

ALASKA DEPARTMENT OF FISH AND GAME
DIVISION OF COMMERCIAL FISHERIES
MANAGEMENT & DEVELOPMENT

COOK INLET AREA

KACHEMAK BAY LITTLENECK CLAM ASSESSMENTS, 1995

BY

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Regional Information Report No.2A96-12

Alaska Department of Fish and Game
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March 1996

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INTRODUCTION

In 1992 the department began conducting stock assessment surveys for Pacific littleneck clams (*Protothaca staminea*). Surveyed beaches were located in Alaska Department of Environmental Conservation (DEC) certified areas within Kachemak Bay, which is in the Southern District in the Cook Inlet Management Area. The surveys were designed to assess the impact of the commercial fishery on clam populations of Chugachik Island, Jakolof Bay, Tutka Bay, Halibut Cove, and Sadie Cove (Gustafson 1995). The goal of this paper is to review the 1995 commercial season and report the results of the stock assessment surveys at Chugachik Island, Bear Cove, and Sadie Cove (Figure 1). In 1995 the clam industry developed a small market for butter clams (*Saxidomus giganteus*); therefore, butter clam data will also be presented for Sadie Cove.

Fishery History

Prior to statehood there was sporadic butter clam harvest in Kachemak Bay. The clams were sold in Anchorage fresh markets and canned during the salmon off season. The annual harvests were not well documented. There were only 2 harvests reported in early U.S. Fish and Wildlife Service annual Cook Inlet reports from 1949 to 1959. In 1949 Kasitsna Bay Packing Company produced 36 (48-1/2 pound can) cases, and in 1955 Tidewater Packing harvested 1,559 kg (3,435 lb) from Nubble Point, Kasitsna Bay (Anonymous 1949-53). After 1955 the canning operation at Kasitsna Bay was abandoned due to high operational costs

(Anonymous 1956). Additionally, the presence of paralytic shellfish poisoning (PSP) in canned product from Alaska led to the collapse of the fishery in southeast and south-central Alaska (Paul & Feder 1976).

The post-statehood commercial hardshell clam fishery began in 1986. The generic term hardshell clams refers to Pacific littleneck and butter clams. The Pacific littleneck clam, sold for human consumption, was the target species of the commercial fishery. The majority of the harvest has been Pacific littleneck clams. In 1989, however, butter clams were sold for sea otter food for a rehabilitation project resulting from the Exxon Valdez oil spill (Kimker 1994). The harvests have ranged from 6,569 to almost 32,245 kg (14,449 to 71,025 lb) (Table 1). The number of participants has increased from 2 to 33 permit holders.

Prior to harvesting clams for human consumption, an area must be certified for water quality by DEC in accordance with the National Shellfish Sanitation Program. Additionally DEC has used a lot sampling technique to test for the presence of PSP. In 1986 Chugachik Island near Bear Cove was certified by DEC. Since then Halibut Cove, Jakolof Bay (June, 1988), Kasitsna Bay (June, 1988), and Tutka Bay (September, 1990) were certified. In December 1994 DEC drew a line from north end of Chugachik Island to Gull Island to Barabara Point, and certified all waters south of that line with the exception of the following: the entrance of Jakolof Bay, Little Tutka, the entrance of Tutka Bay, Tutka Lagoon, the southwest side of Peterson Bay, and waters south of

Ismailof Island in Halibut Cove. Bear Cove was closed conditionally from May 1 to September 30.

Regulatory conservation measures, adopted by the Board of Fisheries in 1990, are a minimum size of 38 mm (1 1/2 in) for littleneck and 63 mm (2 1/2 in) for butter clams. As the fishery grew, commercial fishermen, recreational users, and government agencies all became concerned that more restrictive management was needed to sustain the clam populations. As a result the Board of Fisheries adopted a management plan in the spring of 1994. The management plan included the following provisions:

1. Five subdistricts were established in Kachemak Bay (Figure 2).
2. The subdistricts would be divided into 2 groups that were opened on alternate years.
3. Areas exhibiting high recreational use were permanently closed to commercial fishing within the subdistricts.
4. Weekends, between 11:00 p.m. Friday and 1:00 a.m. Monday, were closed to fishing from May 15 to September 15.
5. An April 1 registration deadline was created.

Additionally the Board directed the department to keep the harvest under the historic high catch of 29,500 kg (65,000 lb).

1995 Commercial Clam Season

The management plan was first implemented in 1995. Areas 1 and 3b were open to commercial clam fishing. Prior to the season,

due to an allocation issue, the department closed the upper half of Bear Cove to establish a control area for the 1995 harvest. Additionally, the Chugachik Island area was closed May 21, 1994 till May 26, 1995 and would not open unless the April 1995 survey indicated an increase in abundance.

The 1995 harvest was 30,292 kg (66,723 lb) of littlenecks, 1,937 kg (4,267 lb) of butters, and small quantity of (catch confidential) cockles (*Clinocardium nuttallii*) taken by 21 diggers. Between January 1 and February 23, 17 diggers harvested 12,213 kg (26,941 lb) of littlenecks from Bear Cove (Table 2). Harvest rates averaged 18.0 kg/hour (39.7 lb/hour). Although the catch rates were high, the department closed Bear Cove on February 23 to reduce the risk of overharvest and divert the harvest to other areas. Additionally, a combination of cold temperatures with high winds were forecasted after February 23 resulting in a windchill that was detrimental to the survival of the sublegal clam bycatch. Therefore, the department closed the fishery in the remaining open areas through March 1. Furthermore, the industry was interested in spreading the harvest over the rest of the year, thus the fishery was closed for the first 15 days of each month.

When the fishery reopened on March 15, the majority of the effort shifted to Sadie Cove with a 11,642 kg (25,644 lb) littleneck clam harvest at an average harvest rate of 19.4 kg/hour (42.65 lb/hour). As the guideline harvest was approached, the clam industry developed a market for butter clams. The butter harvest was 1,937 kg (4,267 lb) from all the remaining open areas (1 and 3b) with 1,909 kg (4,205 lb) taken from Sadie Cove and Tutka Bay.

