8 °C. The 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^{-1}. The pH varied between 7.75 and 7.76.

Water column analyses of Total Suspended Solids (TSS) and Total Volatile Solids (TVS) are presented in Appendix 2. The three water samples collected at this beach averaged

6.7 mg-L^{-1} TSS an 3.8 mg-L^{-1} TVS. Turbidity (nephelometric units) varied between 0.69 and 1.00. These values suggest moderate primary productivity and suspended inorganic particulates and provide no basis for eliminating this beach from consideration for enhancement.

Shellfish Population Characterization. A total of 109 living bivalves were collected in samples at Crab Bay. The distribution of these is provided in Table 5 and pertinent variables from the database are presented in Appendix 3.

Table 5. 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
Saxidomum giganteus (butter clam)	6
Clinocardium nuttallii (Nuttall's cockle)	6
Total living bivalves	**109**

Butter, native littleneck clams and cockles have potential as subsistence shellfish resources and are preferred by Villagers'. No clams were found in an abundance sufficient to support subsistence harvests.

Butter Clams. A total of 6 butter clams were observed in these samples. Their length-frequency distribution is provided in Figure 2. Most of the observed clams were new recruits less than two years old. Only one legal size butter clams was observed in all 20 samples. Descriptive statistics for a limited number of variables are presented in Table 6.

Table 6. Summary descriptive statistics for living butter clams sampled during the Crab Bay survey near the Village of Chenega on June 29, 1996.

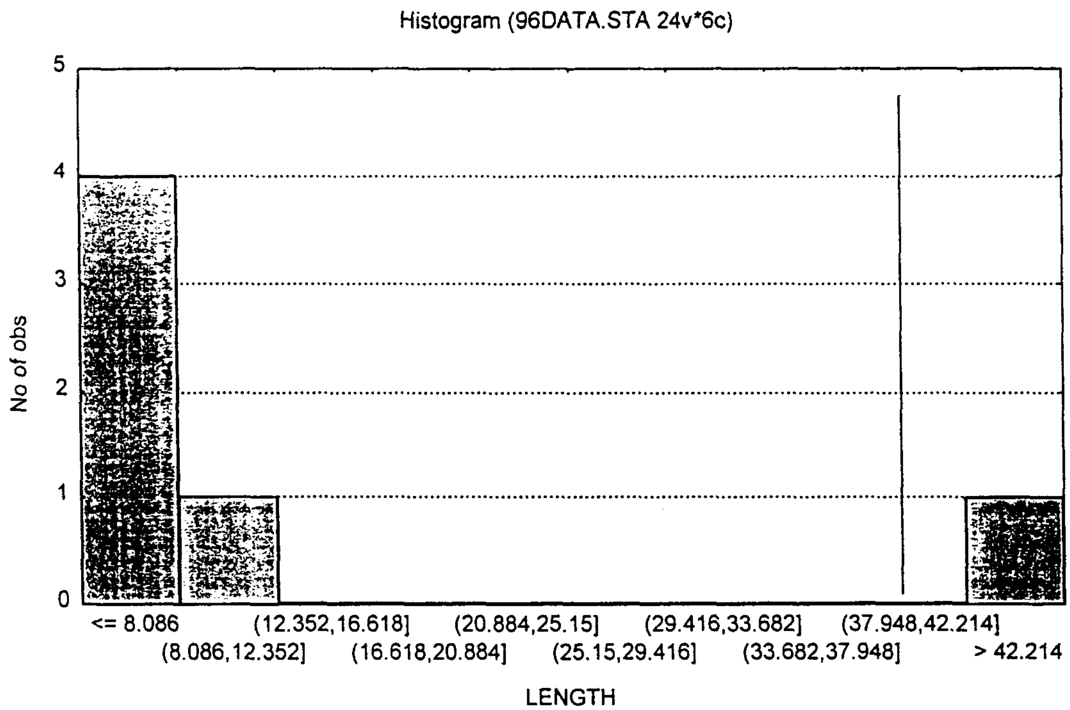
	Valid N	Mean	Minimum	Maximum	Std.Dev.
Length (mm)	6	12.80	3.82	46.5	16.6
Whole weight (gms)	5	4.33	0.14	21.4	9.6
Age	6	2.17	0.00	8.0	2.9
Dry Condition Factor	2	0.38	0.007	0.69	0.44

Non-linear regression was accomplished on aged living and empty butter clam valves to determine von Bertalanfy equation 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 $P = 0.000$. As seen in Table 6, a broad range of clam lengths and ages were included in the analysis and the longest clam (123.4 mm maximum length) exceeded the maximum predicted by the von Bertalanfy equation. This expression is likely a good predictor of butter clam length as a function of age.

Von Bertalanfy Equation **Length = 113.5(1 - exp$^{-0.0672 \times \text{age (years)}}$)**

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. However, the paucity of legal size butter clams attests to the need for enhancement of subsistence shellfish resources. It should be noted that recruitment of butter clams is very low (2.0 per m^{-2} in 1995) at this beach. Therefore, predator control (especially starfish and sea otters) can have a minor, but positive affect on the number of butter clams eventually available for subsistence harvest.

Figure 2. 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).



Cockles. A total of 6 cockles (*Clinocardium nuttallii*) were observed in these samples. Summary statistics are presented in Table 7 and a length-frequency histogram in Figure 3.

Table 7. 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	0.414	0.078

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

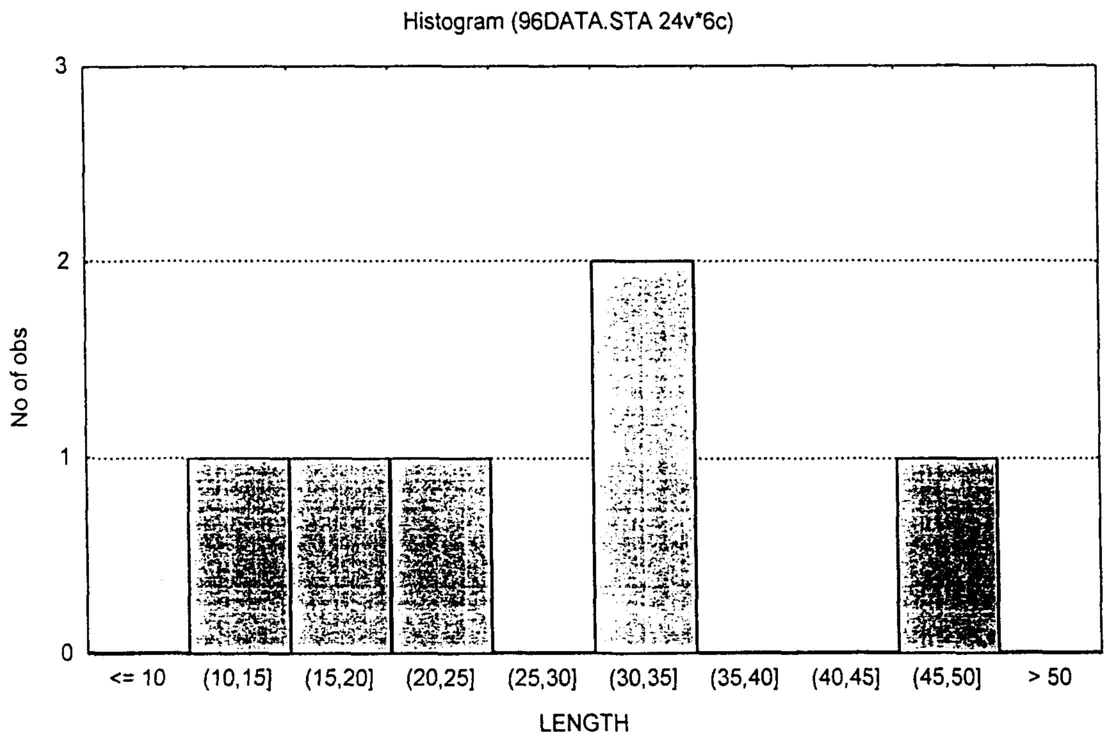


Figure 3. Length-frequency histogram for living cockles (*Clinocardium*) collected in 20, 0.1 m^2 samples at the shellfish survey site in Crab Bay near the Village of Chenega on June 29, 1996.

Native littleneck clams. A total of 97 native littleneck clams were observed in these samples. Very pronounced circular sculpture, apparently not associated with growth checks was observed in eight of these clams. It is thought that these eight clams were *Protothaca tenerrima* rather than *P. staminea.* All clams of the genus *Protothaca* are included in the summary statistics describing littleneck clams presented in Table 8.

Table 8. 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	0.075

Analysis of the native littleneck clam population at Chenega. Figure 4 presents an age - frequency histogram for Chenega native littleneck clams. The native littleneck population is dominated by three and four year old clams that likely settled in 1992 and 1993. Figure 4 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 since then has been

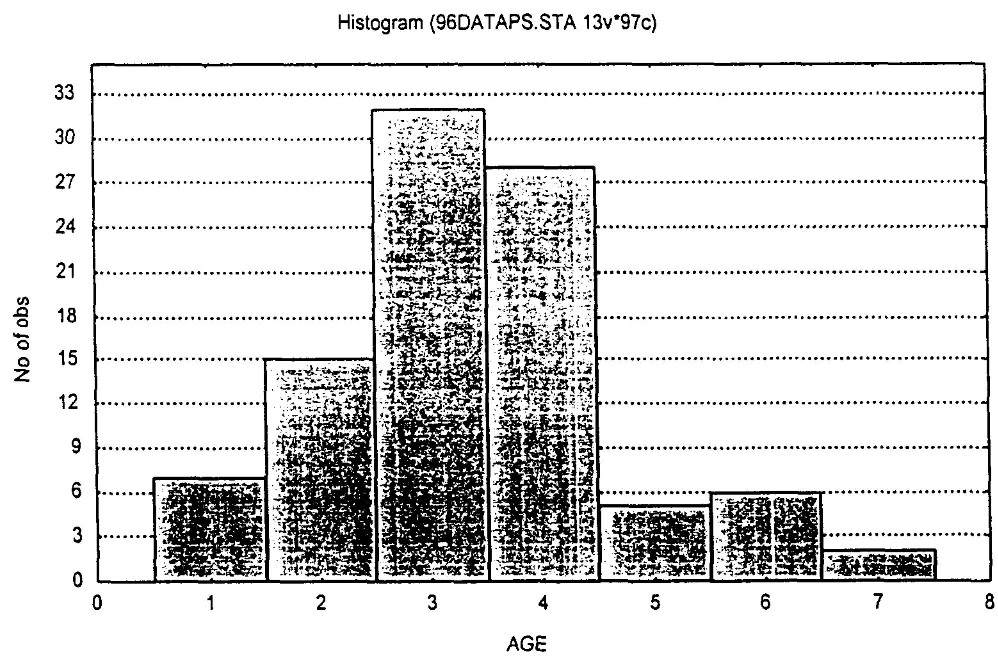


Figure 4. Age – frequency histogram for littleneck clams collected in 20, 0.1 m^{-2} quadrats at Chenega Village on June 29, 1996.

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 approximately 3.5 per 0.1 m^2 - or about 15% of optimum. This is close to the value of 4 recruits per m^2 observed at Tatitlek in the 1995 survey (Brooks, 1995).

Further examination of the population was accomplished using the length - frequency histogram provided in Figure 5, which indicates that larger clams are being eliminated from the population, either by predation or as a result 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 overharvest or predation.

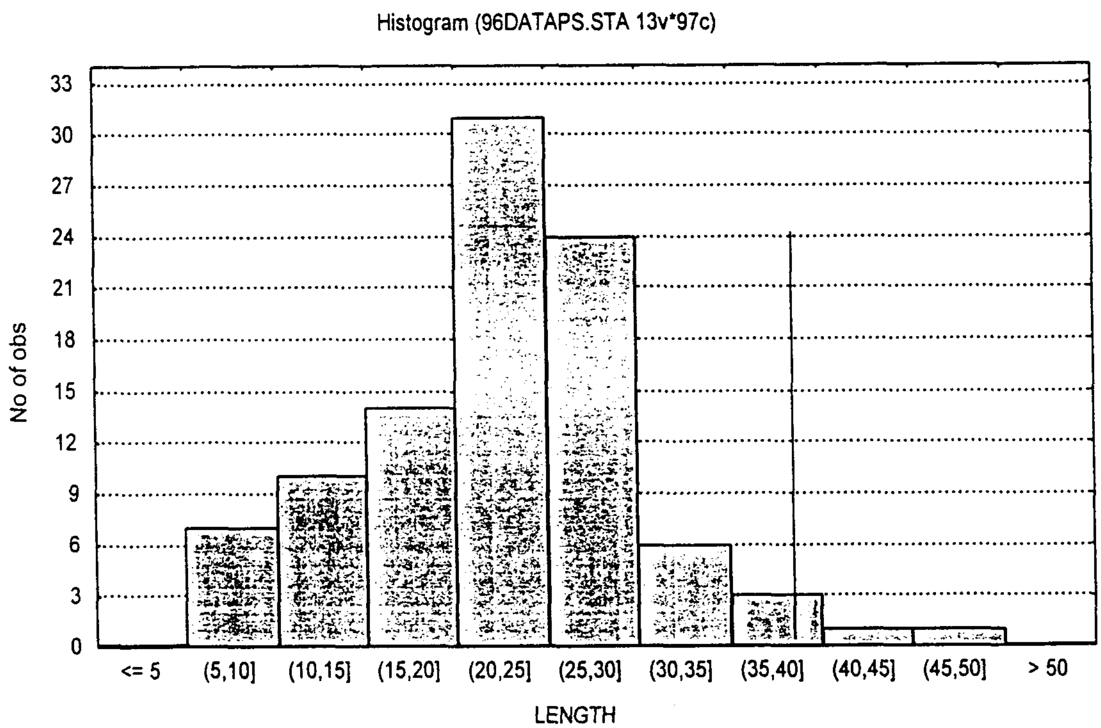


Figure 5. Length - frequency histogram for littleneck clams collected in 20, 0.1 m^2 quadrats at Chenega Village on June 29, 1996. The thin vertical line represents the minimum legal size of 38 mm.

Figures 6 describes the distribution of native littleneck clams as a function of tidal height at Chenega. 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 is not unexpected that native littleneck and butter clams are absent below this elevation.

-1.5' (MLLW). That is probably more a function of changes in the substrate composition than a function of tidal height. It is also interesting to note that both butter clams and native littleneck clams are found at tidal elevations near +3.0' (MLLW). The data for native littleneck clams suggests that the area between -1.0' and +2.5' is suitable for native littleneck clam production on this beach.

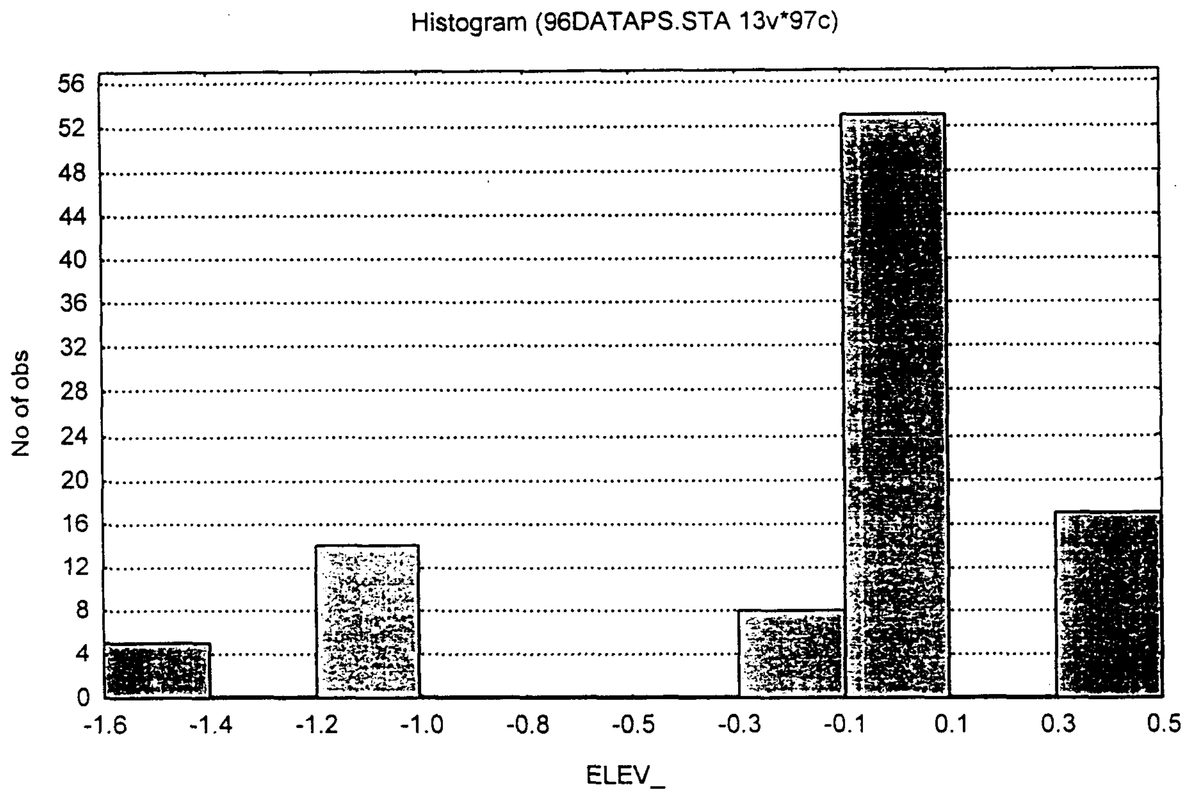


Figure 6. Tidal elevation – clam frequency histogram for littleneck clams collected in 20, 0.1 m^2 quadrats at the Chenega Village shellfish beach on June 29, 1996.

Environmental influence on clam size, age and growth. All 25 variables were included in a square matrix providing Pearson correlation coefficients. This matrix suggests that biological parameters such as length, incremental length growth, whole animal weight, wet tissue weight and condition factor are 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 explain 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 9.

Table 9. 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. In all cases the valid number of cases was 88.

	Tidal elevation	Sediment TVS	Salinity
Length	0.013 P = 0.29	**0.088** **P = 0.005**	**0.352** **P = 0.000**
Length Growth Increment	0.009 P = 0.37	0.000 P = 0.99	0.0014 P = 0.73
Whole Animal Weight	0.008 P = 0.41	**0.22** **P = 0.00**	**0.55** **P = 0.000**
Age	0.017 P = 0.23	**0.09** **P = 0.004**	**0.31** **P = 0.000**
Dry Condition Factor	0.013 P = 0.29	0.016 P = 0.23	**0.12** **0.001**

Clam length is positively correlated with sediment total volatile solids (TVS) and salinity. There is a moderate size stream flowing into Crab Bay behind a berm lying between the upland and the intertidal. This stream enters the bay to the east where it was having a small effect on salinity during this summer sampling period. I suspect it has a much larger effect during the winter and spring. In addition, it likely 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 this meander plain. This is suggested by the positive correlation between length, whole animal weight (correlated with length) and age as a function of salinity in Table 8. In addition, it is likely that the positive correlation with TVS is created by the periodic washing of organic material from intertidal sediments during spring freshets. 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 salinitys' 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, I suspect that this correlation would not be 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.* were observed 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 clam 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 8. The line represents a best polynomial fit to the data. Figure 8 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 (1995) for beaches in the vicinity of Tatitlek, Port Graham and Nanwalek.

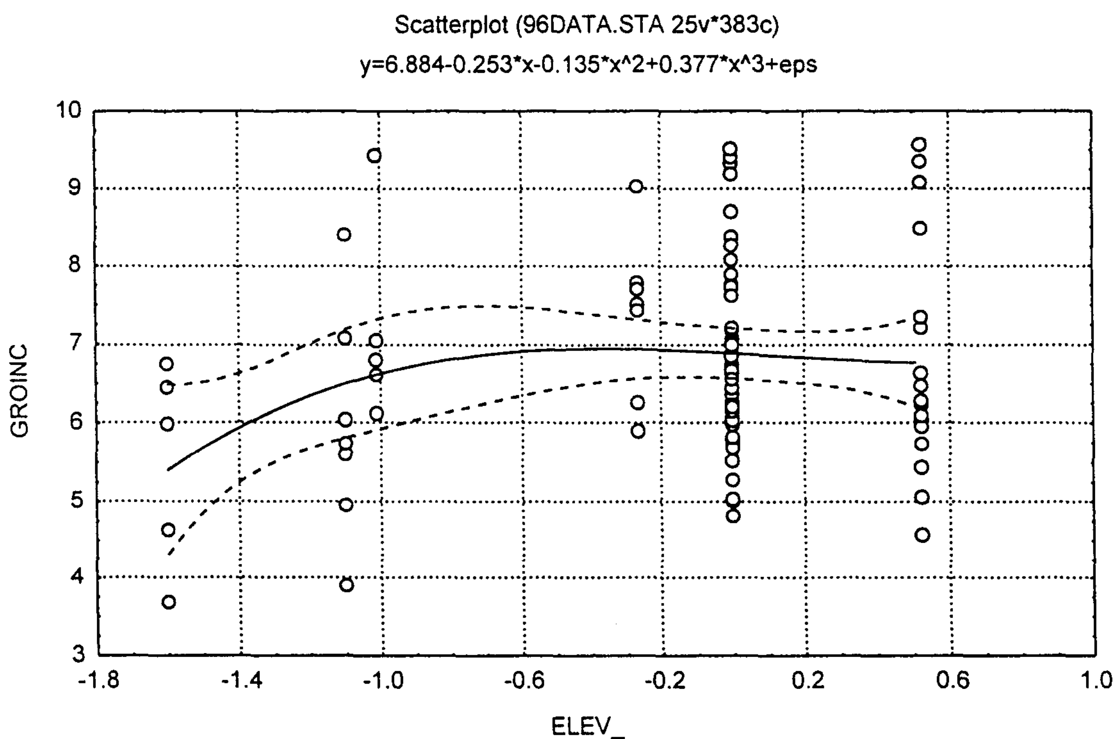


Figure 8. Growth increments (mm/year) as a function of tidal height (feet above MLLW) for native littleneck clams (*Protothaca staminea*) collected in 20, 0.1 m² quadrats at the Chenega Village shellfish beach on June 29, 1996. Ninety-five percent confidence limits on regression predictions are provided.

Age Length analysis. Regression coefficients were developed for the von Bertalanfy equation 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 (Kkolmogorov-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 data base. In Puget Sound, native littleneck clams grow to lengths in excess of 65 mm. However, clams older than 7 years were not observed at Chenega for unknown reasons. A scattergram, including the regression line is provided in Figure 9. The von Bertalanfy equation, and accompanying scatterplot, suggests that clams recruit into the legal size population, at greater than six years of age. The average age at recruitment is ca. 7.3 years.

Native littleneck von Bertalanfy equation for Chenega **Length = 47.61(1 - exp$^{-0.2548 \times age}$)**

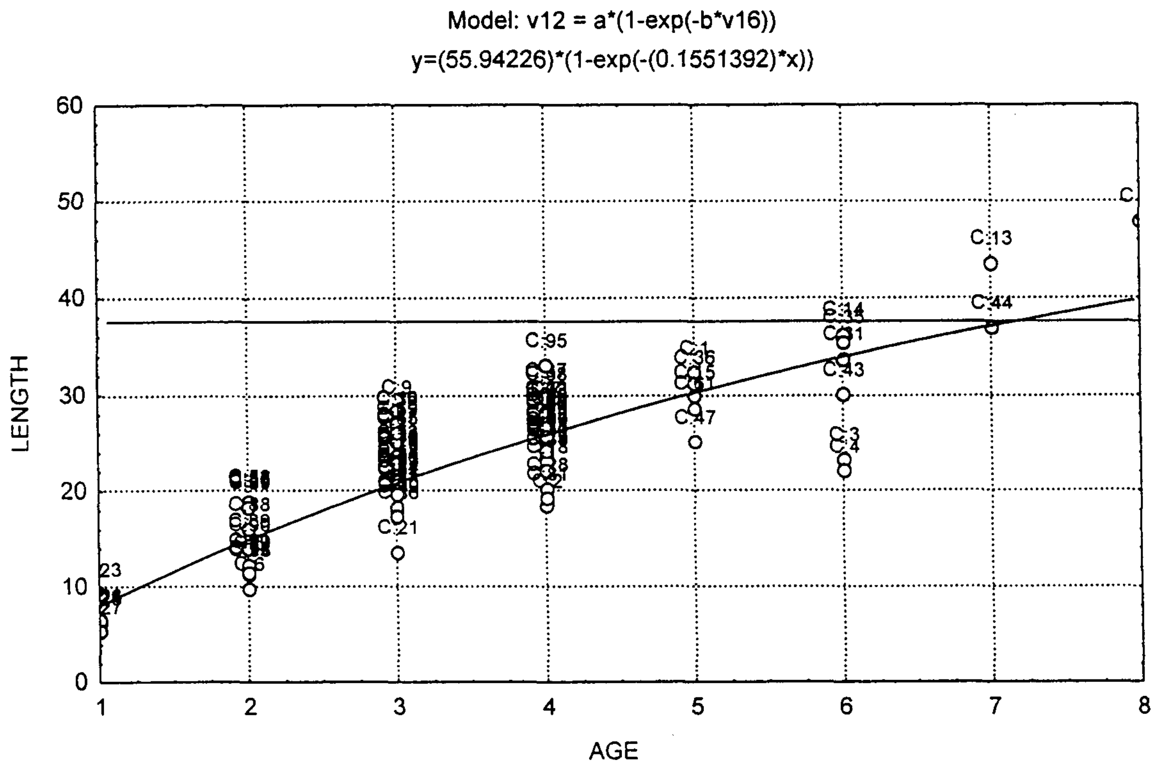


Figure 9. Length (mm) versus age (years) for native littleneck clams (*Protothaca staminea*) collected in 20, 0.1 m^2 quadrats at Chenega Village on June 29, 1996. The solid horizontal line represents the minimum legal size limit ($\geq$ 38 mm).

Edible tissue versus clam length analysis. A length - wet tissue weight histogram is provided in Figure 10 and an age - wet tissue weight histogram in Figure 11. One of the possible management options involves harvesting clams at a lower minimum size.

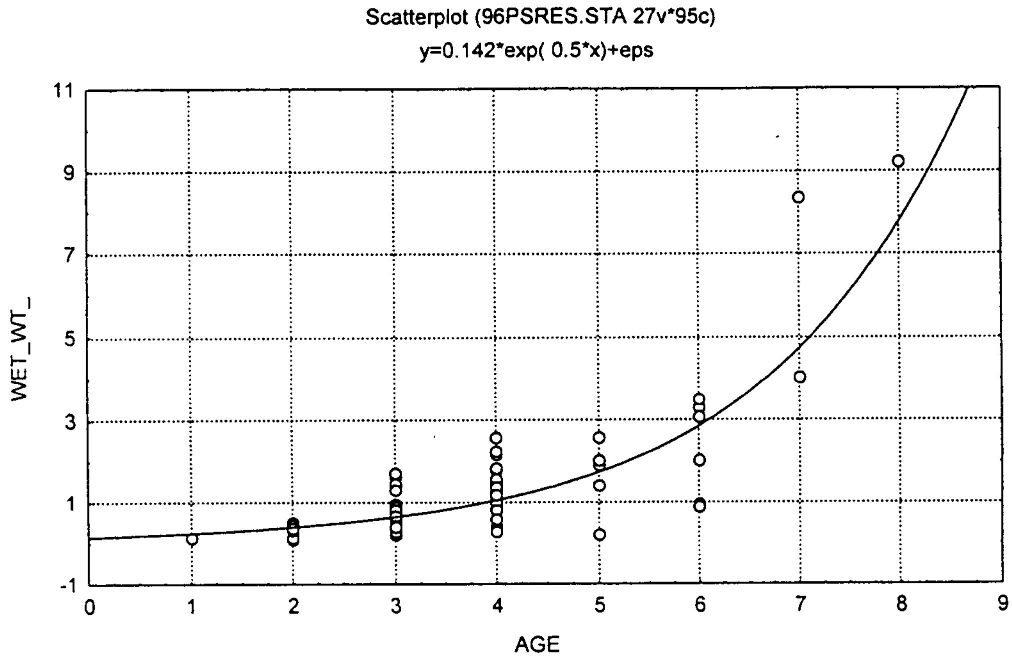


Figure 10. Wet tissue weight (grams) versus age (years) for native littleneck clams (*Protothaca staminea*) collected in 20, 0.1 m^2 quadrats at the Chenega Village shellfish beach on June 29, 1996.

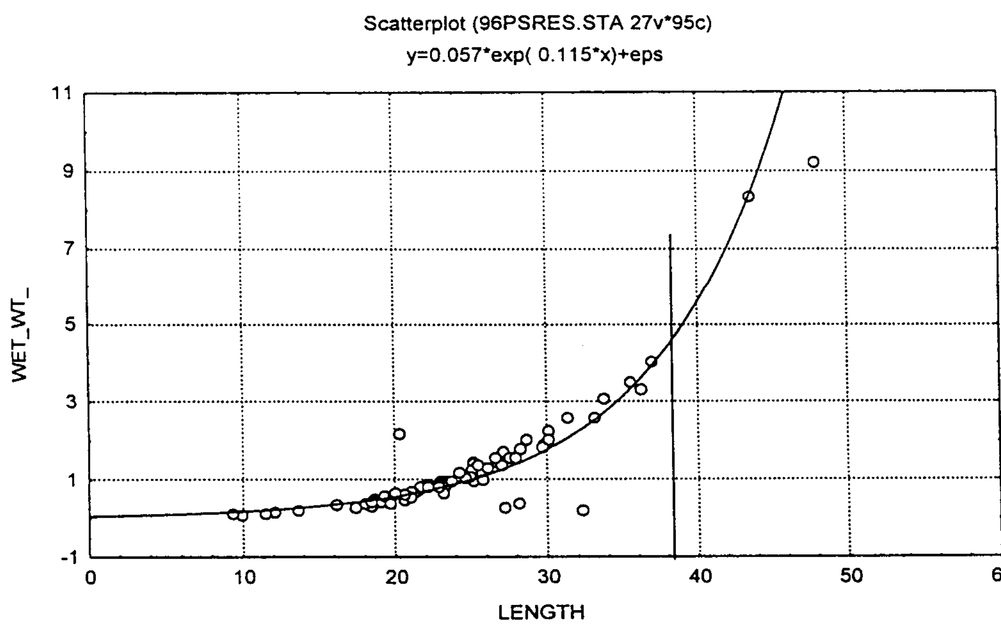


Figure 11. Wet tissue weight (grams) versus length (mm) for native littleneck clams (*Protothaca staminea*) collected in 20, 0.1 m^2 quadrats at the Chenega Village shellfish beach on June 29, 1996. The vertical solid line represents the minimum legal size.

An examination of the data density in Figures 10 and 11 suggests that clams are being removed from the population at an age of approximately 6 years and a size of ca. 35 mm. That length is coincident with the point in the curve where wet tissue weight is beginning to increase significantly as a function of age. Even at 38 mm, clams are still well within the exponential growth phase. 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 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. These conclusions are identical to those resulting from an analysis of the Tatitlek, Port Graham and Nanwalek data reported in Brooks (1995).

Predator density. 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. Villagers' noted that some harvesting has occurred there but associate 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.

Shellfish sanitation. 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 5 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.

Shellfish biomass available for harvest. There is currently no bivalve biomass available for harvest at this Chenega Village beach. The small number of cockles collected during the survey suggests that this species is adapted to this environment and could be cultured, pending development of hatchery, nursery, and grow-out methods.

Summary conclusions and recommendations for shellfish enhancement at Crab Bay near the Village of Chenega. The following recommendations are based on this survey and analysis:

1. **Beach suitability.** The Crab Bay beach contains greater than ten acres of ground suitable for native littleneck clam and cockle enhancement or culture. The physical and chemical parameters examined in this survey are all within acceptable limits. Clam growth, density and size suggest non-significant differences in culture potential over the area of surveyed beach. The small number of legal size clams observed in this survey suggest that both a predator control program and a harvest management plan will be essential to optimizing

future harvests. Enhancement of the eastern third of this beach is not recommended because of the potential for disruption associated with a change in the existing stream channel.

