resources. The beach surveyed on August 27, 1995 during a predicted –0.9' MLLW tide. It was located immediately adjacent to the village at 60° 51.82' N by 146° 41.15' W and is depicted in Figure (5). The surveyed area of beach measured 100 feet wide by 350 feet long. It was bounded on the north by sand and mud substrates covered with a healthy eelgrass (*Zoostera cf. japonica*) bed. The substrate was hardened by boulders and rock outcroppings to the south. The area in between contained substrate suitable for native littleneck clams.

3.1.1. Beach characterization. Figure (6) is a photograph of the sampled beach. A schematic diagram of the sampling design is provided in Figure (7). All of transect (A) and the lower portions of transect (B) were located in the sandy, eelgrass dominated strata, and six transects (C, D, E, F, G and H) were established on the gravel – cobble beach. Four sample stations were evaluated at 22 to 24' intervals on each of the seven orthogonal transects (A through F and H). Transect G was run parallel to the beach at a tidal elevation of +0.5' (MLLW) with an interval of 60'. Thirty-five shellfish samples were collected on seven transects at Tatitlek.

Figure 6. Traditional bivalve subsistence beach near the village of Tatitlek in South Central Alaska. The black garbage bags contain samples awaiting transport to an upland processing station.

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

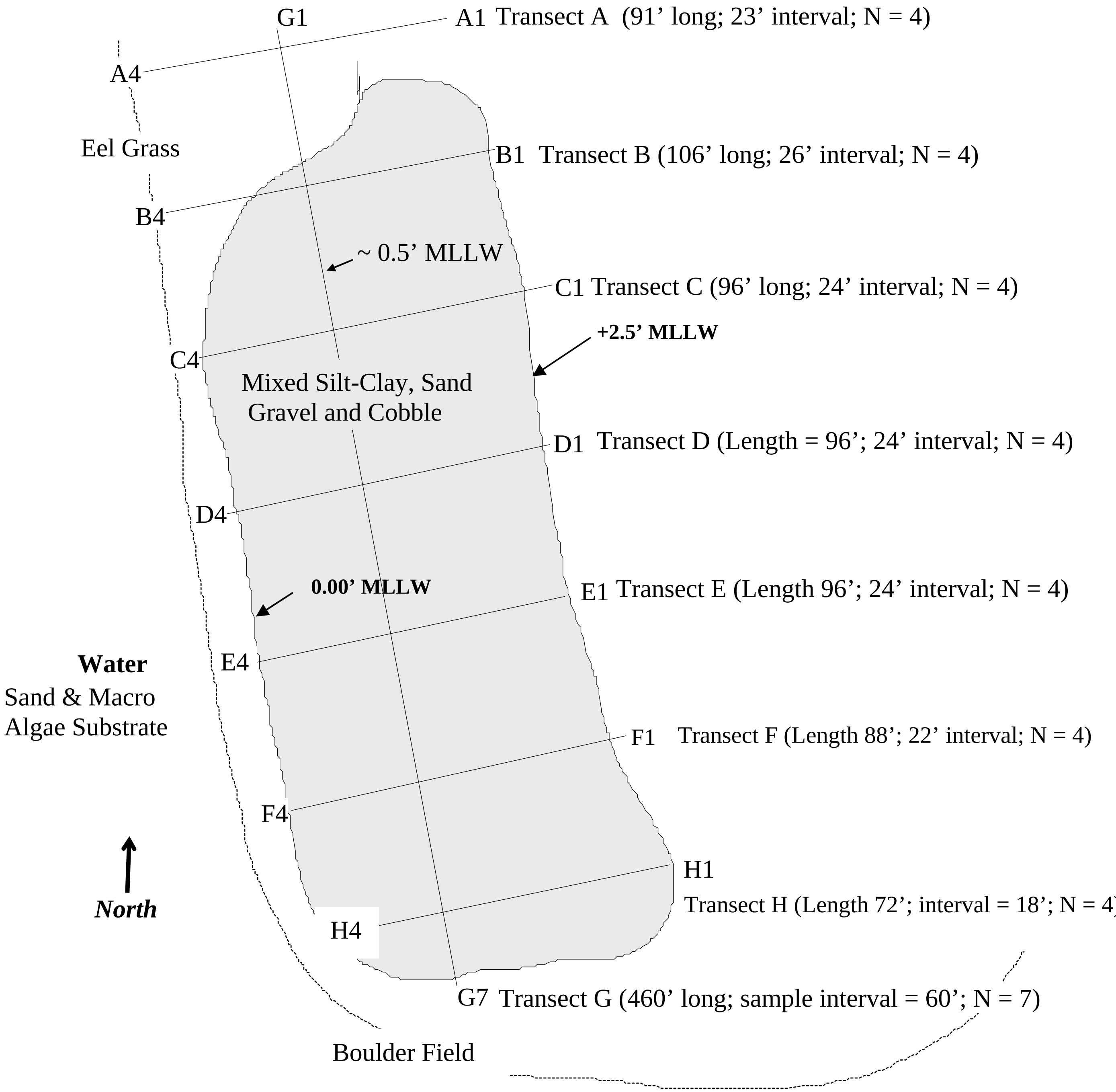

Figure 7. Schematic diagram of the Tatitlek Village shellfish beach. The beach has surveyed in August of 1995.

3.1.2. Water column characterization. Conditions at Tatitlek were acceptable for native littleneck clam culture. Water temperature was 12.0 ^{o}C, salinity equaled 26.0 ppt and dissolved oxygen was 12.5 ppm, which was slightly supersaturated. Currents at slack tide were measured parallel to the beach (085 ^{o}Magnetic) at 9.4 cm/sec. However, Village sources stated that currents are generally strong at this location and can exceed six knots (304 cm-sec^{-1}) during strong tidal exchanges. The three water samples collected at this beach averaged 3.27 mg TSS/L and 2.3 mg TVS/L. These values suggest moderate primary productivity and few suspended inorganic particulates.

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

Table 5. Summary of bivalves collected in 35, 0.1 m^2 samples at the Tatitlek Village beach on August 27, 1995.

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

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

3.1.4. Butter clams. Ninety-seven (97) living butter clams were retrieved from these samples. Their length-frequency distribution is provided in Figure (7). Most clams were small and less than two years old. Only three legal size (>38 mm valve length) butter clams were observed in all 35 samples. Descriptive statistics are provided in Table (6).

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

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

Table 6. Summary descriptive statistics for living and dead butter clams sampled at the Tatitlek Village beach on August 27, 1995. Length and age statistics include 103 empty butter clam valves, which were measured and aged. Other statistics do not.

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

Because of their propensity to retain paralytic shellfish poisons and lack of adequate hatchery technology, butter clams are not considered appropriate for enhancement at this time. However, the Washington State Department of Fish and Wildlife shellfish laboratory at Point Whitney has spawned and raised butter clams in their hatchery (Mr. Brady Blake, personal communication). Several year classes (Ricker, 1975) are evident in the length frequency histogram provided in Figure (8), which also demonstrates a lack of legal size butter clams on this beach. Figure (9) suggests that butter clams recruit regularly to this beach, but that they typically do not survive beyond five years of age or to lengths greater than 38 mm. Predator control will be an important element in any effort to enhance shellfish resources on this beach.

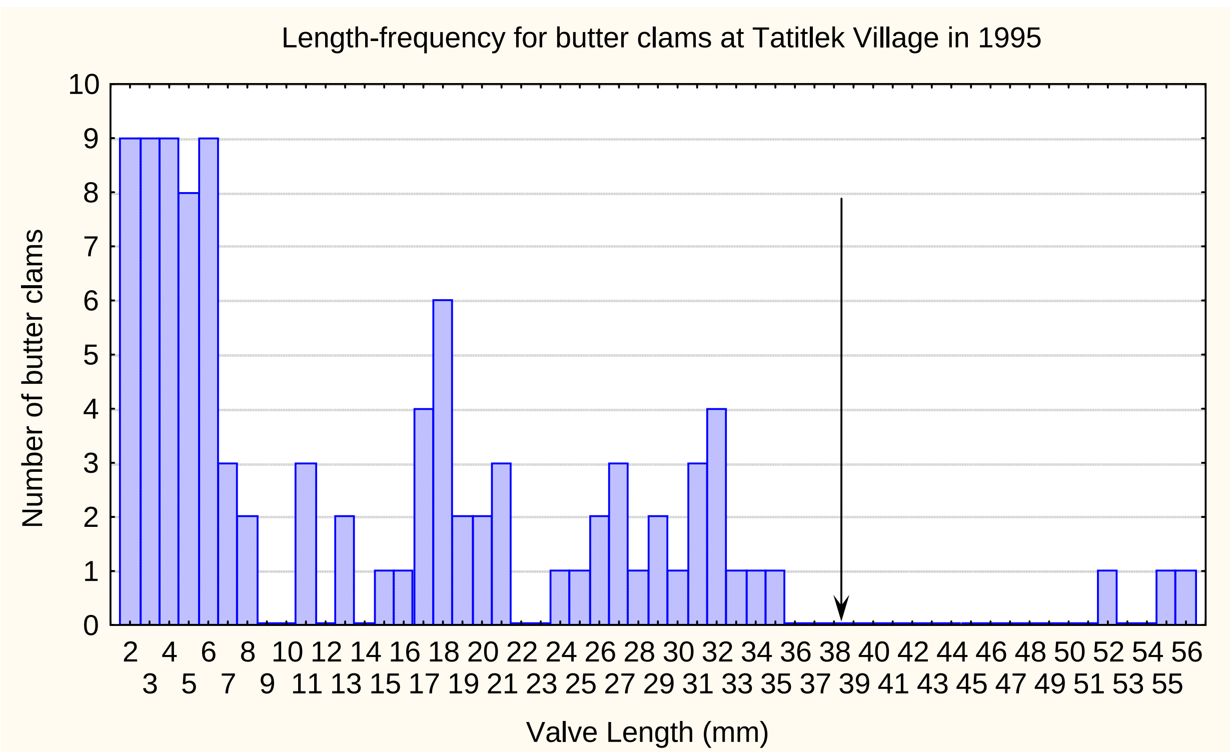

Figure 8. Length frequency histogram for butter clams (*Saxidomus giganteus*) collected in 35, 0.1 m^2 samples at the Tatitlek Village shellfish beach on August 27, 1995. The vertical line describes the minimum legal size (38 mm).

Figure (10) is a photograph taken at low tide on the Tatitlek beach. Large numbers of sunstars (*Pycnopodia helianthoides*) were observed at and below +0.5' MLLW and frilled dogwinkles (*Nucella lamellose*) were observed at tidal elevations greater than ca. +2.0' MLLW. Figure (11) is a photograph of a few of the hundreds of small clams observed on this beach that had been drilled by gastropods. In addition to these predators, numerous shore crabs were observed and sea otters were encountered offshore. Large clams were not found on this beach. However, broken butter clam shells provided equivocal evidence of historical sea otter predation.

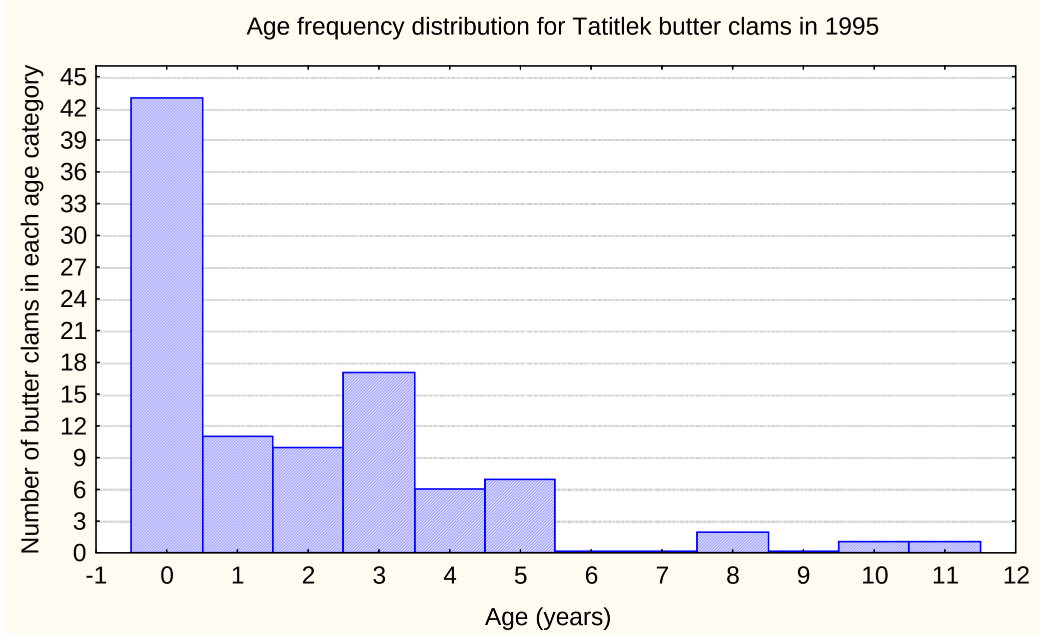

Figure 9. Age-frequency histogram for butter clams (*Saxidomus giganteus*) collected in 35, 0.1 m^2 samples at the Tatitlek Village shellfish beach on August 27, 1995.

Figure 10. Sunstars (*Pycnopodia helianthoides*) and frilled dogwinkles (*Nucella lamellose*) observed on the subsistence beach adjacent to the native village of Tatitlek in Alaska.

Figure 11. Juvenile butter clams (*Saxidomus giganteus*) collected in sediment samples from the subsistence beach adjacent to the native village of Tatitlek in Alaska.

3.1.5. Native littleneck clams. Four Hundred-eighty (480) native littleneck clams were sieved from 35 Tatitlek sediment samples. Summary statistics describing littleneck clams are presented in Table (7). The largest native littleneck clam had a valve length of 45 mm and weighed 19.34 grams. Seventeen (17) legal size clams (valve length $\geq$ 38 mm) were observed in all 35 samples. This equates to a density of approximately 73.9 $g\text{-}m^{-2}$ or 0.016 pounds per square foot. This is approximately one tenth the minimum density considered economical for commercial clam harvests in Washington State (Paul Taylor, personal communication). The conclusion is that there is currently little opportunity for subsistence harvest of butter or native littleneck clams at this Tatitlek village beach.

Comparison of Figures (12) and (13) clearly shows the correspondence between the length and age of at least the first four year classes. Furthermore, these figures suggest that predation, from a variety of sources is taking most clams before they reach 38 mm valve length. No missing year classes are apparent in Figures (12) or (13) suggesting constant recruitment of native littleneck clams to this beach. It appears that shellfish production at this site is limited primarily by predation, disease or loss of clams associated with substrate movement. Based on the history of Manila clams in Puget Sound, a minimum juvenile density of 20 to 30 per 0.1 m^2 is desired for reasonable production. Current native littleneck clam recruitment is approximately four per 0.1 m^2 and survival is unacceptable. The previous discussion regarding predation on butter clams is appropriate for native littleneck clams as well.