The fishery closed June 1, 1995 when the littleneck guideline harvest was reached.

Survey Goals

The objectives of the survey were as follows:

1. Measure the change in relative density (clams/m²) of legal and sublegal clams over time.
2. Estimate the legal and sublegal littleneck clam segments of the population and determine how they change over time.
3. Compare the shell length frequency of littleneck clams to historical data, and determine if there was a change in the average size of legal clams.
4. Compile baseline data for age composition, growth rates and recruitment to legal size of littleneck clams.

During the 1995 season, due to the competitive nature of the fishery, clam digging occurred during some cold windy days. The department closed the fishery from February 23 through March 15 to protect the bycatch sublegal clams from exposure during cold windy conditions. After the closure of Bear Cove, however, there were reports from members of the public of numerous dead clams in Bear Cove. The following objective was therefore added:

1. Compare the number of live and dead whole littleneck clams from a beach commercially dug to a beach in the undug control area of Bear Cove to determine if there was a measurable impact of winter harvest.

METHODS

Field Methods

Surveys were conducted on a minus tide. Arrival at the beach or bay was scheduled for 2 hours prior to low tide at approximately the +0.3 to 0.0 m (+1.0 to 0.0 ft) tide level. Sampling lasted through the minus tide and continued until the water reached the +1.4 m (+4.0 ft) tide level.

Quadrat sampling was used to estimate clam density and biomass. At Chugachik, the quadrat locations were randomly selected. Since sites selected at Bear Cove and Sadie Cove were new, the quadrats were systematically selected based on the length of the beach at varying tide levels. A plastic pipe square with inside dimensions of 0.5 by 0.5 m (19.6 by 19.6 in) was used to dig a consistent size quadrat. All the substrate from inside the quadrat was removed with a clam fork (4 prong garden rake) to a depth of 20 to 34 cm (8.0 to 13.0 in), or somewhat deeper if littlenecks or butter clams were still found.

As the substrate was removed, all clams were placed in a bucket or bag. Subsequently the substrate was raked back into the hole and examined for any clams missed during the initial excavation. The clams were bagged, labeled, and frozen for later age, weight, and length measurements in the lab. In Bear Cove, all live and whole dead littlenecks were saved for laboratory analysis. Clams were considered whole dead clams if both valves were attached by the ligament and had no viscera connected to the shell.

Laboratory analysis consists of measuring the shell length to the nearest 0.1 mm, weighing the whole clam to the nearest 0.1 g, aging the clam using criteria described in Feder and Paul (1973) and recording the length of each visible annulus.

Analytical Methods

Relative density measurements were made by pooling all the quadrats' clams within an area, e.g., Chugachik, to estimate the mean number of legal, sublegal, and total clams per quadrat. The mean was multiplied by 4 to expand the 0.25 m² quadrat to 1.0 m². Population estimates were made by multiplying the mean number clams per square meter by the area of clam habitat. The number of legal and sublegal clams was multiplied by the average weight of the respective size group to give a population estimate in pounds contained within an area (Appendix A).

The F test statistic was used to determine if there was a reduction or change in the average shell length of legal and sublegal littleneck clams over time.

A chi-square test was used to determine if there was a difference in the frequency of live and dead clams at both the opened and closed beaches in Bear Cove.

RESULTS

Chugachik Island

Chugachik Survey Area Description

Chugachik Island is located at the head of Kachemak Bay near Bear Cove. On low tides a semicircular shaped beach forms between the mainland and the southeast side of the island. Most of the commercial littleneck harvest from Chugachik Island came from the -1.5 m to +1.2 m (-5.0 to +4.0 ft) tide area, below the mussel beds. The beach is 550 m wide (between the mussel bed and the -5.0 ft tide line) and averages 190 m long between the island and mainland. The substrate is composed of a mixture of 1 to 8 cm (1/2 to 3 in) in diameter coarse rock and sandy mud mixture. The upper +1.2 m to +0.4 m (+4.0 to +2.0 ft) level includes a large mussel bed that was drained by 2 or 3 small streams. The area of clam habitat was estimated to be 61,254 m² (15.1 acres) (Gustafson 1995).

Chugachik 1995 Survey Results

The Chugachik Island beach was sampled during a -1.4 m (-4.7 ft) low tide on April 17, and a -1.0 m (-3.2 ft) low tide on April 19, 1995. During the 2 days, 35 quadrats were dug (Figure 3). The mean number of littlenecks was 33.8 legal and 19.4 sublegal clams/m². The total mean number of clams was 53.2 clams/m². The population estimate was 2,072,135 legals, 1,190,078 sublegals, totaling 3,262,213 clams. From the laboratory measurements, the average weight of legal and sublegal clams was 27.6 g and 8.2 g,

respectively. This yielded a biomass estimate of 57,191 kg (125,971 lb) of legal clams and 9,759 kg (21,495 lb) of sublegal clams (Table 3).

Chugachik Shell Length Frequency 1992 to 1995

Shell lengths from 1992 through 1995 ranged from 7 mm to 66 mm (Figure 4). Legal clams made up 57.6%, 45.7%, 46.0%, and 63.5% of population from 1992 to 1995, respectively. The average shell lengths of legal clams from 1992 to 1995 were 47.0, 46.8, 46.2, and 47.2 mm, respectively. The average shell lengths were not significantly different between years ($F = 1.458$, $F_{0.05} = 2.614$, $P < 0.05$, $df_{\text{between groups}} = 3$, $df_{\text{within groups}} = 938$). If, however, just the 1994 and 1995 data were compared, there was a difference in the average shell length ($F = 3.951$, $F_{0.05} = 3.857$, $P > 0.05$, $df_{\text{between groups}} = 1$, $df_{\text{within groups}} = 584$). The average shell lengths of the sublegals were 30.5, 31.4, 31.1, and 30.4 mm from 1992 to 1995, respectively. The differences in average shell length were not significant ($F = 1.370$, $F_{0.05} = 2.616$, $P < 0.05$, $df_{\text{between groups}} = 3$, $df_{\text{within groups}} = 823$).