2. **Habitat suitability index (HIS) inputs.** It appears that clams can be successfully grown at tidal elevations between –1.0' and +1.0' MLLW on this beach. Native littleneck clams appear to grow to larger sizes in sediments which contain at least 1.0% TVS. Sediments contained between 5 and 14% fines (silt and clay). These values are considered adequate for native littleneck clam production. Nearly all aspects of native littleneck growth are enhanced by significant amounts of interstitial water movement as evidenced by the presence of oxygen at depth. Anaerobic sediments were not observed at any depth at intertidal elevations above –1.0' MLLW. The RPD was observed at a depth of approximately 5 cm in scattered locations at intertidal elevations lower than –1.0' MLLW. The substrates at this beach contain significant amounts (44 to 71%) of broken shale gravel. This material tends to compact and would be ideal for on-bottom oyster culture. Enhancement efforts should be preceded by a harvest of any existing clams at this site. The digging will help break up the consolidated sediments, improving habitat for juvenile clams.

3. **Predation.** Significant starfish predation was not observed in this survey. Sea otters were not observed preying on shellfish. However, the nature of the intertidal disturbances suggests there were associated either with human harvest or with sea otters. Drills were observed, albeit in low numbers. Any effort at beach enhancement should include a predator watch and removal of starfish, drills, drill egg cases, and crabs. The effects of sea otters should be documented, when they occur. Clam and oyster cages are fairly rigid and capable of excluding starfish, large drills and all but the most aggressive crabs. However, it is unlikely that these plastic mesh cages would discourage a determined sea otter. Caged bivalves should be examined periodically to predators which enter the cages as juveniles and can consume large quantities of shellfish as they grow.

4. **Recruitment** to the Chenega Village beach on Crab Bay occurred in low numbers in each of the last eight year classes. No year classes were missing. However, recruitment, or at least survival of juvenile clams until June 29, 1996, is too low and inadequate in each year class to provide for sustained, subsistence shellfish harvests.

5. **Age at harvest.** The age length analysis suggests that native littleneck clams recruit to the legal size population at an average of 7.3 years. The wet tissue weight – length, and wet tissue weight – age, analysis indicates that harvesting at a valve length less than 38 mm would be an inefficient use of the resource. This beach would likely benefit from development of a harvest management plan by elders in the Village of Chenega. Development of a management plan was not part of the current effort. However, this report provides adequate information for development of an interim plan that should be implemented along with shellfish enhancement activities.

6. **Butter clams.** *Saxidomus giganteus* recruits in small numbers to this beach. However, few butter clams are currently surviving past the juvenile stage. The reasons for this

were not determined. Due to the lack of hatchery and nursery technology, and propensity to retain brevetoxins, butter clam enhancement is not recommended at this time.

7. **Cockles** are a traditional (and preferred) shellfish for Alaskan Villages. The intertidal area of Crab Bay provides suitable substrates for cockle enhancement once culture methods are developed.

8. **Clams available for harvest.** There is currently no harvestable population of clams at this beach.

9. **Shellfish enhancement potential.** In Puget Sound, it is possible to grow greater than 0.5 pounds of native littleneck clams per square foot, in a three year growout period, on similar ground. Because of the slower growth in cold Alaskan waters, yield is probably lower at perhaps 0.07 pounds per square foot per year (0.5 pcf in 7.3 years). The total yield for this beach, assuming ten acres were developed, would then be on the order of 29,633 pounds per year. This likely exceeds the subsistence needs of this village suggesting that more than enough space is available. These estimates are tentative and carefully controlled age and growth studies are required before accurate estimates can be made.

Based on experience in other parts of the world, it is quite possible that the grow-out time to minimum legal harvest size can be reduced by at least one and perhaps two years. This requires nursery techniques in addition to hatchery production of seed. However, reduction of the age at recruitment into the legal size population by at least one year is possible and could mean the difference between a successful enhancement project and a failed one.

Summary. This beach on Crab Bay does not currently support subsistence quantities of hardshell clams. However, environmental factors are satisfactory for growing either littleneck clams or cockles. It should be emphasized that intensive cultivation techniques will be needed to reduce the time needed to grow a legal size clam. Seven years is simply too long to expect people to tend a shellfish culture before they realize any benefit.

Sustained subsistence harvests will require additional seed of the largest possible size, development of effective predatory control measures, and a well designed management plan. Optimizing solutions to these problems will require site specific studies to develop an understanding of clam growth and mortality and effective predator control. All enhancement projects should avoid the eastern portions of Crab Bay which are influenced by the perennial stream. Preliminary, small scale studies to determine the specific suitability of this beach, or any other beach, are recommended prior to any major enhancement effort.

Results

Village of Ouzinke

Village desires. The Village of Ouzinke provided a very warm welcome to the CRRC study team. The people of Ouzinke were enthusiastic and eager to participate in this study and expressed a desire for enhanced subsistence shellfish resources. This exuberance carried through to the work at hand, which was undertaken in a professional and dedicated manner. The author whishes to express his sincere appreciation to the following participants who made this survey extremely enjoyable. A special thank-you to my guide, Mr. Roger Larionoff whose knowledge of the local area was invaluable.

Paul Panamarioff
Maria Skonberg
Lylia Pestrikoff
Melody Anderson
David Pestrikoff
Roger Larionoff
Bill Boskofsky
Sandra Muller

Villagers' expressed a great deal of interest in the intensive or semi-intensive culture of clams and cockles for subsistence purposes. The surveyed beach lies across *Narrow Strait* at a distance of approximately 2.7 kilometers from the village in the vicinity of Precoda Island (locally referred to as Cat Island). It was relatively small, but suitable for culture purposes. The strait and beach are reasonably well protected and should be accessible during many times of the year. Numerous other small beaches, suitable for enhancement, were observed in the vicinity of Ouzinke. Several of these beaches currently hold subsistence levels of primarily butter clams (*Saxidomus giganteus*). There is a suitable beach situated in front of the Village. However, the number of people and heavy use suggest that it likely would not meet National Shellfish Sanitation Program requirements for an Approved classification. Sea otter predation was not evident on any of the several beaches examined in the vicinity of Ouzinke.

Beach characterization. The surveyed beach is located at 57° 48.12' N and 152° 30.05'W. The area judged suitable as native littleneck clam habitat measured 50 to 70' feet wide by 120 feet long (0.17 acres). It is bounded on the west by a cobble field and on the east by a small stream and dominantly 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, an area within Camel Bay contained numerous cockle shells and appeared prime habitat for *Clinocardium* enhancement.

As described in Figure 12, four transects (A, B, C and D) were examined in the most suitable (as clam habitat) part of the 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 which paralleled 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 schedule resulted in a total of 22 shellfish and three 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 Bertalanfy equation.

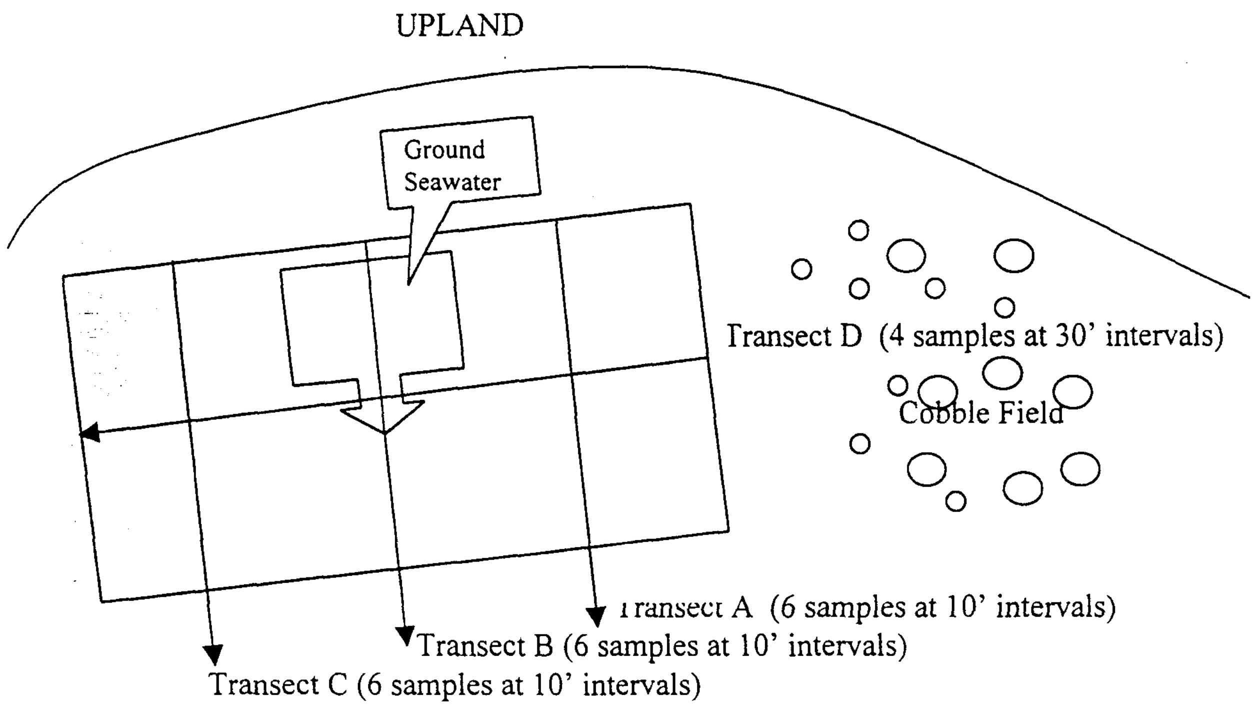


Figure 12. Schematic diagram of the Ouzinke Village shellfish beach located on the southern shore of Narrow Strait. The beach has surveyed on July 2, 1996.

The beach considered suitable for native littleneck clam production has a shallow slope (2%) and well oxygenated substrates to a depth of greater than 20 cm. The foreshore consists of a sand and gravel dunefield that has 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. The results of these analyses are presented in Appendices 1 and 2. Sediments at this Ouzinke clam beach averaged 41.2 $\pm$ 29.6 % gravel, 53.2 $\pm$ 29.3% sand and 5.6 $\pm$ 1.7% fines (silt and clay). 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.

Details of the sediment Total Volatile Solids analysis are presented in Appendix 2. This Ouzinke clam beach contained an average of 1.92 $\pm$ 0.85% volatile solids. Total volatile solids at this beach are within an ideal range for native littleneck clams.

Water Column Characterization. Water conditions at this Ouzinke beach were ideal for aquaculture on the day of this survey. Water temperature was 13.2 °C, salinity 31.2 ppt. Currents on the early ebb tide averaged 39 cm-sec^{-1}and flowed east. Maximum currents in this shallow bay off Narrow Strait are likely much higher. High current speeds are frequently associated with highly productive clam beaches and the observed currents are sufficient to present a continuous flow of available food to the small area being considered for enhancement

Water column analyses of Total Suspended Solids (TSS) and Total Volatile Solids (TVS) are presented in Appendix 2. The three water samples collected at this beach averaged 6.43 mg-L^{-1} TSS and 2.33 mg-L^{-1} TVS. These values suggest moderate 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.

Shellfish Population Characterization. A total of 162 living bivalves were collected in the 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 and length - weight analysis. The distribution of shellfish obtained from the systematic survey is provided in Table 10.

Table 10. 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 clam)	19
Saxidomum giganteus (butter clam)	61
Mya truncata (truncate softshell)	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 nuttalli* were observed in an eel grass meadow and intertidal area at Camel Bay (local name) located three kilometers west of the surveyed beach.

Butter Clams. A total of 61 butter clams were observed in these samples. Their length-frequency distribution is provided in Figure 13. 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 18 samples. Descriptive statistics for a limited number of variables are presented in Table 11. Figure 13 provides a length frequency summary of butter clams collected during this survey. A vertical line is displayed at the minimum legal size of 38 mm valve length.

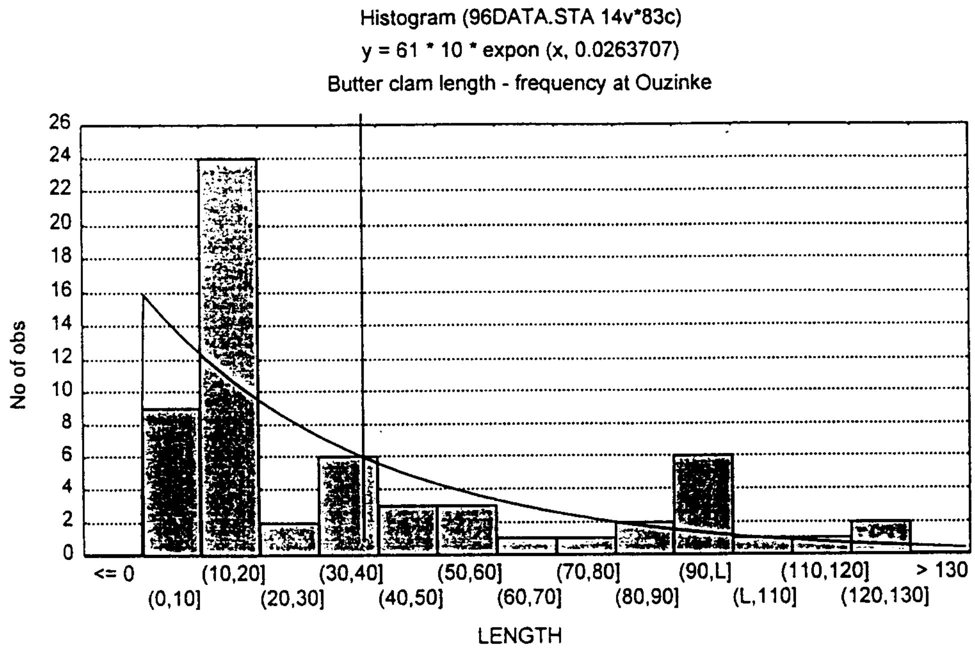


Figure 13. Length frequency histogram for butter clams (*Saxidomus giganteus*) collected in 22, 0.1 m^2 samples at the Ouzinke Village shellfish beach on July 2, 1996. The thin vertical line locates the legal limit (>38 mm).

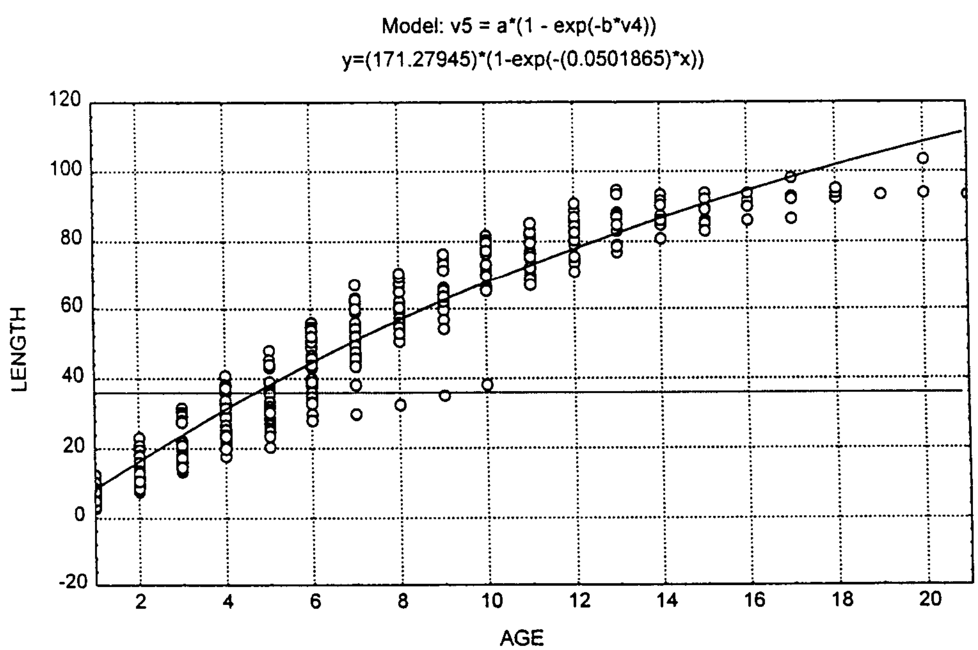


Figure 14. Solution to the von Bertalanfy equation for butter clams collected in 22, 0.1 m^2 samples at the Ouzinke Village shellfish beach on July 2, 1996. The thin horizontal line represents the minimum legal size (38 mm)

Table 11. 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 (gms)	61	53.3	0.16	444.1	104.3
Age	60	6.1	0.00	21.0	5.7
Dry Condition Factor	34	0.91	0.13	2.2	6.2

Non-linear regression was accomplished on aged living and empty butter clam valves to determine coefficients for the von Bertalanfy equation. 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 = 0.037; p = n.s. @ $\alpha = 0.05$). Observed and predicted values are presented in Figure 14.

The resulting Von Bertalanfy 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 to be successfully aged. The smaller coefficient on age suggests that butter clams grow more quickly at Ouzinke than at either Passage Island or Tatitlek.

Length (Ouzinke) $= 171.3(1 - \exp^{-0.050 \times age})$

Length (Passage Island) $= 84.4(1 - \exp^{-0.126 \times age})$

Length (Tatitlek) $= 126.5(1 - \exp^{-0.075 \times age})$

An age-frequency histogram for butter clams is presented in Figure 15. Butter clams 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. Assuming that recruitment in 1994 and 1995 is indicative of other years, a significant proportion of the new recruits appear to survive and enter the harvestable populabtion. A number of hypotheses could be invoked to explain the higher survival in this location. It is remote from the Exxon Valdez oil spill and may represent undisturbed conditions. However, otter pits were not observed on this beach and very few drills and 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 were investigated as part of this study.

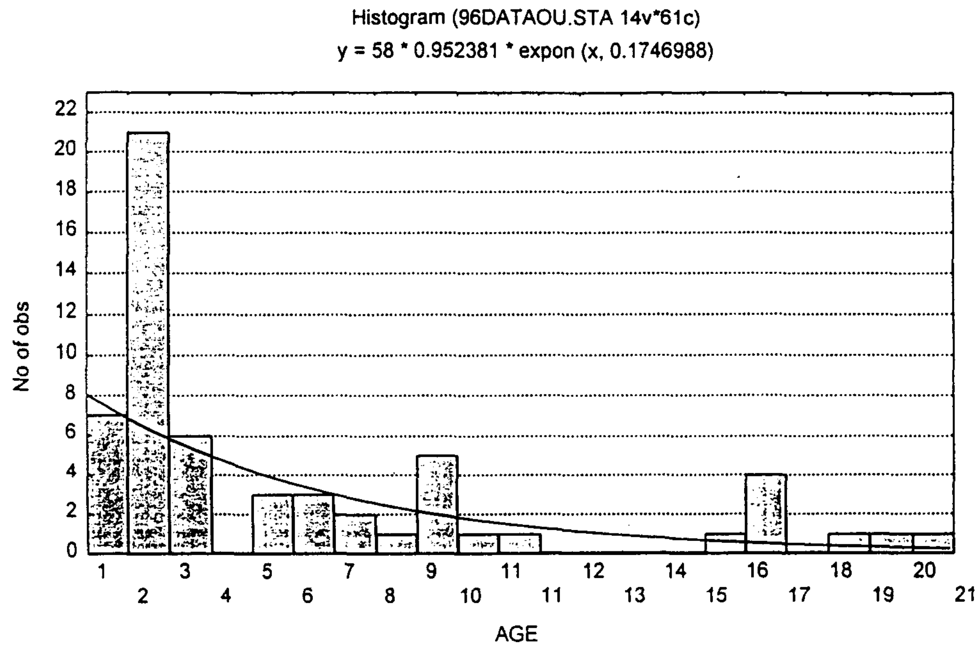


Figure 15. Age-frequency histogram for butter clams (*Saxidomus giganteus*) collected in 22, 0.1 m^2 samples at the Ouzinke Village, Narrow Strait, shellfish beach on July 2, 1996.

Butter clams are 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. Therefore, it will not receive further attention in this report. It should be noted that recruitment of butter clams is low, but occurs fairly regularly, at 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.

Harvestable biomass of butter clams at Ouzinke. This is the first beach surveyed by the CRRC study team that contained subsistence quantities of shellfish. The average weight of butter clams harvested in the 22 samples 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.

Bacteriological water quality at the Ouzinke shellfish beach on Narrow Strait. Three water samples were collected at the survey beach and returned, on ice, to Aquatic Environmental Sciences where they were examined for fecal coliform bacteria using the 5 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. Certification should be obtained for the receiving water from responsible agencies prior to any major enhancement effort.

Native littleneck clams. A total of 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 12.

Table 12. 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 Tis. 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). A total of eight (8) legal size 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 complete lack of subsistence littleneck harvest available on the Ouzinke Village beach at Narrow Strait. Figure 16 suggests steady, but very low recruitment (or survival of recruits past settlement) at this beach.

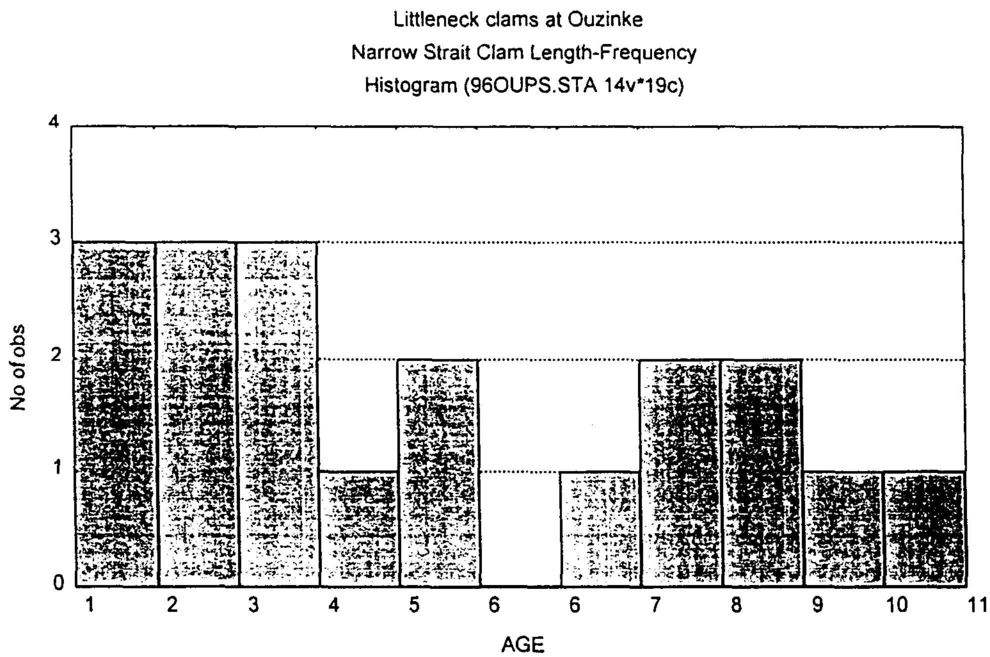


Figure 16. Age – frequency histogram for littleneck clams collected in 22, 0.1 m^2 quadrats at the Ouzinke shellfish beach on July 2, 1996.

Further examination of the population was accomplished using the length - frequency histogram provided in Figure 17. 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 16 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 is required at this site to improve production.

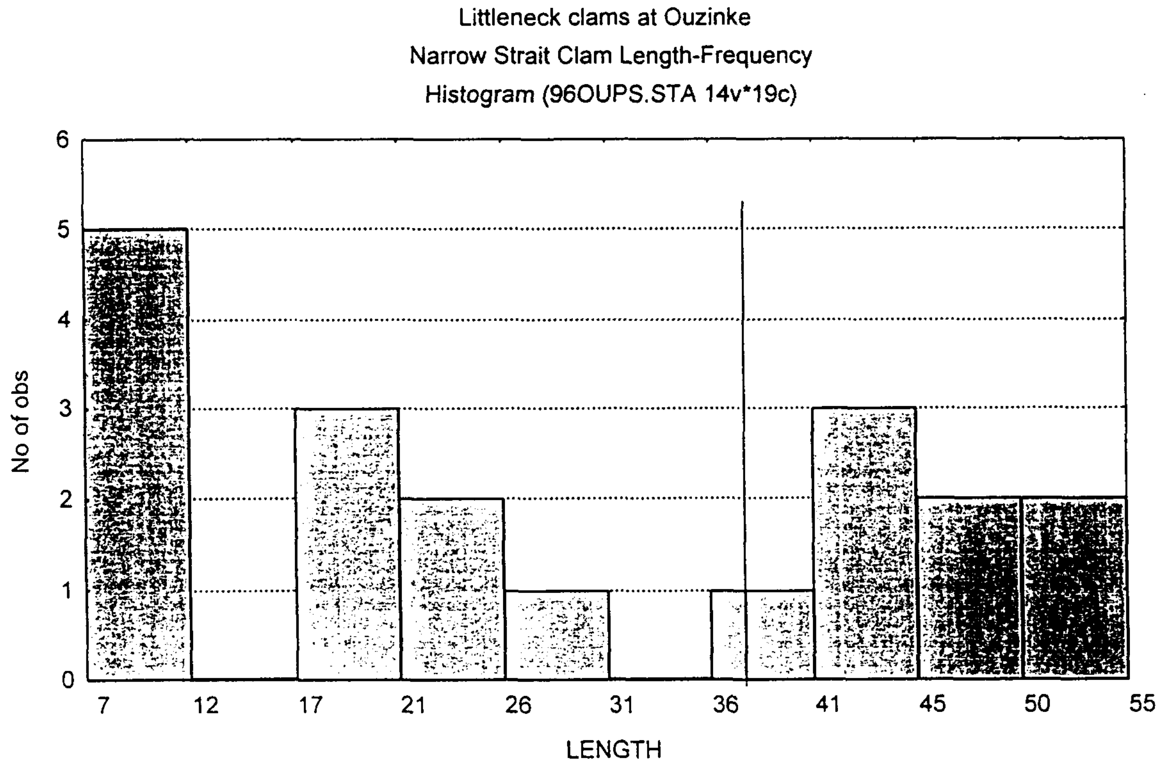


Figure 17. Length - frequency histogram for littleneck clams collected in 22, 0.1 m^2 samples collected at this Ouzinke beach on July 2, 1996. The thin vertical line represents the minimum legal size of 38 mm.

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. At the present time, they do not contribute significantly to shellfish harvests. Older 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 may be appropriate on this beach.

Figure 18 examines the distribution of native littleneck and butter clams as a function of tidal height at this Ouzinke beach. Unlike other beaches surveyed in this study, most of the littleneck clams at this Ouzinke beach were found at relatively deep intertidal elevations. However, the few clams retrieved do not provide a basis for drawing significant conclusions.

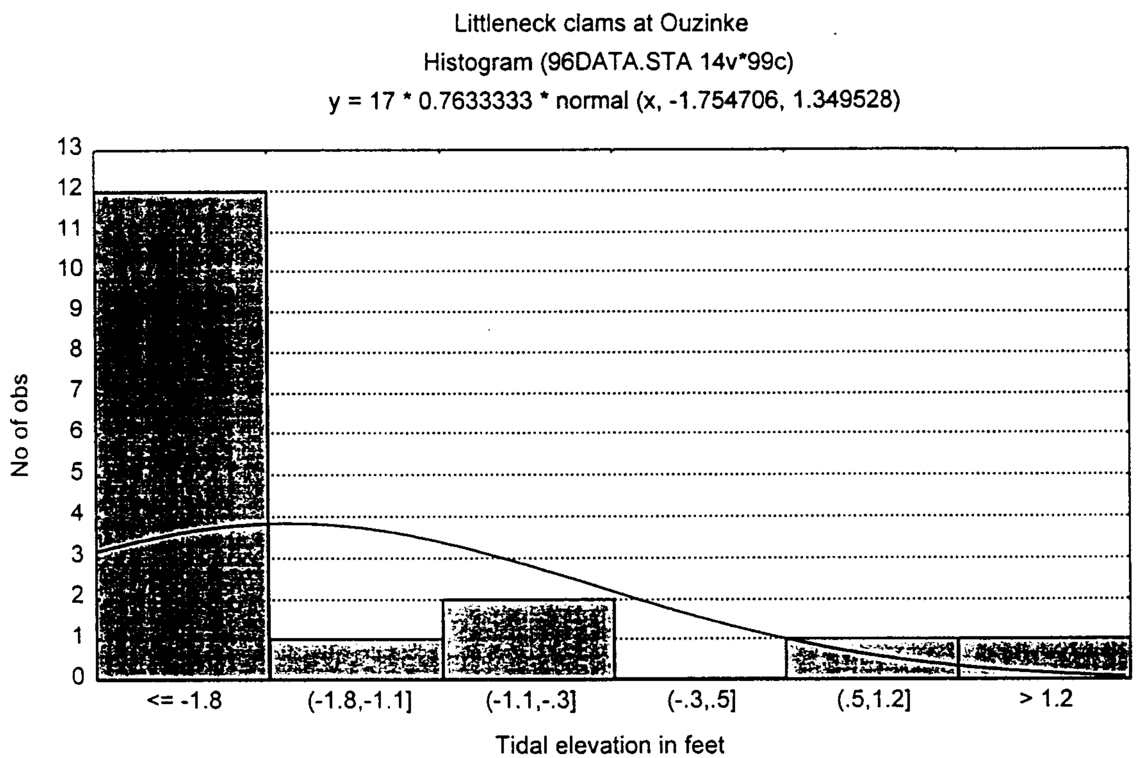


Figure 18. Tidal elevation - frequency histogram for littleneck clams collected in 22, 0.1 m^2 quadrats at the Village of Ouzinke shellfish beach on Narrow Strait on July 2, 1996.

Age - Length analysis. Regression coefficients were developed for the von Bertalanfy equation using non-linear regression. Due to the low numbers of littleneck clams collected in the samples, an attempt was made to expand the database by aging valves from dead clams collected at random on the beach. However, that analysis, which did have normally distributed residuals and explained 94.5% of the variation, resulted in a maximum length of 94.7 mm. This exceeds any reasonable expected size for this clam. No explanation is offered.

The analysis was then conducted using only the age-length data collected from living littleneck clams collected in the samples. Those results were more reasonable. 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. @ $\alpha = 0.05$). A full range of clam valve lengths were 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 19. This equation was solved for a length of 38 mm to obtain the average age of recruitment into the legal size population. The average age of recruitment is 6.13 years when computed using the von Bertalanfy equation based on data from living clams only and 6.56 years when based on measurements from living and dead clam valves combined.