Table 7. Summary descriptive statistics for living native littleneck clams sampled in 35, 0.1 m^2 quadrats at the Tatitlek Village beach on August 27, 1995.

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

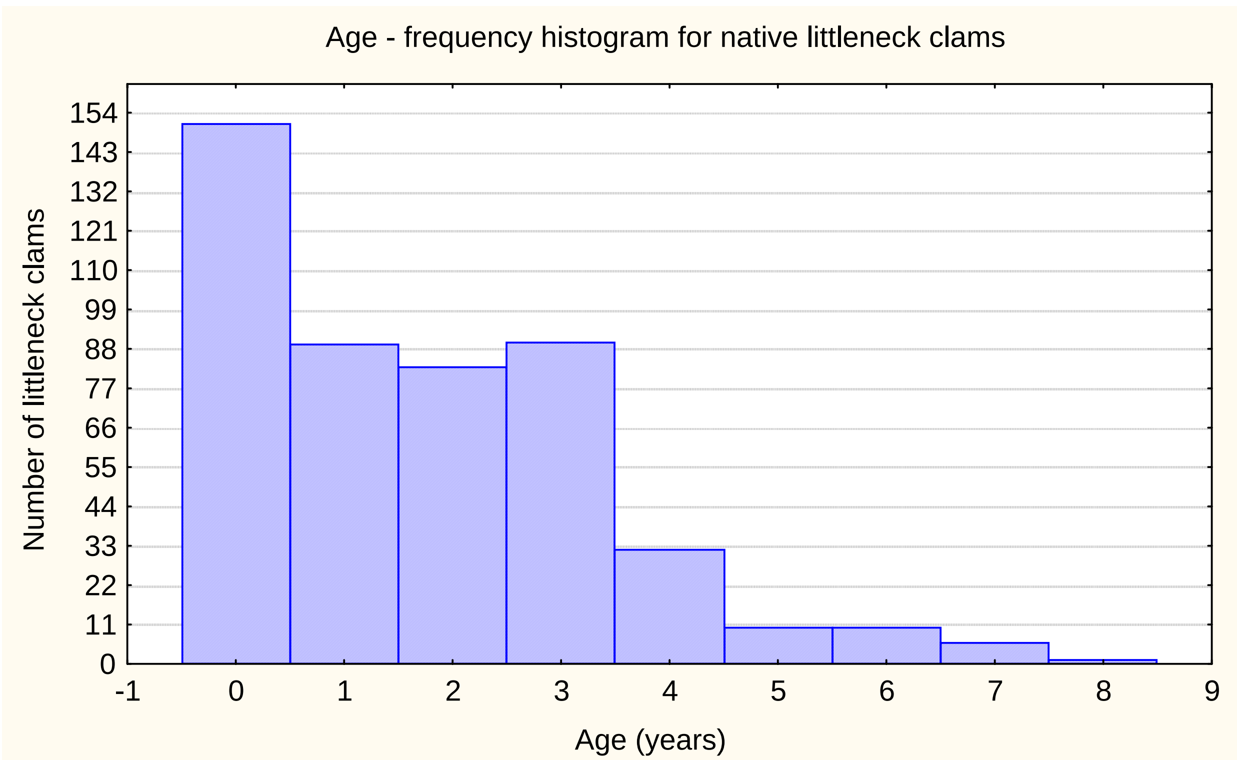

Figure 12. Age – frequency histogram for littleneck clams collected in 35, 0.1 m^2 quadrats at the Tatitlek Village on August 27, 1995.

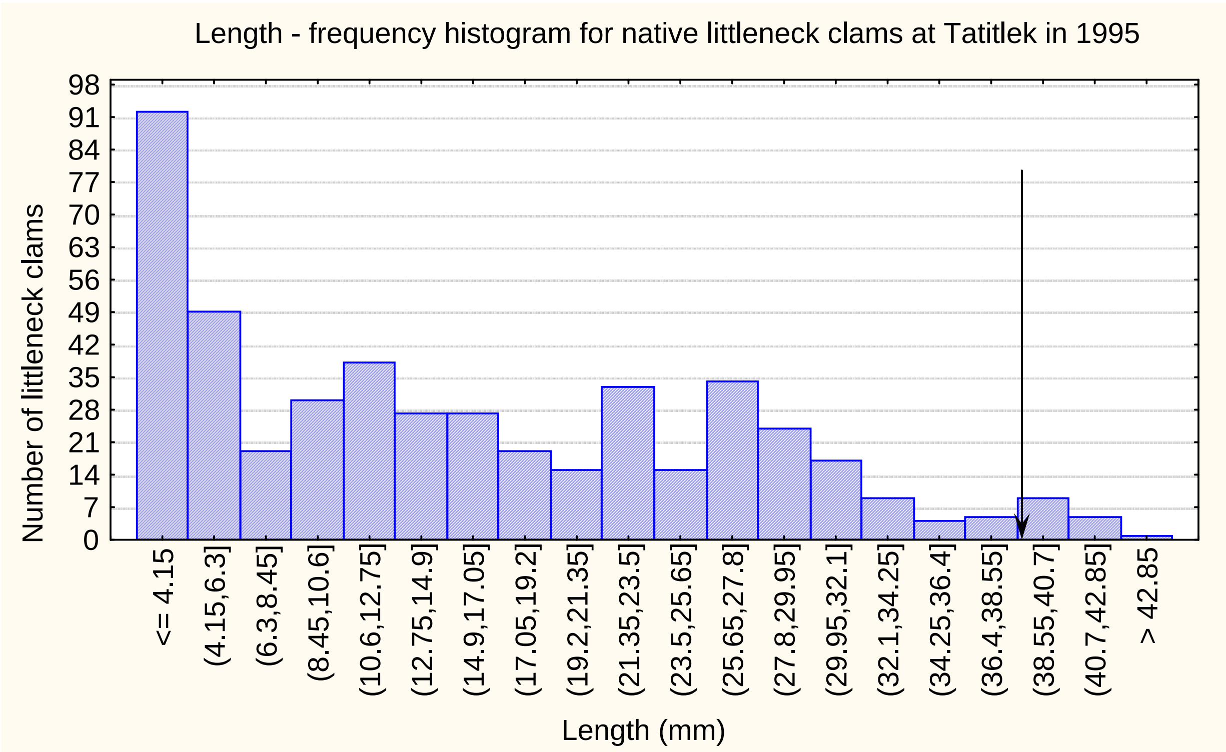

Figure 13. Length – frequency histogram for littleneck clams collected in 35, 0.1 m^2 quadrats at the Tatitlek Village on August 27, 1995. The thin vertical line represents the minimum legal size of 38 mm.

3.1.6. Distribution of clams as a function of tidal height at Tatitlek. Figures (14) and (15) compare the distribution of butter and native littleneck clams as a function of tidal height at Tatitlek. These figures are interesting in that they indicate an optimum tidal range of approximately 0.0' to +2.0' MLLW for native littleneck clams and an optimum of 0.0' to 1.0' MLLW for butter clams. It should be noted that the substrate changes to primarily sand at tidal elevations less than –1.5' at this beach. This substrate change and the presence of large numbers of starfish at lower intertidal elevations are factors that may be responsible for limiting the clam population in deeper water. Also note that both butter clams and native littleneck clams were found at tidal elevations as high as +3.0' MLLW. The data for native littleneck clams at Tatitlek suggests that the area between –1.0' and +2.5' is suitable for native littleneck clam production on this beach. This is essentially the same range described by Nickerson (1977) and Feder and Paul (1973).

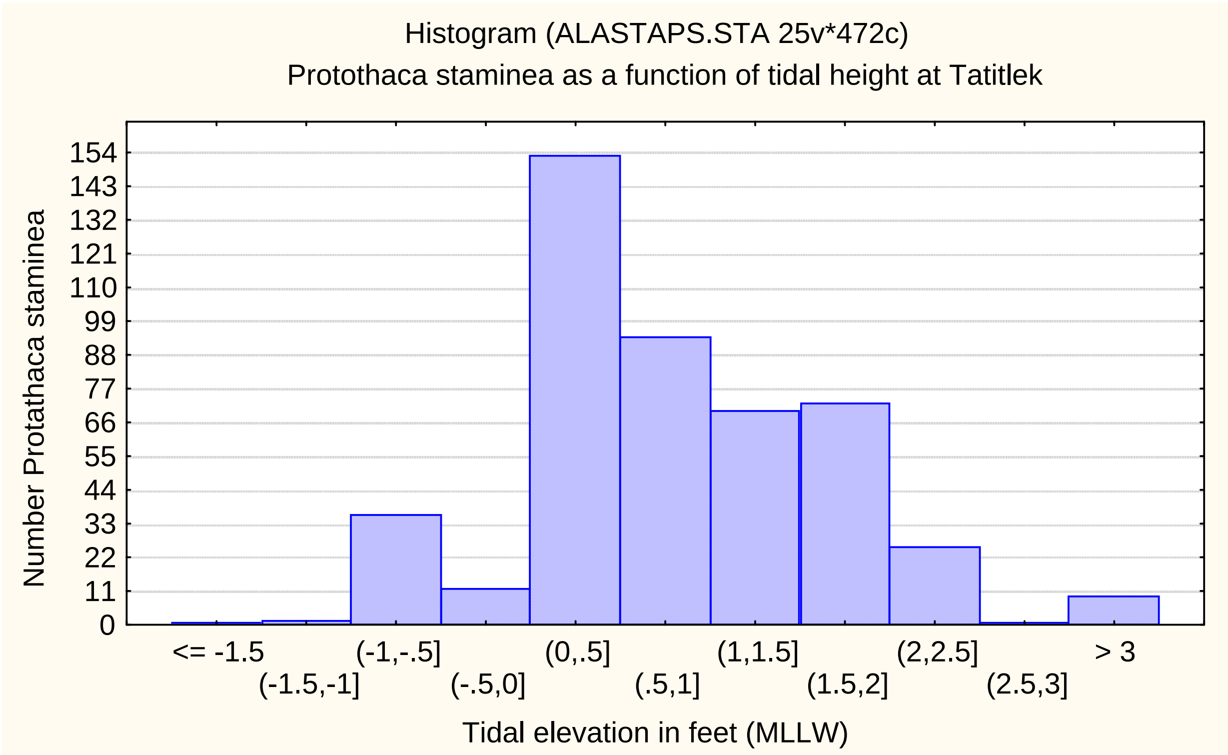

Figure 14. Tidal elevation – frequency histogram for littleneck clams collected in 35, 0.1 m^2 quadrats at the Tatitlek Village shellfish beach on August 27, 1995.

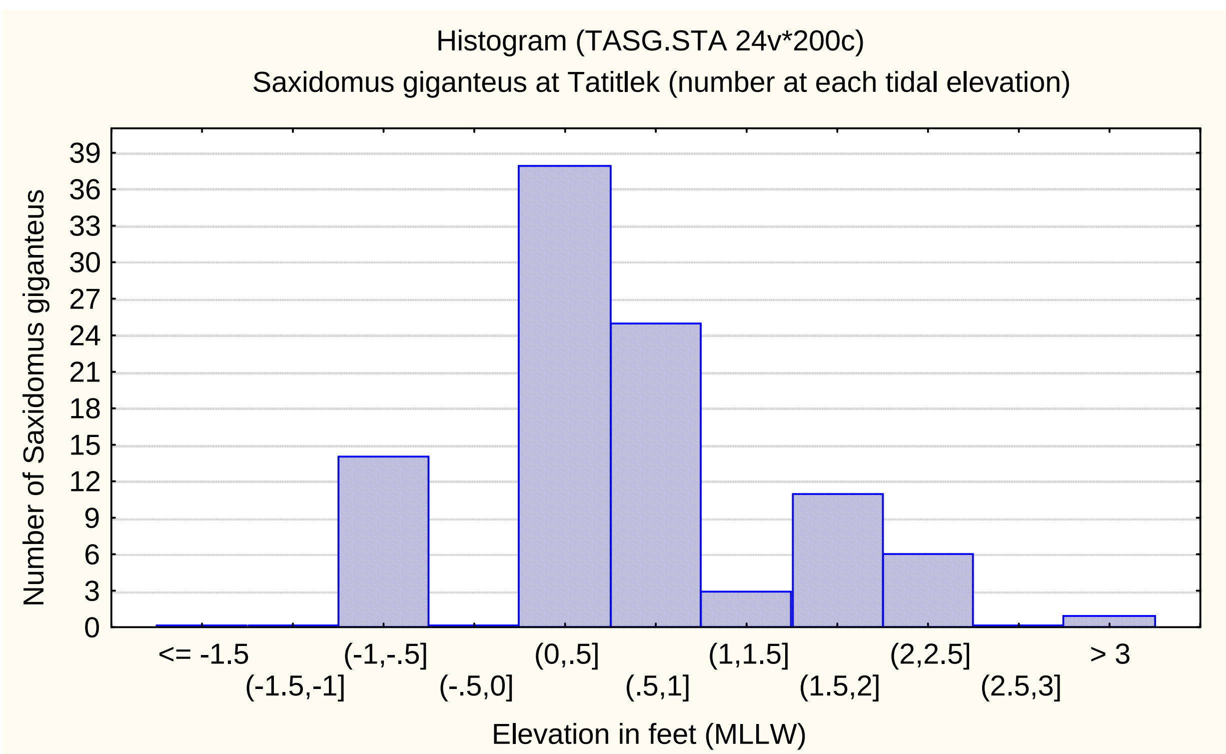

Figure 15. Tidal height – frequency histogram for butter clams (*Saxidomus giganteus*) collected in 35, 0.1 m^2 quadrats at the Tatitlek Village shellfish beach on August 27, 1995.

Average growth increments were calculated by dividing each clam's valve length by its age. This information is presented graphically in Figure (16). The coefficients determined in a linear analysis were statistically significant at $\alpha = 0.05$ but the predictive equation explained less than 3% of the variation in the database. Figure (16) suggests that within the tidal range investigated (which includes all elevations at which clams were found in this survey), mean native littleneck valve growth declined slowly with increasing tidal height. This was particularly true for the clams at the highest elevation (>3.0' MLLW), which apparently grew slower than those found at intermediate elevations. Figure (16) suggests that clam growth should be reasonably constant at beach elevations between –1.5' and +2.5' MLLW.