Chugachik Age Frequency

The littleneck clams from 1992 to 1995 ranged from 3 to over 14 years old. Between 1992 and 1994, age 6 was the most numerous age class (Figure 5). In 1995 ages ranged from 1 and 14, with age 8 being the most numerous age class. For the legals, the 1984 cohort (age 8 in 1992) was the most numerous age class between 1992 to 1994. By 1995, the 1987 cohort (age 8 in 1995) became the most numerous. In all surveys, legal size was

attained as early as age 6 and as late as age 10, with the exception of 1992 when all clams reached legal size by age 9.

Recruitment at Chugachik

Since the substrate was not washed through screens due to time and manpower constraints, only a portion of smaller clams were sampled in the survey. As a result, the survey does not completely sample clams younger than age 5. Therefore, true recruitment or settlement of clams was not measured by the survey. Recruitment will therefore be defined as the total number of clams at ages 6 through 10 which annually reach legal size.

Annual recruitment was calculated by a three phase methodology (Appendix B). First, the average percent of legal clams by age class was calculated by pooling each age class frequency from 1992 through 1995. Second, the average recruitment by age class was calculated by subtracting the percent legal clams at age $(i-1)$ from the percent clams at age i ($\%legal_{(i)} - \%legal_{(i-1)}$). Therefore, on average, 6.2% of age 6, 39.4% of age 7, 40.0% of age 8, 12.2% of age 9, and 2.1% of age 10 clams recruited annually to legal size. Finally, annual recruitment was calculated by multiplying the average percent recruited from the respective age class by the estimated number of clams by age class from a specific year. Then the products (recruits by age class) were summed by year to give the estimated number of recruits for a specific year.

The highest estimated recruitment was 862,123 clams in 1992 and lowest was 317,827 in 1994 (Table 4). Recruitment ranged between 7% and 12% and averaged 10% of the total estimated number of clams.

Annual commercial harvests were accounted on a January 1 to December 31 basis, but the surveys occurred from spring to early summer. To address the discrepancy resulting from the comparison of the annual harvest to the recruitment event that occurred in the midst of the annual harvest period, it seemed more appropriate to compare the number of clams harvested between surveys to recruitment, which was determined by the survey (Table 4). The number of clams harvested between surveys was calculated by dividing the harvest weight by the average weight of legal clams from the respective year's survey. Between July 1, 1991 and the first clam survey, the fishery harvested 43% of the recruits and 5% the estimated total number of clams. Between the 1992 and 1993 survey, the fishery harvested 59% of the recruits and 5% of the estimated number of clams. Between the 1993 and 1994 survey, the harvest jumped to 303% of the recruits and 20% of estimated number of clams. This high harvest rate likely contributed to the decline of the legal segment of the clam population.

Chugachik Age and Growth

The 1995 Chugachik Island clam growth was modeled using von Bertalanffy's model (Figure 6). The model predicted that clams

reached legal size between age 6 and 7 with a growth increment of 4.3 mm.

Bear Cove

Bear Cove Survey Area Description

The Bear Cove survey was conducted after the commercial fishery closed. On April 20, during a -0.5 m (-1.71 ft) tide, 2 sites in Bear Cove were surveyed (Figure 7). Site 1 was located inside the area closed to commercial clamming. The beach was 153 m long and averaged 7 m between the water line and blue mussel beds resulting in an estimated area of clam habitat of 1,010 m². The substrate was composed of coarse angular rocks 6 cm (2 in) in diameter and smaller, with a matrix mixture of broken clam shell and sandy mud. There was a layer of blue clay at a depth of 26 cm (10 in).

Site 2 was located on the southeast tip of Bear Island. The beach was 119 m long. The major portion was 8.2 m wide between the water edge and the blue mussel beds. Large boulders on the west and east sides of the beach, however, reduced the width to 2.3 m and 4.0 m, respectively, between the water line and mussel beds. The estimated clam habitat was 822 m². The substrate was a combination of from large coarse angular rocks 8 to 10 cm (3 to 4 in) in diameter and smaller rocks 2 to 3 cm (1/2 to 3/4 in) in diameter with sandy mud and numerous shells. Additionally, there were numerous broken shell debris in depressions on the beach.

Six quadrats were dug in each site. They were evenly spaced along the length of the beach at different tide elevations. Site 1 was dug during the ebb to low slack tide between 1120 and 1245 hours at tides heights ranging between +0.2 and -0.5 m (+ 0.7 and -1.6 f). Site 2 was dug from low slack to the flood between 1320 and 1435 hours at tide heights ranging between -0.5 and +.3 m (-1.6 and +1.0 f).

Bear Cove Results

Site 1 had 75.3 legals and 69.3 sublegals totaling 144.7 littleneck clams/m² (Table 5). The population estimate was 76,087 legals and 70,027 sublegals totaling 146,113 clams. The average weights were 20.7 and 7.6 g for legals and sublegals, respectively. The resultant biomass estimate was 1,537 kg (3,385 lb) of legals and 532 kg (1,172 lb) of sublegals. The mean number of dead clams were 21.3 clams/m² with 48% legals and 52% sublegals.

Site 2 had 80.0 legals and 68.7 sublegals resulting in a total of 148.7 littleneck clams/m² (Table 6). The population estimate was 65,760 legals and 56,444 sublegals producing a total of 122,204 clams. Average weights were 22.0 and 8.9 g for legals and sublegals, respectively, resulting in a biomass estimate of 1,447 kg (3,187 lb) of legal and 504 kg (1,110 lb) of sublegal clams. The mean number of dead clams were 42.7 clams/m² with 61% legal and 39% sublegal.