Native littlenneck von Bertalanfy equation **Length = 73.8(1 - exp$^{-0.118*age}$)**

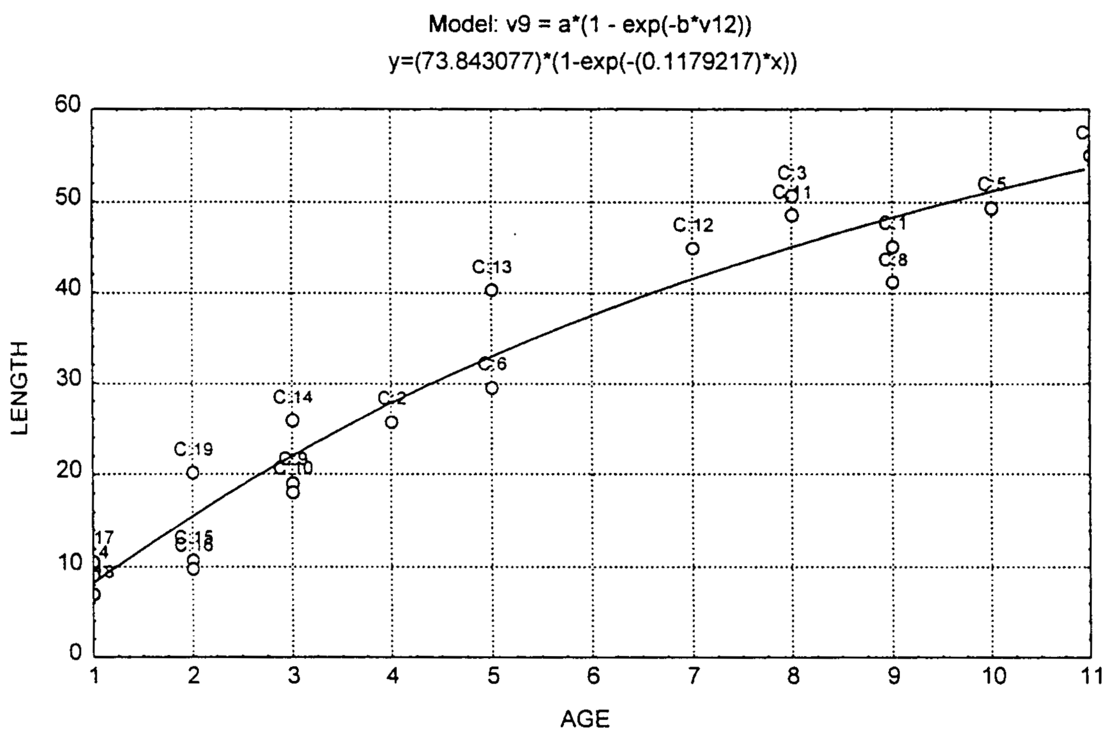


Figure 19. Valve length (mm) as a function of age (years) for native littleneck clams (*Protothaca staminea*) collected in 22, 0.1 m^2 quadrats at the Ouzinke shellfish beach on Narrow Strait on July 2, 1996.

Suitability of the Ouzinke shellfish beach for stock enhancement. From a physical and chemical point of view, the Ouzinke beach is ideal for native littleneck clams. The strong currents passing this point contribute significant food to the rich infaunal community. This survey suggests that the primary constraint to shellfish production is poor juvenile recruitment.

Predator density. Large numbers of predators were not observed on Ouzinke beaches during these surveys. This suggests that minimal protection may be required for an extensive enhancement project at this site. This is the only area surveyed in either 1995 or 1996 which had significant numbers of older clams and few signs of predators.

Shellfish biomass available for harvest in each strata. There is currently a significant shellfish biomass available for harvest on this beach and on several other beaches in the local area. 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 and subsistence harvests would quickly deplete the standing stock. This could be avoided by invoking a locally supported management plan.

Summary conclusions and recommendations for shellfish enhancement at the Village of Ouzinke's, Narrow Strait shellfish beach. Based on this survey and analysis, the following conclusions can be reached:

1. **Beach suitability.** The surveyed Ouzinke beach contains approximately one- fifth acre of ground suitable for native littleneck clam enhancement or culture. The physical and chemical parameters examined in this survey are all within acceptable limits. The beach is readily accessible from the village. The apparent absence of large numbers of predators makes this area unique among the five village beaches surveyed in 1995 and 1996. There is an opportunity here to implement a more extensive enhancement trial.

2. **Habitat suitability index (HIS) inputs.** The observation of a significant flow of saltwater from the interdunal area above the beach is a positive aspect of this beach that will reduce the potential desiccation and overheating in the summer and freezing during winter low tides. Nearly all aspects of native littleneck growth are enhanced by significant amounts of interstitial water movement as evidenced by the presence of oxygen at depth. Coupled with the surveys undertaken in 1995, the growing database provides a basis for making improvements to the U.S. Fish and Wildlife Services Native Littleneck Habitat Suitability Index.

3. **Predation.** Evidence of significant predation was not observed in this survey.

4. **Recruitment** to this Ouzinke beach has been too low to sustain long term subsistence or recreational harvests.

5. **Native littleneck clams.** Few native littleneck clams were observed in samples from this Ouzinke beach. The reason is thought to be poor juvenile recruitment. The age length analysis suggests that native littleneck clams recruit to the legal size population at approximately 6.5 years of age. Harvests should be concentrated in specific areas and take all of the legal size clams. These recommendations should be made part of an overall management plan for the several beaches used by the Village of Ouzinke. Development of a management plan was not part of the current effort and should await completion of adequate growth and mortality studies. However, the data collected herein provides direction for the development of interim plans.

6. **Butter clams** (*Saxidomus giganteus*) also recruit in low numbers to this beach. Growth is somewhat faster than for native littleneck clams and butter clams enter the legal size population at approximately 5.0 years of age. There is a significant standing biomass of butter clams on this, and several other beaches in the area. However, the large biomass consists of older clams that will not be quickly replaced following harvest. These beaches would benefit from the planting of clam seed. Due to the lack of hatchery and nursery technology, and

propensity to retain brevetoxins, butter clam enhancement is not recommended at this time. Enhancement should focus on native littleneck clams.

7. **Cockles** are a traditional (and preferred) shellfish for Alaskan Villages. The primary beach surveyed in this effort is too rocky, with too few fines, to warrant cockle enhancement. However, excellent cockle habitat was observed in Camel Lagoon approximately 3 kilometers west of the surveyed beach.

8. **Mussels** were not observed in abundance on any of the surveyed beaches in the Ouzinke area. Unless unidentified, local sources of seed are available, mussel culture would require the importation of hatchery produced seed or seed collected from other locations.

9. **Clams available for harvest.** There is currently approximately 670 kilograms of butter clams on the surveyed beach that are of legal size.

10. **Beach potential.** In Puget Sound, it is possible to grow greater than 0.5 pounds of native littleneck clams per square foot, in a three year grow-out, on similar ground. Because of the slower growth near Ouzinke, that yield is probably lower at perhaps 0.08 pounds per square foot per year (0.5 pcf in 6 years). The total yield for this beach would then be on the order of 600 pounds per year. These estimates are tentative and require carefully controlled age and growth studies before accurate estimates can be made. There are numerous small shellfish beaches in the vicinity of Ouzinke. Therefore, village subsistence needs must rely on small, disbursed beds – making intensive culture in a single area unlikely. However, as previously stated the enthusiasm of Ouzinke's people, coupled with the apparent lack of significant predation, make extensive enhancement in this area appealing.

Extensive enhancement should include removal of starfish and other obvious predators, followed by raking of the substrate to loosen the top few centimeters and planting of large seed (> 12 mm) just before, or during, the flood tide. Rock and cobble should be placed in a row, below the seeded ground, parallel to the beach. This will help stabilize the substrate and has been shown to enhance recruitment by providing pockets of water behind the receding tide. In areas where predation by starfish and crabs is heavy, or where substrates are moderately unstable, enhancement may include the application of plastic netting (car-cover) over the prepared substrate. However, reduction of the natural age at recruitment into the legal size population by one or two years from the current average of six years is possible and could significantly increase the quantity of shellfish available for subsistence harvests.

Summary. Several beaches in the vicinity of Ouzinke provide an excellent opportunity for growing littleneck clams or cockles. Sustained subsistence harvests will require additional seed, implementation of effective predator control measures, and a well designed management plan. As previously recommended, optimizing solutions to these problems will require site specific studies to develop an understanding of clam growth and mortality, effective predator controls and tidal elevation versus culture depth requirements to prevent freezing during cold winter night-time low tides.

General Recommendations For Shellfish Enhancement At Chenega and Ouzinke

Chenega. The Chenega beach on Crab Bay contains broken shale which compacts fairly easily and is similar to substrates observed in the vicinity of Port Graham. It could be manipulated to provide reasonably good native littleneck clam habitat and would be excellent for ground culture of oysters. This substrate did not contain large quantities of rock and cobble and preparation should be relatively easy. The eastern parts of Crab Bay are heavily influence by fresh water and care must be taken to avoid areas where this potential is high. Intensive culture requires areas of relatively uniform substrate from which cobble larger than 7.5 cm has been removed. This will require some hand labor. If the rock is strategically placed, it can help retain water during low tides and encourage recruitment of wild larvae. This beach could support either native littleneck or cockle culture. The project should start with perhaps 25,000 juvenile clams approximately six to 10 mm in length. The enhancement effort should include a carefully designed growth and mortality study to examine, over a five year period, the growth and survival of native littleneck clams and cockles in intensive culture. These initial studies should also determine the optimum depth requirements (as a function of tidal height) for growing clams in cold Alaskan waters. The experimental design being used at Tatitlek, Nanwalek and Port Graham is also appropriate for Chenega.

Ouzinke. There are several beaches near Ouzinke that could be enhanced. Cockles and native littleneck clams should be placed in cages at this site for growth and mortality studies. Intensive culture would require extensive handwork to remove cobble and rock from culture areas on beaches surveyed in 1996. This factor, coupled with an apparently reduced level of predation, suggests that extensive enhancement would be appropriate in this area. However, the enthusiasm and energy of the people of Ouzinke should be recognized and could be focused in a model to demonstrate the potential for either extensive or intensive shellfish culture. In Washington State, the author has promoted the establishment of shellfish "Victory Gardens" for small communities and waterfront property owners. Ouzinke would be an excellent candidate for an Alaskan trial of the same concept.

Seed Production. The Qutekcak hatchery should receive continued support in its efforts to develop a reliable source of native littleneck clam seed. In addition, CRRC should continue its investigation of the potential for raising native littleneck clam seed to the largest size possible in floating nurseries. In Puget Sound, the location of floating, upwelling nursery systems is critical to their success. I strongly recommend that CRRC investigate several locations as candidate sites for optimizing use of their two upwellers. Lastly, current efforts to develop hatchery and nursery production of cockle (*Clinocardium nuttallii*) seed should be continued.

Village Training. The growth and mortality studies should be conducted by the respective villages. The training programs undertaken at Nanwalek, Tatitlek and Port Graham in 1996 will be discussed in a succeeding section. I recommend that the materials developed in support of the 1996 program be used to conduct workshops at any future Villages where enhancement projects are undertaken.

Harvest Management Plan. Harvest management of shellfish resources in Alaska is of special importance because of the slow growth, particularly of native littleneck clams. Individual management plans should be developed and implemented by Village Elders at each village to insure that existing shellfish, and those produced in enhancement projects are harvested in a sustainable way.

Figure 20 presents a scatterplot of all native littleneck clams measured and aged in this 1995 survey. The scatterplot is fitted with a non linear solution to the von Bertalanfy equation. The results indicate that native littleneck clams enter the legal population at an age greater than four and only half of the clams are greater than 38 mm by age seven. Even four years is a long time to maintain a culture and control predators before a harvest is enjoyed. That, in part, is the reason for emphasizing development of enhancement techniques for the faster growing cockle.

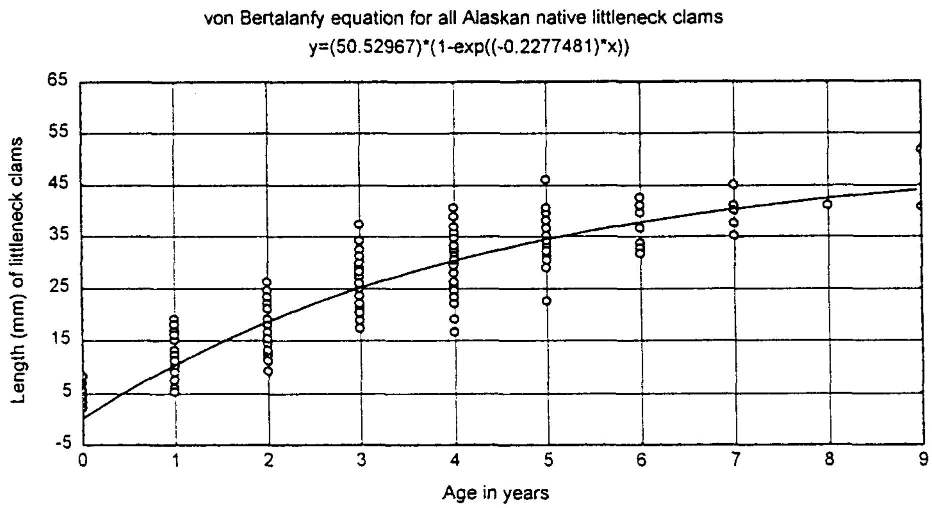


Figure 20. Scatterplot describing length of native littleneck clam valves as a function of age in 1995 samples collected at shellfish beaches in the vicinity of Tatitlek and Nanwalek in Alaska. A non linear solution to the von Bertalanfy equation is provided and the resulting regression plotted on the graph.

Feder and Paul (1973) found minor variations in the incremental growth of valves in littleneck clams from Prince William Sound. They found an average age of recruitment into the legal size population of 8 to 10 years. That is on the high end of the 5 to 10 year age at recruitment estimated by ADFG (1995). Examination of Figure 26 suggests that native littleneck clams reach a minimum size of 38 mm at an average age between five and >9 years. Solving the von Bertalanfy equation given in Figure 26 for age at a length of 38 mm suggests that the average clam reaches a minimum legal size at 6.12 years of age. These estimates are all similar on the top end but this report and ADFG (1995) suggests that recruitment into the minimal legal size class occurs at an earlier age that suggested by Feder and Paul (1973).

Part II: Native littleneck clam (Protothaca staminea) enhancement studies at the villages of Nanwalek, Port Graham and Tatitlek

Shellfish Restoration Program
EVOS DPD Project #95131

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. When appropriate methods for shellfish enhancement have been developed at these villages, the enhancement program will likely be expanded to include other Alaskan Indian Villages such as Ouzinkie and Chenega Bay. These clams will be used as a source of subsistence food to replace the natural clam resource that has been lost or depleted.

Village workshops. Educational workshops were held for the villages of Tatitlek, Nanwalek and Port Graham. 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. Each Villager was provided with a copy of the handouts included as Appendix 4 to this report.

The second part of each workshop was devoted to introducing 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 complete set of tools, protocols and data sheets necessary to implement the quarterly sampling. The following equipment was provided to each village:

1. Two sets of stainless steel Vernier calipers
2. One hand trowel
3. Two clam harvest rakes
4. One hard bristle brush for cleaning clam cages
5. Two cafeteria trays for sorting shellfish.
6. 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 and 300 mussels used in the caged growth and mortality studies. This activity was closely monitored by the CRRC study team. A total of nine Villagers 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.

Shellfish enhancement studies. Beaches at Tatitlek, Nanwalek and Port Graham were surveyed in 1995 (Brooks, 1995). The results of those surveys have been used to develop site specific littleneck clam and mussel enhancement study projects at these same villages.

There are numerous techniques that can be used to enhance shellfish populations, particularly clam populations. The purpose of the present study is to assess growth and mortality of native littleneck clams under controlled conditions, which minimize the potential for predation. This information is important in verifying growth rates predicted by ADFG (1995), Feder and Paul (1973) and Brooks (1995) using winter valve checks. Specific enhancement recommendations will be made pending outcome of these studies.

The 1996 shellfish enhancement studies involved placement of seed clams (*Protothaca staminea,* 5 mm to 15 mm valve length) in a replicate, blocked design which is examining growth and mortality as a function of tidal height and in the presence or absence of "car-cover" predator exclusion netting. A uniform seeding density of 30 seed clams per square foot was used throughout these studies.

Clam (*Protothaca staminea*) seed supply. Juvenile clams were provided by the Qutekcak Shellfish Hatchery from stocks spawned in 1994 and 1995 by Mr. Jeff Hetrick and Carmen Young. Twenty-three thousand juvenile clams from the 1994 cohort were grown indoors for one year and then transferred into gravel filled trays placed in a pond managed for optimum phytoplankton growth. Valve lengths in these two year old clams varied between 3.3 and 12.5 mm. A smaller cohort of 1,200 clams was available from the 1995 spawn. These juveniles were grown indoors in upwellers until May, 1996, when they were transferred to pearl nets hanging in the pond. At one year of age they averaged 17.9 $\pm$ 0.6 mm. This rapid growth attests to the improved growth possible with even moderately enhanced nursery techniques. A description of the pond, its management, and phytoplankton productivity should be available in the 1995 and 1996 Qutekcak Hatchery annual reports for this project. These clams were mixed at the hatchery and randomly subsampled to provide three stocks of ca. 8,067 clams for each village. These subsamples were shipped to each village within two days of placement in the study plots.

Growth and mortality of caged clams. One hundred seed clams will be placed in "Norplex™" clam bags for a detailed growth and mortality study. The valve lengths of all clams placed in these bags will be 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 on the data sheets provided by Aquatic Environmental Sciences.

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 shovelfull of sieved (1/2" sieve) gravel.

Bags were then nestled into the substrate to a minimum depth of 4". The top surfaces of each bag extended a minimum of 1" 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. Identical study lay-outs, described in Figure (21), were used at all three Villages. This part of the study required measurement of 900 clam seed per village (2,700 total).

The study plan required that bags be retrieved at three month intervals and the valve length of each surviving clam measured and recorded to the nearest 0.1 mm. All empty clam shells were to be retrieved, measured and archived. Fouling organisms were removed from the bags and a shovelfull of sieved (1/2") gravel added. Clam bags were then carefully renestled in the sediment and the 100 premeasured clams sprinkled on top of the sediment in the bag prior to securing the end with split PVC and electrical ties. Villagers were cautioned to retrieve clam bags individually and to measure and replace the clams in one bag before removing the next bag.

Clam enhancement using Car-cover netting. A minimum of 4' was required between each treatment and block. This provided access to the treatment for sampling without disturbing adjacent plots. All large (>10.0 cm diameter) rock and cobble were 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. Car-cover 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.). After all plots were prepared, the tidal elevation of the center of each plot or bag was measured against a known tidal elevation. 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 will be sampled annually and processed in a similar manner. During annual monitoring, sediment samples will be taken from each of the car-covered, uncovered seeded area and control to determine the biophysical effects associated with the various treatments.

Clam enhancement with protective netting. Additional 1.0 x 2.0 meter sites were prepared as described above except that car-cover netting was not installed.

Seeding of netted and unnetted substrates. Littleneck clams provided by the Qutekcak hatchery were divided into 12 subsamples of approximately 600 clams each. Clams were sprinkled onto the netted and un-netted sites as the flood tide covered them. This required a total of 600 clams/station x 2 treatments (netted and uncovered) x 2 tidal heights (+1.5 feet and -1.5' MLLW) x 3 replicates = 7,200 clams per village. When combined with the 900 clams required in the bagged growth and mortality study, a total of 8,100 seed clams were seeded at each village (24,300 seed clams total).

Maintenance. Village culturists were encouraged to monitor these studies on a weekly basis, or as tidal conditions permit. They were cautioned that all rips in the netting must be repaired and all predators removed. Badly damaged nets should be replaced with as little disturbance to the culture as possible. Water temperature, air temperature and salinity should be measured and recorded at least bi-weekly.

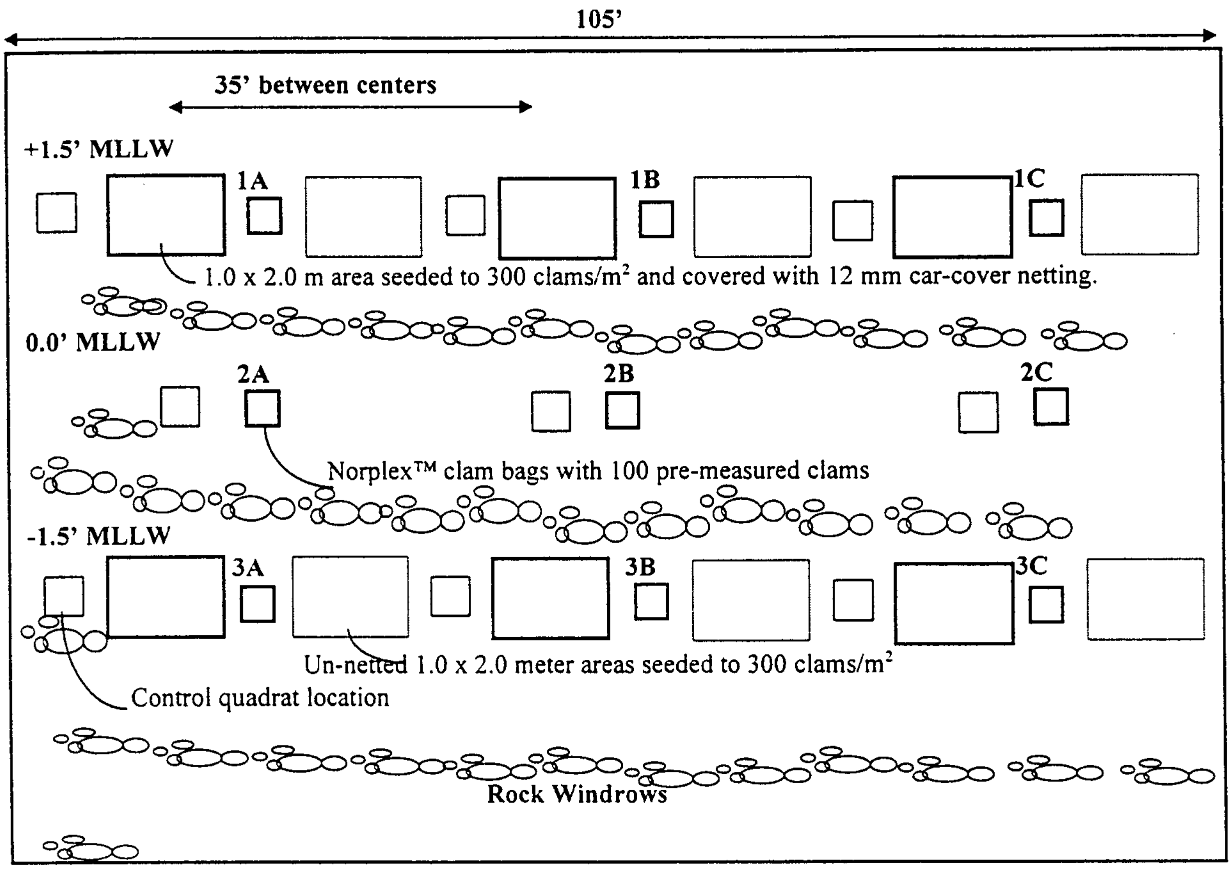


Figure 21. Study design for clam enhancement studies at previously surveyed beaches at the villages of Tatitlek, Nanwalek and Port Graham.

Data collection for netted and un-netted treatments. Clams in netted and un-netted plots will be examined annually during the 1997, 1998 and 1999 field work. Clam plots will be evaluated by noting the presence of predators, uncovering the netted plots and collecting three randomly selected 0.035 m^2 samples from each plot. The clams in the samples will be counted, measured at the beach site and immediately replaced at a shallow depth with the substrate taken from the quadrat. The netting will then be replaced.

A sediment sample will be collected from the top four inches adjacent to each treatment cluster. The RPD will be measured at each of these points and a second sediment sample retained for total volatile solids and sediment grain size analysis. The substrate will be characterized to include the following:

A. Substrate color
B. Presence of attached macroalgae
C. Presence of predators

D. Evidence of excessive littoral drift or log damage
E. Oily sheen
F. Odor (hydrogen sulfide, ammonia or petroleum)
G. A photographic record of the site will be made to describe the general area, seeding treatments, shoreline, fetch, and substrate type.
H. Water temperature and salinity will be measured.
I. At a minimum, each annual beach survey will include:

1. 18 sediment samples (50 gm each) for sediment grains size analysis
2. 18 sediment samples for Total Volatile Solids analysis.

Sediment grain size will be determined using the sieve and pipette method. Sediments greater than 1 cm will be pooled. Additional sieves sizes will include 2 mm, 1 mm, 500 µm, 125 µm, 63 µm. Silt (>3.9 µm) and clay (<3.9 µm) will be differentiated using the pipette method.

Sediment Total Volatile Solids will be determined by drying a sediment sample at 103 $\pm$ 2 °C until no further weight reduction is observed and then ashing the sample at 550 °C until no further weight loss is recorded.

Results – Tatitlek. Six people from the Village of Tatitlek participated in all events associated with this enhancement study. The Villagers were enthusiastic, learned to use the vernier calipers quickly and were very meticulous in following instructions. The educational workshop was held on June 28, 1996 and the clams and mussels planted on June 29, 1996 during a predicted –1.8' MLLW tide which ocurred at 0642 hours. The study was conducted within the area surveyed at this beach in 1995. The study area is described in Figure 22.

Beach preparation. The –1.5', 0.0' and + 1.5' MLLW tidal elevations were determined with reference to the low tide. The location of each plot was then determined by the CRRC study team. The beach at Tatitlek contained significant amounts of large cobble and rock. The substrate was cultivated to a depth of approximately 15 centimeters at each treatment. All clams larger than 1.0 cm were removed. All rock and cobble was moved below the treatment to form a small berm (<30 cm in height).

Netted treatment sites. Tatitlek villagers prepared each netted treatment site by clearing and cultivating an area approximately 1.0 by 2.0 meters of all large cobble and rock. A shallow trench (ca. 15 centimeters deep) was then dug around the area to be seeded. A precut piece of plastic netting (Carcover) was stretched over the treatment and its perimeter buried in the trench. Previously subsampled clams (ca. 600 clams per sample) were gently spread over the netted area as the tide flooded each treatment. The clams were observed digging into the substrate and no clams were observed floating. This procedure is described in Figure 23.

Un-netted treatment sites. Similar treatment sites were cultivated, but no Carcover installed. These unprotected plots were seeded in a manner similar to the Carcover treatments.

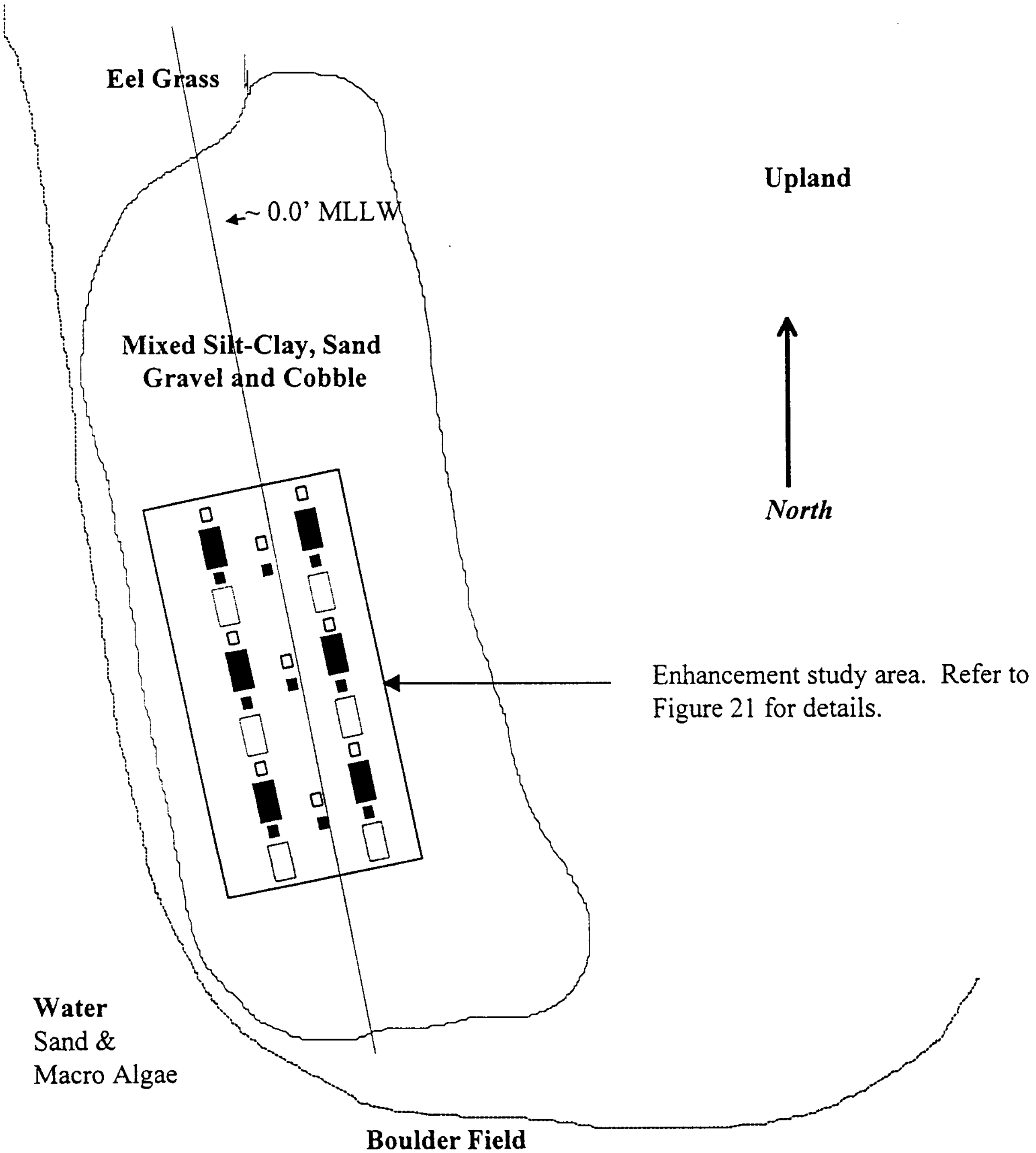


Figure 22. Schematic diagram of the Tatitlek Village shellfish beach and location of the enhancement study area. The beach has surveyed in August of 1995. The native littleneck clam enhancement study began on June 28, 1996.

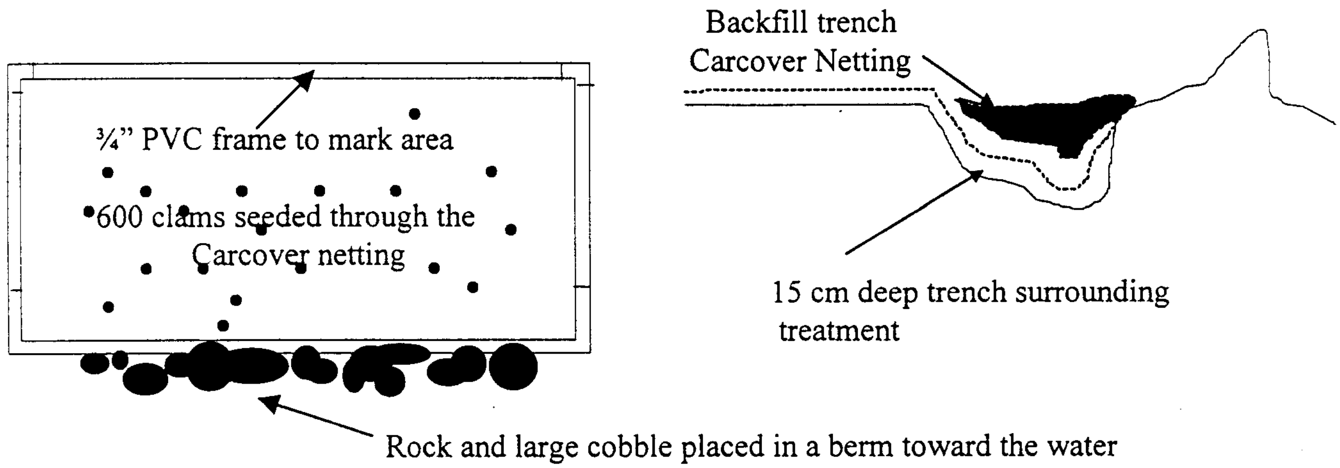


Figure 23. Schematic representation of the netted treatments used during the 1996 shellfish enhancement study at beaches in the vicinity of the native Villages of Tatitlek, Nanwalek and Port Graham.

Controls. The control quadrats noted in Figure 21 were cultivated (substrate loosened and large rock removed). However no clams or netting were provided at these locations.

Caged native littleneck clam growth and mortality study. Shallow pits were dug in the substrate at those locations noted in Figure 21 where Norplex™ cages were placed for the growth and mortality study. Norplex™ clam cages were filled with one or two shovelfulls of screened sediment from which wild clams and predators were removed. The bags were nestled in the previously dug depressions and rocked back and forth to level the added substrate. One hundred previously measured clams were then gently spread on top of the sediment inside the bag. The open end was secured with a piece of split PVC pipe and three electrical ties. A piece of 24 inch rebar was driven into the substrate at the top of each bag.