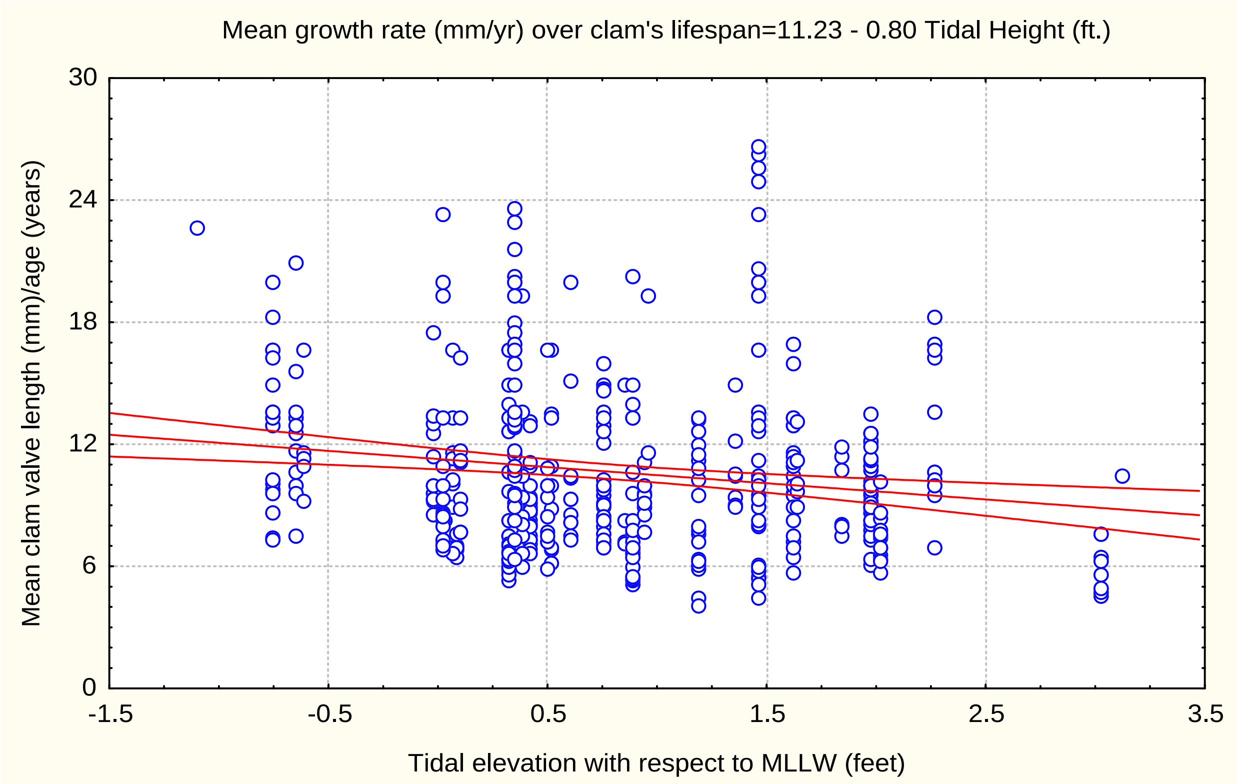

Figure 16. Growth increments (mm/year) as a function of tidal height (feet above MLLW) for native littleneck clams (*Protothaca staminea*) collected in 35, 0.1 m^2 quadrats at the Tatitlek Village shellfish beach on August 27, 1995. 95% confidence limits on the mean are provided as dashed lines in this figure.

3.1.7. Age-length analysis for native littleneck clams at Tatitlek. Regression coefficients were developed for the von Bertalanffy model using nonlinear regression. The resulting expression (Figure 17) explained 87.2% of the variation and the ANOVA determined probability that the regression coefficients were all equal to zero was P = 0.000. The residuals appear normal. However, some caution is in order because no clam valves exceeding 45 mm were included in the database. In Puget Sound, native littleneck clams grow to lengths in excess of 65 mm (Brooks, unpublished). However, clams older than 8 years were not observed at Tatitlek and the maximum predicted valve length (47.61 mm) may be inaccurate.

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

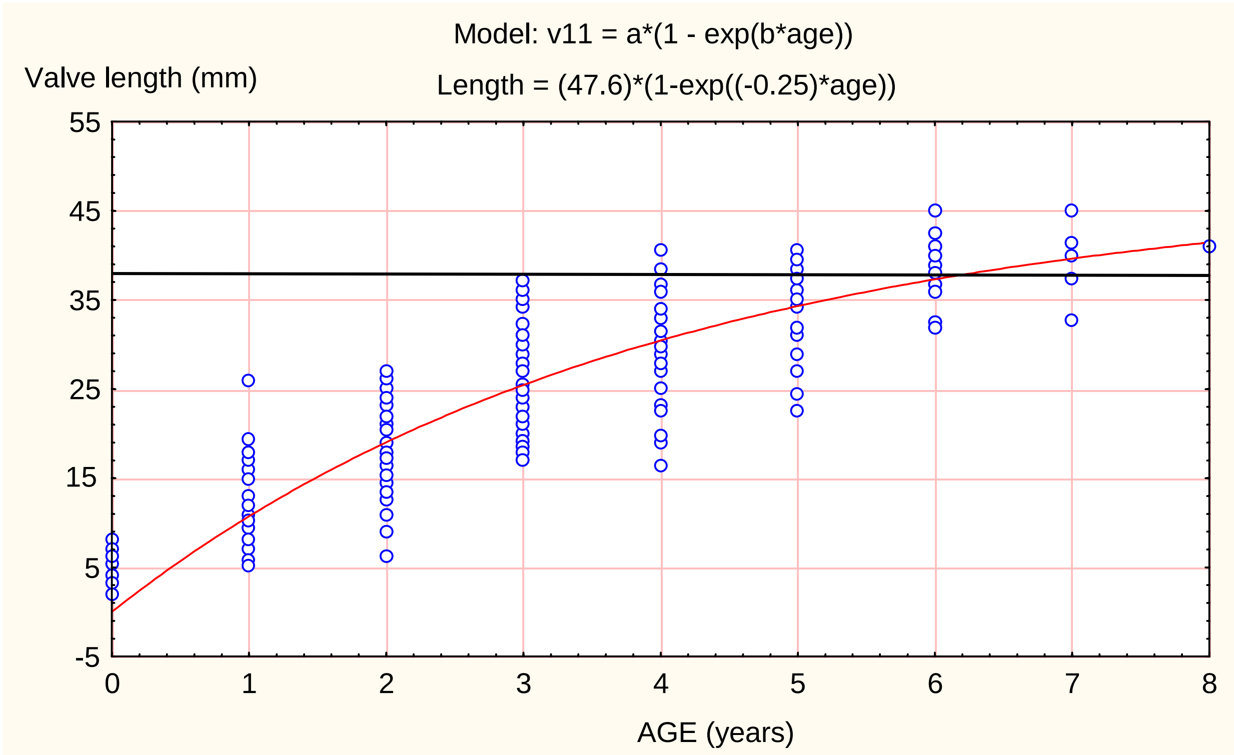

Figure 17. Length (mm) versus age (years) for native littleneck clams (*Protothaca staminea*) collected in 35, 0.1 m^2 quadrats at the Tatitlek Village on August 27, 1995. The solid horizontal line represents the minimum legal size limit ($\geq$ 38 mm).

The von Bertalanffy equation, and accompanying scatterplot, indicates that clams recruit into the legal size population ($\geq$ 38 mm), at between 4 years and >7.0 years. The average age at recruitment was six years.

3.1.8. Edible tissue versus clam length analysis. A length – wet tissue weight histogram is provided in Figure (18) and an age – wet tissue weight histogram in Figure (19). One of the possible management options involves harvesting clams at a shorter minimum valve length. However, Figures (18) and (19) suggest that this is not an appropriate alternative.

An examination of the length-frequency data in Figure (13) suggests that clams are being removed by predation at approximately 30 mm. That length is coincident with the length range where wet tissue weights are beginning to increase significantly as a function of length in Figure (18). Even at 38 mm, clams are still well within the exponential growth phase. In this database, clams that were 8 years old, with a valve length of 42 to 45 mm, had wet tissue weights of approximately 7.5 grams. This is significantly higher than the wet tissue weight of 4.5 grams associated with six-year-old clams just reaching the current minimum harvest size of 38 mm. Reducing the minimum harvest size to 30 mm (a size preceding the heaviest predation) would result in a harvest of approximately 2.5 grams wet tissue weight per clam. Nickerson (1977) observed peak increases in the rate of biomass increase (first derivative of biomass versus time) at an age of approximately 7 years (corresponding to a valve length of ca. 38 mm) with a slow decline in this important rate at older ages. Wet tissues are eaten – not the whole animal, and this discussion suggests that lowering the minimum size at harvest to avoid predation would significantly reduce the subsistence value of the resource to native Alaskans.

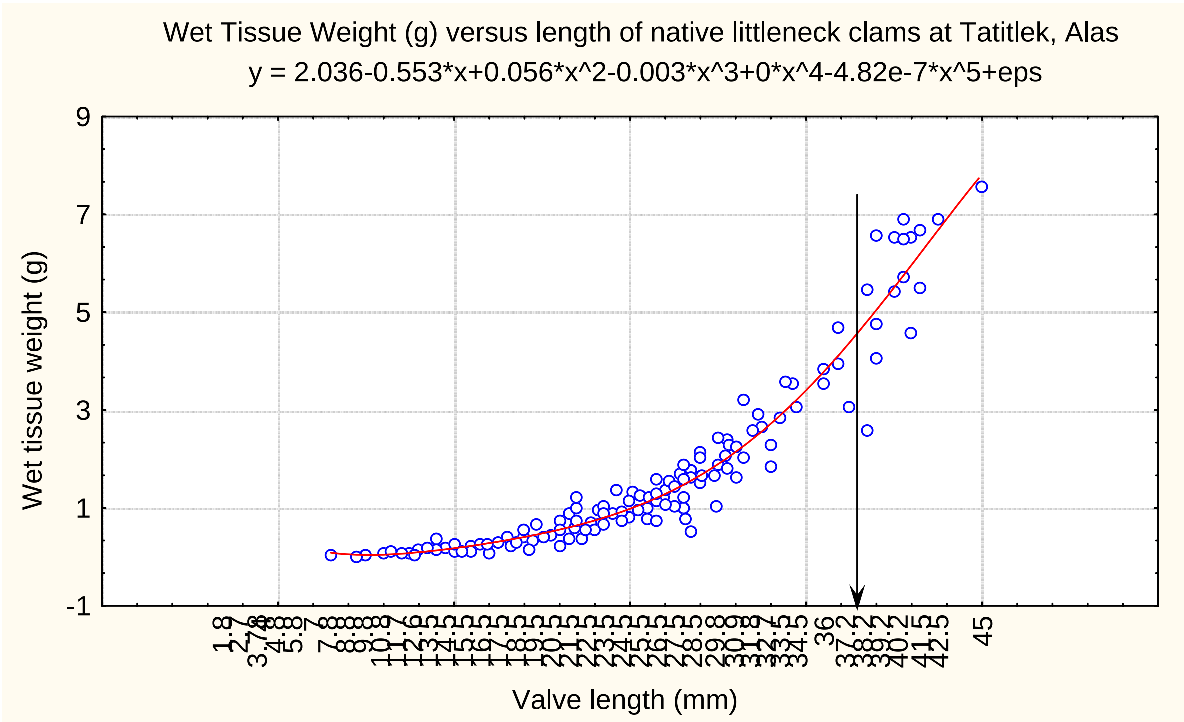

Figure 18. Length (mm) versus wet tissue weight (in grams) for native littleneck clams (*Protothaca staminea*) collected in 35, 0.1 m^2 quadrats at the Tatitlek Village shellfish beach on August 27, 1995. The vertical solid line represents the minimum legal size.

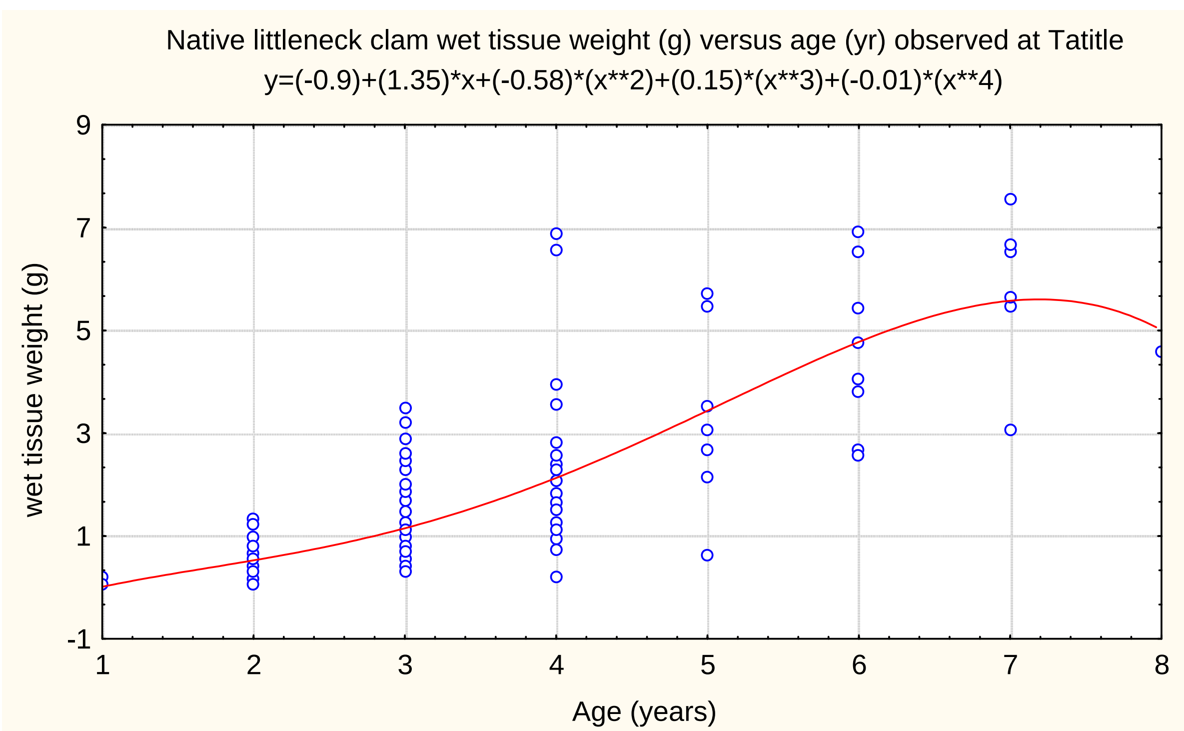

Figure 19. Age (yr) versus wet tissue weight (grams) for native littleneck clams (*Protothaca staminea*) collected in 35, 0.1 m^2 quadrats at the Tatitlek Village shellfish beach on August 27, 1995.

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

Table 8. Number of starfish (*Pycnopodia helianthoides, Pisaster ochraceus*) and presumed sea otter (*Enhydra lutris*) pits observed at the Tatitlek village shellfish beach on August 27, 1995. All counts are provided in numbers per square meter.