The mean number of dead clams/m² at site 2 was twice the number of site 1. The number of live to dead clams between sites was significantly different ($\chi^2 = 8.095$, $df = 1$, $P = 0.005$).

Bear Cove Length Frequency

Site 1 littleneck clam shell lengths ranged from 11.0 to 56.5 mm. Legal clams were 53.7 percent of the clams measured and average shell length was 43.1 mm (Figure 8). Sublegal clam average shell length was 30.4 mm.

Site 2 littleneck clams shell lengths ranged from 12.3 to 56.9 mm. Legal clams were 57.8% of the clams measured and average shell length was 44.6 mm. Sublegal clam average shell length was 31.4 mm.

The average shell length of legal clams from site 2 was larger than site 1 ($F = 7.065$, $F_{0.05} = 3.882$, $P > 0.05$, $df_{\text{between groups}} = 1$, $df_{\text{within groups}} = 230$). Conversely, the average shell length of sublegals was the same ($F = 1.087$, $F_{0.05} = 3.887$, $P < 0.05$, $df_{\text{between groups}} = 1$, $df_{\text{within groups}} = 205$).

Bear Cove Age Frequency

At site 1, clams ranged from age 2 to older than 14. The most numerous age class was age 7, which was 21.4% of the clams (Figure 9). Age 8 was 20.4%, followed by age 6 (14.5%), age 9 (12.1%), and age 10 (10.2%). Ages 2, 3, 4, 5, 11, 12, and +14 were all less than 10% of the clams aged.

Site 2 clam ages ranged from age 2 to 14. Age 8 clams were the most numerous age class (20.1%), followed by age 6 (18.2%), age 9 (15.7%), age 7 (15.3%), and age 5 (10.5%).

Sadie Cove

Sadie Cove is located south of the Homer spit. The bay is characterized by steep beaches that have varying sizes of gravel and rock substrate. The southwest side was sampled at 4 sites with 5 to 10 quadrats dug per site (Figure 10). Because the clam industry developed a market for butter clams, their density and population estimates are presented. Sites 1 and 2 were representative of the typical beach in Sadie Cove. Sites 3 and 4 were selected to target butter clams on the basis of the presence of numerous butter clam shells in windrows on the beach.

The southwest side of Sadie Cove was 9,106 m (5.7 miles) in length. The average slope length (mussel beds to water line) of the sites sampled in 1993 through 1994 was 7 meters. This gives an estimated clam habitat of 63,498 m².

1995 Sadie Cove Survey Results

The 1995 Sadie Cove survey was conducted on May 15 and 16 during -1.6 and -1.7 m (-5.4 and -5.7 ft) tides, respectively. During the 2 days, 27 quadrats were dug at 4 sites (Figure 10). For all stations the mean number of littlenecks was 36.9 legals and 16.4 sublegals totaling of 53.3 clams/m² (Table 7). The butter clams were 8.0 legals and 8.7 sublegals resulting in 16.7 total

clams/m². Littleneck population estimates for the southwest side of Sadie Cove were 3,023,192 legal and 1,347,688 sublegal totaling 4,370,800 clams. Average weight of legal littlenecks was 27.8 g resulting in a biomass estimate of 84,045 kg (185,121 lb). The average weight of sublegal littleneck was 7.9 g resulting in a biomass estimate of 10,647 kg (23,451 lb).

Butter clam relative density was 8.0 legals and 8.7 sublegals totaling 16.7 clams/m². Population estimates were 655,632 legals and 716,339 sublegals totaling 1,371,971 clams. Legal butter clam average weight was 156.2 g giving a biomass estimate of 102,410 kg (225,572 lb). Sublegal average weight was 22.5 g equaling a biomass estimate of 16,118 kg (35,501 lb).

Sadie Cove Length Frequency

Littleneck clams shell length ranged from 3.9 mm to 60.9 mm during the 1993 and 1995 surveys (Figure 11). Since the sites sampled were not the same between years no comparison were made.

Butter clams shell length ranged from 16.3 mm to 106.7 mm during the 1993 and 1995 surveys (Figure 12). Since different sites were dug between years no comparison were made.

DISCUSSION

Chugachik

The decline in abundance of Pacific littleneck legal clams first identified in the 1993 survey continued in 1994 and 1995. The relative density declined 50% from 67.2 to 33.8 clams/m² between 1992 and 1995 (Table 8). Since the 1994 survey there was a 7% decline.

The reduction in the sublegal clam density was even more dramatic with a 62% decline from 1992 to 1995. Between the 1994 and 1995 survey the numbers dropped 55%. Whether this decline was due to environmental conditions or fishing is speculative. Since the survey has only been conducted for 4 years, there has not been time to evaluate settlement success because the survey does not completely sample ages 1 through 4.

Recruitment to legal size has ranged from 7% to 12% of the estimated total number of clams (legals and sublegals) and averaged 10%. Between the 1992 and 1994 surveys, the commercial fishery harvested 59 % to 303% of the estimated number of clams recruited to legal size (Table 4). To keep the population stable, the harvest rates should be no greater than the average recruitment, 10% of the estimated total number of clams.

A survey in 1996 should be conducted to continue monitoring the clam population. This will aid in determining when and at what level Chugachik could may open to commercial harvest.

Bear Cove

The relative density of both sites in Bear Cove was high with site 2 (open) having 80.0 legals and 68.7 sublegals clams/m² and site 1 (closed) having 75.3 legals and 69.3 sublegals clams/m². The total density (legals + sublegals) was the second and third highest observed in the ADF&G clam surveys in Kachemak Bay (Table 8). The average shell length of legals at site 2 was larger than site 1.