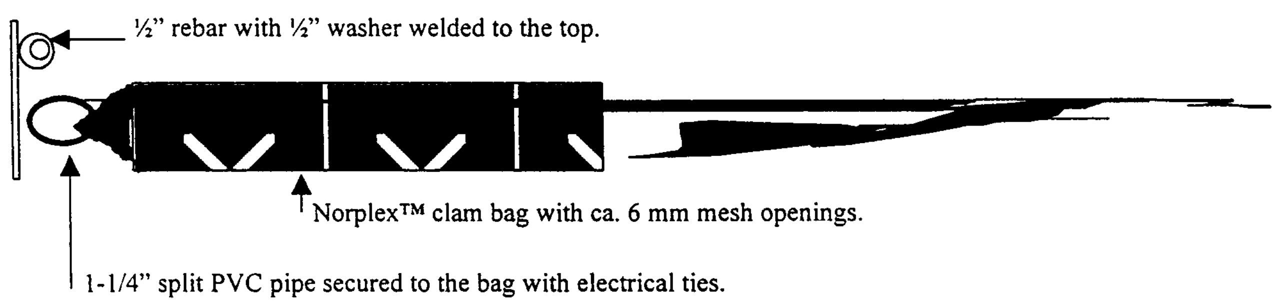


Figure 24. Schematic representation of the native littleneck caged clam growth and mortality study conducted at the Villages of Tatitlek, Nanwalek and Port Graham.

The rebar had a steel washer welded to the top. The bag was secured to this washer with large, UV protected electrical ties. Each bag was identified with an inside plastic tag, the PVC closure was marked and a third label was secured to the rebar with electrical ties. The perimeters of the pits were then filled with native substrate such that only two to three centimeters of the bag was exposed above the surface.

Predator control. The beach at Tatitlek held very large numbers of *Pycnopodia helianthoides.* Three bushel baskets of these starfish were collected on the beach and removed to an area above the high water mark. Villagers were encouraged to remove starfish on a continual basis – at least once each quarter during examination of the caged shellfish. In addition, it was emphasized that care needed to be taken when replacing the substrate in these bags to not introduce small starfish, crabs or drills.

Sediment physical and chemical characteristics. Sediment samples collected at Tatitlek in 1996 were lost in shipping. Sediment analyses from the 1995 survey of this same beach will be used as a baseline. That data is provided in Appendix 1. Study area sediments contained an average of 65.7% gravel, 25.9% sand and 8.3% fines (silt and clay). Total volatile solids averaged 1.3% in these same sediments.

Growth and mortality. Survival of clams, by tidal height, is provided in Table 13 and Figure (25) for Tatitlek. Maximum average survival occurred at 0.0' MLLW. Minimum average survival of 70% occurred at the highest intertidal elevation of 1.5' MLLW. This is encouraging, because significant winter kill was not experienced by clams held at even this highest intertidal elevation. Greatest survival of 90% occurred in replicates held at 0.0' MLLW. Average survival for all replicates was 81%. Some caution is warranted in interpreting this data because 116 clams were counted in replicate 3C on September, 27, 1996. No explanation is offered for the additional clams. However, it is unlikely that they represented newly settled recruits because the minimum length recorded on September 27 was 10 mm. A more detailed analysis will be possible at the end of the 1997 sampling year. However, if an annual survival rate of 81% is assumed, then it is reasonable to expect that 28% of the clams will survive during a six year grow-out. Based on experience with manila clams in Puget Sound, it is likely that non-catastrophic mortality rates will decline as the clams age and survival will likely be higher than this prediction.

Table 13. Survival of 100 native littleneck clams caged in Norplex™ cages and cultured at three intertidal elevations at the Alaskan native village of Tatitlek. Each value is the average of three replicates.

Days in Culture	Transect 1 (+1.5' MLLW)	Transect 2 (0.0' MLLW)	Transect 3 (-1.5' MLLW)
0	100	100	100
92	79	95	94
201	70	90	82

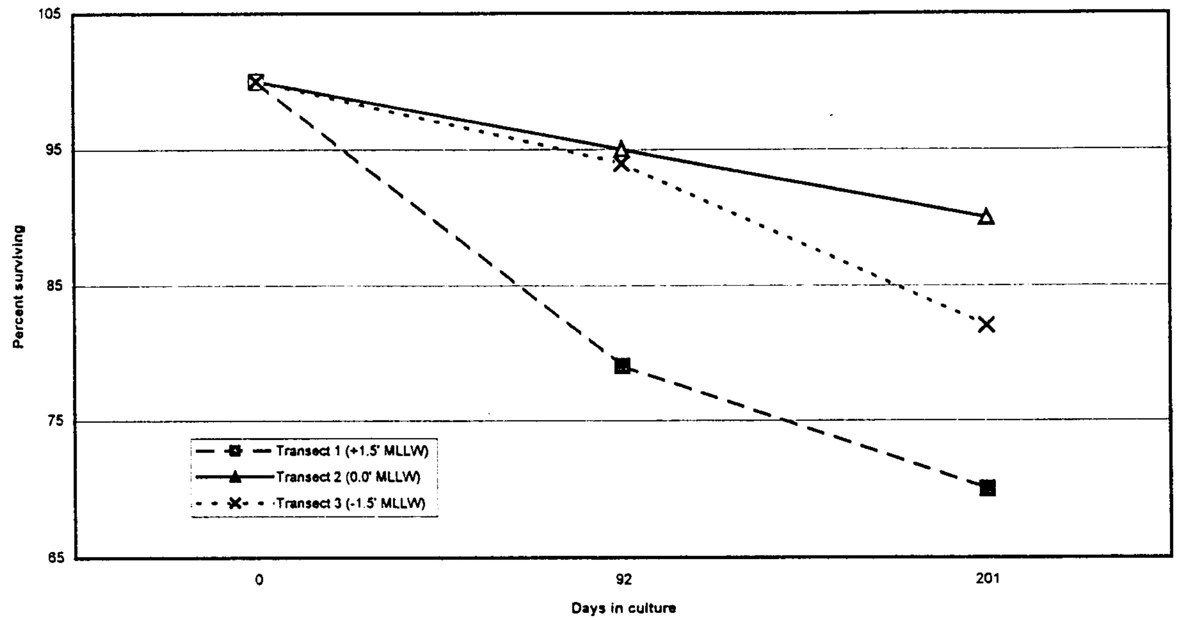


Figure 25. Percent survival of 900 caged native littleneck clams held in three replicates of 100 animals each at each of three tidal heights in the Tatitlek shellfish enhancement study.

Growth of caged littleneck clams at Tatitlek. A detailed analysis of survival and growth in these caged studies will be undertaken for the 1998 annual report. The September 27, 1996 and January 14, 1997 sampling dates do not provide sufficient data to establish clear growth trends. However, the mean length for each of the three replicates at each tidal height is provided in Table 14 and Figure 26. Growth appears to be similar at each height from the end of June until September. A slight decrease in the mean length was noted in all samples between September and January. This is likely associated with re-adsorption at the periphery of the valves during periods of low food supply. The author has previously seen this in mussels (*Mytilus edulis trossulus*). However, I am unaware that this trait has been documented in *Protothaca staminea.* Confirmation would require marking of individual clams and following their growth characteristics over at least one full season.

Table 14. Mean valve length (mm) of three replicates of native littleneck clams grown in Norplex^{TM} clam cages at each of three intertidal elevations at the native Village of Tatitlek in Alaska.

Days in Culture	Transect 1 (+1.5' MLLW)	Transect 2 (0.0' MLLW)	Transect 3 (-1.5' MLLW)
0	12.81	13.25	12.28
92	16.51	16.96	15.73
201	16.36	16.82	16.10
Incremental Growth	3.55	3.57	3.82

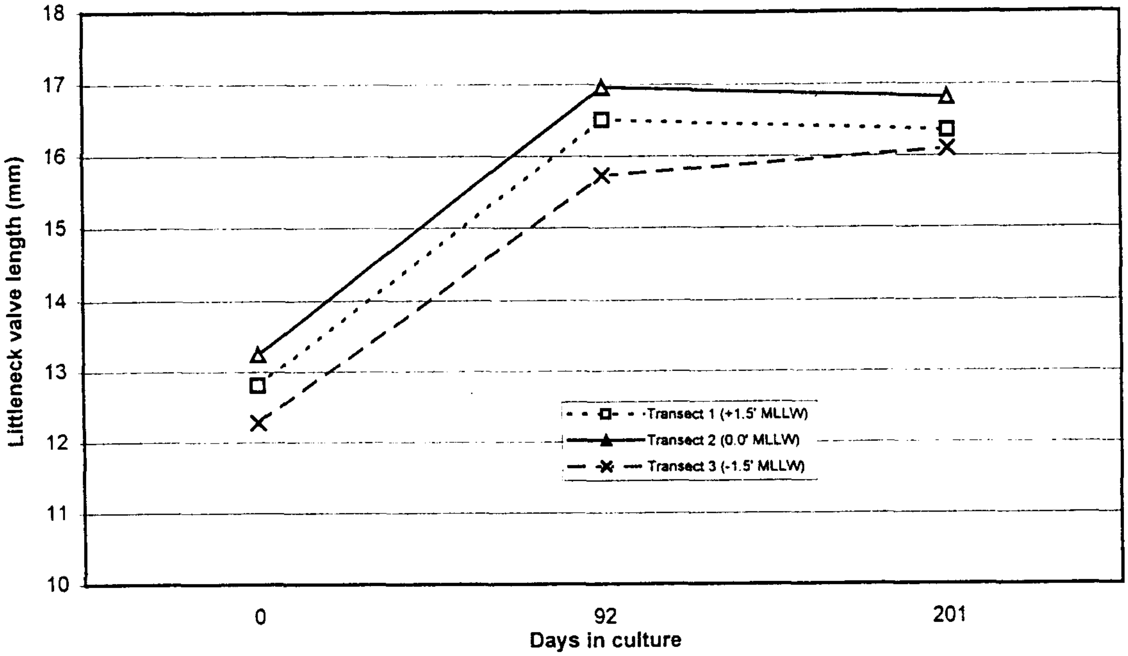


Figure 26. Mean length of littleneck clams caged in the growth and mortality study at the Village of Tatitlek. Each value is the mean of three replicates at that tidal height. The number of clams in each replicate varies between 70 and 100.

In January, 1997, the majority of the clams in this study were 30.5 months old (set in June of 1994). The von Bertalanfy equation for Tatitlek predicts an increase in valve length of 3.68 mm between the ages of 24 and 30.5 months. Interestingly, the mean increase observed over this same age span in the caged clams was 3.65 mm. If the observed trends continue, it appears that growth may be negatively correlated with tidal height. This is expected, because clams located at lower intertidal elevations are immersed for longer periods of time. However, in this study, all of the treatments are at fairly low intertidal elevations at none of the treatments are exposed for significant periods of time.

It has previously been noted (Brooks, 1995) that it takes, on average, 6.3 years for native littleneck clams to recruit into the legal size class at Tatitlek. Brooks (1995) has hypothesized that modern hatchery and nursery techniques could reduce that time by at least one year. Because of production failures at the Qutekcak hatchery, we did not have seed in 1996 to introduce into the newly constructed FLUPSY's (floating upwell systems). However, it should be noted that the 1995 cohort of clam seed, raised in upwellers in the Qutekcak hatchery, averaged 17.9 $\pm$ 0.64 mm (N = 46, 95% CI on the mean) valve length at the end of one year. The von Bertalanfy equation predicts a valve length of 10.7 mm at one year and a length 17.9 at 1.85 years of age. Therefore, the rather primitive nursery techniques undertaken with the 1995 year class appear to have resulted in significant additional growth totaling nearly one year. Confirmation of increased growth associated with modern nursery techniques must await the production of a new cohort of native littleneck clams at the Qutekcak hatchery. Hopefully that will occur in 1997.

Caged mussel experiments at Tatitlek. Wild caught mussel (*Mytilus edulis trossulus*) seed was transplanted from high in the intertidal at Tatitlek to three tiers of a five tier lantern net. The valve lengths of 100 mussels were measured and placed into each of the top three tiers. Additional, unmeasured mussels were placed in the bottom two tiers. The Tatitlek replicates averaged 27.8, 29.8 and 30.8 mm. The lantern net was hung from a buoy in the marina and data sheets provided for quarterly measurement. Unfortunately, the lantern net could not be located until after the January sample. No additional data was obtained on mussel growth or mortality. Mussels were not recognized as preferred food at any of the Villages included in these studies. It is likely that this was a factor in the result. Surviving mussels in the lantern net will be examined during the 1997 field season and a second effort made to obtain Village support for data collection.

Summary. Survival in the nine replicates of caged clams at Tatitlek has been excellent and growth similar to that observed in wild clams at this site. Nineteen ninety-seven will be the first full year of culture for these clams. The results will provide a basis for more fully evaluating the potential to enhance subsistence shellfish resources at this village. However, the results from 1996 are very encouraging.

Results – Port Graham. Five people from the Village of Port Graham participated in the events associated with this enhancement study. The Villagers learned to use the vernier calipers quickly and the clams and mussels were successfully measured. The educational workshop was held on July 3, 1996 and the clams and mussels planted on July 4, 1996 during a predicted low tide of –4.4' MLLW at 1138 hours. The study was conducted within the area surveyed at this beach in 1995. The study area is described in Figure 27.

Beach preparation. The location of each plot was determined by the CRRC study team. The desired –1.5', 0.0' and + 1.5' MLLW tidal elevations were estimated during the ebb tide. Confirmation of these elevations at low tide indicated that all treatments were placed at a tidal elevation 0.75' lower than desired. No effort was made to change the prepared locations of –2.25', -0.75' and +0.75' MLLW. The beach at Port Graham consisted of 60.7 $\pm$ 18.6% gravel, 28.2 $\pm$ 16.6% sand and 11.1 $\pm$ 3.20% fines (silt and clay). There was very little cobble or rock and very little preparation was required. Total Volatile Solids, by station are provided in Table 15. The average value in this survey was 2.15 $\pm$ 0.41% volatile solids.

Table 15. Total volatile solids observed at each Port Graham netted treatment during establishment of intensive culture trials in July, 1996.

Treatment Replicate	(3) -2.25' MLLW	(2) -0.75' MLLW	(1) +0.75' MLLW
A	2.06		2.70
B	1.79		1.71
C	2.14		2.53

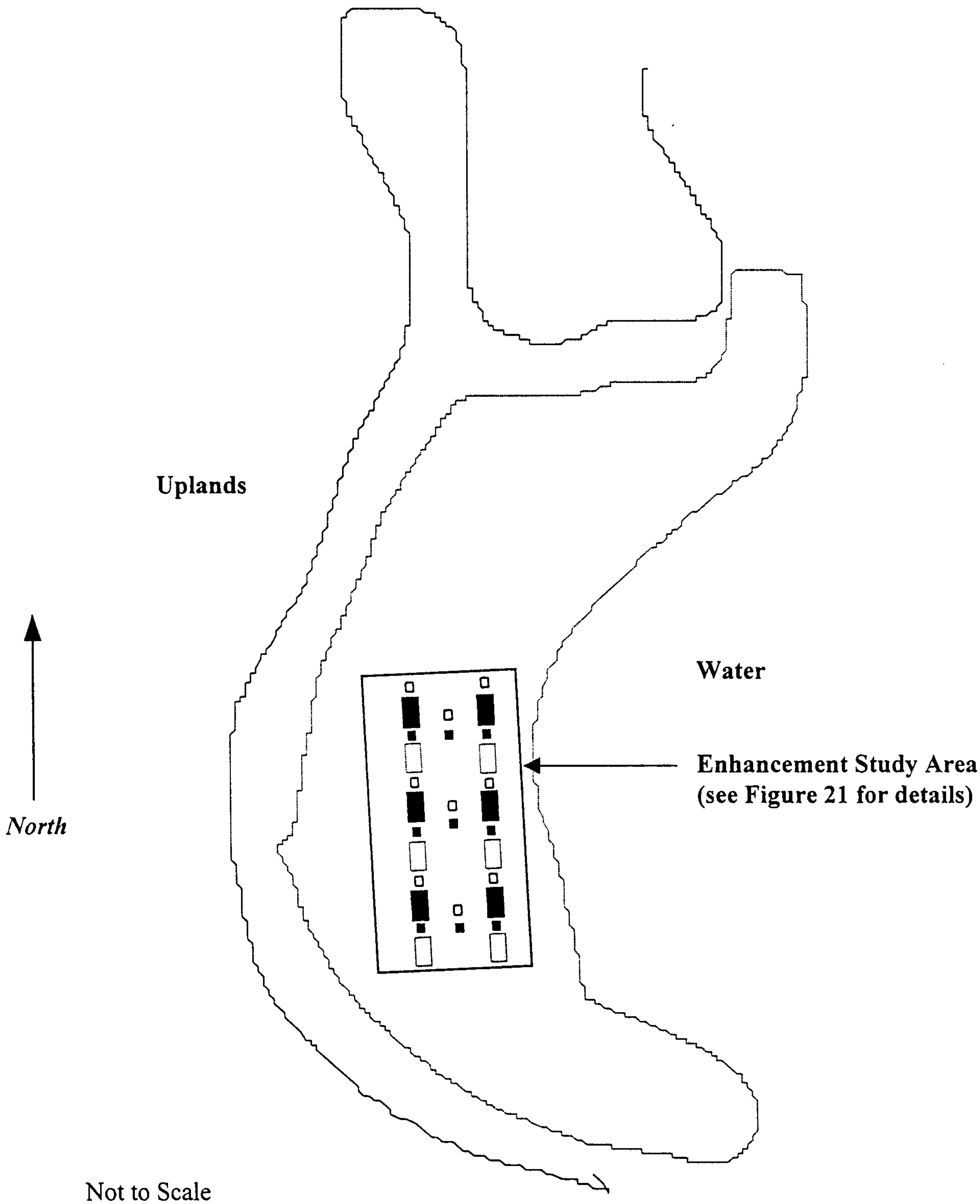


Figure 27. Schematic diagram of the Port Graham Village shellfish beach at Murphy Slough. The beach was surveyed in August of 1995 and enhancement studies began on July 4, 1996.

This combination of sediment grain size and total volatile solids, combined with the significant interstitial water flow observed during sampling and beach preparation make this an ideal substrate for intensive culture of manila clams, and presumably for native littleneck clams as well. Study results will determine how other factors, such as temperature, salinity, primary productivity, currents, and etc., influence long term clam growth and survival.

Netted treatment sites. Port Graham villagers prepared each treatment site by lightly raking an area approximately 1.0 by 2.0 meters. A shallow trench (ca. 15 centimeters deep) was then dug around the area to be seeded. A precut piece of plastic netting (Car-cover) was stretched over the treatment and its perimeter buried in the trench. Previously subsampled clams (ca. 600 clams per sample) were gently spread over the netted area as the tide flooded each treatment. The clams were observed digging into the substrate and no clams were observed floating.

Un-netted treatment sites. Similar treatment sites were cultivated, but no Car-cover installed. These unprotected plots were seeded in a manner similar to the Car-cover treatments. This procedure was described in Figure 23.

Control sites. Control stations described in Figure 21 were prepared in an identical manner. However, no netting was installed and no clams were seeded to these plots.

Caged native littleneck clam growth and mortality study. The control quadrats noted in Figure 21 were cultivated. However no clams or netting were provided at these locations. Shallow pits were dug in the substrate at those locations noted in Figure 26. Norplex™ clam cages were filled with one or two shovelfulls of screened sediment from which wild clams and predators were removed. The bags were nestled in the previously dug depressions and rocked back and forth to level the added substrate. One hundred previously measured clams were then gently spread on top of the sediment inside the bag. The open end was secured with a piece of split PVC pipe and three electrical ties. A piece of 24 inch rebar was driven into the substrate at the top of each bag. The rebar had a steel washer welded to the top. The bag was secured to this washer with UV protected electrical ties. Each bag was identified with an inside plastic tag, the PVC closure was marked and a third label was secured to the rebar with electrical ties. The perimeters of the pits were then filled with native substrate such that only two to three centimeters of the bag was exposed above the surface. This design was described in Figure 24.

Predator control. Very few predators were observed on the enhancement beach at Port Graham. Villagers were encouraged to remove starfish on a continual basis, at least once each quarter, during examination of the caged shellfish. In addition, it was emphasized that care needed to be taken when replacing the substrate in these bags to not introduce small starfish, crabs or drills.

Growth and mortality. Survival of clams, by tidal height, is provided in Table 16 and Figure (28) for Port Graham. Average survival for all replicates, at all tidal elevations, was

82%. This value is very similar to the 81% observed at Tatitlek. Minimum average survival for any three replicates was 74% at – 2.25' MLLW. Maximum survival (91%) was recorded at 0.0' MLLW, which, from all data collected to date, appears to be the optimum intertidal elevation for littleneck clams in South Central Alaska. This is encouraging, because significant winter kill was not experienced by clams held at even the highest intertidal elevation (+0.75' MLLW). Caution must be exercised in evaluating this data because 115 clams were counted in replicated 2A and 103 in replicate 3B during the October 26, 1996 sampling. No explanation is offered for the additional clams. However, it is unlikely that the additional 16 clams represented newly settled recruits because the minimum length recorded on October 26, 1996 was 14 mm.

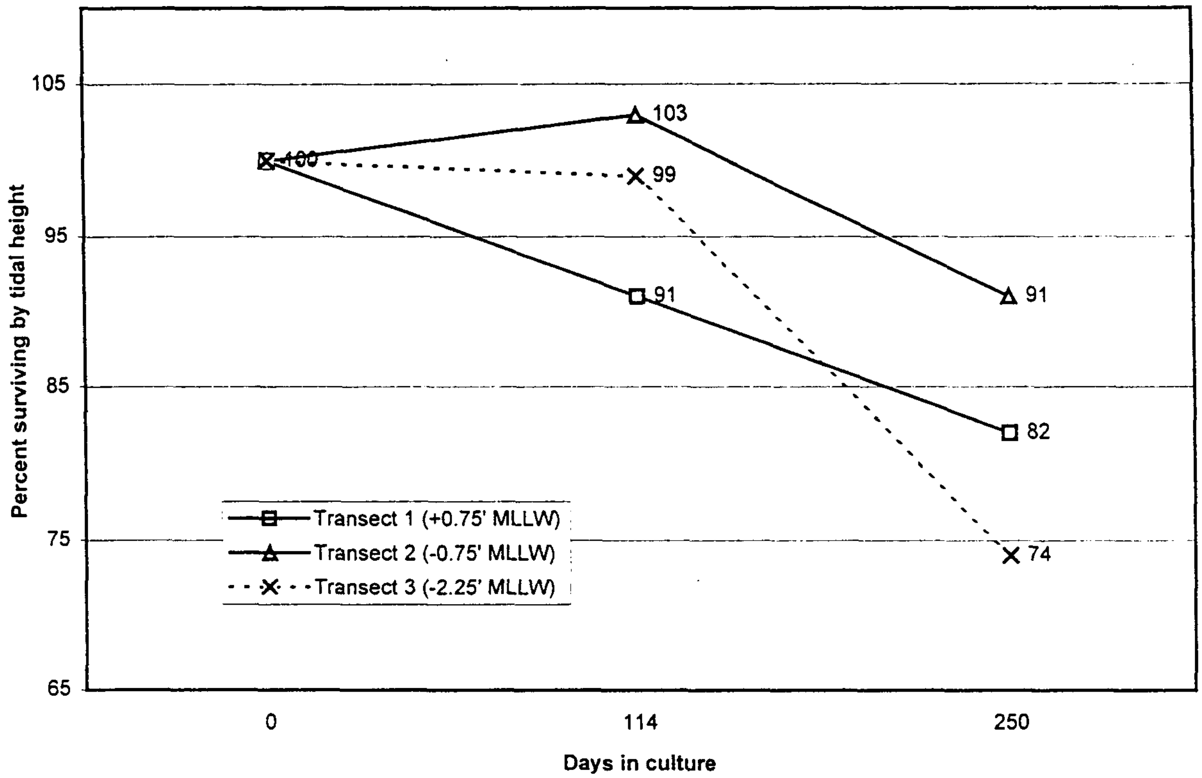


Figure 28. Percent survival of 900 caged native littleneck clams held in three replicates of 100 animals each at each of three tidal heights in the Port Graham shellfish enhancement study.

Table 16. Mean survival of three replicates of native littleneck clams raised in Norplex™ cages at three intertidal elevations.

Days in Culture	Transect 1 (+0.75' MLLW)	Transect 2 (-0.75' MLLW)	Transect 3 (-2.25' MLLW)
0	100	100	100
114	91	103	99
250	82	91	74

Growth of caged littleneck clams at Port Graham A detailed analysis of survival and growth in these caged studies will be undertaken for the 1998 annual report. The October 26, 1996 and March 11, 1997 sampling dates do not provide sufficient data to establish clear growth trends. However, the mean length for each of the three replicates at each tidal height is provided in Figure 29 and Table 17. Growth appears to be similar at each height from the end of June until September. Unlike Tatitlek, growth appears to have continued through the winter at the two lower intertidal elevations at Port Graham. A slight decrease in the mean length was noted in the +0.75' samples between October, 1996 and March, 1997.

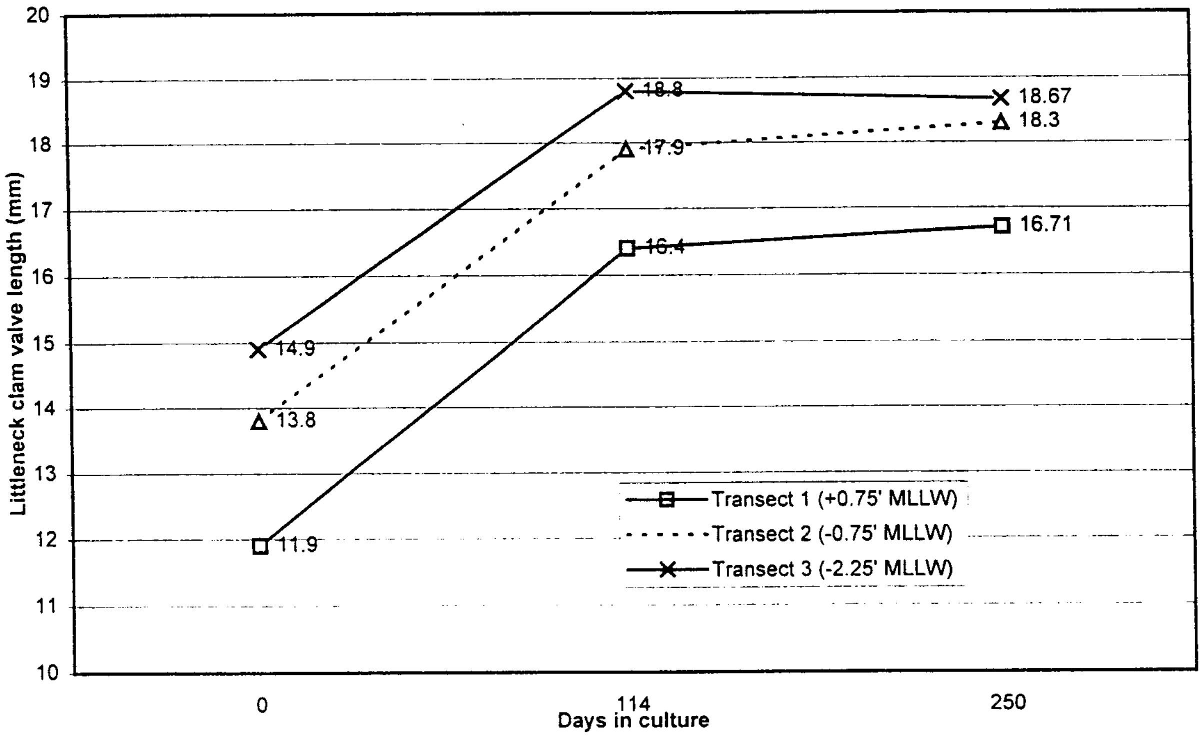


Figure 29. Mean length of littleneck clams caged in the growth and mortality study at the Village of Port Graham. Each value is the mean of three replicates at that tidal height. The number of clams in each replicate varies between 41 and 115.

Table 17. Average valve lengths (mm) of three replicates of 100 each native littleneck clams grown at three intertidal elevations in Norplex™ clam cages.

Days in Culture	Transect 1 (+0.75' MLLW)	Transect 2 (-0.75' MLLW)	Transect 3 (-2.25' MLLW)
0	11.9	13.8	14.9
114	16.4	17.9	18.8
250	16.71	18.3	18.67
Growth increment	4.81	4.5	3.77

This preliminary data is encouraging because the mean growth increment of 4.4 mm occurred following spring phytoplankton blooms. Data developed in 1997 will provide a first assessment of growth through a full season. However, the 1996 data is encouraging.

In March, 1997, the majority of the clams in this study were 32.5 months old (set in June of 1994). An insufficient number of littleneck clams were collected during the 1995 field survey at Murphy Slough in Port Graham to develop regression coefficients for the von Bertalanfy equation. However, the von Bertalanfy equation for all South Central Alaskan littleneck clams collected during the 1995 surveys predicts an increase in valve length of 4.77 mm between the ages of 24 and 32.5 months. Interestingly, the mean increase observed over this same age span in the caged clams was 4.4 mm. Maximum growth (4.8 mm) occurred at the highest intertidal elevation (+0.75' MLLW) which is within the optimum range previously recorded in surveys of these Village beaches (Brooks, 1995). The lowest growth increment (3.77 mm) occurred at the lowest intertidal elevation (-2.25' MLLW) which is below the optimum intertidal elevation previously determined. The point is that this early information suggests that the von Bertalanfy predictions are in general agreement with these results.

These early results must be viewed with caution because it is reasonable to assume significant variation in seasonal growth at northern latitudes associated with the high variation in solar insolation (and primary productivity). These results are presented only to provide some initial insight into the growth patterns.

Caged mussel experiments at Port Graham. Wild caught mussel (*Mytilus edulis trossulus*) seed was transplanted from high in the intertidal at Port Graham to three tiers of a five tier lantern net. The valve lengths of 100 mussels were measured and placed into each of the top three tiers. Additional, unmeasured mussels were placed in the bottom two tiers. The Port Graham replicates averaged 39.41, 40.27 and 40.57 mm. The lantern net was hung from a buoy and data sheets provided for quarterly measurement. Unfortunately, the lantern net has apparently dissappeared. No additional data was obtained on mussel growth or mortality. Mussels were not recognized as preferred food at any of the Villages included in these studies. It is likely that this was a factor in the result. An attempt will be made to locate the lantern net containing mussels set out in 1996. If it cannot be located, a second effort will be made to obtain Village support during the 1998 field season.

Summary. Survival in the nine replicates of caged clams at Port Graham has been excellent and growth similar to that observed in wild clams at other sites. Nineteen ninety-seven will be the first full year of culture for these clams. The results will provide a basis for more fully evaluating the potential to enhance subsistence shellfish resources at this village. However, the results from 1997 are very encouraging.

Results – Nanwalek. Four people from the Village of Nanwalek participated in the events associated with this enhancement study. The Villagers learned to use the vernier calipers quickly and the clams and mussels were successfully measured. The educational workshop was held on July 3, 1996 with the Village of Port Graham. Clams and mussels were planted on July 5, 1996 during a predicted –2.8' MLLW tide which occurred at 1225 hours. The study was conducted within the Passage Island area surveyed in 1995. The study area is described in Figure 30.

Beach preparation and characterization. The location of each plot was determined by the CRRC study team. The beach at Port Graham consisted of 56.0 $\pm$ 11.4% gravel, 38.9 $\pm$ 11.3% sand and 5.1 $\pm$ 0.4% fines (silt and clay). There was a significant amount of cobble and rock on this beach and these sediment grain size values represent the matrix left after removing the large material. All cobble and rock was removed from the cultivated areas and piled in a berm below each treatment. Total Volatile Solids, by station are provided in Table 18. The average value in this survey was 1.80 $\pm$ 0.44% volatile solids.