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

3.1.10. Summary and recommendations for native littleneck clam enhancement at the village of Tatitlek. The following summary and conclusions are based on this survey:

- **Existing bivalve resources.** Few clams were available for harvest at this Tatitlek village beach. However, there were significant quantities of small mussels (*Mytilus edulis trossulus*), along the extreme high tide line. In many parts of the world, blue mussels are considered a delicacy. Villagers suggested that this is not a traditional food. However, their sheer volume at this site, and their acceptance in other parts of the world, suggest that this could be a valuable subsistence resource. This is particularly true because mussels are amenable to floating culture. The seed could be harvested from the high intertidal areas where the mussel grows slowly, and placed in lantern nets at the Village's oyster culture facility – or away from piling on the new ferry terminal.

- **Substrate suitability.** The Tatitlek Village Beach contains approximately one 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. Clam growth, density and size suggest non-significant differences in culture potential over the area of surveyed beach. If the predation problem is solved, several physical enhancement practices could be employed here to increase natural recruitment and to make this rocky, high-energy, beach more amenable to intensive clam culture.

- **Culture depth (tidal level and depth in sediments).** Native littleneck clams were found at depths greater than 15 cm on this beach. This may be a regional adaptation for survival during cold winter, nighttime, low tides. Typically, cultured clams are protected from potential predators by placing them in sturdy mesh bags. These bags are then partially buried in the substrate. If Alaskan littleneck clams dig deeper to avoid freezing in winter, the placement of clams in bags at shallow depths could jeopardize the cultures. Therefore, consideration should be given to placing bags at lower tidal elevations or to burying the bags deeper in the substrate.

- **Predation.** Significant starfish predation was observed at Tatitlek. Several sunflower stars were observed with intact native littleneck clams in their guts. In addition, while sea otters were not observed preying on bivalves, the evidence observed during this survey suggests that they may be significant predators on larger clams. If confirmed, sea otter predation presents a new dimension in predator control. 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. Reasonable and effective methods to control sea otter predation (if it is eventually documented) may present a challenge.

Starfish, crabs and predatory gastropods should periodically be removed from the beach. This would likely reduce early loss of clams and allow more of the natural set to reach a minimum harvest size – absent any other enhancement effort.

- **Natural clam recruitment** to the Tatitlek Village beach occurred in low numbers in each of the last eight year-classes observed. No year classes were missing. However, natural recruitment (or at least survival until August 27, 1995) was too low in each year class to stock this beach to harvest densities greater than 0.15 pounds per square foot.

- **Age and size at harvest.** The age length analysis suggested that native littleneck clams recruit to the legal size population ($\geq$ 38 mm) at between four and >7.0 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.

- **Butter clams.** *Saxidomus giganteus* recruit naturally to this beach. However, few butter clams survived to harvest size. Due to the lack of hatchery and nursery technology, and propensity to retain brevetoxins, butter clam enhancement is not recommended at this time.

- **Cockles** are a traditional (and preferred) shellfish for Alaskan natives. The primary beach surveyed in this effort was too rocky, with too few fines, to warrant cockle enhancement. The beach lying to the northwest was sandy and suitable for cockle production. However, this beach was covered with a luxurious eelgrass (*Zoostera cf. japonica*) bed. Disruption of the ecologically valuable eelgrass meadow in an effort to enhance the cockle resource is not recommended.

- **Mussels.** The presence of large quantities of blue mussel (*Mytilus edulis trossulus*) seed should not be overlooked. These mussels are eagerly sought in other parts of the world. If the copious seed supply were removed from the high intertidal, placed in lantern nets, and submerged continually at the Villages aquaculture facility, it could quickly provide as much shellfish as the village might desire.

- **Management recommendations.** The beach at Tatitlek represents a higher energy environment that was not considered optimum because of sediment instability. Otherwise, it appeared to be of acceptable quality for growing littleneck clams. Sustained subsistence harvests will require additional seed of the largest possible size; development of effective predator control measures; and establishment of a well-designed management plan. Without effective predator control, any enhancement plan will be futile.

The easiest and quickest way to increase the supply of subsistence shellfish is to utilize the mussel resource by placing seed in lantern nets and submerging them continuously where they will quickly grow to an adequate size. Based on the Villagers' lack of interest in mussels, any mussel culture effort should be combined with efforts to increase the residents' appreciation of mussels as a valuable (and delicious) source of food.

3.2. Bivalve inventory results at Passage Island for the village of Nanwalek. Mr. Dale Bowers was very helpful and expressed a great deal of desire to re-establish a subsistence shellfishery near Nanwalek. In addition to Passage Island, which is a traditional harvest area, Mr. Bowers identified other beaches that might be candidates for enhancement. The beach closest to the village lies at a low tidal elevation and is very exposed to a long fetch across Cook Inlet. Primarily for the second reason, the beach at Passage Island was chosen for these studies.

Mr. Bowers expressed concern that traditional shellfish resources were depleted and unable to supply village needs. He felt that sea otter predation was a major problem. The village had adequate boat and human resources and indicated a willingness to expend significant effort to restore their shellfish resources. Passage Island is located about 11.5 nautical miles from the village along a very rugged and exposed coastline. Tending a shellfish culture at Passage Island from Port Graham would be problematical, especially in winter.

3.2.1. **Passage Island beach characterization.** The beach most suitable for enhancement was located at 59^{o} 22.11' N by 151^{o} 52.53' W. It measured 130 feet wide by 140 feet long and covered 0.42 acres (Figure 20). It was bounded on the west by a boulder field and by deep water on all other sides. Brown kelp (*Laminaria sp.)* was abundant in the nearshore area. The beach contained large quantities of broken horse clam (*Tresus capax*) and butter clam (*Saxidomus giganteus*) shells associated with what could have been otter pits. The area contained reasonable substrate for native littleneck clams. It was not considered suitable for cockles. Although Passage Island provided some protection, the beach was exposed to storm winds from the southeast and represented a higher energy environment than was desired for the growout studies (Figure 21). The beach was accepted in deference to village elders.

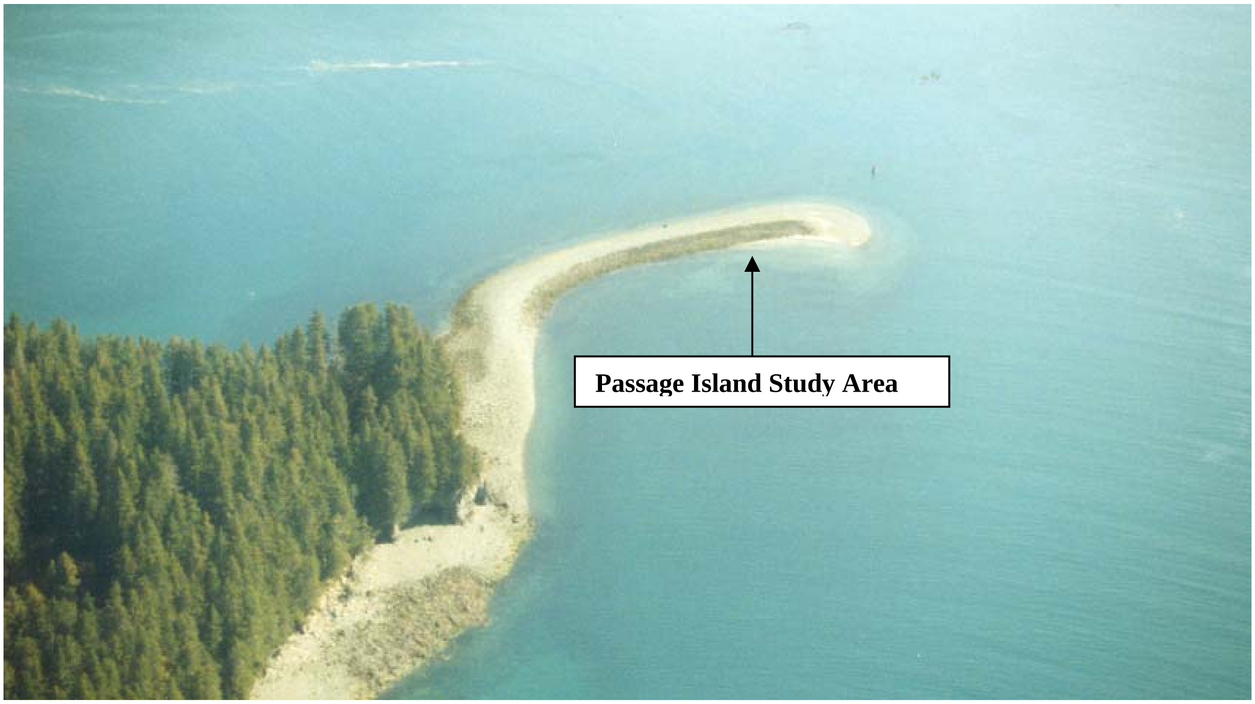

Figure 20. Aerial photograph of the eastern tip of Passage Island with the bivalve study area delineated.

Figure 21. A portion of the beach surveyed at Passage Island.

As described in Figure (22), three transects (A, B and C) were examined in that part of the beach where clams were found. Six shellfish and three sediment samples were analyzed on each of these transects giving a total of 18 shellfish and 9 sediment samples. In addition, 19 bivalves were collected in a random dig to supplement the growth data. These additional cases were not included in assessing bivalve response to environmental parameters such as tidal height.

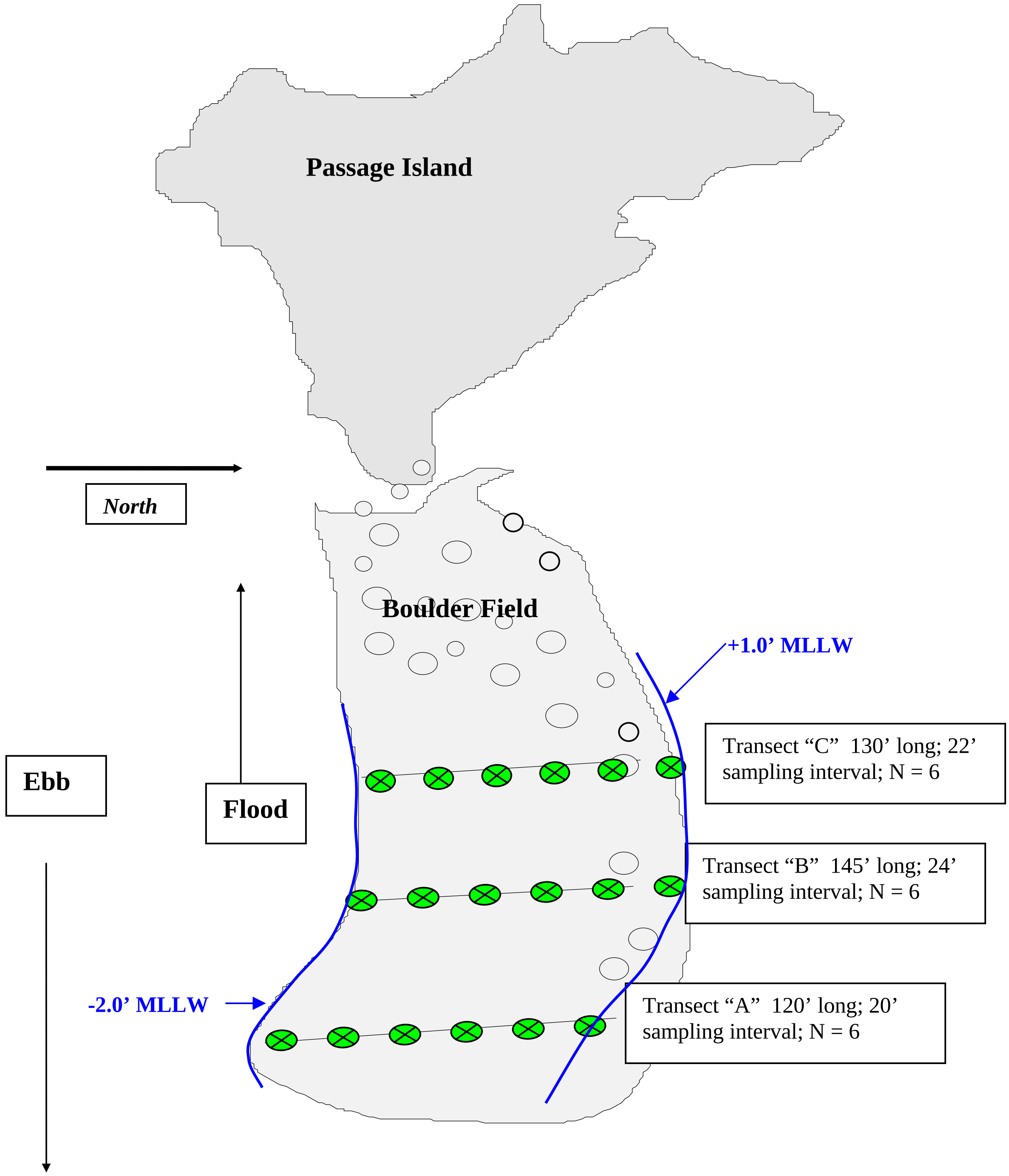

Figure 22. Schematic diagram of the Nanwalek Village shellfish beach at Passage Island. The beach has surveyed in August of 1995.

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

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

3.2.3. Bivalve population characterization. One hundred sixty-two living bivalves were collected in the 18 systematic random samples collected at Passage Island. An additional 19 bivalves were collected in random samples and 49 empty butter and native littleneck clam shells were collected to supplement the age – length analysis. The distribution of shellfish obtained from the systematic survey is provided in Table (9).

Table 9. Summary of bivalves collected in 18, 0.1 m^2 samples at the Nanwalek Village beach at Passage Island on August 26, 1995.

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

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

Butter clams. Forty-one butter clams were observed in these samples. Their length-frequency distribution is provided in Figure (23). Most of the observed clams were new recruits less than two years old. Six legal size butter clams were observed in the 18 samples. Descriptive statistics for a limited number of variables are presented in Table (10).