There is evidence that digging clams during cold temperatures can affect the survival of clams. The commercial harvest from site 2 was 1,755 lb. On some tides digging occurred during subfreezing windy conditions. The ratio of dead versus live at clams site 2 (open) was significantly larger than site 1 (closed). High mortality of Japanese littlenecks (*Tapes philippinarum*) in British Columbia was attributed to freezing that occurred during periods of low tides (Bower 1992). The principal cause of mortality was damage to the gill consisting of necrosis of the ciliated epithelium and adhesion of the gill filament. The mortalities were higher in clams near the surface. Although there may be some site specific reason for the mortality observed at Bear Cove site 2 beach, it is prudent to restrict harvest during cold freezing conditions that could result in gill freezing and subsequent mortality. Additionally, bringing sublegal clams to the surface may adversely affect the clams.

Sadie Cove

Survey location sites were different between years; therefore, direct comparison of littleneck densities of legals and sublegals between years data may be misleading. Future surveys on the southwest side of Sadie Cove should be conducted at the same sites as the 1993 and 1994 surveys.

The emergence of a butter clam harvest led segments of the industry to target on butter clams thereby slowing the pace of littleneck clam harvest. In attempts to confirm the presence of beaches that were predominantly butter clams, sites 3 and 4 were dug. In all sites dug only one quadrat was composed of exclusively butter clams, which was a single sublegal clam. In all other quadrats, littlenecks were found with butter clams. Therefore, once the littleneck guideline harvest level was attained, all clam and mussel harvesting was closed in order to protect littleneck clams that would be dug during butter clam harvest.

Management Implications

The stock assessment at Chugachik has shown growth rates that are slow and variable with littleneck clams reaching legal size between age 6 and 10. When 1995 shell length data were applied to a von Bertalanffy's growth model legal size was reached between age 6 and 7. Between 1992 and 1995 recruitment to legal size has varied from 7% to 12% of the total number of estimated clams with an averaged 10%. The clam harvest between 1993 and 1994 exceeded recruitment and influenced the decline of the legal

segment of the population. With variable recruitment, annual harvest rates should not exceed recruitment and allow for some degree of natural mortality. Therefore, conservative harvest rates would be less than 10% of the population estimate.

In Bear Cove the winter mortality of unharvested clams was twice at site 2 (open) compared to site 1 (closed). The Board of Fisheries directed the department to manage the fishery conservatively. Therefore, to reduce the likelihood of the commercial fishery causing mortality to sublegal clams, winter harvest should be restricted during cold windy conditions.

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Table 1. Hardshell clam harvest for Kachemak Bay, Southern District, Cook Inlet Management Area, 1986 to 1995.

Year	No. of permits	No. of landings	Pacific littlenecks lb	Butter clams lb	Cockles lb	Total lb
1986	5	18	17,303	-		17,303
1987	8	69	12,214	206	2,347	14,767
1988	2	32	14,449	-	-	14,449
1989	9	41	2,584	13,675 ^a	3,581 ^b	19,840
1990	19	62	35,744	-	-	35,744
1991	19	78	47,486	85	-	47,571
1992	21	117	54,631	-	-	54,631
1993	33	159	63,676	-	-	63,676
1994	32	104	44,291	-	-	44,291
1995	21	93	66,723	4,267	(confidential)	71,025
Average	16.9	77	35,910	1,823	596	38,330

^a Includes 13,348 pounds sold as otter food as a result of Exxon Valdez oil spill.

^b Includes 1,982 pounds sold as otter food as a result of Exxon Valdez oil spill.

Table 2. Pacific littleneck clam harvest by DEC certified beach and ADF&G shellfish statistical area Southern District, Cook Inlet Management Area, from 1986 to 1995.

Year	Stat area 241-14			Stat area 241-15			Stat area 241-16						Southern District							
	Chugachik lb	Number of permits	Bear Cove lb	Number of permits	Other areas	Number of permits	Halibut Cove lb	Number of permits	Jakolof lb	Number of permits	Kasitsna lb	Number of permits	Tutka lb	Number of permits	not specified lb	Number of permits	Sadie lb	Number of permits	lb	permits
a 1986	17,303	5																	17,303	5
1987	12,214	8																	12,214	8
b 1988	14,449	2																	14,449	2
1989	-						-	-	2,584	9									2,584	9
c 1990	18,956	7					-	-	17,838	12									35,744	19
1991	15,349	5					-	-	1,464	3			19,807	9	10,816	3			47,586	19
1992	26,971	12					-	-	18,544	10	872	2	7,586	9	658	2			54,631	21
1993	44,313	20					-	-	13,029	11	597	1	5,737	9					63,676	33
1994	26,986	20					5,957	7	7,608	15	284	1	3,456	12					44,291	32
1995	-	-	26,941	17	4,566	11	-	-	-	-	-	-	(confidential)	2			25,644	20	66,723	21
d Average	17,654	9	26,941	17	4,566	11	851	1	8,724	9	351	1	9,147	8			25,644	20	35,920	17

a Chugachik Island was DEC certified 1986.

b Jakolof Bay, Kasitsna Bay, and Halibut Cove were DEC certified June 1988.

c Tutka Bay was DEC certified September 1990.

d Average since DEC certification.

Table 3. Number of Pacific littleneck clams by quadrat, and population estimate statistics from Chugachik Island survey, April 17 & 19, 1995.

	Quadrat	Legal	Sublegal	Total
	1	2	5	7
	2	3	2	5
	3	2	2	4
	4	1	2	3
	5	15	0	15
	6	21	5	26
	7	18	10	28
	8	0	2	2
	9	9	1	10
	10	2	31	33
	11	16	3	19
	12	16	10	26
	13	4	2	6
	14	5	2	7
	15	1	1	2
	16	7	6	13
	17	13	4	17
	18	8	0	8
	19	17	1	18
	20	2	2	4
	21	0	0	0
	22	8	5	13
	23	12	6	18
	24	2	11	13
	25	14	7	21
	26	3	0	3
	27	4	7	11
	28	11	1	12
	29	0	1	1
	30	6	3	9
	31	19	13	32
	32	23	7	30
	33	16	8	24
	34	12	6	18
	35	4	4	8
Total		296	170	466

-Continued-

Table 3. Continued.