Table 18. Total volatile solids observed at each Nanwalek (Passage Island) netted treatment during establishment of intensive culture trials in July, 1996.

Treatment Replicate	(3) –1.50' MLLW	(2) 0.00' MLLW	(1) +1.5' MLLW
A	1.71		2.33
B	1.42		2.21
C	1.29		1.84

This combination of sediment grain size and total volatile solids suggests that this beach provides good conditions for intensive culture of manila clams, and presumably for native littleneck clams as well. According to Nanwalek and Port Graham villagers', this beach experiences very high currents, which should benefit intensively cultured clams by increasing food transport over the culture.

Netted treatment sites. Nanwalek villagers prepared each treatment site by removing all large cobble and rock to form a slight berm just below the treatment. The substrate in each 1.0 x 2.0 meter area was loosened to a depth of ca. 10 cm and raked smooth. A shallow trench (ca. 15 centimeters deep) was then dug around the area to be seeded. A precut piece of plastic netting (Car-cover) was stretched over the treatment and its perimeter buried in the trench. Previously subsampled clams (ca. 600 clams per sample) were gently spread over the netted area as the tide flooded each treatment. The clams were observed digging into the substrate and no clams were observed floating. This procedure was described in Figure 23.

Un-netted treatment sites. Similar treatment sites were cultivated, but no Car-cover installed. These unprotected plots were seeded in a manner similar to the Car-cover treatments.

Control sites. At each treatment, a control site was established. These control sites were cultivated as described above. However, no netting was installed and no clams were seeded.

Caged native littleneck clam growth and mortality study. Shallow pits were dug in the substrate at those locations noted in Figure 30. Norplex™ clam cages were filled with one

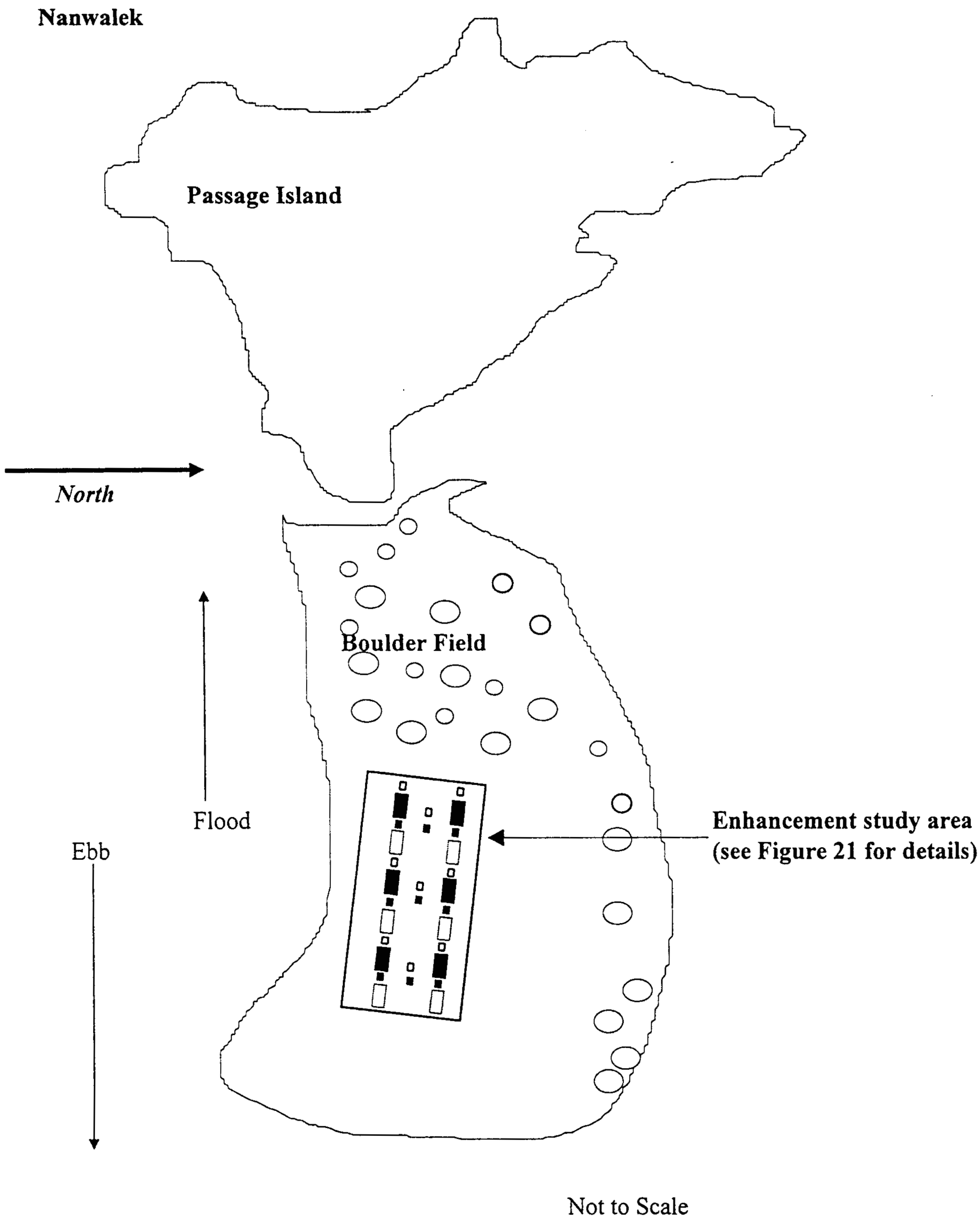


Figure 30. Schematic diagram of the Nanwalek Village shellfish beach at Passage Island. The beach was surveyed in August of 1995 and enhancement studies initiated in 1996.

or two shovelfulls of screened sediment from which wild clams and predators were removed. The bags were nestled in the previously dug depressions and rocked back and forth to level the added substrate. One hundred previously measured clams were then gently spread on top of the sediment inside the bag. The open end was secured with a piece of split PVC pipe and three electrical ties. A piece of 24 inch rebar was driven into the substrate at the top of each bag. The rebar had a steel washer welded to the top. The bag was secured to this washer with UV protected electrical ties. Each bag was identified with an inside plastic tag, the PVC closure was marked and a third label was secured to the rebar with electrical ties. The perimeters of the pits were then filled with native substrate such that only two to three centimeters of the bag was exposed above the surface. This design was described in Figure 24.

Predator control. Villagers were encouraged to remove starfish on a continual basis – at least once each quarter during examination of the caged shellfish. In addition, it was emphasized that care needed to be taken when replacing the substrate in these bags to not introduce small starfish, crabs or drills. Numerous pits (presumably created by sea otters) were observed on this beach. The effectiveness of cages and carcover in disguising shellfish from sea otters is unknown. In part, this study will examine that question.

Littleneck clam growth and mortality at Passage Island. The CRRC study team has been unable to obtain any data from the Passage Island study. Hopefully, the cultures will be intact by the time of our summer 1998 field season. Concern was expressed regarding the remoteness of this site from the village of Nanwalek in the 1995 report. The lack of data forthcoming since these shellfish were planted substantiates that concern. Because of the considerable time, effort and expense involved in establishing this study, I recommend that we continue to encourage the Village of Nanwalek to participate and that we monitor the cultures annually during the summer field season

Caged mussel experiments at Nanwalek. Wild caught mussel (*Mytilus edulis trossulus*) seed was transplanted from high in the intertidal at Port Graham to three tiers of a five-tier lantern net. The valve lengths of 100 mussels were measured and placed into each of the top three tiers. Additional, unmeasured mussels were placed in the bottom two tiers. The Nanwalek replicates averaged 39.74, 37.13 and 40.65 mm valve length. The lantern net was hung from a buoy and data sheets provided for quarterly measurement. No additional data was obtained on mussel growth or mortality. Mussels were not recognized as preferred food at any of the Villages included in these studies. It is likely that this was a factor in the result. If the lantern net can be found, surviving mussels will be examined during the 1997 field season and a second effort made to obtain Village support for data collection.

Summary for Nanwalek (Passage Island). The absence of any data from the Passage Island study suggests that sites remote from participating villages are inappropriate for shellfish enhancement. In addition, this experience suggests that Village commitment is essential to successful enhancement efforts.

Enhancement Study Conclusions. The limited efforts at nursering the 1995 native littleneck clam cohort in the Qutekcak hatchery may have increased juvenile growth by an amount equivalent to 0.85 years. Floating upwell nurseries have proven themselves very effective throughout the world. However, they are most effective where primary productivity is high. I examined one of the two Flupsys at Chenega. It appeared to be of excellent design and was functioning properly. I suspect that optimum performance will require careful evaluation of a number of potential sites. The program goal of reducing native littleneck growth by one to two years will depend in large part on the success of these upwellers.

Growth and survival of caged littleneck clams at Tatitlek and Port Graham is excellent and suggest that enhancement may provide increased subsistence levels of shellfish to native Villages where existing resources are currently depleted. Growth rates through the first nine months of this study suggest that the von Bertalanfy regression coefficients for native littleneck clams developed during the 1995 surveys make reasonable predictions. These results are very preliminary and the 1997 annual report will provide information from the first 1.5 years of study. Reasonable conclusions may evolve from that report regarding the efficacy of the techniques being investigated in these studies.

Bag culture of clams and oysters is a proven method of reducing drill, crab and starfish predation. Its effectiveness against sea otters is untested. The challenge from this predator is likely to come in the future when the clams reach a size that is appealing to the otters. The effectiveness of Car-cover in protecting juvenile clams will first be evaluated in the 1997 field season. If effective, this provides an inexpensive method of deterring many predators with minimal labor. Hand picking of predators (starfish, crab and drills) is an easily understood management tool which may increase the natural production of shellfish on Village beaches. Hopefully, villagers will understand the importance of controlling predators and routinely reduce their numbers.

The mussel culture study has been a failure. It appears that Village interest in mussels is lacking and that they have no desire to evaluate this source of shellfish. Mussels are a prized food resource in most areas of the world and it is unfortunately the Alaskan natives do not recognize them as valuable. Based on performance in other areas, I suspect that the blue mussel could provide a steady source of tasty, high quality protein. In addition, seed transferred from the high intertidal into lantern nets, or any form of suspended culture that is protected from predators, should reach harvest size in as little as one season. We will likely try the mussel study again in 1997.

Part III: Literature Search and Development of Spawning Techniques for the Basket Cockle (Clinocardium nuttallii)

Introduction. During the 1995 shellfish surveys at the Alaskan Native Villates of Tatitlek, Port Graham and Nanwalek, villagers repeatedly expressed a preference for cockles. Villages in Port Graham reported that cockles were common in the 1970's and early 1980's, but virtually disappeared several years before the *Exxon Valdez* oil spil. 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. References identified in this search are provided in Appendix 5.

Cockle (*Clinocardium nuttallii*) growth. 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) observe that "the Pacific cockle's checks or growth lines are known to be unreliable for aging purposes (false checks) is 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 to von Bertalanfy 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 which appear to be annuli. Cockle valves were collected at Chenega, Ouzinke and Thorndyke Bay in Washington State and the apparent annuli used to determine a length at age relationship. These relationships are displayed in Figures 31, 32 and 33. Figure 34 presents the results of non-linear regression analysis on each of these data sets. In each case the coefficient of determination was greater than 92% and the regression residuals were not significantly different from a normal distribution. The maximum predicted length in each case exceeds the maximum size observed by this author by a factor of two. Cockles are rarely observed with more than ten major valve checks. It is possible that they grow rapidly to that age where they either die or are removed from the population by predation. All of these hypotheses require verification in caged studies using cockles of known age.

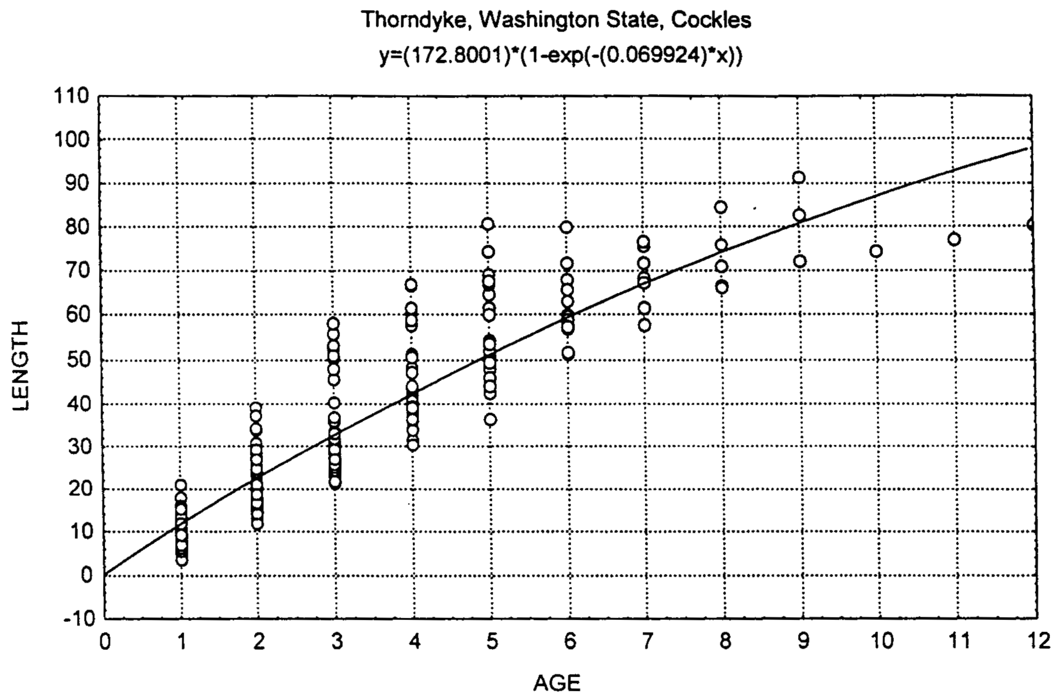


Figure 31. Length at age with von Bertalonfy regression for cockles collected from Thorndyke Bay in Washington State.

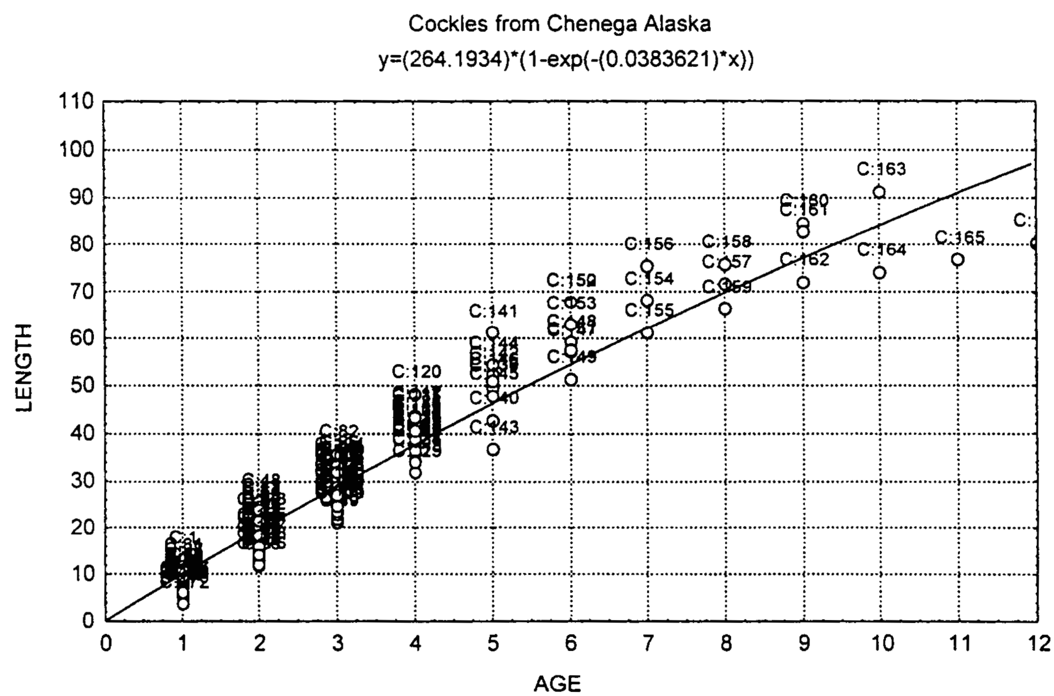


Figure 32. Length at age with von Bertalonfy regression for cockles (*Clinocardium nuttallii*) from Chenega, Alaska.

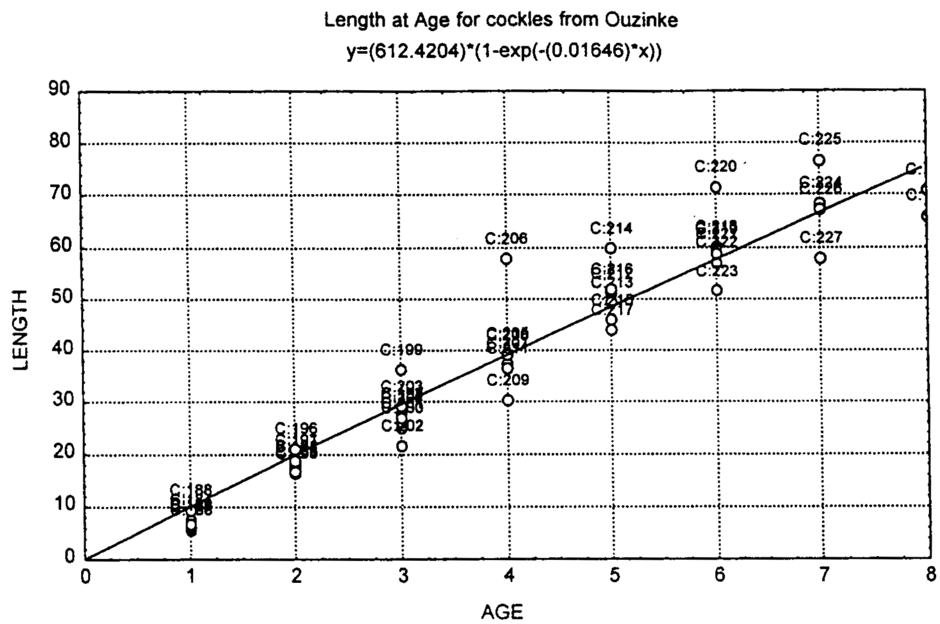


Figure 32. Length at age with von Bertalonfy regression for cockles (*Clinocardium nuttallii*) from Ouzinke, Alaska.

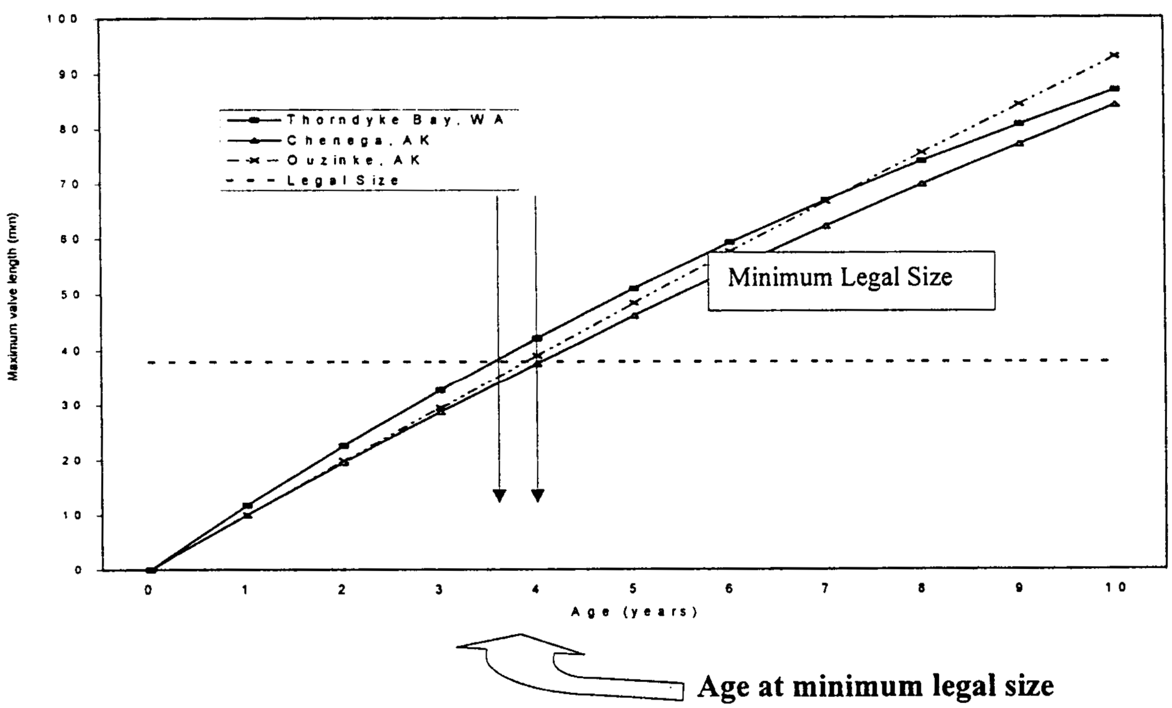


Figure 33. Age-length relationships for cockles (*Clinocardium nuttallii*) from Thorndyke Bay, Washington, Chenega, Alaska and Ouzinke, Alaska. The age at a minimum legal size of 38 mm valve length is indicated.

Interpretation of Figure 33 suggests that Nuttall's cockle reaches a minimum legal size of 38 millimeters in between 3.5 and 4.0 years. The lower figure is for Washington State and the upper for Chenega, Alaska. This is approximately half the time required for native littleneck clams to reach the same size. Therefore, cockle culture could provide a favored food source in a relatively short period of time. It should be noted that these values are far lower than the 34.3 to 50.3 mm valve length at one year of age reported by Gallucci and Gallucci (1982).

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 did 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 hemaphroditic nature of this species was confirmed by Strathmann (1987). He adds that oocytes are ca. 80 µm in diameter and have jelly coats over 50 µm thick. At 15 °C, first cleavage takes place within one hour and early veligers develop with 18 hours. None of the literature (including Strathman, 1987) reported actually spawning cockles – let alone raising them through metamorphosis.

Efforts to spawn cockles at Pacific Rim Mariculture in 1996. Cockles were collected from Thorndyke Bay in Washington State in July and August of 1996. They were held in marine aquaria at 15 °C overnight. Both cohorts 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, pasturized, 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, 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 (2×10^6) 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 attempt. The addition of food did not stimulate spawning.

1997 spawning trials. These efforts will continue in 1997 beginning in April. Initial efforts will continue to focus on thermal shocks and the addition of excess phytoplankton. However, if success is not achieved using these traditional methods, we will try the following techniques in 1997:

1. Cockles will be sacrificed, homogenized and sieved in an attempt to obtain viable gammettes. This will be the method of last resort. However, cockles may be examined for sperm. When found, the animal will be sacrificed and macerated in an attempt to obtain mature sperm suspensions that can be added to the water in an effort to stimulate spawning.

2. A 0.5 molar solution of KCl will be injected into the base of the foot in mature cockles. We may also add excess KCl solution to a tank in an effort to induce spawning.

3. Hydrogen peroxide has been used to induce spawning in *Mytilus californianus* (Strathman, 1987). We will mimic the procedures reported by that author.

Conclusion. Cockles used in spawning experiments in 1996 have been fixed in Davidson's shellfish fixative and preserved in 70% ethyl alcohol. The same procedure will be used in 1997 if spawning is not successfully completed. It may be appropriate to examine these animals histologically to determine their reproductive state if we are again unable to obtain viable gametes from both males and females. Unfortunately, there is no literature describing successful methods of inducing spawning in this animal. It should be noted that similar difficulties have been observed in the initial attempts to spawn a variety of shellfish.

The preliminary work on cockle growth in Alaska and Washington, coupled with anecdotal evidence form shellfish growers suggests that cockles do grow very quickly. This fact, coupled with native preference for this species, suggests that it is an excellent candidate for subsistence shellfish enhancement in Alaska. A short shelf-life will not be a significant factor in the use of this animal for subsistence purposes.

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Appendix 1 Sediment Grain Size

Chenega (1996) Weights expressed as a percent of the total sediment dry weight

	Gravel	Sand 1	Sand 2	Sand 3	Total Sand	Silt	Clay	Total Sediment	Total Silt &
Sample	>2 mm	>1mm	> 250 mic	>63 Mic		>3.9 Mic	<3.9 Mic	(grams)	Clay
C2	58.20	7.25	11.52	8.96	27.73	7.65	6.42	100	14.07
C5	51.30	13.36	16.26	10.04	39.65	5.14	3.91	100	9.05
B3	63.06	10.24	13.42	4.52	28.18	5.11	3.66	100	8.77
D3	67.49	5.00	9.89	7.08	21.97	6.14	4.41	100	10.54
B2 0.0'	45.25	13.64	25.18	10.49	49.31	2.92	2.53	100	5.44
B 19	59.70	14.07	17.83	2.58	34.48	3.31	2.51	100	5.82
B3 -1.0	71.12	8.10	13.30	2.64	24.04	2.35	2.50	100	4.85
A 0.0'	43.83	15.30	23.02	8.44	46.76	5.29	4.13	100	9.41

Tatitlek (1995) Weights expressed as a percent of the total dry sediment.

	Gravel	Sand 1	Sand 2	Sand 3	Total Sand	Silt	Clay
Sample	>2 mm	>1mm	> 250 mic	>63 Mic		>3.9 Mic	<3.9 Mic
TA A3	0.62	0.86	3.07	55.94	59.87	27.08	12.43
TA A4	16.82	0.88	3.29	43.11	47.27	25.55	10.35
TA B3	59.25	6.58	14.77	9.79	31.14	6.33	3.28
TA C2	75.84	3.87	6.03	5.82	15.72	5.55	2.89
TA D2	78.77	4.37	7.95	3.72	16.04	3.37	1.82
TA E3	56.46	12.15	19.15	4.36	35.66	4.41	3.47
TA F4	84.15	1.98	4.29	3.61	9.88	3.07	2.90
TA G1	52.22	3.03	11.79	20.63	35.46	8.02	4.30
TA G5	57.25	13.55	17.80	2.97	34.32	4.99	3.44
TA H3	61.62	12.22	13.25	3.24	28.71	5.49	4.17

Ouzinke (O), Port Graham (P) & Nanwalek (N) (1996) Weights expressed as a percent of dry sediment weight.

	Gravel	Sand 1	Sand 2	Sand 3	Total Sand	Silt	Clay	Total Sediment	Total Silt &
Sample	>2 mm	>1mm	> 250 Mic	>63 Mic		>3.9 Mic	<3.9 Mic	(grams)	Clay
OA3	44.88	18.61	9.79	20.39	48.79	3.12	3.20	100	6.33
OC1	50.77	14.86	17.76	11.66	44.27	2.60	2.36	100	4.95
OD3	27.80	3.39	7.33	55.86	66.58	2.51	3.12	100	5.62
PA2	58.36	4.20	9.33	15.43	28.97	9.14	3.54	100	12.67
PA3	66.10	8.86	8.67	6.93	24.46	7.95	1.49	100	9.45
PA1	30.59	1.84	14.36	37.93	54.12	9.37	5.91	100	15.28
PB3	82.47	2.57	6.00	2.18	10.75	4.48	2.31	100	6.78
PC1	71.55	10.38	2.32	4.94	17.64	6.92	3.89	100	10.81
PC3	55.08	16.04	9.77	7.42	33.22	7.25	4.45	100	11.70
N1A	54.52	2.05	22.63	16.23	40.91	2.15	2.42	100	4.57
N3A	57.13	8.51	20.18	8.42	37.11	2.86	2.91	100	5.76
NB1	43.26	1.07	19.37	31.10	51.54	2.41	2.80	100	5.20
NB3	75.55	8.45	7.06	4.14	19.65	2.10	2.70	100	4.80
NC1	49.83	3.19	22.92	18.93	45.05	2.55	2.57	100	5.13
NC3	55.53	8.44	21.84	9.07	39.35	2.18	2.94	100	5.12

Appendix 2a. Water Total Suspended Solids and Total Volatile Solids determination.

Chenega and Ouzinke – WATER TSS and TVS Determination.

Sample	Matrix	Total Vol.	Salinity	Volume	Tare (550)	Wt. (102) B	Wt. (550) B	TSS /L	TVS/L
Chenega 1	Water	300	25.0	300.0	1.4022	1.4042	1.4031	0.00667	0.0037
Chenega 2	Water	300	25.1	300.0	1.4068	1.4095	1.4080	0.009	0.0050
Chenega 3	Water	300	28.0	300.0	1.3931	1.3944	1.3936	0.00433	0.0027
Ouzinke 1	Water	300	31.5	300.0	1.4052	1.4070	1.4064	0.006	0.0020
Ouzinke 2	Water	300	31.0	300.0	1.4020	1.4041	1.4032	0.007	0.0030
Ouzinke 3	Water	300	31.2	300.0	1.3922	1.3941	1.3935	0.00633	0.0020

Sample	Matrix	Turbidity	PH
Chenega 1	Water	0.95	7.75
Chenega 2	Water	1	7.76
Chenega 3	Water	0.69	7.75
Ouzinke 1	Water	0.89	7.78
Ouzinke 2	Water	0.88	7.88
Ouzinke 3	Water	0.94	7.89

Appendix 2b. Sediment Total Volatile Solids

Ouzinke, Port Graham and Nanwalek Sediment Total Volatile Solids

Sample	Sample wt.	Tare (550)	Wt. (102) A	Wt. (102) B	% Change	Wt. (550) A	Wt. (550) B	% Change	TVS/g
OA3	30.7165	1.2840	27.4771	27.4726	-0.0164	27.0682	27.0418	-0.0010	0.0164
OC1	25.0640	1.2992	24.4226	24.4179	-0.0192	24.0110	23.9898	-0.0009	0.0185
OD3	48.1015	1.2906	37.0099	37.0064	-0.0095	36.1982	36.1902	-0.0002	0.0229
PA2	49.1149	1.2878	38.8848	38.8858	0.0026	38.2590	38.2446	-0.0004	0.0171
P3A	44.5591	1.2891	36.0935	36.0965	0.0083	35.3860	35.3779	-0.0002	0.0206
PA1	37.8287	1.2664	29.0035	29.0021	-0.0048	28.2770	28.2531	-0.0008	0.0270
P3B	41.6058	1.2752	33.9216	33.9159	-0.0168	33.4100	33.3316	-0.0024	0.0179
P1C	42.0748	1.2868	34.3152	34.3086	-0.0192	33.5380	33.4729	-0.0019	0.0253
P3C	42.9860	1.2903	35.4631	35.4584	-0.0133	34.7741	34.7276	-0.0013	0.0214
N1A	38.5930	1.2882	33.8242	33.8160	-0.0242	33.1446	33.0572	-0.0026	0.0233
N3A	32.0139	1.2850	30.8744	30.8748	0.0013	30.4130	30.3679	-0.0015	0.0171
N1B	39.9523	1.2998	36.1577	36.1598	0.0058	35.4757	35.3909	-0.0024	0.0221
N3B	37.8817	1.2784	34.0772	34.0840	0.0200	33.7038	33.6186	-0.0025	0.0142
N1C	40.1085	1.5903	36.3058	36.3026	-0.0088	35.6841	35.6623	-0.0006	0.0184
N3C	43.3559	1.5704	40.8420	40.8504	0.0206	40.4505	40.3434	-0.0027	0.0129

Note: O = Ouzinke; P = Port Graham and N = Nanwalek (1996 Tatitlek sediment samples were destroyed during shipping.)