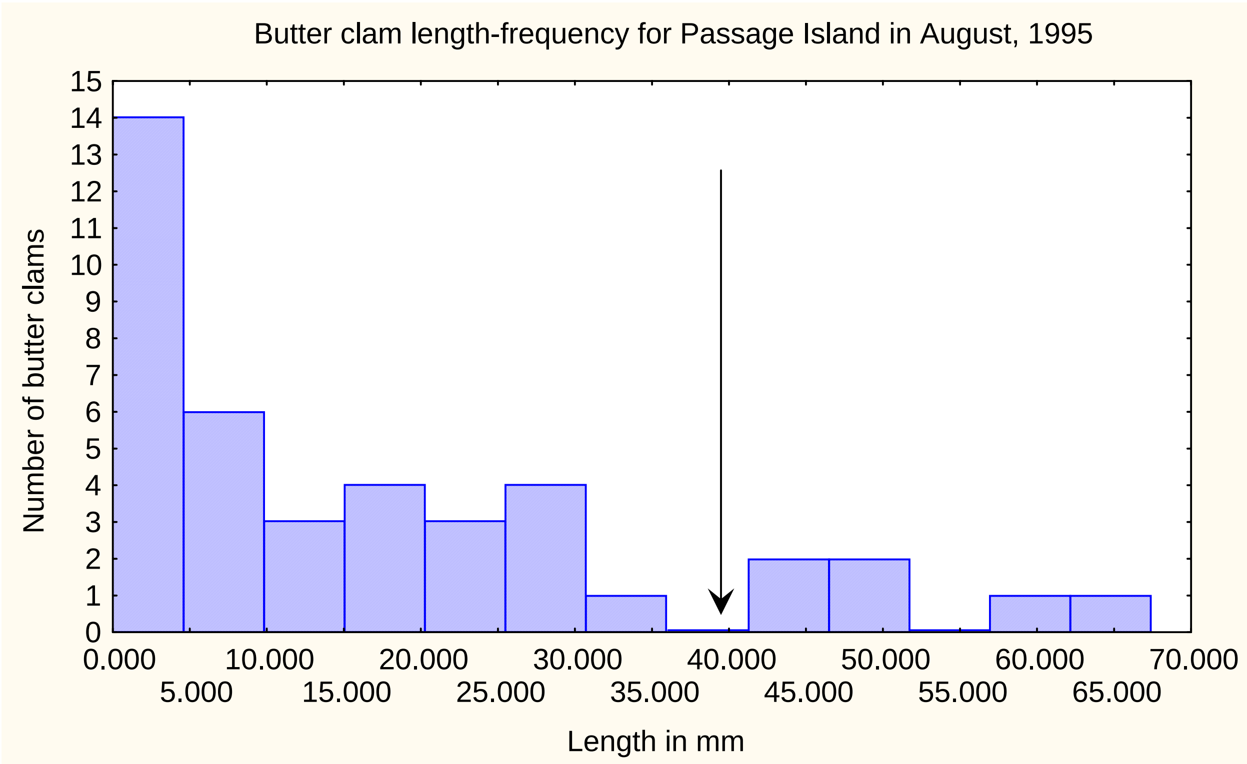

Figure 23. Length frequency histogram for butter clams (*Saxidomus giganteus*) collected in 18, 0.1 m^2 samples at Nanwalek Village's, Passage Island beach on August 26, 1995. The thin vertical line locates the legal limit ($\geq$38 mm).

Table 10. Summary descriptive statistics for living butter clams sampled at the Nanwalek Village's Passage Island beach on August 26, 1995.

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

Non-linear regression was accomplished on aged living and empty butter clam valves to determine coefficients for the von Bertalanffy model. The resulting equation explained 94.7% of the variation and the ANOVA determined probability that the regression coefficients were all equal to zero was P = 0.000. Observed and predicted values are presented in Figure (24).

The resulting Von Bertalanffy equation for Passage Island is compared with the results from Tatitlek. The results of the Passage Island data reflect the paucity of large clams in these samples. In addition, the larger coefficient on age suggests that butter clams grow more quickly at Passage Island than at Tatitlek.

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

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

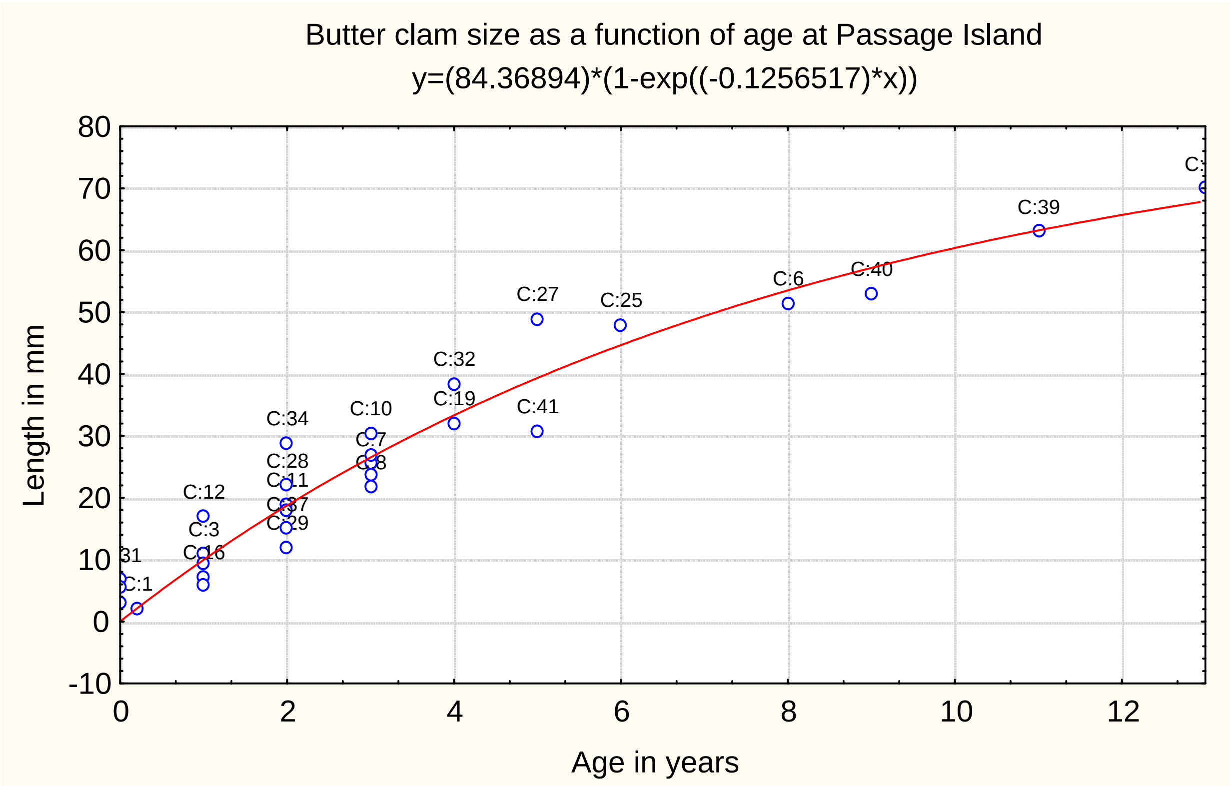

Figure 24. Solution to the von Bertalanffy model for butter clams collected in eighteen, 0.1 m^2 quadrats at Passage Island, Alaska, in August 1995.

An age-frequency histogram for butter clams from Passage Island is presented in Figure (25). Butter clams recruited into the legal size population at between four and five years of age (mean = 4.75 years). However, very few reached a legal size of $\geq$ 38 mm. Most of the mortality occurred at ages less than three years. This suggested that predators such as drills, starfish or birds were taking the small clams. From the presence of possible otter pits on the beach, the otters were exacerbating the situation by taking the few remaining large clams. The There were no apparent missing year classes for ages less than six years and recruitment of butter clams to Passage Island appears to occur regularly. However, recruitment has not been in sufficient numbers to sustain a healthy population in the presence of natural predation and mortality.

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

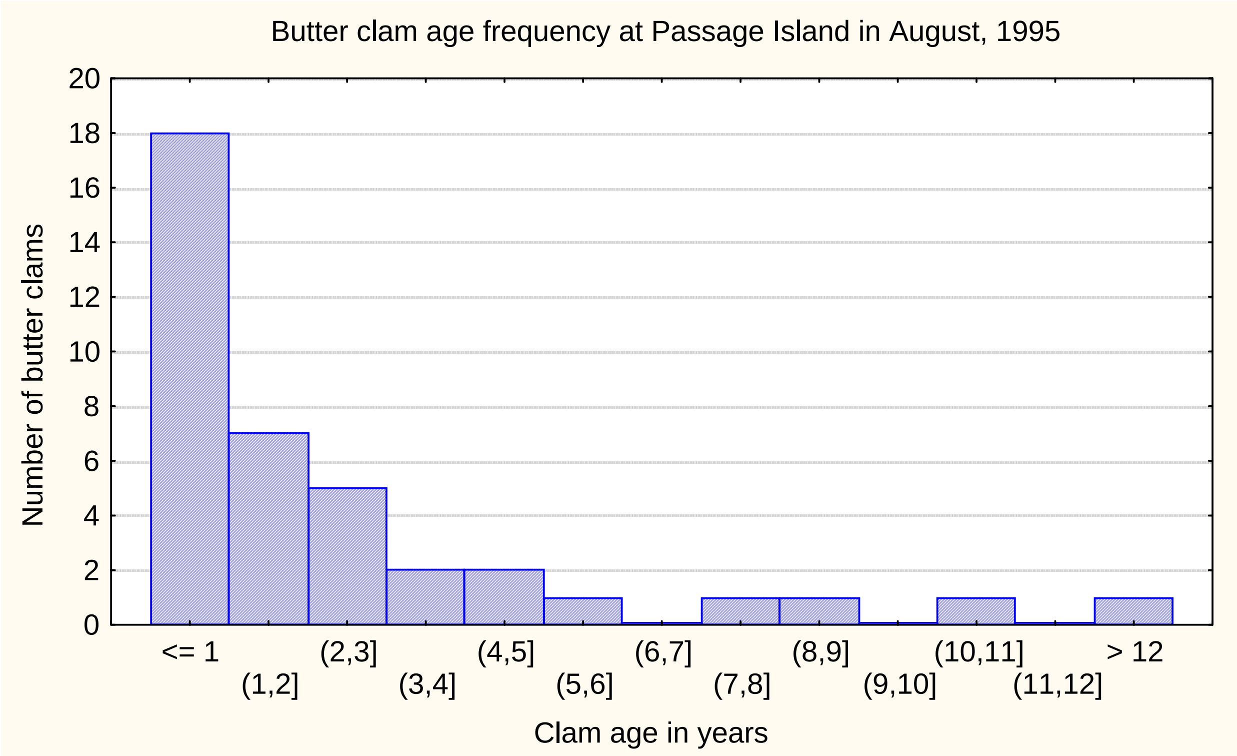

Figure 25. Age-frequency histogram for butter clams (*Saxidomus giganteus*) collected in 18, 0.1 m^2 samples at Nanwalek Village's, Passage Island shellfish beach on August 26, 1995.

Native littleneck clams. One hundred five (105) native littleneck clams were observed in the eighteen samples from Passage Island. Seven additional littleneck clams were obtained in the random digging efforts. Summary statistics for littleneck clams are provided in Table (11).

Table 11. Summary descriptive statistics for living native littleneck clams sampled in 18, 0.1 m^2 quadrats at the Nanwalek Village's beach at Passage Island on August 26, 1995.

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

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

An age frequency histogram for native littleneck clams on Passage Island is presented in Figure (26). The 1994 and 1995 year classes were very low suggesting sporadic recruitment. However, this is confounded by the presence of significant numbers of drilled clamshells in the size range three to four mm. Older clams appeared to be removed from the population shortly after reaching legal size (4 to 5 years).

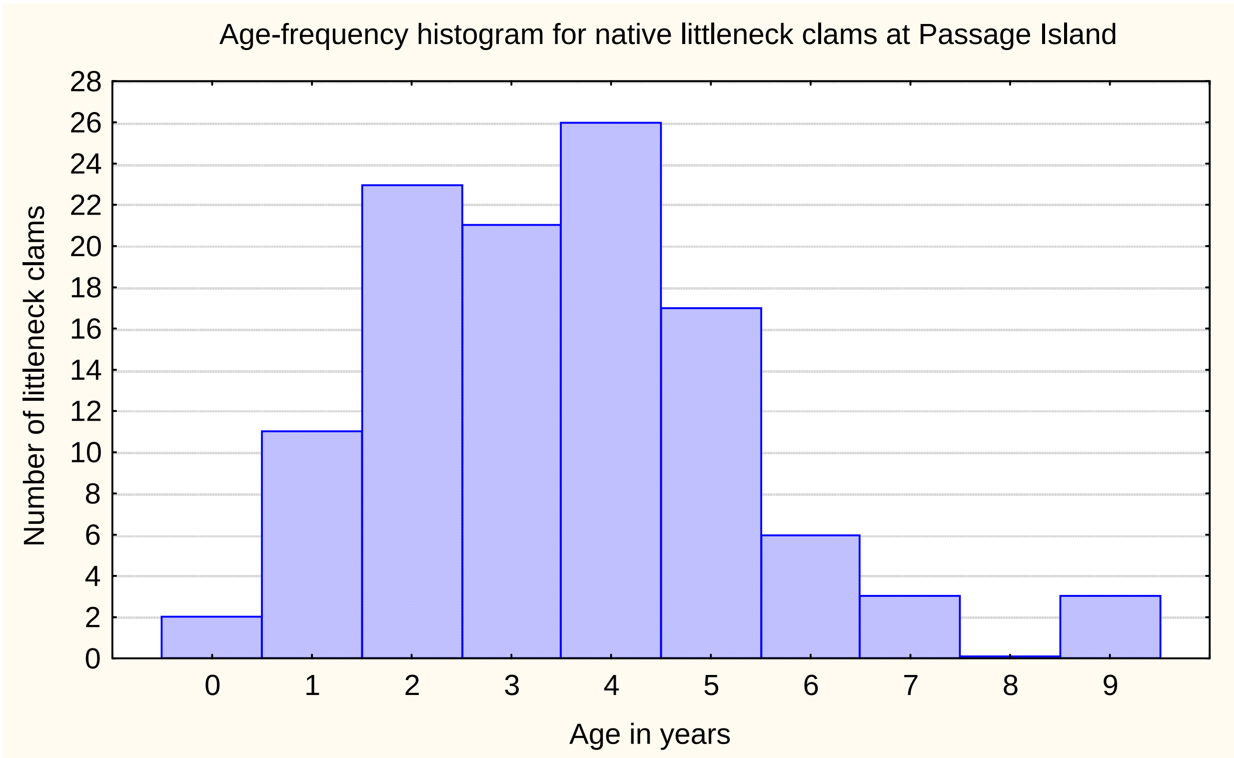

Figure 26. Age – frequency histogram for littleneck clams collected in 18, 0.1 m^2 quadrats at Passage Island on August 27, 1995.

Further examination of the population was accomplished through the length – frequency histogram provided in Figure (27). This histogram also suggests low recruitment in the recent past. The frequency observed in each of the year classes in Figure (26) should be divided by 1.8 to obtain the number of recruits per square meter since the area examined to obtain the data was 0.1 m^2/quadrat x 18 quadrats = 1.8 meters. Doing this suggests that recruitment, on average, was approximately 13 clams per square meter – far below the minimum of 400 to 700 clams per square meter typically seeded to fully utilizes beaches in Puget Sound.

This analysis indicates that current clam densities are insufficient to warrant subsistence harvests at Passage Island. Even if recruitment is enhanced, it appears that predation will still remove clams from the Passage Island population before they reach a minimum legal size. Starfish and drills are relatively easy to control. However, this beach will be difficult to protect from sea otters because of its remoteness from the village. If Passage Island is to become a valuable shellfish resource for the Village of Nanwalek, then reliable predator control measures must be developed. Seeding the beach without predator control will simply supply sub legal size clams for predators.