	Legals	Sublegals	Total
Mean number of clams / quadrat	8.4	4.9	13.3
Mean number of clams / m ²	33.8	19.4	53.2
Total area considered (m ²)	61,254	61,254	61,254
Pop. est based on all quadrats	2,072,135	1,190,078	3,262,213
Upper range: (95% CI)	2,631,533	1,652,272	4,283,805
Lower range: (95%CI)	1,512,737	727,884	2,240,621
Percent error	27.0	38.8	23.8
Average weight per clam			
from lab samples (g)	27.6	8.2	20.5
Population estimate in kilograms	57,191	9,759	66,950
Population estimate in pounds	125,971	21,495	147,466

Table 4. Recruitment and harvest for legal littleneck clams at Chugachik Island, 1992 to 1995.

Year	Percent of total no. clams	Recruitment number of clams	Between Survey		
			Harvest number of clams	Harvest % of number recruited	Harvest % of total no. clams
1992	12%	862,123	368,681 ^a	43%	5%
1993	8%	447,365	265,529 ^b	59%	5%
1994	7%	317,827	962,768 ^c	303%	20%
1995	11%	373,098	(closed)		
Total		2,000,413	1,596,978		
Average ^d	10%			80%	

^a Harvest between July 1, 1991 and July 2, 1992.

^b Harvest between July 2, 1992 and May 6, 1993.

^c Harvest between May 7, 1993 and April 29, 1994.

^d Average of 1992 through 1995 estimated recruitment and estimated number of clams harvested, which includes 1995 when there was no harvest.

Table 5. Number of Pacific littleneck clams by quadrat, and population estimate statistics from Bear Cove site 1 (closed) collected April 20,1995, after the closure of the commercial fishery.

Site	Quadrat	Legals littlenecks	Sublegals littlenecks	Total live littlenecks	Dead whole littlenecks
1	1	28	8	36	2
	2	19	8	27	5
	3	20	23	43	2
	4	10	35	45	3
	5	22	22	44	14
	6	14	8	22	6
Total		113	104	217	32
Mean number of clams/quadrat		18.8	17.3	36.1	5.3
Mean number of clams/m ²		75.3	69.3	144.6	21.3
Total area considered (m ²)		1,010	1,010	1,010	1,010
Population estimate		76,087	70,027	146,113	21,547
Upper range:(95% CI)		96,369	106,236	177,483	36,243
Lower range:(95% CI)		55,804	33,817	114,744	6,851
Percent error		26.7	51.7	21.5	68.2
Average weight per clam					
from lab samples (g)		20.2	7.6	14.2	
Population estimate in kilograms		1,537	532	2,069	
Population estimate in pounds		3,385	1,172	4,557	

Table 6. Number of Pacific littleneck clams by quadrat, and population estimate statistics from Bear Cove site 2 (open) conducted April 20,1995, after the closure of the commercial fishery.

Site	Quadrat	Legals littlenecks	Sublegals littlenecks	Total live littlenecks	Dead whole littlenecks
2	1	16	5	21	4
	2	45	16	61	12
	3	14	3	17	2
	4	28	11	39	5
	5	2	1	3	5
	6	15	67	82	36
Total		120	103	223	64
Mean number of clams/quadrat		20.0	17.2	37.2	10.7
Mean number of clams/ m ²		80.0	68.7	148.7	42.7
Total area considered (m ²)		822	822	822	822
Population estimate		65,760	56,444	122,204	35,072
Upper range: (95% CI)		104,605	122,300	226,905	68,915
Lower range: (95% CI)		26,915	9,412	36,327	1,229
Percent error:		59.1	116.7	64.0	96.5
Average weight per clam					
from lab samples (g)		22.0	8.9	15.6	
Population estimate in kilograms		1,447	504	1,951	
Population estimate in pounds		3,187	1,110	4,297	

Table 7. Number of Pacific littleneck and butter clams by quadrat, and population estimate statistics from the Sadie Cove survey, May 15 & 16, 1995.

Site	Quadrat	Legal littleneck	Sublegal littleneck	Total littleneck	Legal butter	Sublegal butter	Total butter
1	1	0	0	0	0	0	0
	2	0	0	0	0	4	4
	3	33	2	35	7	3	10
	4	41	11	52	6	2	8
	5	3	0	3	1	0	1
	6	3	0	3	4	0	4
	7	7	1	8	5	2	7
	8	26	7	33	7	10	17
	9	1	0	1	0	2	2
	10	0	0	0	0	0	0
2	1	20	0	20	0	1	1
	2	3	0	3	0	1	1
	3	29	6	35	1	2	3
	4	38	14	52	6	3	9
	5	15	4	19	2	3	5
3	1	1	1	2	0	1	1
	2	0	0	0	0	1	1
	3	7	17	24	10	2	12
	4	0	2	2	0	1	1
	5	0	7	7	3	1	4
	6	2	3	5	0	1	1
	7	7	19	26	2	4	6
4	1	0	0	0	0	0	0
	2	0	0	0	0	0	0
	3	1	6	7	0	10	10
	4	10	6	16	0	3	3
	5	2	5	7	0	2	2
All sites	Totals	249	111	360	54	59	113

-Continued-

Table 7. Continued.