Chenega Sediment Total Volatile Solids

Sample	Sample wt.	Tare (550)	Wt. (102) A	Wt. (102) B	% Change	Wt. (550) A	Wt. (550) B	% Change	TVS/g
C2	29.2648	1.2868	19.8768	19.8727	-0.0206	19.0211	19.0113	-0.0005	0.0463
C5	30.6652	1.2887	25.7179	25.7135	-0.0171	25.0697	25.0626	-0.0003	0.0266
B3	32.5789	1.2892	26.4350	26.4348	-0.0008	25.8877	25.8791	-0.0003	0.0221
D3	32.0266	1.2857	22.6871	22.6868	-0.0013	21.8898	21.8846	-0.0002	0.0375
B2 0.0'	31.2819	1.2977	25.2044	25.1992	-0.0206	24.6871	24.6800	-0.0003	0.0217
B 19	30.4362	1.3005	24.5356	24.5325	-0.0126	24.0540	24.0502	-0.0002	0.0208
B3 -1.0	36.0204	1.2834	30.4481	30.4444	-0.0122	29.844	29.8400	-0.0001	0.0207
A 0.0'	33.5876	1.2923	25.8446	25.8392	-0.0209	25.1862	25.1800	-0.0002	0.0269

Appendix (3)

Partial data base providing appropriate parameters examined during the 1996 baseline survey of shellfish resources at the Villages of Chenega and Ouzinke, Alaska

Chenega and Ouzinke Clam Database

data file: 96DATA.STA [383 cases with 21 variables]

	1 SITE	2 STATION	3 CLAM__	4 ELEV_	6 GROINC	11 SPECIES	12 LENGTH	13 WHOLE_WT	14 DRY_WT	15 WET_WT_	16 AGE	18 DRY_COND
1	Chenega	CB0	1.000	-1.600	5.8100	SG	46.4800	21.4314	3.4551	10.7944	8.0	.689242
2	Chenega	CB0	2.000	-1.600	6.4560	PT	32.2800	7.9000	.6396	.2072	5.0	.401453
3	Chenega	CB0	3.000	-1.600	4.6300	PS	18.5200	1.6185			4.0	
4	Chenega	CB0	4.000	-1.600	6.8900	SG	6.8900				1.0	
5	Chenega	CB1	1.000	-1.100	3.8883	PS	23.3300	2.5114	.2830	.9614	6.0	.310540
6	Chenega	CB1	2.000	-1.600	3.6817	PS	22.0900	2.4289	.2577	.8761	6.0	.267074
7	Chenega	CB1	3.000	-1.100	6.0450	PS	12.0900	.2763	.1122	.1862	2.0	.074117
8	Chenega	CB1	4.000	-1.100	4.9600	PS	9.9200	.1430	.0667	.0948	2.0	.054933
9	Chenega	CB1	5.000	-1.100	5.2100	SG	5.2100	.0319	.0606	.0660	1.0	.065593
10	Chenega	CB2	1.000	-.850	9.4600	SG	9.4600	.1362			1.0	
11	Chenega	CB2	2.000	-.850	4.9400	SG	4.9400	.0216			1.0	
12	Chenega	CB2	3.000	-.850	3.8200	SG	3.8200	.0139			1.0	
13	Chenega	CB3	1.000	-1.010	11.2500	CN	33.7500	7.8842	.5878	.2443	3.0	.324858
14	Chenega	CB3	2.000	-1.010	7.0475	PT	28.1900	4.9579	.3796	.3891	4.0	.267283
15	Chenega	CB3	3.000	-1.010	6.8050	PT	27.2200	3.6951	.3188	.2954	4.0	.229386
16	Chenega	CB3	4.000	-1.010	9.4367	PS	28.3100	5.6249	.5036		3.0	.371105
17	Chenega	CB3	5.000	-1.010	6.1250	PS	12.2500	.2177			2.0	
18	Chenega	CB3	6.000	-1.010	6.6000	PS	6.6000	.0405			1.0	
19	Chenega	CB4	1.000	.520	5.9875	PS	47.9000	25.8433	2.8349	9.2174	8.0	.464754
20	Chenega	CB4	2.000	.520	6.2257	PS	43.5800	19.5113	2.7031	8.3411	7.0	.519069
21	Chenega	CB4	3.000	.520	6.0400	PS	36.2400	10.3580	.7486	3.3230	6.0	.356270
22	Chenega	CB4	4.000	.520	5.9640	PS	29.8200	5.3761	.4581	1.9018	5.0	.303510
23	Chenega	CB4	5.000	.520	9.0733	PS	27.2200	4.6130	.3404	1.6662	3.0	.264982
24	Chenega	CB4	6.000	.520	8.4900	PS	25.4700	3.9676	.2874	1.3696	3.0	.243998
25	Chenega	CB4	7.000	.520	7.2000	PS	21.6000	2.3837	.2044	.7791	3.0	.208548
26	Chenega	CB4	8.000	.520	7.3433	PS	22.0300	2.4743	.2067	.8591	3.0	.224744
27	Chenega	CB4	9.000	.520	6.0867	PS	18.2600	1.0565	.1462	.3713	3.0	.138623
28	Chenega	CB4	10.000	.520	4.5667	PS	13.7000	.5407	.1064	.2159	3.0	.088171
29	Chenega	CB4	11.000	.520	5.7350	PS	11.4700	.3595	.0879	.1376	2.0	.075635
30	Chenega	CB4	12.000	.520	9.3400	PS	9.3400	.1064	.0765	.1223	1.0	.068760
31	Chenega	CB4	13.000	.520	6.4800	PS	6.4800	.0415			1.0	
32	Chenega	CB4	14.000	.520	6.2900	PS	6.2900	.0359			1.0	
33	Chenega	CB4	15.000	.520	6.6300	PS	6.6300	.0583			1.0	
34	Chenega	CB4	16.000	.520	5.4500	PS	5.4500	.0511			1.0	
35	Chenega	CB4	17.000	.520	5.0600	PS	20.2400	1.6989	.1832	2.1822	4.0	.159016
36	Chenega	CC0	1.000	-1.600	6.7325	PS	26.9300	5.3386	.4266	1.4138	4.0	.312772
37	Chenega	CC0	2.000	-1.600	5.9750	PS	23.9000	3.6395	.3029		4.0	.286269
38	Chenega	CC0	3.000	-1.600	8.7500	CN	17.5000	1.6387			2.0	

Chenega and Ouzinke Clam Database

	1 SITE	2 STATION	3 CLAM__	4 ELEV_	6 GROINC	11 SPECIES	12 LENGTH	13 WHOLE_WT	14 DRY_WT	15 WET_WT_	16 AGE	18 DRY_COND
39	Chenega	CC1	1.000	-1.100	5.6183	PS	33.7100	8.4652	.7053	3.0975	6.0	.398898
40	Chenega	CC1	2.000	-1.100	15.9200	CN	31.8400	6.0968	.5992	2.6354	2.0	.370833
41	Chenega	CC1	3.000	-1.100	7.0625	PS	28.2500	4.6388	.3787	1.7876	4.0	.273359
42	Chenega	CC1	4.000	-1.100	8.3933	PS	25.1800	3.6862	.3710	1.4552	3.0	.336067
43	Chenega	CC1	5.000	-1.100	5.7300	PS	22.9200	2.6030	.2413	.9730	4.0	.200546
44	Chenega	CC2	1.000	-.980		PS	25.5300	2.4001				
45	Chenega	CC2	2.000	-.980		PS	24.1900	1.1015				
46	Chenega	CC2	3.000	-.980		CN	11.5600	.2637				
47	Chenega	CC3	1.000	-.270	5.9100	PT	35.4600	10.5991	.7717	3.5245	6.0	.365524
48	Chenega	CC3	2.000	-.270	6.2620	PS	31.3100	7.0869	.5268	2.5897	5.0	.327030
49	Chenega	CC3	3.000	-.270	7.5150	PT	30.0600	6.7865	.4689	2.2665	4.0	.299940
50	Chenega	CC3	4.000	-.270	7.4200	PS	29.6800	5.2960	.4330	1.8551	4.0	.286143
51	Chenega	CC3	5.000	-.270	9.0200	PS	27.0600	4.9680	.3562	1.7411	3.0	.282325
52	Chenega	CC3	6.000	-.270	6.2475	PS	24.9900	3.3288	.2692	1.1461	4.0	.236883
53	Chenega	CC3	7.000	-.270	7.7767	PT	23.3300	2.7186	.1934	.8418	3.0	.190534
54	Chenega	CC3	8.000	-.270	7.7067	PT	23.1200	2.6270	.2117	.8575	3.0	.204163
55	Chenega	CC5	1.000	.600	11.8350	CN	23.6700	3.4152	.2427	1.2131	2.0	.231788
56	Chenega	CD1	1.000	0.000	5.0117	PT	30.0700	5.8580	.4737	2.0454	6.0	.305239
57	Chenega	CD2	1.000	0.000	12.2725	CN	49.0900	23.9175	1.5789	9.9661	4.0	.414393
58	Chenega	CD2	2.000	0.000	5.2714	PS	36.9000	13.1023	.8283	4.0441	7.0	.369694
59	Chenega	CD2	3.000	0.000	6.8750	PS	27.5000	4.8433	.3390	1.5638	4.0	.264948
60	Chenega	CD2	4.000	0.000	6.6975	PS	26.7900	4.2016	.3095	1.5067	4.0	.233876
61	Chenega	CD2	5.000	0.000	5.0240	PS	25.1200	3.9668	.2927	1.4068	5.0	.264624
62	Chenega	CD2	6.000	0.000	6.0625	PS	24.2500	2.7762	.2199	1.0738	4.0	.198912
63	Chenega	CD2	7.000	0.000	5.7550	PS	23.0200	3.0188	.2560	.9461	4.0	.210305
64	Chenega	CD2	8.000	0.000	7.7567	PS	23.2700	2.5461	.1967	.8683	3.0	.167571
65	Chenega	CD2	9.000	0.000	6.9867	PS	20.9600	1.9690	.1538	.5981	3.0	.158172
66	Chenega	CD2	10.000	0.000	7.1867	PS	21.5600	2.0241	.1709	.7502	3.0	.180086
67	Chenega	CD2	11.000	0.000	7.1933	PS	21.5800	2.1671	.2112	.8364	3.0	.215272
68	Chenega	CD2	12.000	0.000	7.0800	PS	21.2400	1.9476	.1635	.6794	3.0	.169665
69	Chenega	CD2	13.000	0.000	7.0067	PS	21.0200	1.8281	.1577	.7116	3.0	.181593
70	Chenega	CD2	14.000	0.000	9.3300	PS	18.6600	1.3919	.1409	.5083	2.0	.150246
71	Chenega	CD2	15.000	0.000	9.4000	PS	18.8000	1.4639	.1163	.4393	2.0	.140310
72	Chenega	CD2	16.000	0.000	9.5100	PS	19.0200	1.1744	.1264	.4256	2.0	.145366
73	Chenega	CD2	17.000	0.000	9.1900	PS	18.3800	1.1446	.1147	.3426	2.0	.119694
74	Chenega	CD2	18.000	0.000	5.9933	PS	17.9800	1.2459	.1159	.4016	3.0	.140184
75	Chenega	CD3	2.000	0.000	5.7340	PS	28.6700	5.9271	.4187	2.0443	5.0	.309810
76	Chenega	CD3	3.000	0.000	6.6700	PS	26.6800	4.2187	.3395	1.4439	4.0	.281225
77	Chenega	CD3	4.000	0.000	6.9900	PS	27.9600	4.0318	.3659	1.5721	4.0	.267887
78	Chenega	CD3	5.000	0.000	6.7500	PS	27.0000	4.0606	.2936	1.3766	4.0	.230566
79	Chenega	CD3	6.000	0.000	8.3633	PS	25.0900	2.9197	.2650	.9838	3.0	.225927
80	Chenega	CD3	7.000	0.000	6.6550	PS	26.6200	4.4422	.3631	1.5840	4.0	.306037
81	Chenega	CD3	8.000	0.000	6.2475	PS	24.9900	3.3445	1.3782	1.2738	4.0	1.522040

Chenega and Ouzinke Clam Database

	1 SITE	2 STATION	3 CLAM__	4 ELEV_	6 GROINC	11 SPECIES	12 LENGTH	13 WHOLE_WT	14 DRY_WT	15 WET_WT_	16 AGE	18 DRY_COND
82	Chenega	CD3	9.000	0.000	6.3575	PS	25.4300	3.9819	.3092	1.3760	4.0	.272440
83	Chenega	CD3	10.000	0.000	8.7000	PS	26.1000	3.9667	.3076	1.3026	3.0	.260292
84	Chenega	CD3	11.000	0.000	6.2325	PS	24.9300	3.0553	.2475	1.0903	4.0	.222684
85	Chenega	CD3	12.000	0.000	6.1450	PS	24.5800	2.8841	1.0281	1.0281	4.0	1.160193
86	Chenega	CD3	13.000	0.000	6.4350	PS	25.7400	3.0642	.2228	.9995	4.0	.171465
87	Chenega	CD3	14.000	0.000	7.8833	PS	23.6500	2.6614	.2173	.9707	3.0	.203533
88	Chenega	CD3	15.000	0.000	6.0425	PS	24.1700	3.3881	.2639	1.1824	4.0	.253079
89	Chenega	CD3	16.000	0.000	7.6267	PS	22.8800	2.6242	.2055	.8765	3.0	.192622
90	Chenega	CD3	17.000	0.000	7.7200	PS	23.1600	2.1490	.1872	.6688	3.0	.167340
91	Chenega	CD3	18.000	0.000	7.6133	PS	22.8400	2.7007	.2073	.8059	3.0	.203285
92	Chenega	CD3	19.000	0.000	5.5225	PS	22.0900	2.1883	.2259	.8146	4.0	.249630
93	Chenega	CD3	20.000	0.000	6.8567	PS	20.5700	1.9979	.1393	.4963	3.0	.132571
94	Chenega	CD3	21.000	0.000	6.9867	PS	20.9600	1.8601	.1481	.5596	3.0	.152127
95	Chenega	CD3	22.000	0.000	4.8125	PS	19.2500	1.7131	.1576	.5749	4.0	.179889
96	Chenega	CD3	23.000	0.000	6.6267	PS	19.8800	1.8846	.1873	.6296	3.0	.219351
97	Chenega	CD3	24.000	0.000	6.8667	PS	20.6000	1.8605	.1763	.6132	3.0	.191545
98	Chenega	CD3	25.000	0.000	6.6600	PS	19.9800	1.9403	.1635	.6514	3.0	.186416
99	Chenega	CD3	26.000	0.000	6.1533	PS	18.4600	1.3585	.1373	.4387	3.0	.163989
100	Chenega	CD3	27.000	0.000	5.7833	PS	17.3500	.8632	.1100	.2915	3.0	.127612
101	Chenega	CD3	28.000	0.000	6.5567	PS	19.6700	1.3281	.1610	.4127	3.0	.164434
102	Chenega	CD3	29.000	0.000	8.0750	PS	16.1500	.7810	.1269	.3765	2.0	.195077
103	Chenega	CD3	30.000	0.000	7.2150	PS	14.4300	.6126			2.0	
104	Chenega	CD3	31.000	0.000	6.9900	PS	13.9800	.4396			2.0	
105	Chenega	CD3	32.000	0.000	6.1900	PS	12.3800	.3414			2.0	
106	Chenega	CD3	33.000	0.000	5.7750	PS	11.5500	.3305			2.0	
107	Chenega	CD3	34.000	0.000	5.6750	PS	11.3500	.2576			2.0	
108	Chenega	CD3	35.000	0.000	5.8100	PS	11.6200	.2832			2.0	
109	Chenega	CD4	1.000	0.000	8.2650	PS	33.0600	6.8924	.5373	2.5972	4.0	.281158
110	Ouzinke	OA1	1.000	1.980	5.0256	PS	45.2300	24.0276	2.7381	8.4026	9.0	.489183
111	Ouzinke	OA2	1.000	.650	10.2833	SG	123.4000	444.1000	184.7000	335.1000	12.0	1.984024
112	Ouzinke	OA2	2.000	.650	9.4800	SG	123.2400	414.5000	185.4000	342.6000	13.0	2.237609
113	Ouzinke	OA2	3.000	.650	9.4983	SG	113.9800	346.0000	179.1000	312.6000	12.0	1.802385
114	Ouzinke	OA3	1.000	-.430	8.3267	SG	74.9400	78.9030	8.1856	33.1360	9.0	.799476
115	Ouzinke	OA3	2.000	-.430	5.2056	SG	46.8500	29.6432	3.0576	11.3412	9.0	.550810
116	Ouzinke	OA4	1.000	-2.180	5.7700	SG	17.3100	.8836	.1219	.3654	3.0	.137266
117	Ouzinke	OA4	2.000	-2.180	7.9350	SG	15.8700	.7520	.1521	.4337	2.0	.226769
118	Ouzinke	OA4	3.000	-2.180	5.4150	SG	10.8300	.1728			2.0	
119	Ouzinke	OA4	4.000	-2.180	7.7100	SG	7.7100	.0731			1.0	
120	Ouzinke	OA5	5.000	-2.980	5.4067	SG	16.2200	.6656	.1611	.3865	3.0	.209423
121	Ouzinke	OB1	1.000	1.400	6.4500	PS	25.8000	4.0220	1.5248	2.7628	4.0	.262455
122	Ouzinke	OB4	1.000	-1.930	6.3300	PS	50.6400	38.2326	4.2884	16.4008	8.0	.792422
123	Ouzinke	OB4	2.000	-1.930	9.1000	PS	9.1000	1.2540			1.0	
124	Ouzinke	OB5	1.000	-2.430	6.8033	SG	61.2300	45.5937	6.5549	23.0736	9.0	.932973

Chenega and Ouzinke Clam Database

	1 SITE	2 STATION	3 CLAM__	4 ELEV_	6 GROINC	11 SPECIES	12 LENGTH	13 WHOLE_WT	14 DRY_WT	15 WET_WT_	16 AGE	18 DRY_COND
125	Ouzinke	OB5	2.000	-2.430	7.3938	SG	59.1500	43.7106	5.8616	21.2179	8.0	.869685
126	Ouzinke	OB5	3.000	-2.430	6.5144	SG	58.6300	44.3592	6.2802	22.0206	9.0	.964746
127	Ouzinke	OB5	4.000	-2.430	6.2056	SG	55.8500	42.1559	5.6803	19.7461	9.0	.942217
128	Ouzinke	OB5	5.000	-2.430	4.9430	PS	49.4300	30.3817	2.5036	11.0808	10.0	.667563
129	Ouzinke	OB5	6.000	-2.430	6.8100	SG	47.6700	23.7428	2.8775	7.7699	7.0	.831008
130	Ouzinke	OB5	7.000	-2.430	6.2967	SG	37.7800	10.2836	1.1469	4.8012	6.0	.526666
131	Ouzinke	OB5	8.000	-2.430	7.2700	SG	36.3500	9.7107	.8667	3.5050	5.0	.424812
132	Ouzinke	OB5	9.000	-2.430	5.6017	SG	33.6100	7.5854	1.0720	4.2706	6.0	.615297
133	Ouzinke	OB5	10.000	-2.430	5.9180	PS	29.5900	6.2508	.6722	2.8012	5.0	.474368
134	Ouzinke	OB5	11.000	-2.430	6.5100	SG	19.5300	.9002	.1387	.4377	3.0	.129913
135	Ouzinke	OB5	12.000	-2.430	7.5150	SG	15.0300	.6651	.1176	.3467	2.0	.194788
136	Ouzinke	OB5	13.000	-2.430	7.1000	SG	14.2000	.5312			2.0	
137	Ouzinke	OB5	14.000	-2.430	7.1500	SG	14.3000	.3712			2.0	
138	Ouzinke	OB6	1.000	-2.600	7.2736	SG	80.0100	65.5519	7.1058	30.7236	11.0	.587296
139	Ouzinke	OB6	2.000	-2.600	5.0009	PS	55.0100	43.0276	4.6964	18.5347	11.0	.755544
140	Ouzinke	OB6	3.000	-2.600	4.5811	PS	41.2300	16.0101	2.6939	7.8438	9.0	.575932
141	Ouzinke	OB6	4.000	-2.600	4.0800	SG	40.8000	12.8923	1.3904	5.9558	10.0	.540951
142	Ouzinke	OB6	5.000	-2.600	6.3050	SG	37.8300	10.9380	1.1240	5.0824	6.0	.507665
143	Ouzinke	OB6	6.000	-2.600	6.0133	SG	18.0400	1.0955	.1746	.5970	3.0	.214217
144	Ouzinke	OB6	7.000	-2.600	4.7467	SG	14.2400	.4433			3.0	
145	Ouzinke	OB6	8.000	-2.600	4.8233	SG	14.4700	.4832			3.0	
146	Ouzinke	OB6	9.000	-2.600	6.3800	SG	12.7600	.3968			2.0	
147	Ouzinke	OB6	10.000	-2.600	6.6650	SG	13.3300	.3699			2.0	
148	Ouzinke	OB6	11.000	-2.600	7.0550	SG	14.1100	.2761			2.0	
149	Ouzinke	OB6	12.000	-2.600	6.0900	SG	12.1800	.3124			2.0	
150	Ouzinke	OB6	13.000	-2.600	5.4950	SG	10.9900	.2552			2.0	
151	Ouzinke	OB6	14.000	-2.600	5.0500	SG	10.1000	.2181			2.0	
152	Ouzinke	OB6	15.000	-2.600	4.6550	SG	9.3100	.1274			2.0	
153	Ouzinke	OB6	16.000	-2.600	4.2100	SG	8.4200	.1406			2.0	
154	Ouzinke	OC3	3.000	.480	6.8000	SG	6.8000	.0656			1.0	
155	Ouzinke	OC4	1.000	-.350	10.6350	SG	21.2700	2.2758	.3303	1.2011	2.0	.398891
156	Ouzinke	OC4	2.000	-.350	6.3967	PS	19.1900	1.7580	.2272	.7087	3.0	.300506
157	Ouzinke	OC4	3.000	-.350	6.0600	PS	18.1800	1.4634	.1850	.5457	3.0	.230689
158	Ouzinke	OC4	4.000	-.350	5.0900	SG	10.1800	.2517			2.0	
159	Ouzinke	OC6	1.000	-2.100	6.1880	SG	30.9400	7.2500	.8811	3.5892	5.0	.541634
160	Ouzinke	OC6	2.000	-2.100	8.7150	SG	17.4300	.6052			2.0	
161	Ouzinke	OC6	3.000	-2.100	6.6240	MT	66.2400	102.9292	10.2936	39.6262	10.0	1.351213
162	Ouzinke	OC6	4.000	-2.100	7.0940	MT	70.9400	41.8624	6.0817	24.4417	10.0	.624932
163	Ouzinke	OC6	5.000	-2.100	6.5640	MT	65.6400	37.1844	4.9383	19.9797	10.0	.558852
164	Ouzinke	OC7	1.000	-2.600	6.0738	PS	48.5900	23.5929	3.1792	10.8364	8.0	.542001
165	Ouzinke	OC7	2.000	-2.600	6.4286	PS	45.0000	18.3246	2.7105	8.3916	7.0	.479802
166	Ouzinke	OC7	3.000	-2.600	8.0740	PS	40.3700	14.2119	2.5315	6.7982	5.0	.525567
167	Ouzinke	OC7	4.000	-2.600	5.7029	SG	39.9200	13.2143	2.6214	7.5582	7.0	.577841

Chenega and Ouzinke Clam Database

	1 SITE	2 STATION	3 CLAM__	4 ELEV_	6 GROINC	11 SPECIES	12 LENGTH	13 WHOLE_WT	14 DRY_WT	15 WET_WT_	16 AGE	18 DRY_COND
168	Ouzinke	OC7	5.000	-2.600	8.6333	PS	25.9000	4.0015	.4449	1.6756	3.0	.390605
169	Ouzinke	OC7	6.000	-2.600	4.5740	SG	22.8700	2.2053	.3251	1.1330	5.0	.358615
170	Ouzinke	OC7	7.000	-2.600	6.3850	SG	12.7700	.4085			2.0	
171	Ouzinke	OC7	8.000	-2.600	6.3150	SG	12.6300	.3026			2.0	
172	Ouzinke	OC7	9.000	-2.600	5.9350	SG	11.8700	.3611			2.0	
173	Ouzinke	OC7	10.000	-2.600	5.3550	PS	10.7100	.2868			2.0	
174	Ouzinke	OC7	11.000	-2.600	5.1350	SG	10.2700	.2126			2.0	
175	Ouzinke	OC7	12.000	-2.600	10.0000	SG	10.0000	.2085			1.0	
176	Ouzinke	OC7	13.000	-2.600	4.9350	PS	9.8700	.2078			2.0	
177	Ouzinke	OC7	14.000	-2.600	8.7100	SG	8.7100	.1443			1.0	
178	Ouzinke	OC7	15.000	-2.600	10.7000	PS	10.7000	.1396			1.0	
179	Ouzinke	OC7	16.000	-2.600	6.9700	PS	6.9700	.0661			1.0	
180	Ouzinke	OD1	1.000	-1.000	5.5282	SG	93.9800	176.0000	94.3752	156.1000	17.0	1.989374
181	Ouzinke	OD1	2.000	-1.000	4.5238	SG	95.0000	211.6000	88.7925	154.0000	21.0	1.552477
182	Ouzinke	OD2	1.000	-1.260	5.4505	SG	103.5600	224.4000	92.3869	166.8000	19.0	1.476629
183	Ouzinke	OD2	2.000	-1.260	5.6053	SG	95.2900	191.9000	88.9960	152.7000	17.0	1.507905
184	Ouzinke	OD2	3.000	-1.260	5.8538	SG	93.6600	189.2000	87.0629	150.9000	16.0	1.488746
185	Ouzinke	OD2	4.000	-1.260	5.7906	SG	98.4400	217.3000	87.8264	160.0000	17.0	1.384255
186	Ouzinke	OD2	5.000	-1.260	4.7355	SG	94.7100	199.9000	89.7239	152.0000	20.0	1.628350
187	Ouzinke	OD2	6.000	-1.260	5.1941	SG	88.3000	176.7000	87.2454	149.0000	17.0	1.650663
188	Ouzinke	OD3	1.000	-1.6'	7.4450	SG	14.8900	.1080			2.0	
189	Ouzinke	OD3	2.000	-1.6'	8.1700	SG	8.1700	.0530			1.0	
190	Ouzinke	OD3	3.000	-1.6'	7.0200	SG	7.0200	.0540			1.0	
191	Ouzinke	OD4	1.000	-1.930	10.1100	PS	20.2200	1.8884	.2402	.7209	2.0	.287005
192	Ouzinke	OD4	2.000	-1.930	4.2200	SG	4.2200	.0159			1.0	
193	Ouzinke	LAGOON	1.000		4.2525	PS	51.0300	35.3027	3.6868	13.7625	12.0	.624910
194	Ouzinke	LAGOON	2.000		4.9078	PS	44.1700	27.9145	3.4503	11.3967	9.0	.758381
195	Ouzinke	LAGOON	3.000		4.7600	PS	47.6000	31.2502	3.4637	14.9190	10.0	.652716
196	Ouzinke	LAGOON	4.000		4.8567	PS	43.7100	21.5909	2.6938	9.5018	9.0	.505573
197	Ouzinke	LAGOON	5.000		5.3100	PS	42.4800	18.3202	2.6173	8.1320	8.0	.507818
198	Ouzinke	LAGOON	6.000		5.1975	PS	41.5800	13.1821	1.8090	4.3710	8.0	.213116
199	Ouzinke	LAGOON	7.000		4.7022	PS	42.3200	17.6609	1.2939	6.1426	9.0	.453078
200	Ouzinke	LAGOON	8.000		4.3800	PS	39.4200	14.9779	1.3292	5.8920	9.0	.552830
201	Ouzinke	LAGOON	9.000		4.9137	PS	39.3100	13.0015	1.1689	4.3752	8.0	.478533
202	Ouzinke	LAGOON	10.000		6.4583	PS	38.7500	12.9198	1.0214	4.8338	6.0	.433852
203	Ouzinke	LAGOON	11.000		6.1100	PS	36.6600	11.7884	.8334	4.3072	6.0	.401629
204	Ouzinke	LAGOON	12.000		4.3062	PS	34.4500	11.6061	.8606	3.8440	8.0	.441679
205	Ouzinke	LAGOON	13.000		4.6943	SG	32.8600	7.8084	.7288	3.0478	7.0	.410687
206	Ouzinke	LAGOON	14.000		6.4500	PS	32.2500	6.9315	.6336	2.5882	5.0	.372347
207	Ouzinke	LAGOON	15.000		4.9550	PS	29.7300	6.8439	.4987	2.3137	6.0	.334375
208	Ouzinke	LAGOON	16.000		6.0633	PS	18.1900	1.2577	.0978	.2796	3.0	.040024
209												
210												

Alaskan Native Village
Shellfish Enhancement Program

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.

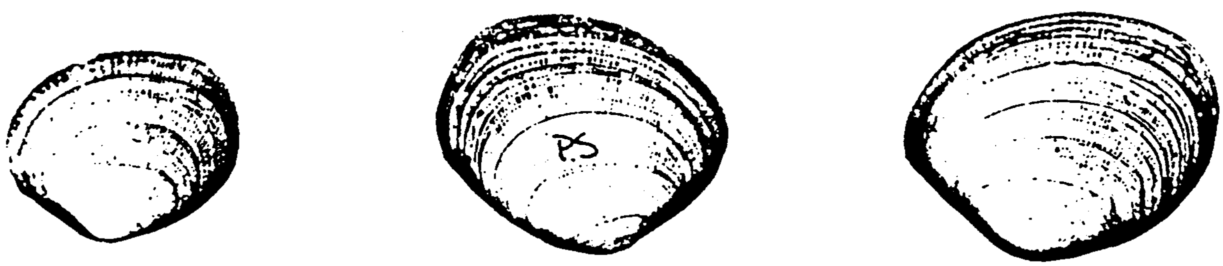
In 1995, the Chugach Regional Resource Council (CRRC) started a shellfish enhancement program at the Villages of Port Graham, Nanwalek and Tatitlek. In 1996, the program is being expanded to include the Villages of Ouzinkie and Chenega Bay. More than 8,000 clams will be planted at Port Graham, Nanwalek 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.

Appendix 4

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.

Less than one year old | one to two years old | two to three years old | three to four years old



Four to five years old | five to six years old | six to seven years old

We did find lots of 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 clam shells. 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

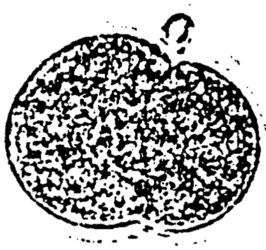
What can we do to grow more clams for Villagers? In years past, several people have tried to raise native littleneck clams in hatcheries. Everyone failed. But in 1994, the Qutekcak hatchery in Seward figured out how to grow these tricky clams. They have raised about 25,000 clams that we will use for 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.

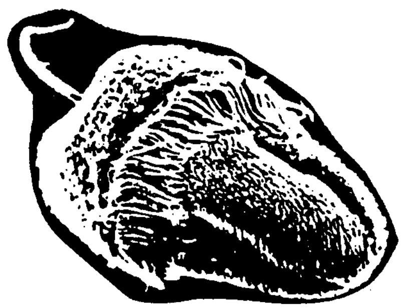
When the clams get ready to settle out of the water and dig into the bottom, they metamorphose and lose the *Velum* in favor of a strong foot for digging, and siphons and gills for collecting food. After metamorphosis, clams and oysters need more algae than can be grown in a hatchery.

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.

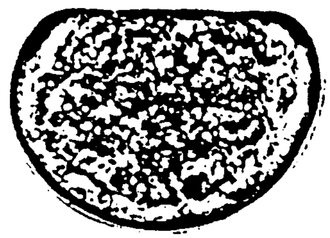
Figure 3. How little clams and oysters grow.