Figure (28) describes the distribution of native littleneck clams as a function of tidal height at Passage Island. Most of the clams were found within a narrow tidal range of –0.5’ to +1.5’ MLLW. Substrates to –1.8’ MLLW were included in this survey. However, very few clams were found at these lower elevations.

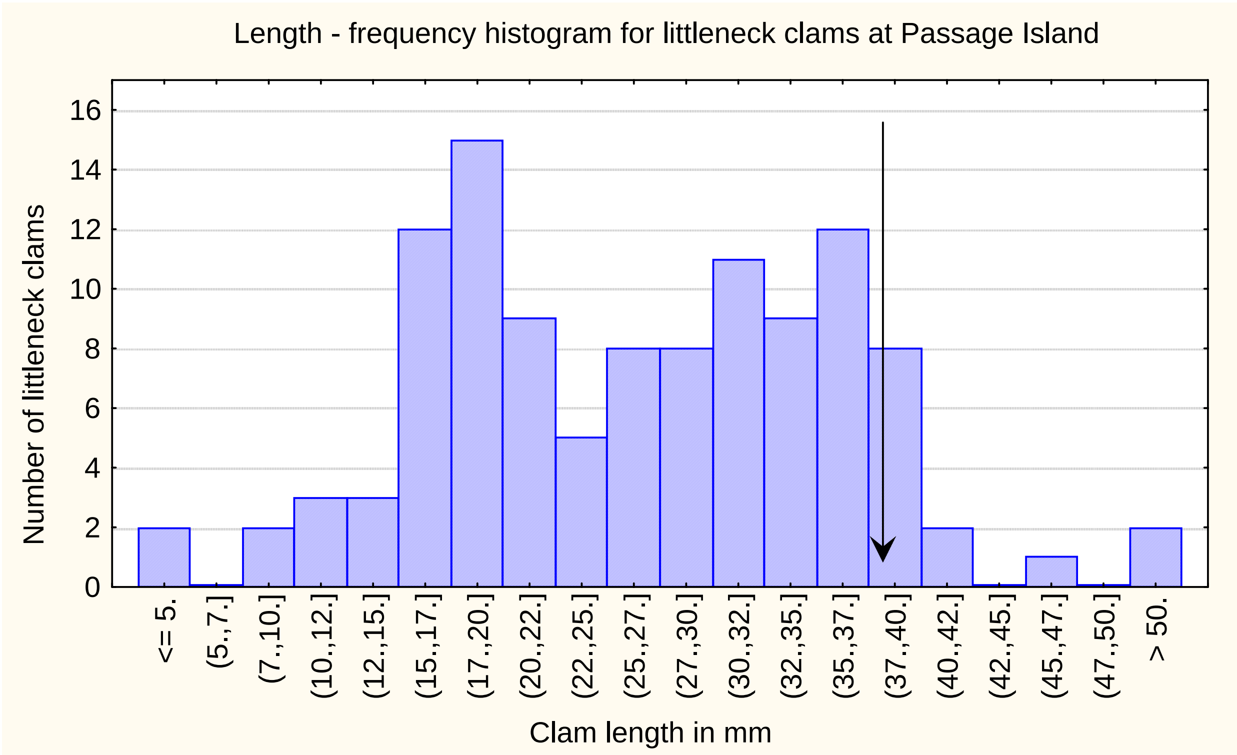

Figure 27. Length – frequency histogram for littleneck clams collected in 18, 0.1 m^2 quadrats at the Passage Island shellfish beach on August 26, 1995. The thin vertical line represents the minimum legal size of 38 mm.

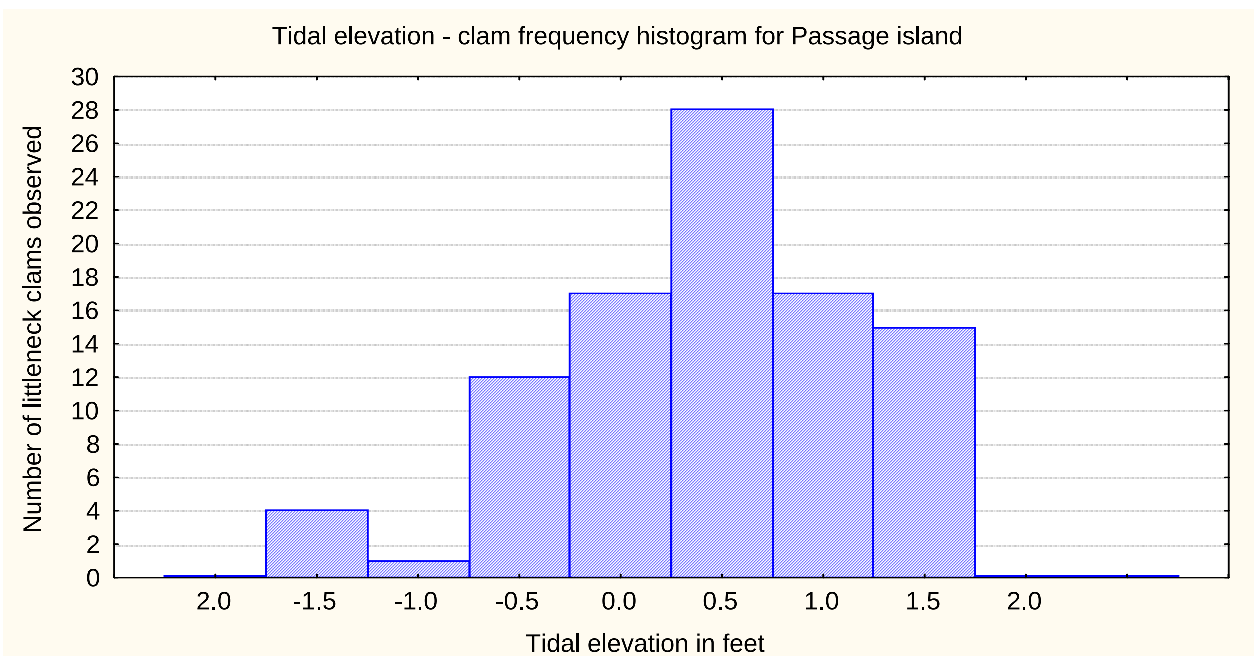

Figure 28. Tidal elevation – frequency histogram for littleneck clams collected in 18, 0.1 m^2 quadrats at Passage Island on August 26, 1995.

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

3.2.5. Native littleneck clam growth as a function of age and length. Average annual growth increments were calculated by dividing the total valve length by clam age and examined as a function of age. Incremental growth of native littleneck clams at Passage Island is described in Figure (29). Some clams in the 10 to 15 mm size range appeared to have achieved that size in a single year. In other clams of the same size, an apparent annulus appears at about 1.5 mm, suggesting minimal growth during the first year. Perhaps those clams were spawned late in the year and over-wintered just after metamorphosis. The larger clams, without the check at 1.5 mm, may have spawned early in the spring or summer and enjoyed an entire growing season before winter. This could explain the large variation observed in growth increments for the one-year-old clams.

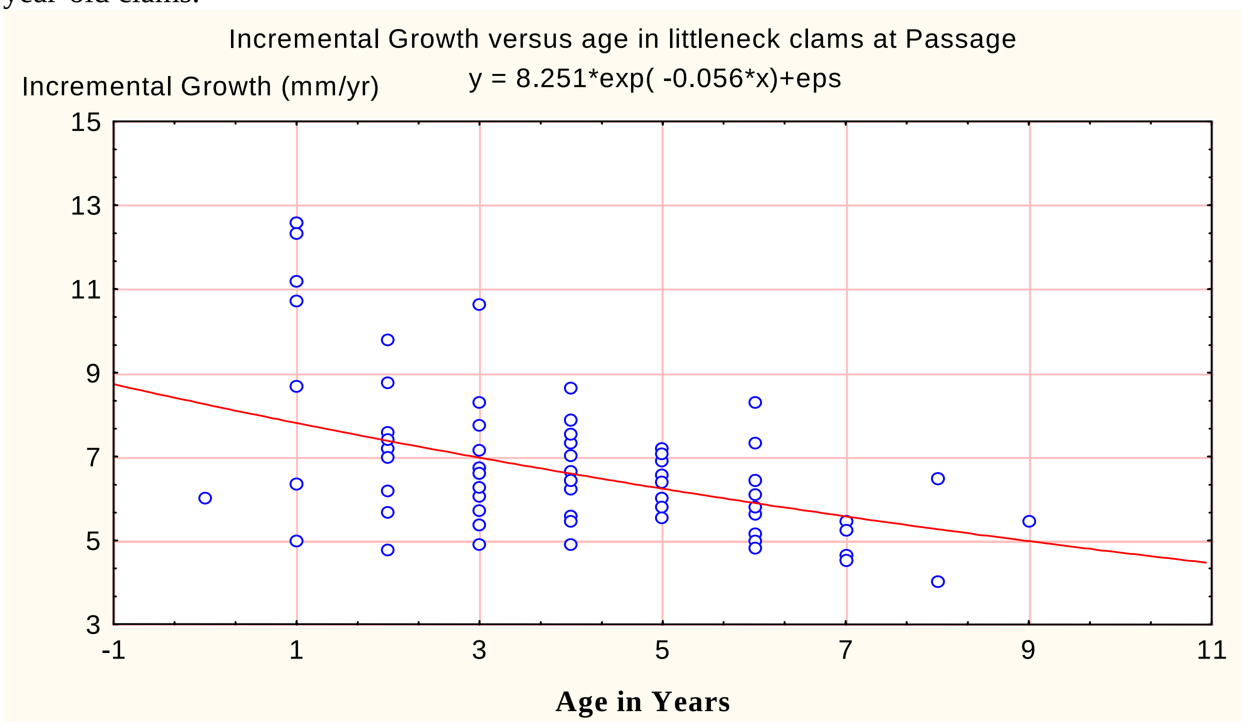

Figure 29. Average annual growth increments (mm/year) as a function of age (years) for native littleneck clams (*Protothaca staminea*) collected in 18, 0.1 m^2 quadrats at Passage Island, Alaska on August 26, 1995.

The data in Figure (29) suggests that incremental growth in valve length decreases significantly after age six. The average incremental growth methodology used in this analysis underestimates the reduction in growth as a function of age. Furthermore, it should be noted that native littleneck clam valve shape changes with age. The clams depth and width increases more that the length increases in older clams. Therefore, wet tissue weights continue to increase significantly in older clams, even though growth in valve length slows. This was nicely demonstrated by Nickerson (1977) who showed peak rates of length increase occurred at about three years of age in littleneck clams while peak increases in biomass occurred at an age of between six and seven years.

Within the area surveyed on Passage Island, clam growth does not appear to be a function of tidal height. The observed growth increments are plotted against tidal height in Figure (30). The regression coefficients were not statistically significant.

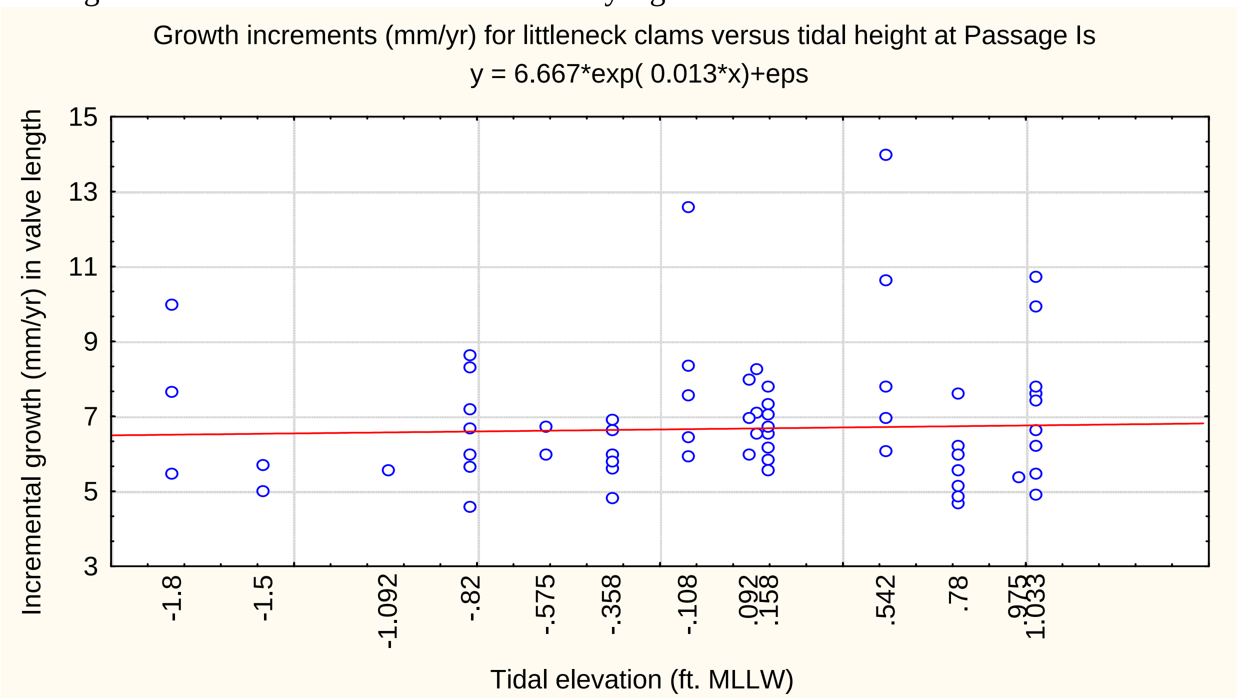

Figure 30. Growth increments (mm/year) as a function of tidal height (feet above MLLW) for native littleneck clams (*Protothaca staminea*) collected in 18, 0.1 m^2 quadrats at Passage Island, Alaska on August 26, 1995.

3.2.6. Native littleneck clam age – length analysis at Passage Island.

Regression coefficients were developed for the von Bertalanffy model using nonlinear regression. The resulting equation explained 81.2% of the variation and the ANOVA determined probability that the regression coefficients were all equal to zero was P = 0.000. The residuals were normally distributed. A full range of clam valve lengths was available for the analysis and it appears valid. Predicted and observed values of valve length, as a function of age, are presented, together with the regression line in Figure (31). This equation was solved for a length of 38 mm to obtain an average age of recruitment into the legal size population of 5.76 years. This was approximately one year longer than was required for butter clams at Passage Island.