	Legal littleneck	Sublegal littleneck	Total littleneck	Legal butter	Sublegal butter	Total butter
Mean number of clams/quadrat	9.2	4.1	13.3	2.0	2.2	4.2
Mean number of clams/m ²	36.9	16.4	53.3	8.0	8.7	16.7
Total area considered (m ²)	63,742	63,742	63,742	63,742	63,742	63,742
Population estimate	2,351,372	1,048,202	3,399,574	509,936	557,152	1,067,088
Upper range:(95% CI)	3,594,601	1,573,844	5,168,445	790,964	803,128	1,594,092
Lower range:(95% CI)	1,108,142	522,559	1,603,701	228,908	311,177	540,085
Percent error	52.9	50.1	45.4	55.1	44.1	39.4
Average weight per clam						
from lab samples (g)	27.8	7.9	23.5	156.2	22.5	87.5
Population estimate in kilograms	65,368	8,281	73,649	79,652	12,536	92,188
Population estimate in pounds	143,983	18,240	175,969	175,445	27,612	203,057

Table 8. Results from the ADF&G Pacific littleneck clam surveys in DEC certified areas of Kachemak Bay, 1990 to 1995.

Location Year	Number of Sites	Number of quadrats dug	Relative density clams / square meter			Population est. million clams			Average shell length (mm.)		Average weight (grams)		Population est. pounds of clams /d		
			Legal	Sublegal	Total	Legal	Sublegal	Total	Legal	Sublegal	Legal	Sublegal	Total		
Chugachik															
1992	1	12	67.2	50.4	117.6	4.1	3.1	7.2	47	30.5	27.5	7.6	249,929	51,576	301,505
1993	1	16	41.0	48.8	89.8	2.5	3	5.5	46.8	31.4	30	9.4	165,951	61,827	227,778
1994	1	33	36.4	42.8	79.2	2.2	2.6	4.8	46.2	31.1	26.8	8.4	131,485	48,630	180,115
1995	1	35	33.8	19.4	53.2	2.0	1.2	3.2	47.2	30.4	27.6	8.2	125,971	21,495	147,466
Bear Cove (closed)															
(Numbers of clams one beach only)															
1995 (live)	1	6	75.3	69.3	144.6	76,087	70,027	146,114	43.1	30.5	20.2	7.6	3,385	1,172	4,557
(dead)			10.0	11.3	21.3										
Bear Island (open)															
(Numbers of clams one beach only)															
1995 (live)	1	6	80.0	68.7	148.7	65,760	56,444	122,204	44.6	31.4	22	8.9	3,187	1,110	4,297
(dead)			26.0	16.7	42.7										
Jakolof															
1992	6	42	22.1	2.2	24.3	1.6	0.2	1.8	48.5	32.1	34.1	10.1	110,025	4,358	114,383
1993	11	53	26.2	10.4	36.6	1.8	1	2.8	47.1	29.1	28.9	7.2	108,227	15,831	124,058
Tutka															
1990 /a (3 transects)	1	24	24.8	36.8	61.6				46.1	26.1	25.1	5.8			
1992	8	39	16.8	2	18.8				46.9	35.6	29.1	12.9			
1993	4	22	13.6	4.8	18.4				47.4	29.4	28.4	6.8			
Halibut Cove (Ismailof Island one beach)															
(Numbers of clams one beach only)															
1994	1	8	77.6	96.4	174.0	91,683	114,160	205,843	44.2	31.8	22.7	8.8	4,584	2,213	6,797
Sadie Cove (west side)															
1993	2	17	27.6	35.2	62.8	1.8	2.2	4.0	43.9	31.3	24.5	9.1	95,506	44,793	140,299
1994 /b	4	24	35.2	27.6	62.8	2.2	1.8	4.0	45.2	30.6	27.5	9.1	135,467	35,190	170,657
1995 /c	4	27	36.9	16.4	53.3	2.4	1.0	3.4	45.8	28.5	27.8	7.9	143,983	18,240	162,223

/a The 1990 Tutka survey substrate was washed through small screens. The methodology was different than the 1992-94 surveys.

The legal component may be comparable.

/b The 1994 2 sites were the same as 1993 and 2 were different.

/c The 1995 sites were different from 1992 and 1993.