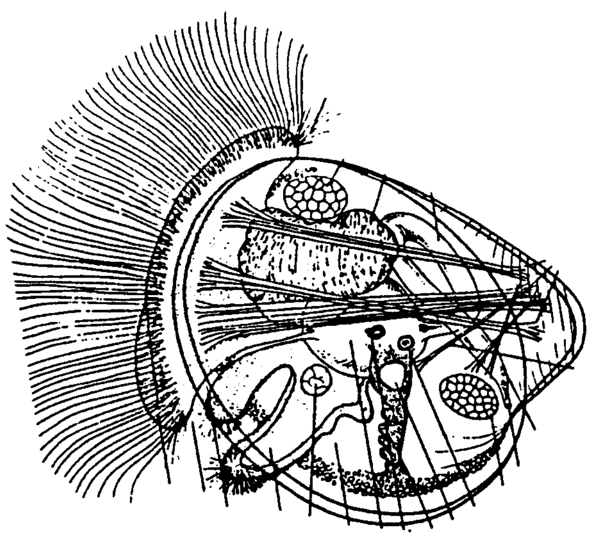
Fertilized egg starting to divide
(one hour old)



Trochophore larvae
(12 hours old)

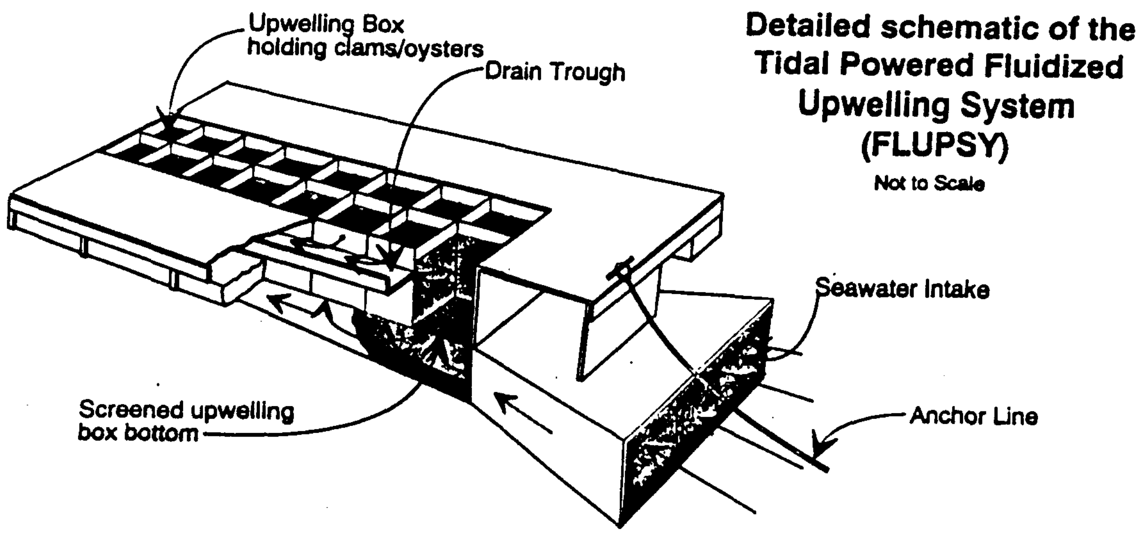


"D" hinge larvae
(24 hours old)



"Veliger larvae"
(Swims in water for about three weeks)

"Pediveliger larvae"
Ready to metamorphose and live in the gravel



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.

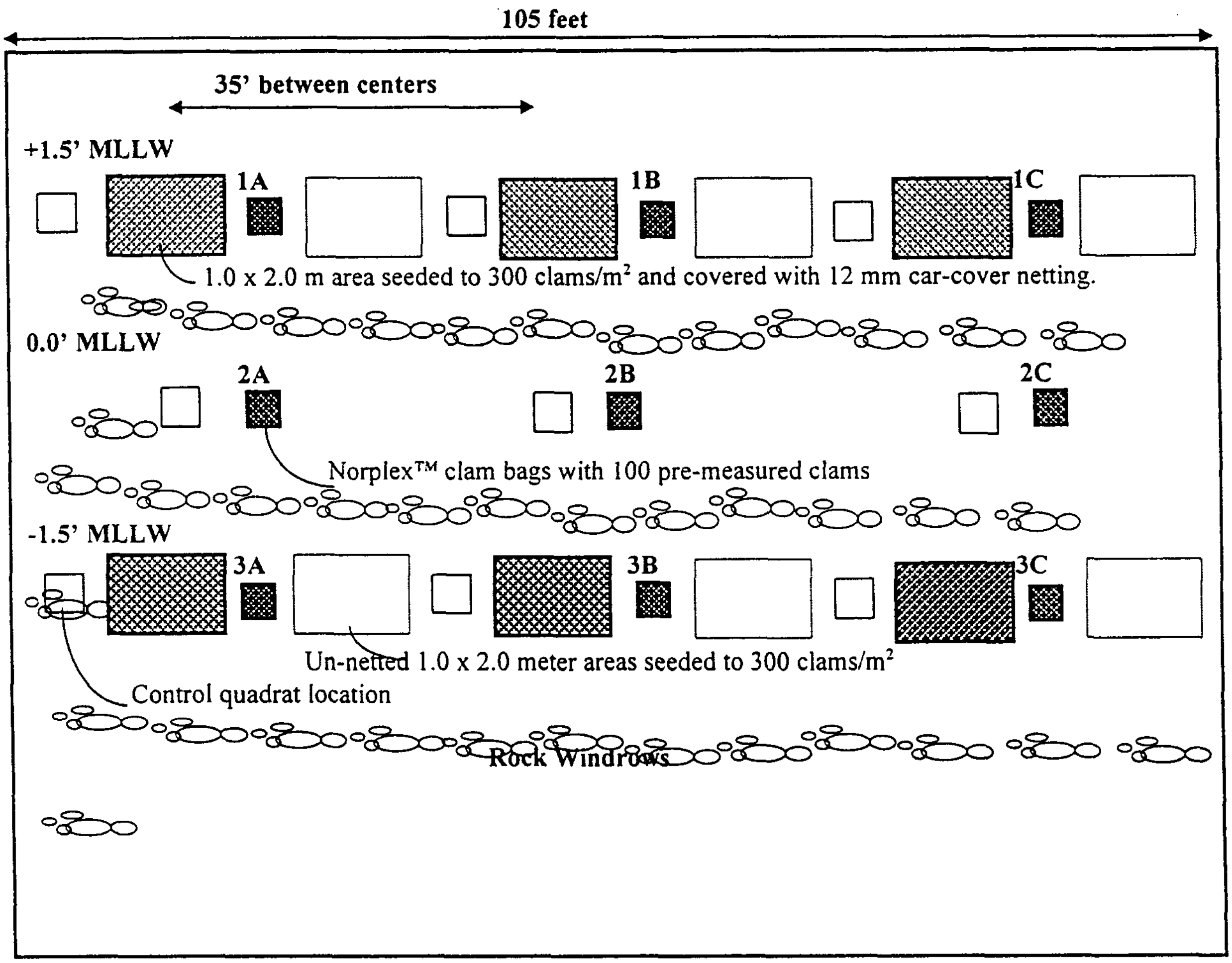
Village shellfish enhancement in 1996. Thanks to the hard work at the Qutekcak hatchery, we have about 25,000 strong little clams to plant in 1996. We're going to use about 8,000 of them at Port Graham, Nanwalek and Tatitlek to study how fast these clams grow and how many survive with and without efforts 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.

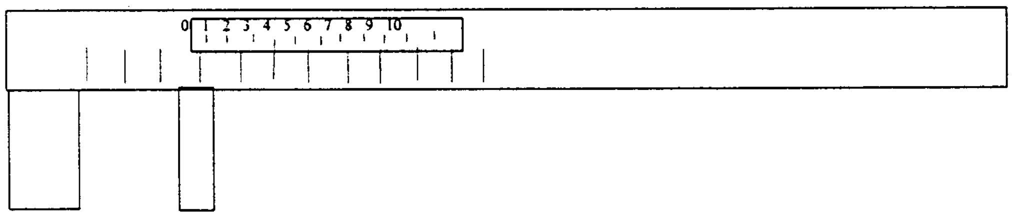
Figure 5. Study design for clam enhancement studies at previously surveyed beaches at the villages of Tatitlek, Nanwalek and Port Graham.



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

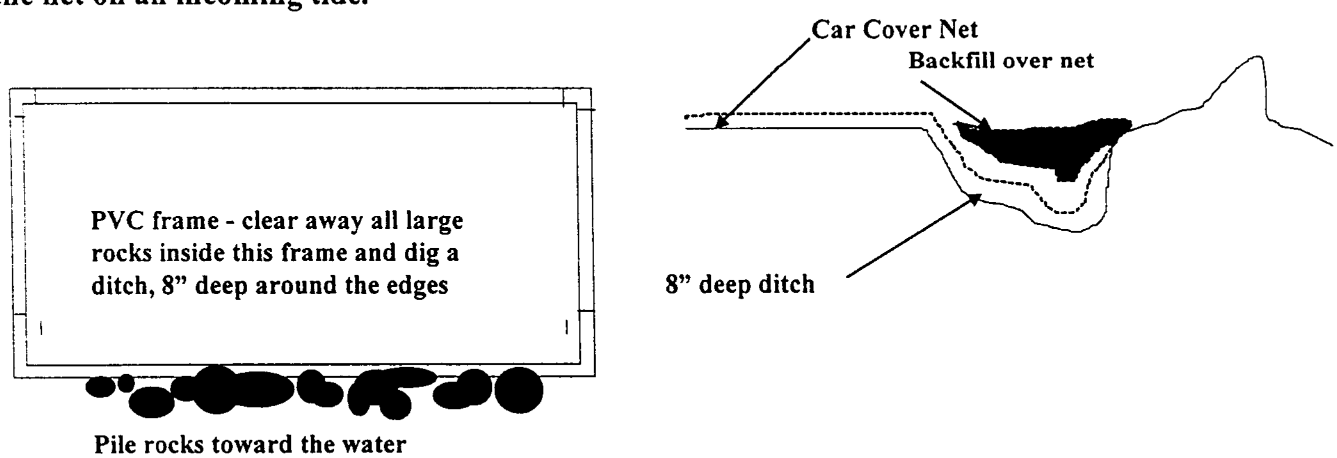
Figure 6. Vernier calipers measuring something that is 3.3 millimeters long.



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.

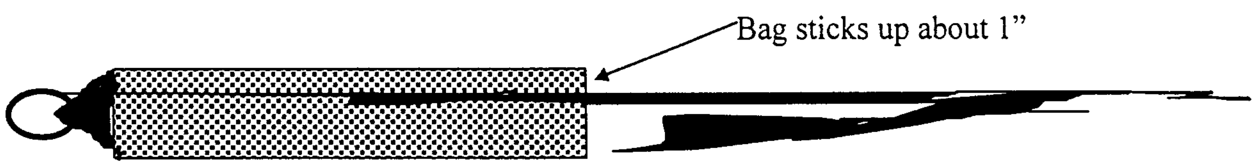
f. Count any empty clam shells you find in the bags and make a note of the number on the data sheet.

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
Aquatic Environmental Sciences
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 general public - like you do on the beach. I've included a good recipe for steamed mussels and hope you'll 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 very deep. The cockle shells we found told us that they grow pretty 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 Villages 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 occur in the water can cause serious disease and even death. These dinoflagellates 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 and vomiting and pain in your chest and arms. In really 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.

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 sea water. 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. Its 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

f. separate data sheet for each clam bag. There are nine bags and you should have nine data sheets when you finish.

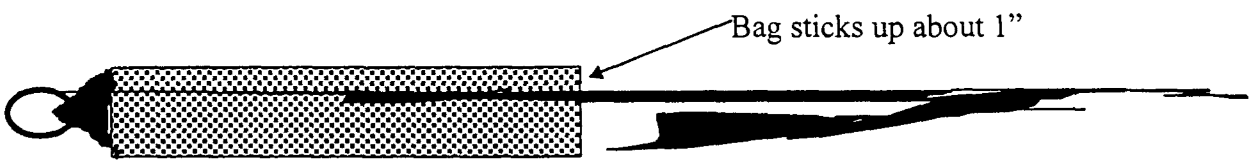
g. Count any empty clam shells you find in the bags and make a note of the number on the data sheet.

h. Note any predators in the bags like small crabs or snails. Note any tears or damage to the bags.

i. Place a shovel full of small 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.

j. Slide the PVC closure over the opening of the bag and secure it with an electrical tie.

k. 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. ________

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:

Appendix II. Project Report: Results of Razor Clam Survey For the Village of Eyak.

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

Results of Razor Clam Survey for the Village of Eyak

EVOS Project 96131

Produced by:
Jeff Hetrick
Alaska Aquafarms
P.O. Box 7
Moose Pass, Alaska 99631
(907) 288-3667

April, 1997

Results of Razor Clam Survey for the Village of Eyak

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1. Introduction

This report outlines a survey of a selected beach near the village of Eyak, Prince William Sound. The survey attempts to identify and inventory razor clam populations at a traditional harvest area, characterize the substrate and water quality and test predator control methods. The information contained within will be the baseline for future efforts to restore razor clam Siliqua patula populations for subsistence use and harvest near the Cordova area.. This survey is part of Exxon Valdez Oil Spill (EVOS) Restoration Project 96131 Nanwalek/Port Graham/Tatitlek Subsistence Clam Restoration.

2. Background

Razor clams were once the basis for an important commercial and recreation fishery near Cordova previously 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 environmental changes in flow from the Copper River land shifts from the 1964 earthquake and 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.

Razor clam biology

Razor clams are found on open sandy beaches from central California to the Aleutian Island in Alaska. In the Prince William Sound the razor clam populations are concentrated in the Copper River Delta and Orca Inlet near Cordova. The classic razor clam growing area possess heavy surf, strong tidal currents, long shore bars and troughs.

The razor clam can be hermaphroditic with populations generally maintaining a 1:1 sex ratio. Sexual maturity is related to size which is assumed to be approximately 100 mm. Razor clams are broadcast spawners releasing millions of gametes with chance fertilization. Spawning is triggered by temperature, food availability and size (maturity). The spawning season is protracted throughout the summer, however a majority of the spawn occurs within several days generally coinciding with temperatures exceeding 15C.

After fertilization the larvae are planktonic for a short period and form veligers within two weeks. After about three weeks of development they have taken on the common clam shape and become sessile. The foot is fully developed at 5 weeks and at 8 weeks the velum is gone and the shell becomes elongated. The clams are fully set at ten weeks. Ideal temperature for early developing razor clams is 11-17C.

Once set, juvenile clams over 20 mm in length usually remain in the upper 60mm of sand. As the clams grow they continue a vertical migration and ultimately settle at about 20 cm when mature. Razor clams thrive in exposed dense sandy beaches with heavy tidal flow and currents. The continual flow of water is thought to satisfy the high demand for oxygen and the constant movement of substrate helps prevent suffocation.

Fine grain sand (.15 to .2 mm) with a low clay fraction and gentle beach slopes aid areas in holding water (and feed) in the sand between tides. This creates a typical hard surface and quicksand subsurface texture. Prime beaches are devoid of heavy siltation which may cause suffocation in early life stages.

Like most bivalves molluscs, razor clams are filter feeders extracting algae, predominately diatoms and <u>Chatercerous</u> as a food source. In areas of high productivity razor clams thrive and grow rapidly. Growth rates are higher during the first four years of development where the clams reach an average of 90 mm in the Cordova area and 115 mm by age 5. Razor clams range from +1.5' to -40' subtidal. The densest and fastest growing populations usually occur below the zero tide line because of the sustained ability to feed.

Razor clams experience their highest mortality after setting. Seagulls, ducks and small fish prey heavily. Losses are also significant because of siltation and substrate movement caused by the tides and . Once the clams set and safely burrow to 20mm in depth their mortality to predation is limited until they reach a size suitable for otters and birds of prey.

Because of the brevity of the swimming larval stage and the tendency of the larvae to remain in the sand vertical dispersal is limited. Juvenile clams burrow into the sand and take on adult life forms after 10 - 12 weeks of development. Their movement is limited spacing themselves according to density. After the clams reach 60mm or more their voluntary lateral movement is thought to be limited to less than a meter.

Razor clams are well known for their fast vertical movement attributed to their uniquely shaped foot which hydraulically expands to serve as an anchor. When moving the muscles contract to pull the clam downward enabling the clam to avoid predation and respond to instability of sandy beaches.

Richard " Dick" Nickerson conducted extensive research on razor clam populations in the Cordova area in the late 1960's and early 1970's. His work provides insight into razor clam biology specific to this project. His analysis of the life histories, sexual characteristics, spawning, growth rates and age-length-weight relationships provide a valuable baseline for this project and yields information for potential enhancement techniques and comparisons with "wild populations".

Likewise, Nickersons's studies of population dynamics and habitat relationships focusing on tidal height and substrate exposure are extremely important in evaluating beach areas suitable for razor clam reintroduction or enhancement.

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.

6. References

Lassuy, D.R., and D. Simons. 1989. Species profiles: life histories environmental requirements of coastal fishes and invertebrates (Pacific northwest)-- Pacific razor clam. U.S. Fish. Wild. Serv. Biol. Rep. 82 (11.89) U.S. Army Corps of Engineers, TR-EL_82-4. 16pp.

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

Trowbridge, Charlie 1997. Prince William Sound Management Area 1996 Report to the Alaska Board of Fisheries . Regional Informational report No. 2A97-. Alaska Department of Fish and Game, Anchorage. 37pp

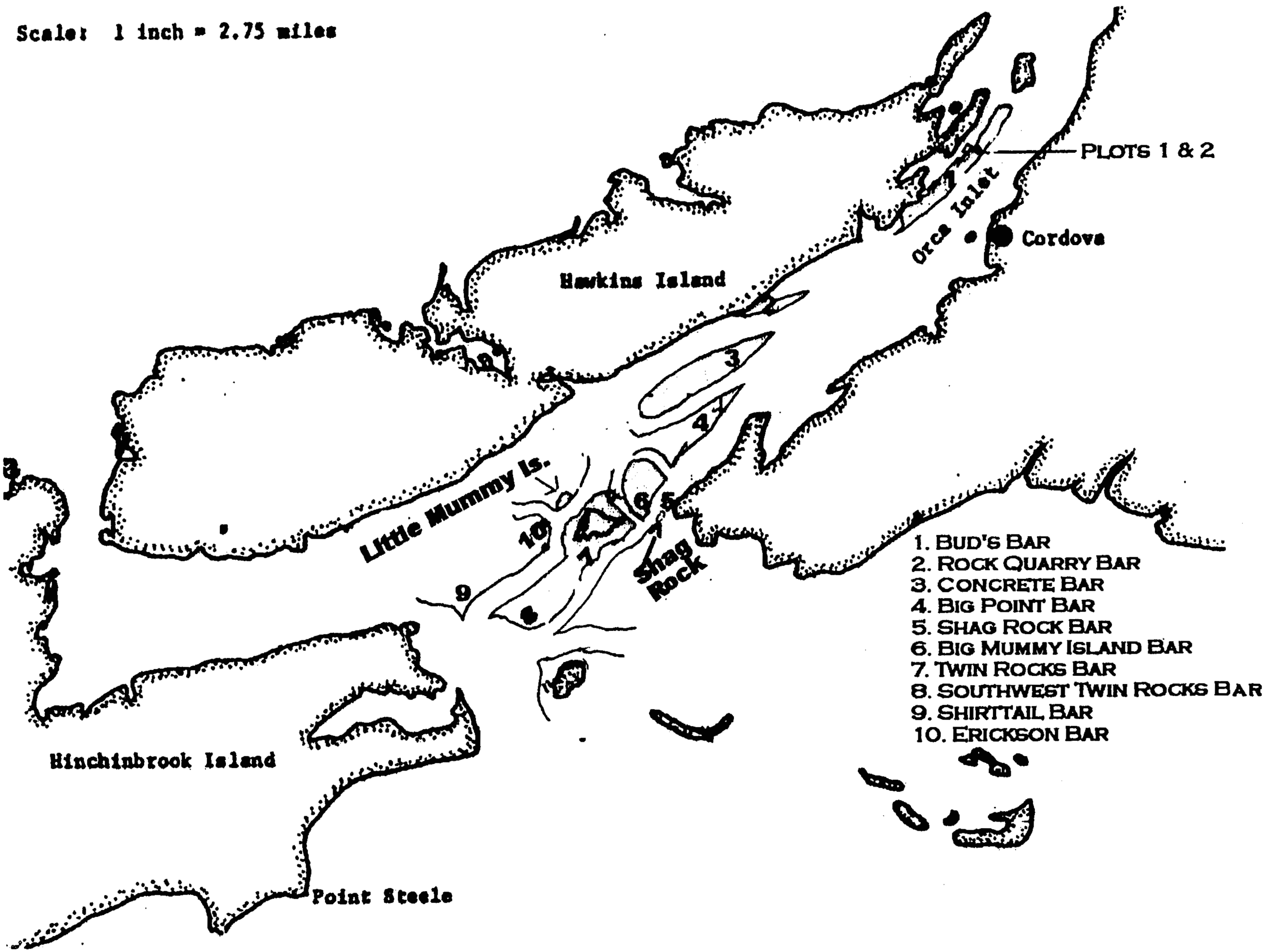


Figure 1. Study beach locations.

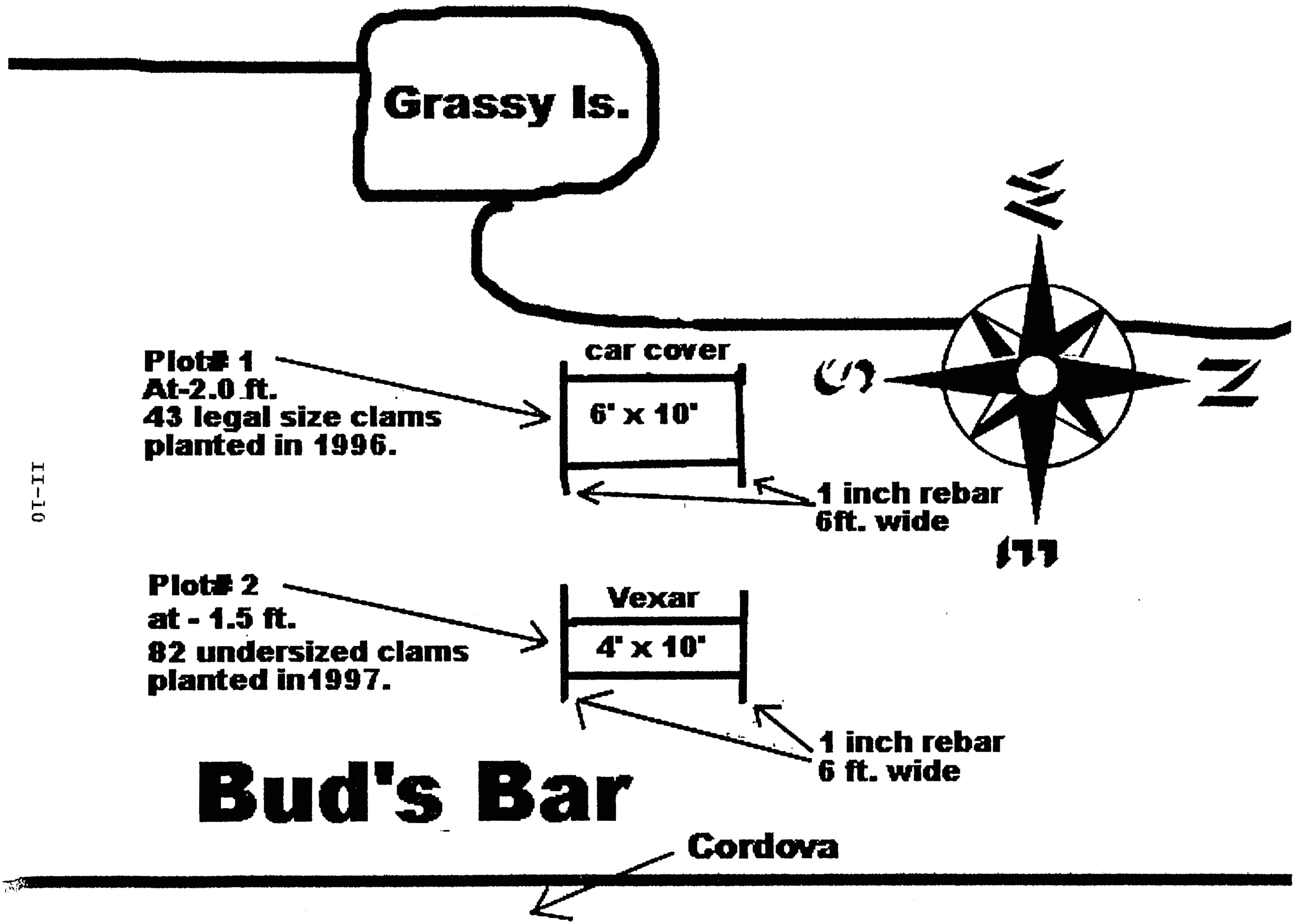


Figure 2. Sampling layout.

7. Appendices

ALASKA TESTLAB
A Division of DOWL, Incorporated

AASHTO ACCREDITED
CONSTRUCTION MATERIALS TESTING LABORATORY

Northern Testing Laboratories
8005 Schoon St
Anchorage, Alaska 99518

W.O.#A27041
September 25, 1996

Attention: Ms. Angie Caudell

Subject: Particle-Size Analysis
Trail Lakes Hatchery

Dear Ms. Caudell:

The particle-size distribution of your soil was measured in the laboratory. The published methods for this test are:

- ASTM C 117, "Material Finer Than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing;"
- ASTM C 136, "Sieve Analysis of Fine and Coarse Aggregates;"
- ASTM D 422, "Particle Size-Analysis of Soils;"
- AASHTO T-11, "Material Finer Than 75-µm Sieve in Mineral Aggregates;"
- AASHTO T-27, "Sieve Analysis of Fine and Coarse Aggregates;"
- AASHTO T-30, "Mechanical Analysis of Extracted Aggregate;"
- AASHTO T -88, "Particle Size Analysis of Soils;" and
- AK DOT/PF ATM T-7, "Sieve Analysis of Fine and Coarse Aggregates."

Alaska Testlab's standard procedure is in conformance with these standards, with the following descriptions:

- The coarse fraction of non-extracted soils is not washed unless the coarse particles appear to be significantly coated with fines;
- The fine fraction of the soil is *always* washed;
- The plus 3-inch fraction is not routinely included in the test due to the large sample mass required for a representative sample; The estimated percentage of plus 3 inch material in the sample is shown on the test report; and
- The mass of the coarse and fine test fractions are reported.

The soil is classified in accordance with ASTM D 2487, "Classification of Soils for Engineering Purposes (Unified Soil Classification System)." The frost classification is identified in accordance with Corps of Engineers and Municipality of Anchorage (MOA) procedures.

The test results are attached. If you have any questions regarding the test procedures or the results, please call me.

Sincerely,
ALASKA TESTLAB

David Andersen

Howard K. Weston, P.E., or
David L. Andersen, P.E.

4040 B STREET • ANCHORAGE • ALASKA • 99503-5999 • 907/562-2000 • FAX 907/563-3953

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 filtering ~~funneling~~ 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.

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

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

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

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

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

Julie Schaefer
1/27/97

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.

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

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

Jaire Sleinfe[?]
1/27/97

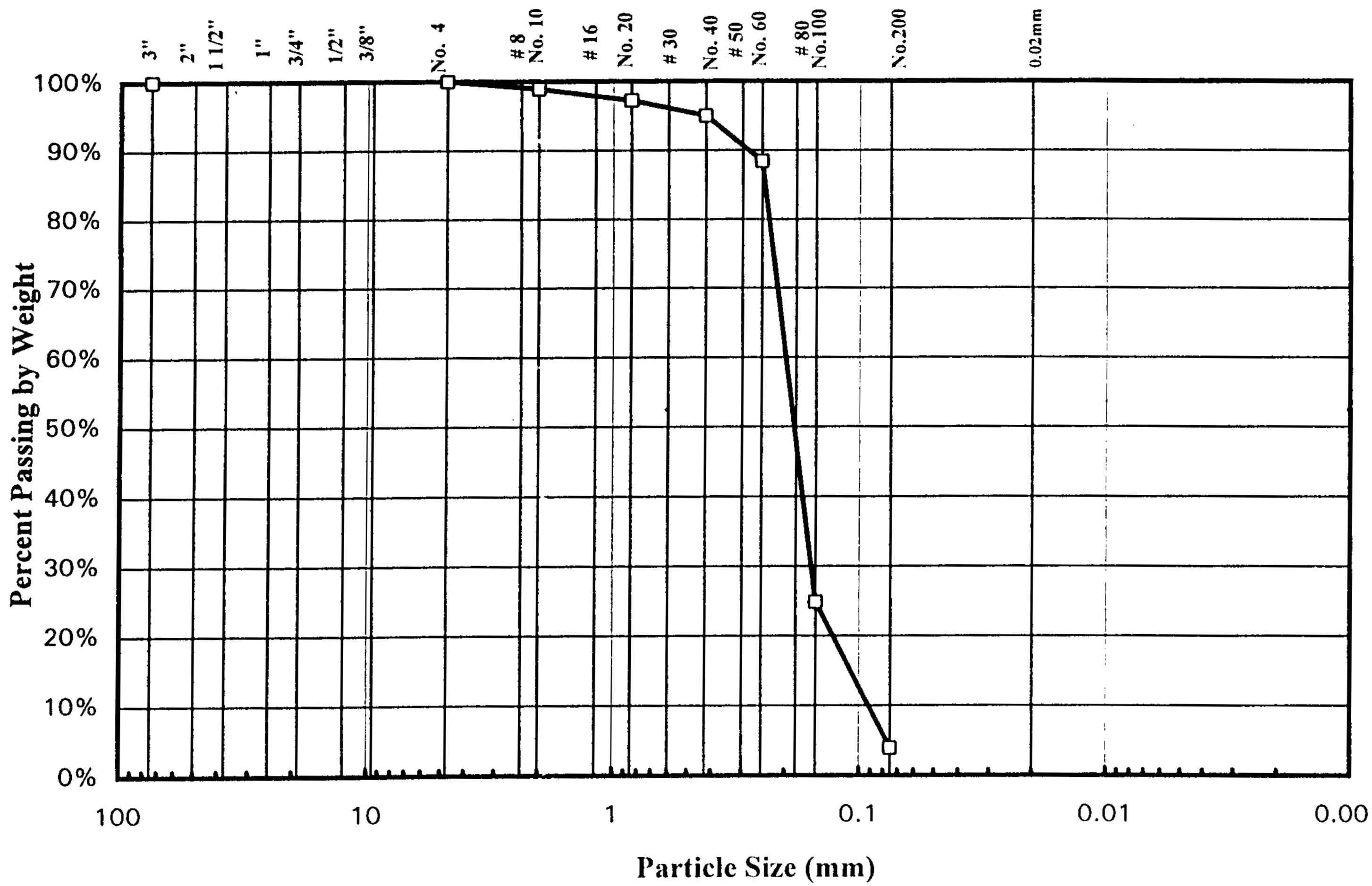
ALASKA TESTLAB
A Division of DOWL, Incorporated
4040 B Street Anchorage, Alaska 99503
(907) 562-2000 FAX (907) 563-3953