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

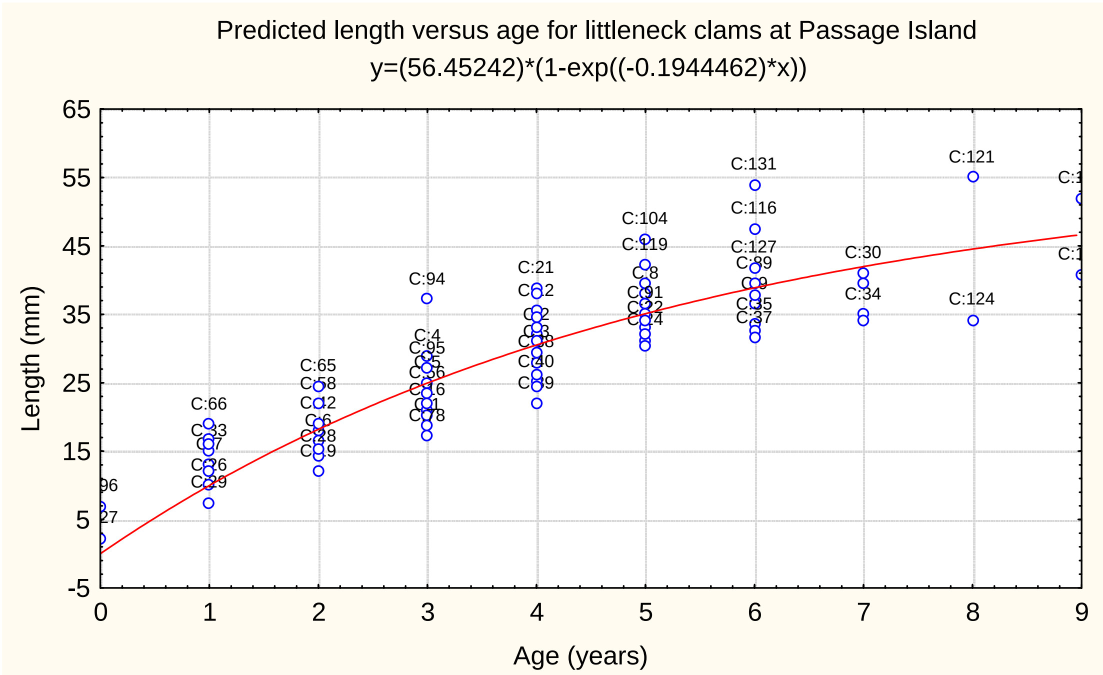

Figure 31. Valve length (mm) as a function of age (years) for native littleneck clams (*Protothaca staminea*) collected in 18, 0.1 m^2 quadrats at Passage Island, Alaska on August 26, 1995.

3.2.7. Edible native littleneck clam tissue versus clam length analysis. A length – wet tissue weight histogram is provided in Figure (32) and an age – wet tissue weight histogram in Figure (33). We tissue weights were increasing exponentially near the minimum legal size suggesting that harvest should be delayed as long as predation allows.

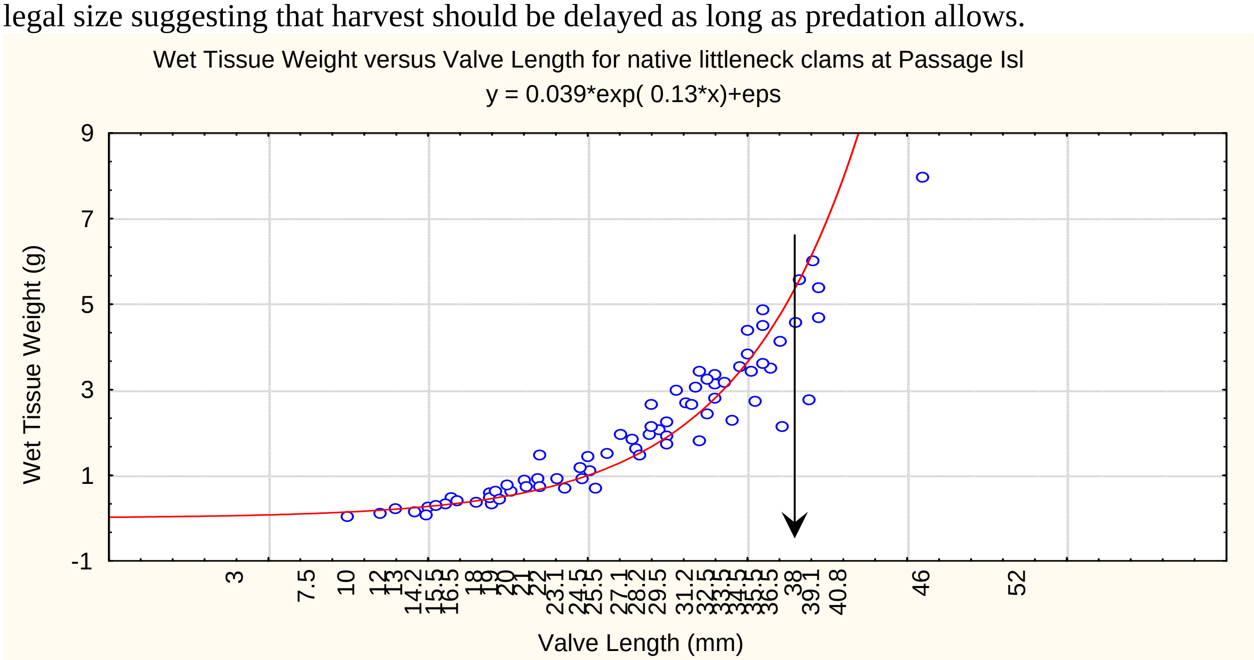

Figure 32. Length (mm) versus wet tissue weight (grams) for native littleneck clams (*Protothaca staminea*) collected in 18, 0.1 m^2 quadrats at Passage Island on August 26, 1995. The vertical solid line represents the minimum legal size.

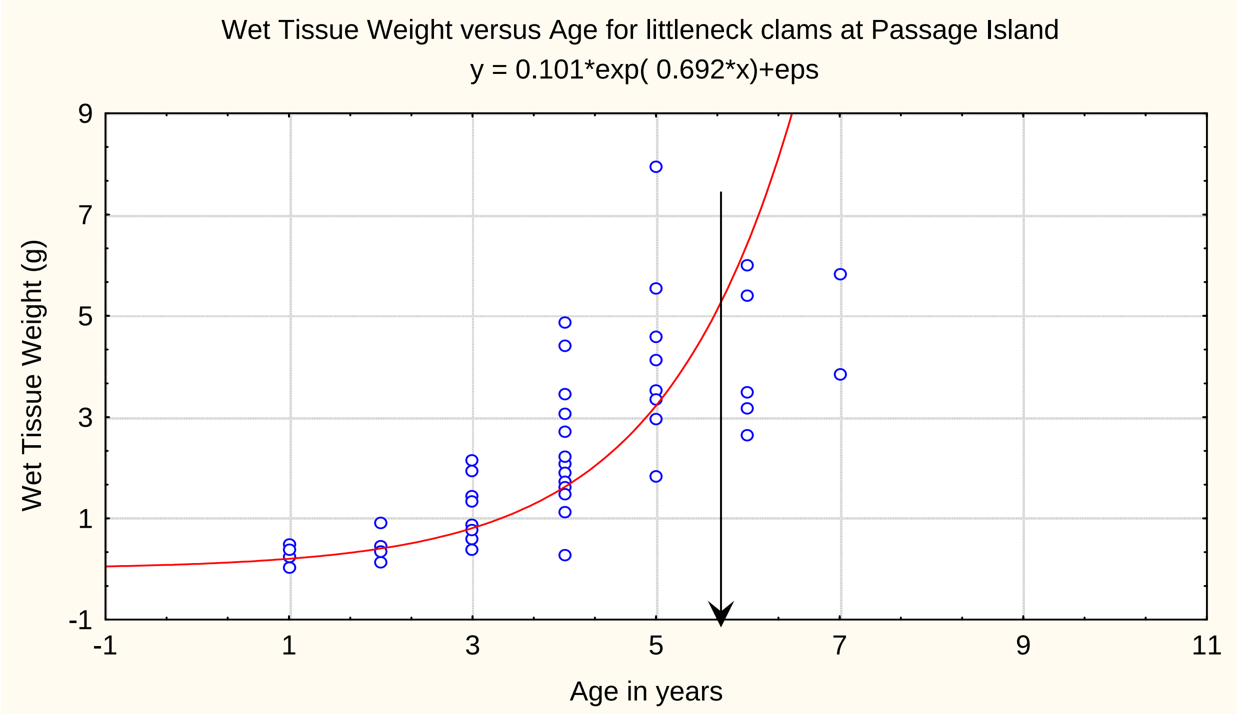

Figure 33. Age (yr) versus wet tissue weight (g) for native littleneck clams (*Protothaca staminea*) collected in 18, 0.1 m^2 quadrats at Passage Island on August 27, 1995. The vertical solid line represents the minimum legal size.

An examination of the data density in Figure (24) suggests a decrease in the rate of accumulation of wet tissues beyond an age of six years. However, there are too few data points for clams larger than 38 mm valve length to have confidence in this hypothesis and the available data suggests that growth is exponential to at least six years.

3.2.8. Predators at Passage Island. Large numbers of predators were not observed at Passage Island. Small drills (cf. *Nucella lamellosa*) were observed, as were numerous (100's) of very small (<4 mm) drilled clamshells similar to those observed at Tatitlek (see Figure 11). Numerous, small round pits (approximately 0.6 meters in diameter and 15 centimeters deep) were found on the beach. These pits were very similar to those observed at Tatitlek and may have been associated with either sunstar or sea otter predation. Villagers' assured us that these pits were from sea otters and that no harvests had been conducted at this site for several years.

3.2.9. Bivalve biomass available for subsistence harvests. The numbers of clams observed on Passage Island are insufficient to warrant subsistence harvests.

3.2.10. Summary conclusions and recommendations for native littleneck clam enhancement at Passage Island. The following conclusions and recommendations are based on this survey:

- Insufficient bivalve resources were found on this beach to warrant subsistence harvests.

- Sustained subsistence harvests will require additional seed, development of effective predator control measures, and an appropriate management plan. 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.

- It should be emphasized that any enhancement plan must solve the currently unacceptable predation rates on shellfish stocks. Without effective predator control, any enhancement plan will be futile. The remoteness of Passage Island from Nanwalek will make future study or enhancement activities difficult.

- The age length analysis suggests that native littleneck clams recruit into the legal size population at approximately 5.75 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.

- Growth of butter clams appeared to be somewhat faster than for native littleneck clams at Passage Island. Butter clams appeared to enter the legal size population at approximately 4.75 years. Very few had survived to harvest size on the date of this survey. Due to the lack of hatchery and nursery technology, and propensity to retain brevetoxins, butter clam enhancement is not recommended at this time.

- The high exposure of this site to wind and waves implies that an enhancement plan should include implementation of options such as bags or plastic netting that help stabilize substrates. Otherwise, seeded clams will either be washed out of the sediments or buried. However, these more intensive practices require regular maintenance if they are to be effective. The remoteness of Passage Island from the village of Nanwalek will make winter maintenance difficult.

3.3. Results for Murphy's Slough near the native village of Port Graham.

Subsistence shellfish resources near Port Graham were discussed with Mr. Pat Norman and local salmon hatchery personnel. Typical of other villages, Mr. Norman expressed a sincere interest in re-establishing a subsistence clam fishery near Port Graham. Village residents felt that the recent decline in shellfish production was caused by the 1964 earthquake and an increase in the sea otter population. A once plentiful cockle population had disappeared and Mr. Norman was particularly interested in re-established a cockle fishery. The bivalve inventory and beach characterization was accomplished on August 25 and 26, 1995 during a predicted low tide of –1.3' MLLW.

Port Graham shellfish culture team

3.3.1. **Beach characterization.** Initially, two beaches in Duncan and Tulcan Sloughs were identified for survey. Test digging on the evening of August 25, 1995 found few butter or native littleneck clams in these sloughs, which were expansive, relatively shallow, and crisscrossed by several streams. The substrate was composed of moderate quantities of fines (silt-clay) and significant quantities of small (<3 to 5 cm) broken shale. The angular nature of the shale resulted in a more tightly packed substrate that would likely inhibit the burrowing of bivalves. No butter or littleneck clams were found anywhere in Duncan or Tulcan Sloughs. The clam in greatest abundance was the truncated softshell (*Mya truncata*). These clams were 4 to 6 cm in valve length. They could provide the basis for a very limited subsistence shellfishery. However, this species does not appear to be prized and the clam density was very low – making subsistence harvests difficult.

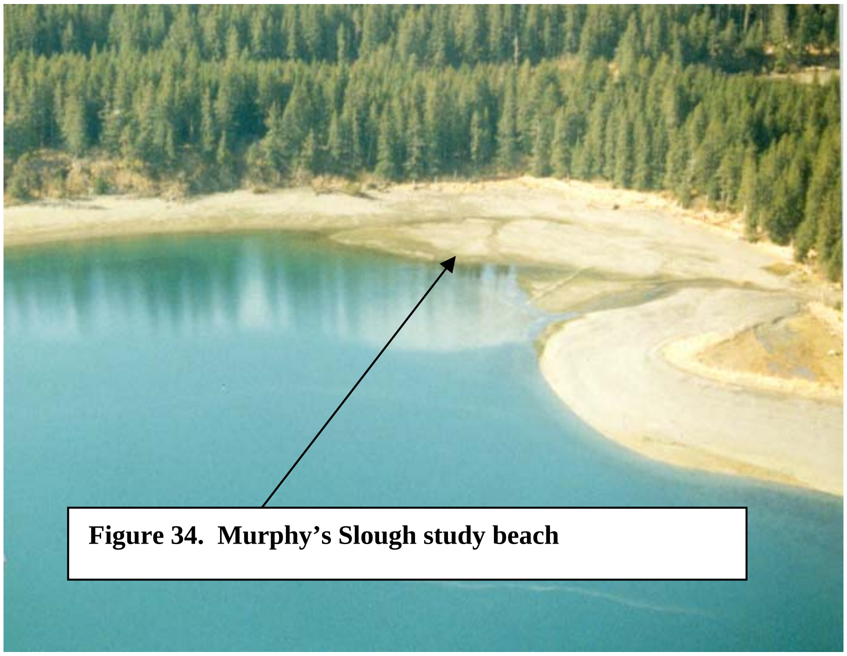

Figure 34. Murphy's Slough study beach

Because of the paucity of shellfish in Duncan Slough, a beach located around the point to the east of Tulcan Slough called Murphy's Slough (Figures 34 and 35) was surveyed. This beach measured 200' wide by 1000' long and covered approximately five acres. The beach slopes gradually into deep water and was very well protected from storm winds. The substrate was composed of moderately coarse, broken, shale. It was not compacted and a significant quantity of pore water was present. Murphy's Slough appeared to be a good beach for shellfish enhancement or intensive culture. Figure (34) is an aerial photograph of the beach; Figure (35) describes the substrate; and Figure (36) is a schematic diagram describing the systematic random sample used to evaluate this beach.