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		

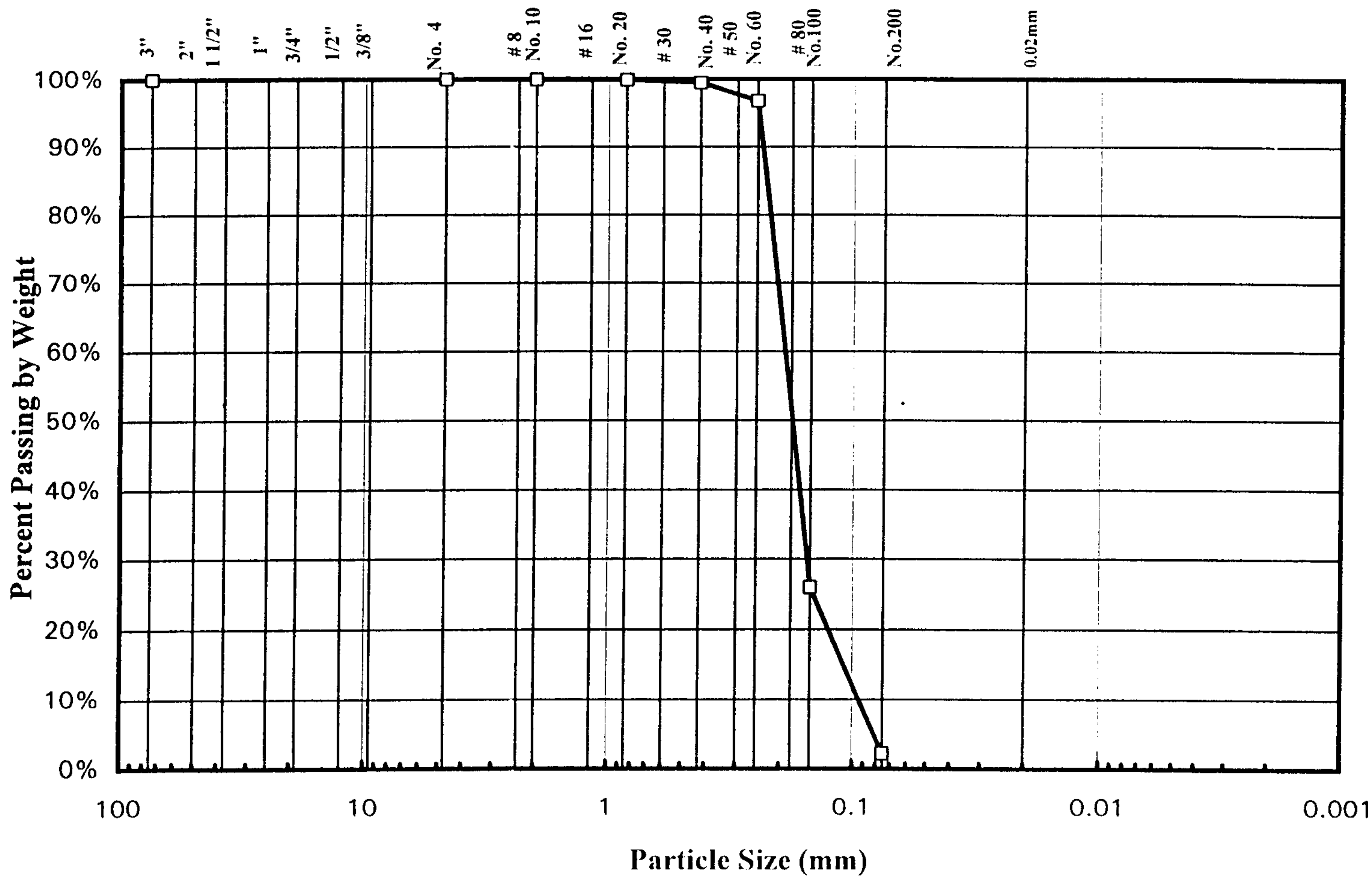
ALASKA TESTLAB
A Division of DOWL, Incorporated
4040 B Street Anchorage, Alaska 99503
(907) 562-2000 FAX (907) 563-3953

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		

ALASKA TESTLAB
A Division of DOWL, Incorporated
4040 B Street Anchorage, Alaska 99503
(907) 562-2000 FAX (907) 563-3953

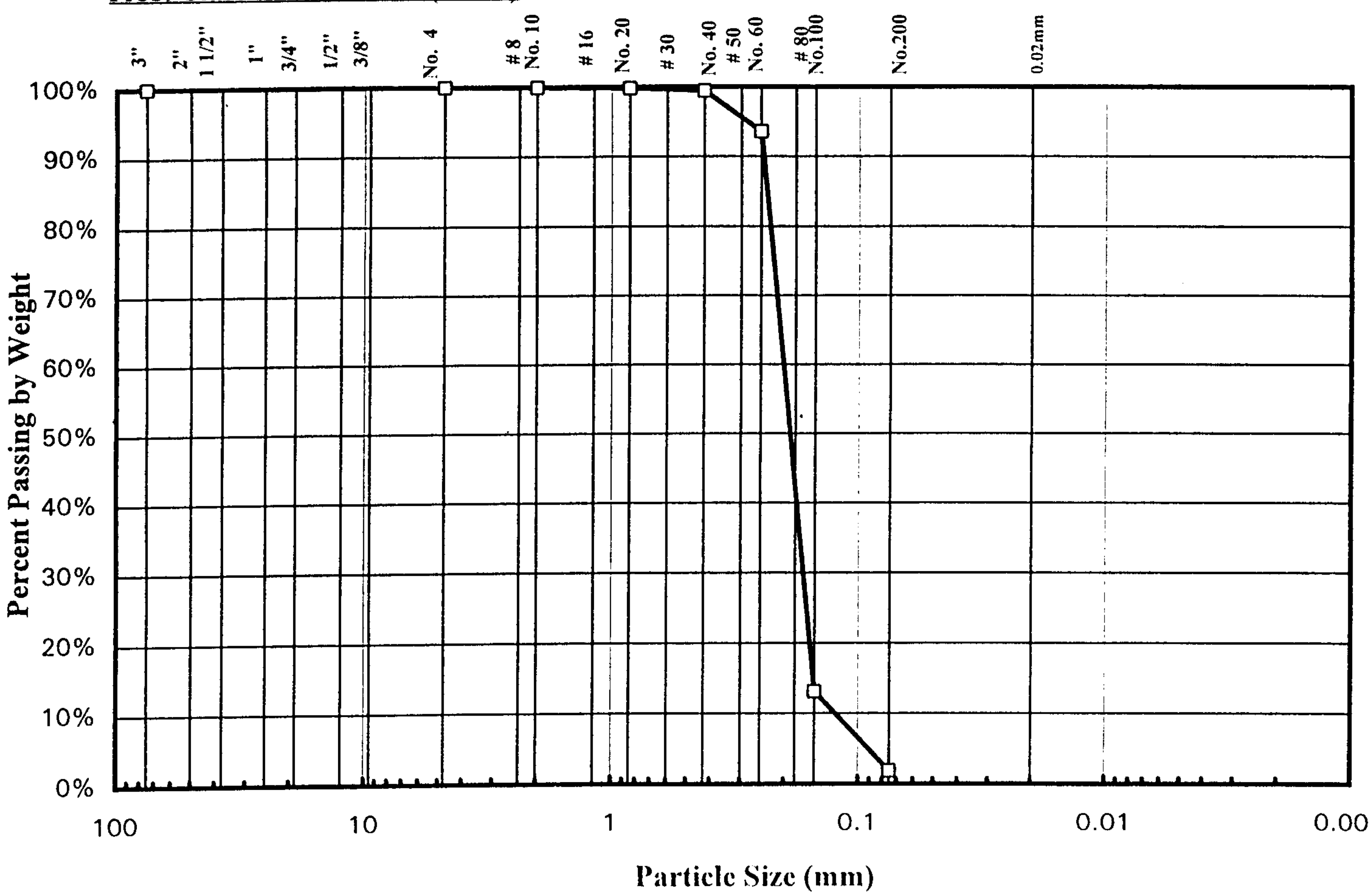
Client: Northern Testing Laboratories
Project: Trail Lakes Hatchery

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		

ALASKA TESTLAB
A Division of DOWL, Incorporated
4040 B Street Anchorage, Alaska 99503
(907) 562-2000 FAX (907) 563-3953

Client: Northern Testing Laboratories

Project: Trail Lakes Hatchery

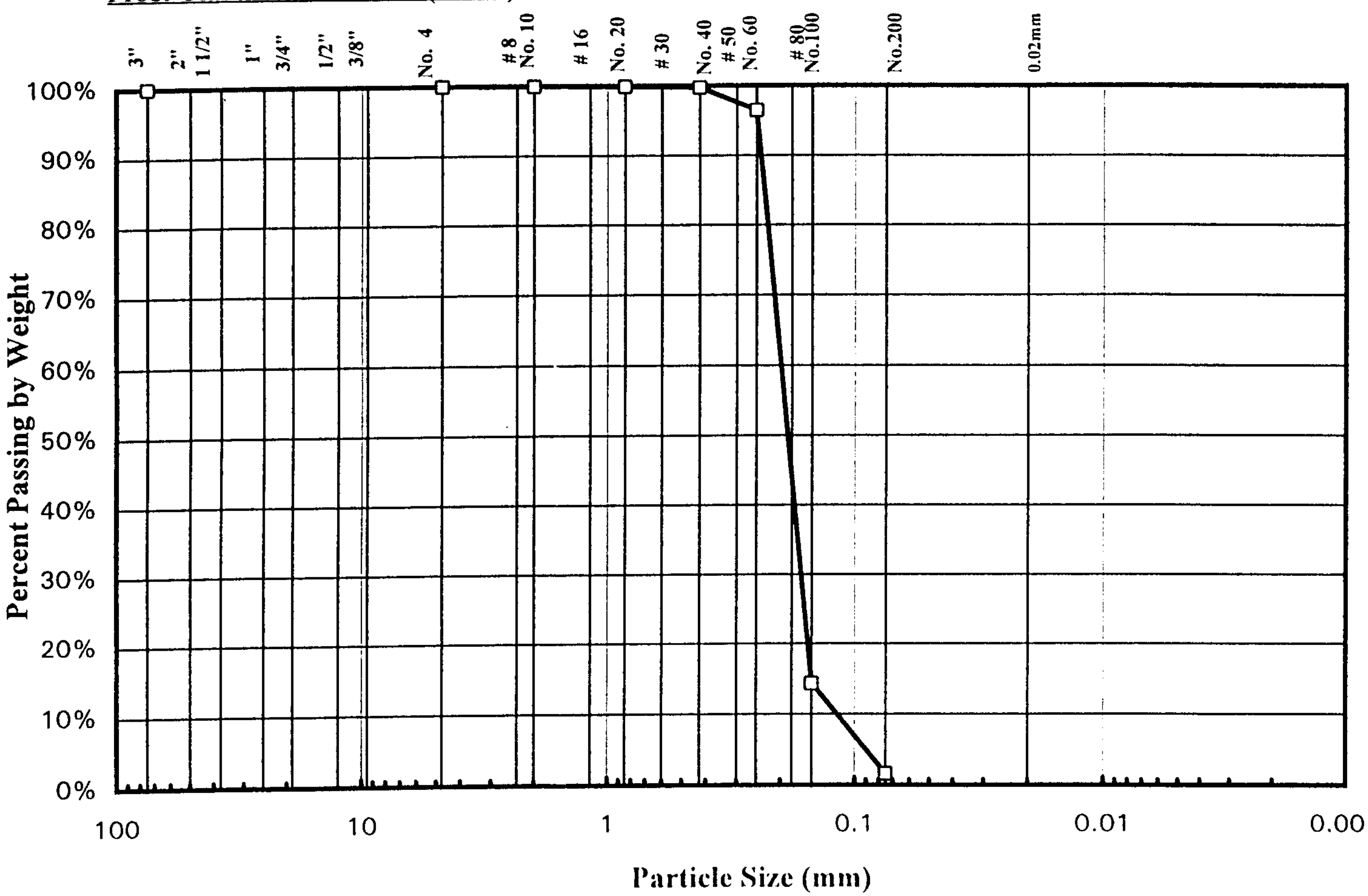
Location: Sample 1B @ 1.5'
Submitted by Client

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		

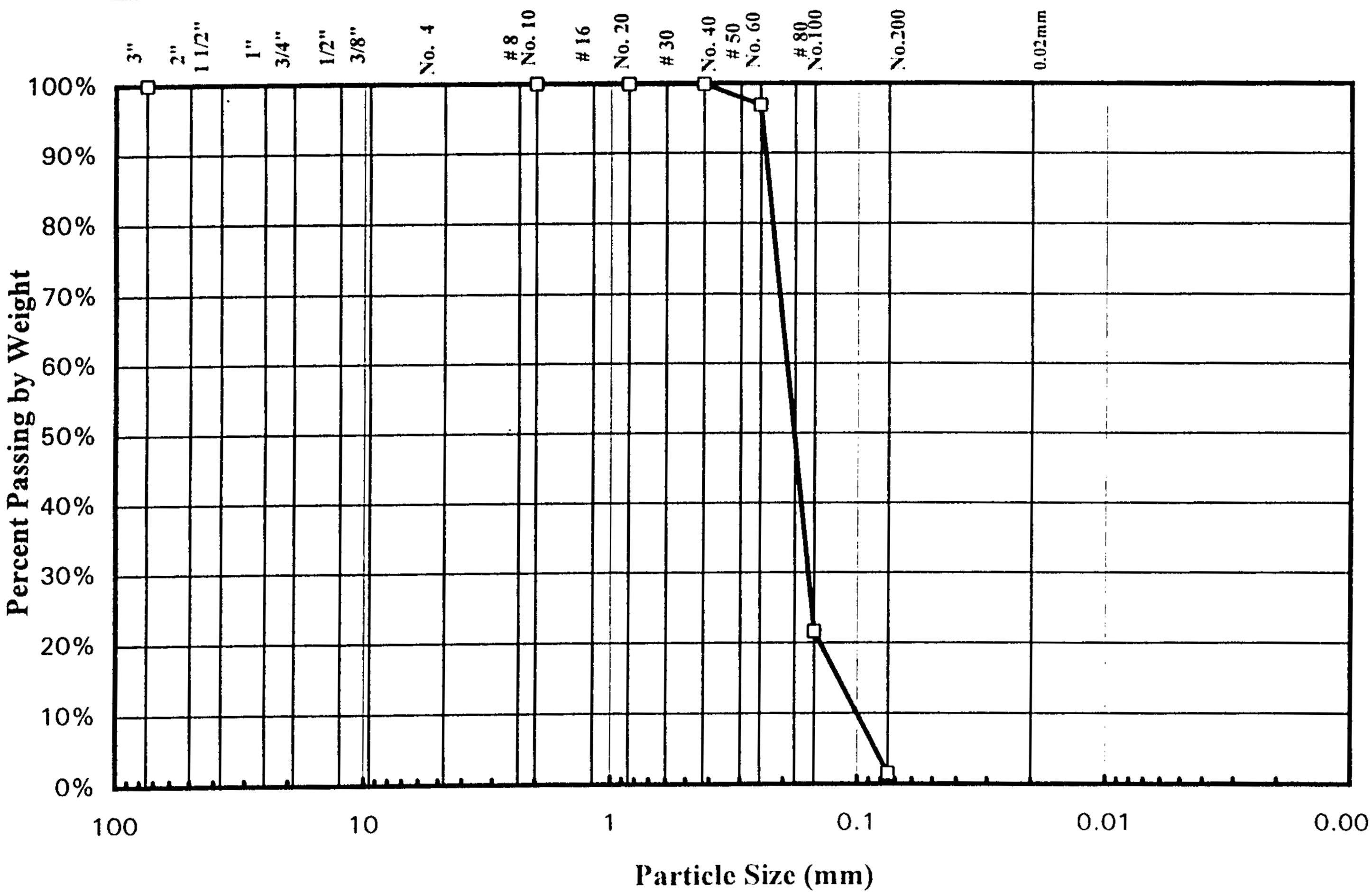
ALASKA TESTLAB
A Division of DOWL, Incorporated
4040 B Street Anchorage, Alaska 99503
(907) 562-2000 FAX (907) 563-3953

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		

ALASKA TESTLAB
A Division of DOWL, Incorporated
4040 B Street Anchorage, Alaska 99503
(907) 562-2000 FAX (907) 563-3953

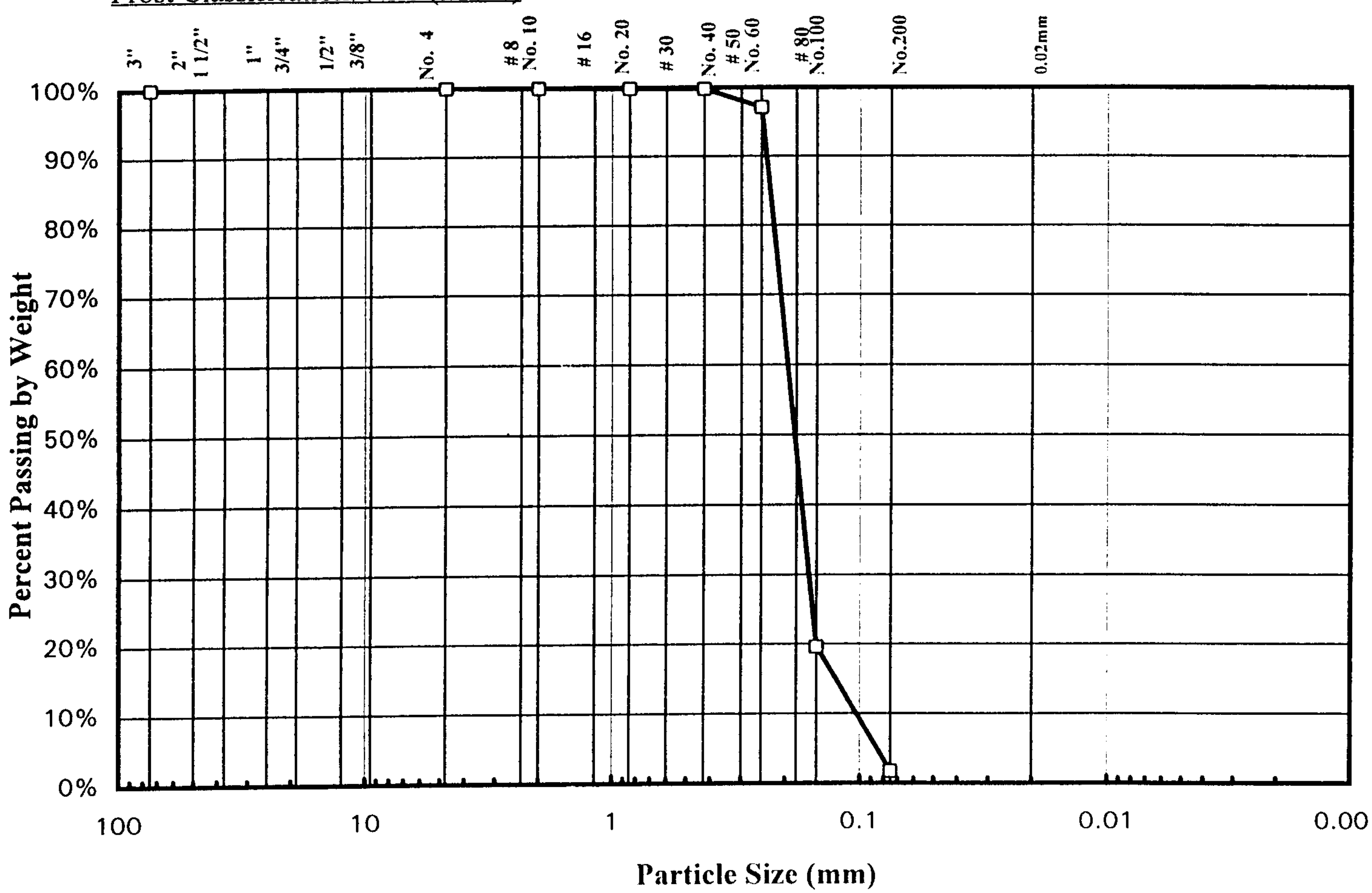
Client: Northern Testing Laboratories
Project: Trail Lakes Hatchery

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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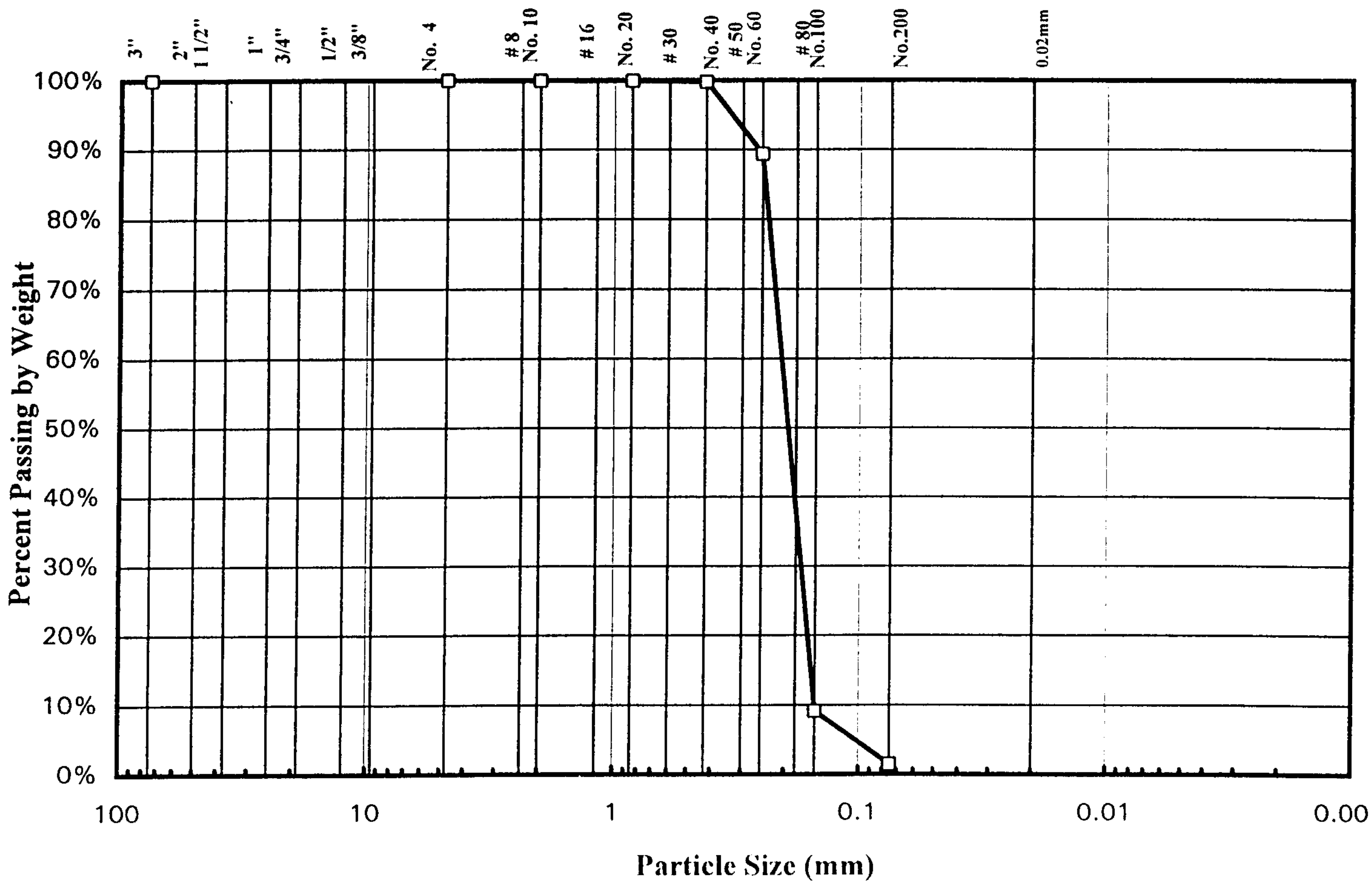
ALASKA TESTLAB
A Division of DOWL, Incorporated
4040 B Street Anchorage, Alaska 99503
(907) 562-2000 FAX (907) 563-3953

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		

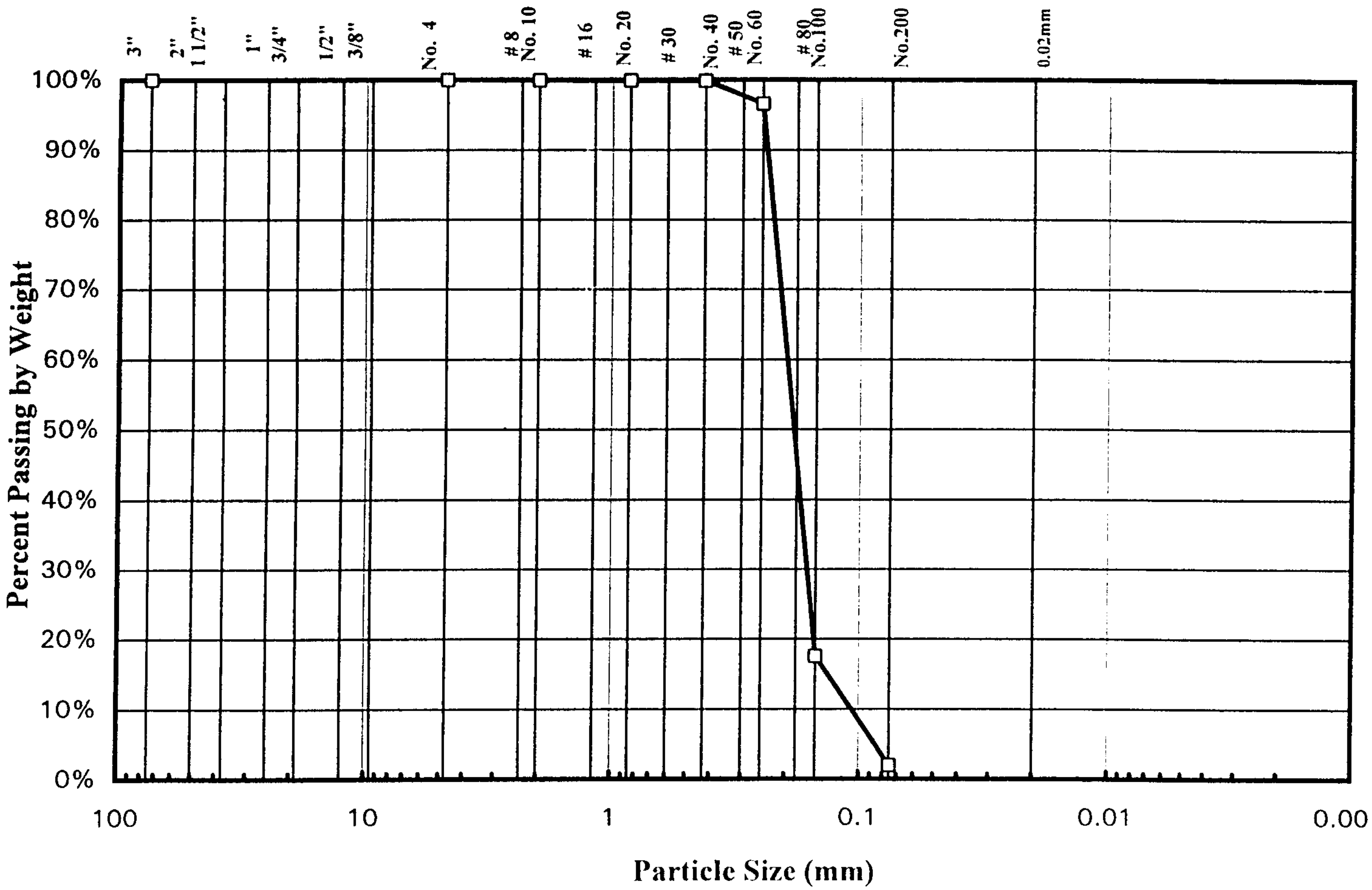
ALASKA TESTLAB
A Division of DOWL, Incorporated
4040 B Street Anchorage, Alaska 99503
(907) 562-2000 FAX (907) 563-3953

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
A Division of DOWL, Incorporated
4040 B Street Anchorage, Alaska 99503
(907) 562-2000 FAX (907) 563-3953

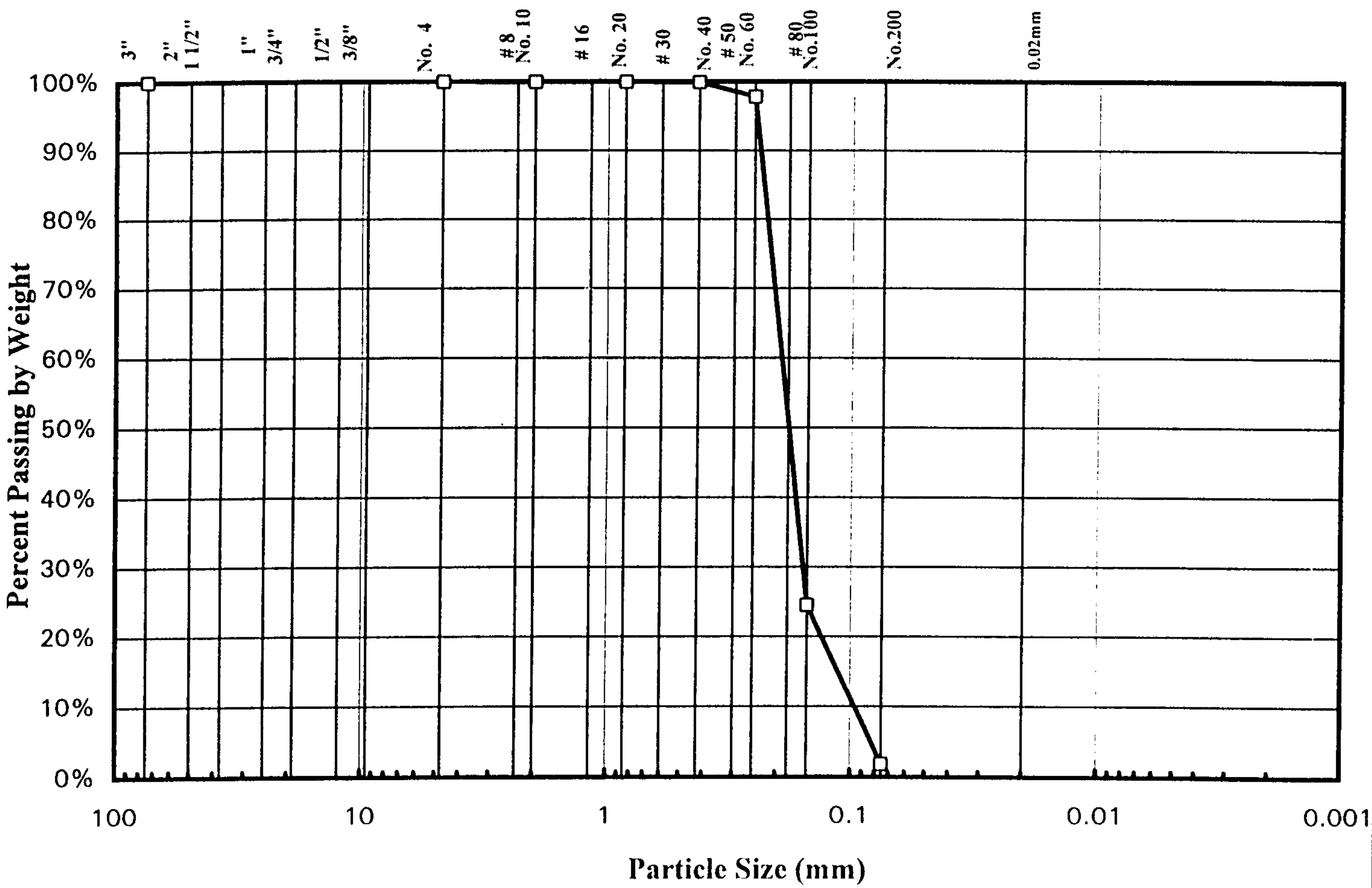
Client: Northern Testing Laboratories
Project: Trail Lakes Hatchery

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		

II-25

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

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

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

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

Julie Schaefer
-ported 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

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

** 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 Analyz
A146976	EPA 160.3	Solids	%	77.0				09/13/
A146976	SM 2540E	Total Volatile Solids	mg/dry Kg	5200		1.00		09/13/

Reported By: Anthony J. Lange
Chemistry Supervisor

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

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 Analyz
A146976	EPA 160.3	Solids	%	77.0				09/13/
A146976	SM 2540E	Total Volatile Solids	mg/dry Kg	5200		1.00		09/13/

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: 09/10/96
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 Analyz
A146885	SM 2540D	Total Suspended Solids	mg/L	12		1.0		09/06/
A146885	SM 2540E	Volatile Suspended Solids	mg/L	2.0		1.0		09/10/

Reported By: Julie Schaefer
Environmental Analyst