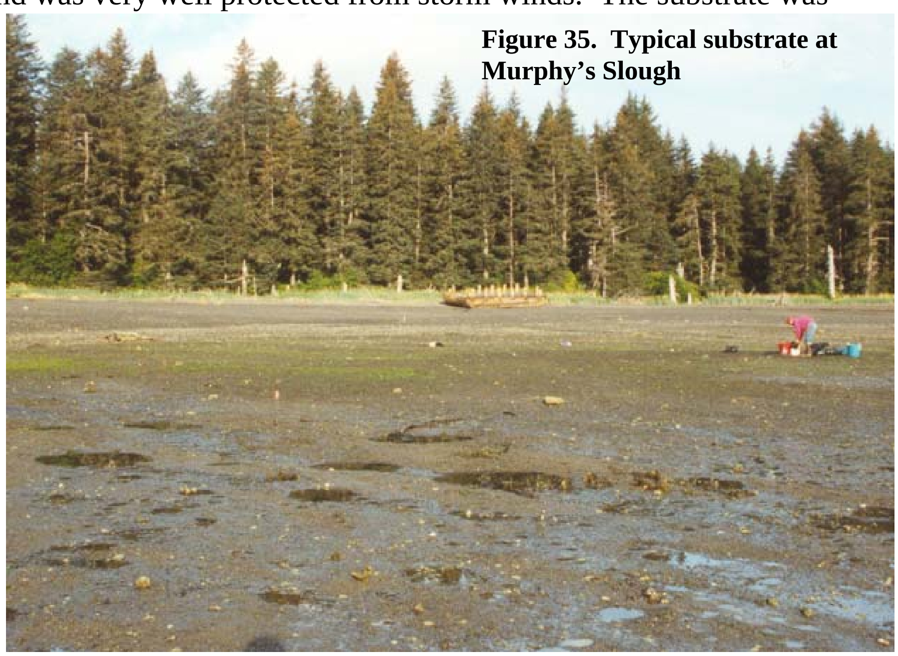

Figure 35. Typical substrate at Murphy's Slough

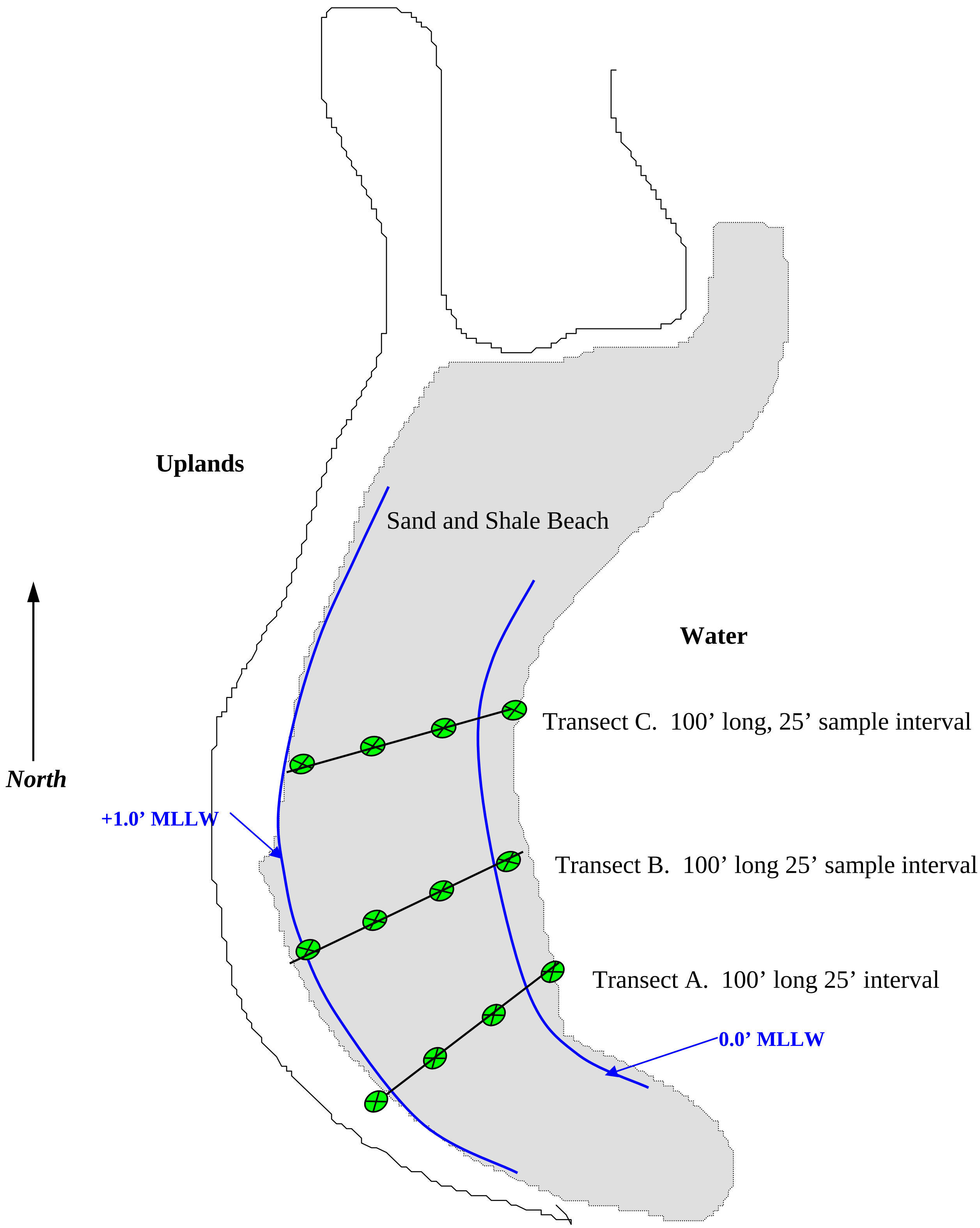

Figure 34. Schematic diagram of the Port Graham Village shellfish beach at Murphy’s Slough. The beach has surveyed in August of 1995. The 12 each 0.1-m2 samples collected during the survey are identified in green.

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

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

3.3.3. Bivalve population characterization. Shellfish were not abundant at this site and only 65 living bivalves were collected in twelve systematic random samples at Murphy's Slough near Port Graham. An additional 41 empty bivalve shells were collected at random locations on the beach. The distribution of clams obtained from the systematic survey is provided in Table (12).

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

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

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

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

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

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

3.3.4. Summary and conclusions for Murphy's Slough near Port Graham.

Based on this survey and analysis, the following conclusions can be reached:

- No harvestable populations of clams were found at the beaches (and tidal elevations) surveyed in Port Graham.

- Several beaches near Port Graham appeared suitable for the intensive culture of clams and cockles. The bottoms were relatively flat and firm. In some areas, the broken shale was well packed making the substrate unsuitable for burrowing bivalves. In others areas, like Murphy's Slough, sediments were loose and contained significant quantities of interstitial water with a very deep RPD. Of all the beaches examined during these surveys, Murphy's Slough presented the best opportunity for cockle enhancement.

- Phytoplankton production and supply may ultimately limit clam production in Murphy's Slough. Brooks (2000c) has described methodologies for assessing the bivalve carrying capacity for small inlets and bays. These methodologies could be applied in Port Graham.

- The lack of native littleneck clams and butter clams in Murphy's Slough appears related to poor or no recruitment of these species. No littleneck clam and few butter clam juveniles were observed. Cockles, once plentiful according to village residents, were nearly absent and no juveniles were observed. The near term re-establishment of a subsistence shellfish resource will require outside sources of seed.

- Like other beaches surveyed in 1995, the intertidal at Murphy's Slough was pock marked with what appeared to be otter pits. There were numerous broken butter clam shells lying next to some of these pits. This suggests that otters may be taking the few clams that reach legal size. Juvenile (< 5 mm) butter clam shells were observed with drill holes in them. However, few gastropods were observed. Predation by starfish and drills did not appear as severe in Murphy's

Slough as it did at Tatitlek. However, adequate predator control or exclusion is recommended as part of any enhancement project.

- Murphy's Slough presents better cockle habitat than any other beach examined in these surveys. In addition to being a preferred food by Villagers, it appears that cockles grow rapidly in Alaska. The few cockleshells that were collected suggest that a minimum legal size of 38 mm could be achieved within perhaps three years. In Puget Sound, Washington, feral populations of cockles (*Clinocardium nuttallii*) appear to reach commercial size ($\geq$ 38 mm) in one to two years (Brooks, unpublished). The combination of cockle and native littleneck enhancement could provide a reasonably short-term supply of cockles and a longer-term supply (within five to seven years) of native littleneck clams. Cockles are not commonly raised in intensive culture and to the best of the author's knowledge; no commercial hatcheries were producing seed. Section 5 of this report describes successful, but preliminary, efforts to produce and nursery cockle seed in hatcheries and to raise them to market size in growout experiments.

- Mussel (*Mytilus edulis trossulus*) seed is present in the upper parts of the intertidal at numerous places near Port Graham. These mussels could be caged and hung from buoys in the bay to provide an almost immediate (one year) supply of shellfish. However, like the other native village residents, mussels do not appear to be a traditional subsistence food source and some experimentation and outreach would be required. The high potential productivity associated with blue mussels should be explored, at least on an experimental basis, by the Port Graham village.

3.4. Recommendations for native littleneck clam enhancement at Tatitlek, Nanwalek (Passage Island) and Port Graham (Murphy's Slough)

3.4.1. Nanwalek and Tatitlek. Passage Island and the Tatitlek beach represent high-energy environments with significant quantities of large rock. Otherwise, they are representative of typical native littleneck clam habitat. Both beaches enjoy high current speeds. These physical conditions offer the promise of relatively fast native littleneck growth. Intensive culture requires areas of relatively uniform substrate from which cobble larger than 7.5 cm has been removed. This preparation required significant hand labor at both beaches. The rock was placed seaward from the test cultures to help retain water during low tides and to encourage recruitment of wild larvae (Toba *et al.* 1992). Tatitlek is recommended for native littleneck clam enhancement – but not for cockle enhancement. Native littleneck clam suitability studies are recommended for Passage Island. However, the remoteness of Passage Island will make sampling difficult, particularly in winter, and maintenance of intensive cultures problematic. Both beaches will require bag culture and/or plastic netting to stabilize sediments.

3.4.2. Port Graham. There are several extensive beaches in Port Graham that could be used for bivalve culture. The beach at Murphy's Slough has an ideal substrate. Future bivalve production will likely be more limited by food (detritus and living phytoplankton) than by the availability of suitable substrates. Preliminary growth and mortality studies to substantiate this areas suitability for bivalve culture should be followed by an analysis of the systems bivalve carrying capacity before planning significant enhancement efforts. Based on this authors experience, small to moderate scale subsistence enhancement efforts (10 to 100 acres) are unlikely to approach the carrying capacity of Murphy's Slough.

3.4.3. Predator Control. Control of starfish and drills is easily accomplished by hand picking and removal to an upland area. No direct or unequivocal evidence of sea otter control predation in intertidal areas was observed during these surveys. However, if it occurs, it may present a significant problem. The literature did not reveal any reference to this subject because intensive bivalve culture is uncommonly practiced in areas with large otter populations.

3.4.5. Harvest management plan. Harvest management of shellfish resources in Alaska is of special importance because of the anticipated slower growth, particularly of native littleneck clams. Individual management plans should be developed by each village to insure that shellfish produced in enhancement projects are harvested in a sustainable way.

Figure (37) presents a scatterplot of all native littleneck clams measured and aged in the 1995 surveys. The scatterplot is fitted with a nonlinear solution to the von Bertalanffy model. The results suggest that native littleneck clams enter the legal population at an age greater than four years and that only half of the clams appeared to reach a valve length of 38 mm by age seven.

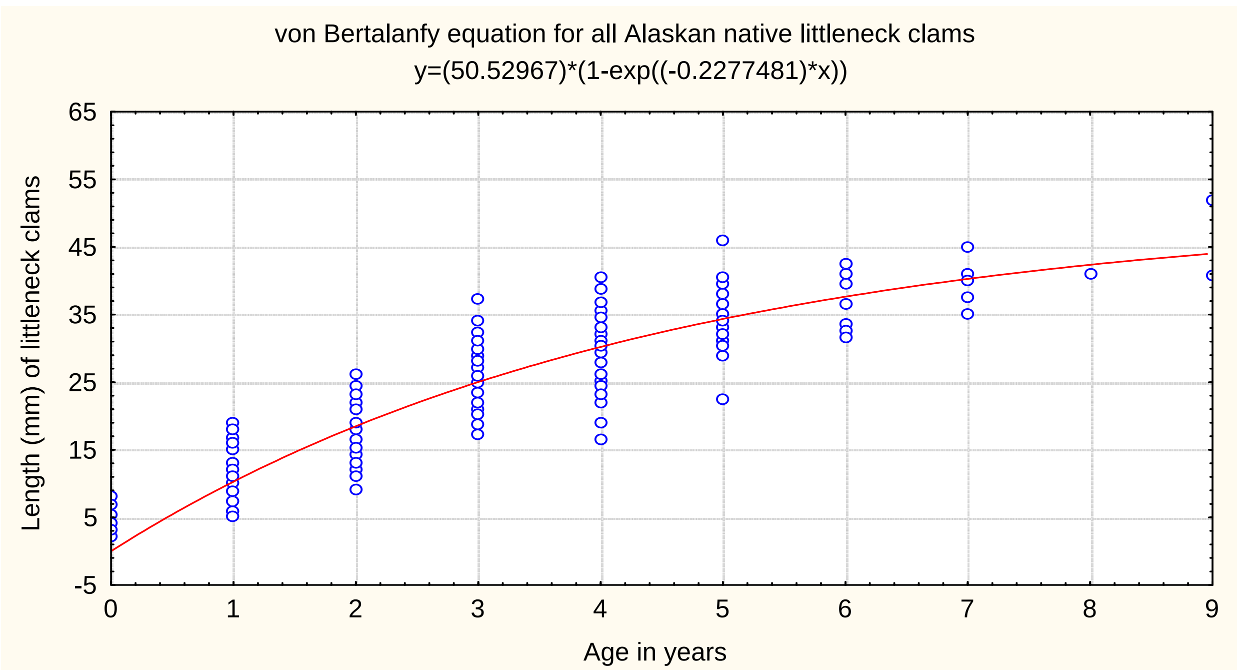

Figure 37. Scatterplot describing length of native littleneck clam valves as a function of age in 1995 samples collected at shellfish beaches near Tatitlek and Nanwalek. A nonlinear solution to the von Bertalanffy model is provided and the resulting regression plotted on the graph.

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). Figure (37) suggests that native littleneck clams reach a minimum size of 38 mm at an age between five years and >9 years. Solving the von Bertalanffy equation given in Figure (37) 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