/d 1lb = 0.454 kg

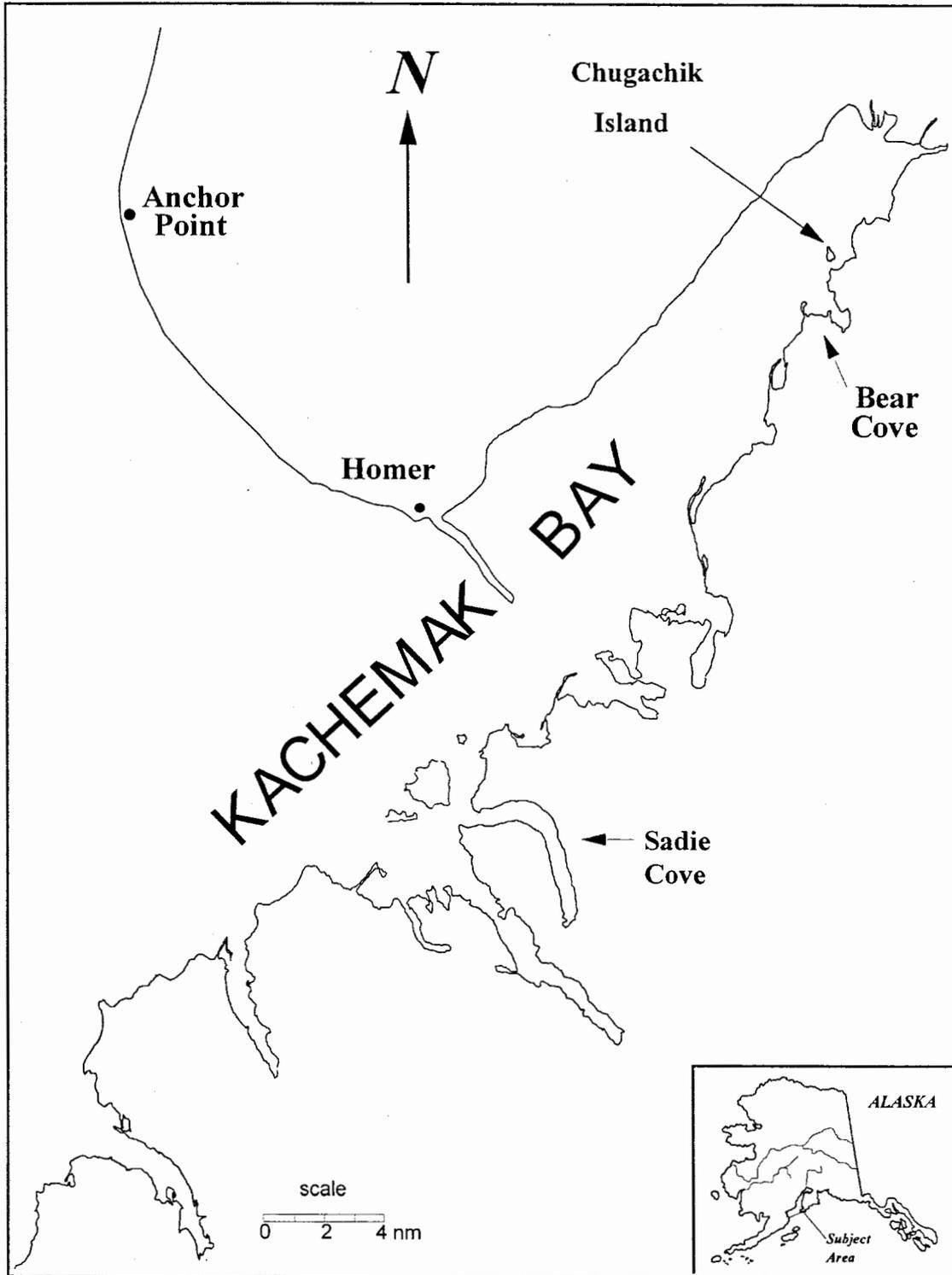


Figure 1. Location of the ADF&G clam survey in Kachemak Bay, Southern District of the Cook Inlet Management Area, 1995.

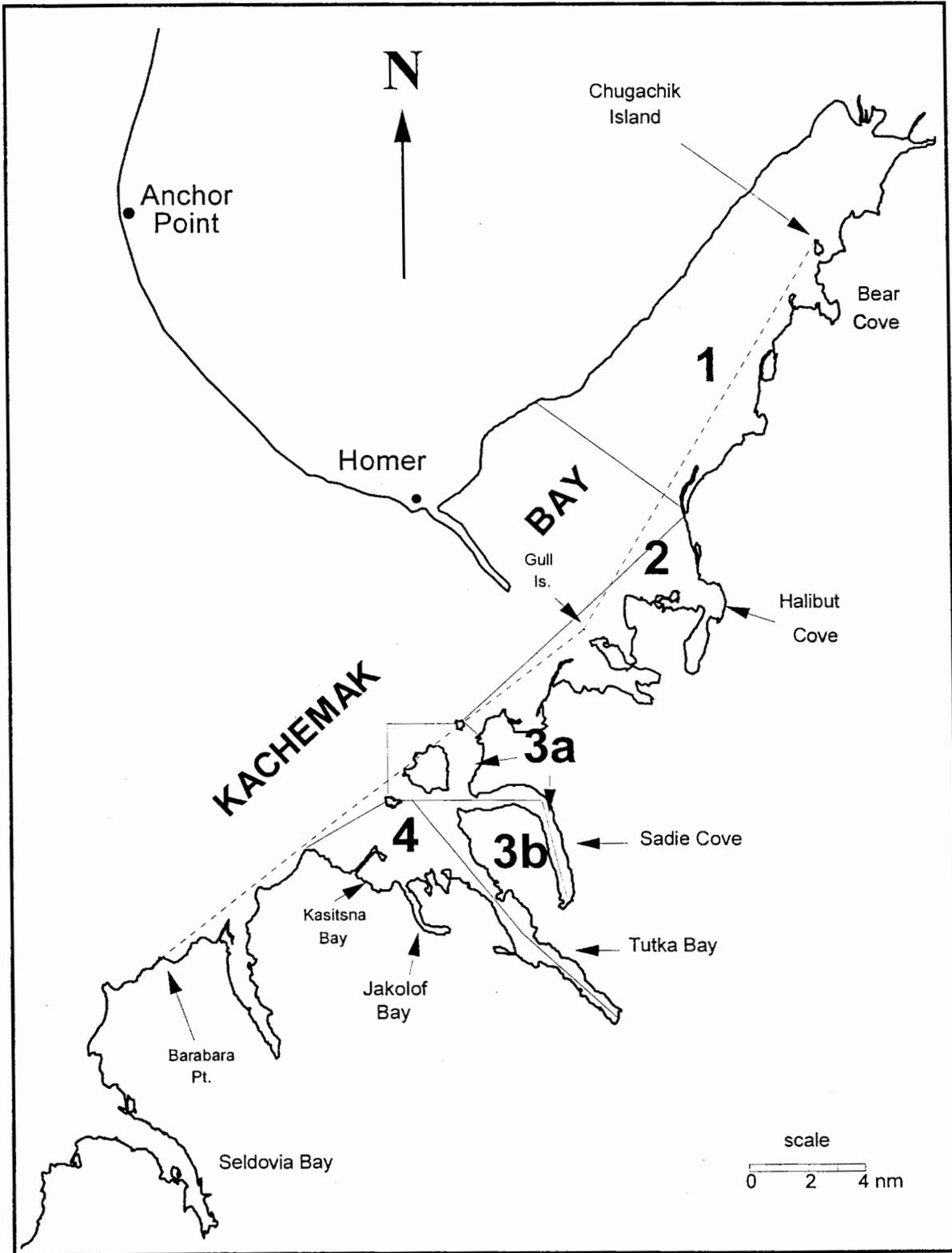


Figure 2. Clam and mussel subdistricts in the Southern District of the Cook Inlet Management Area.

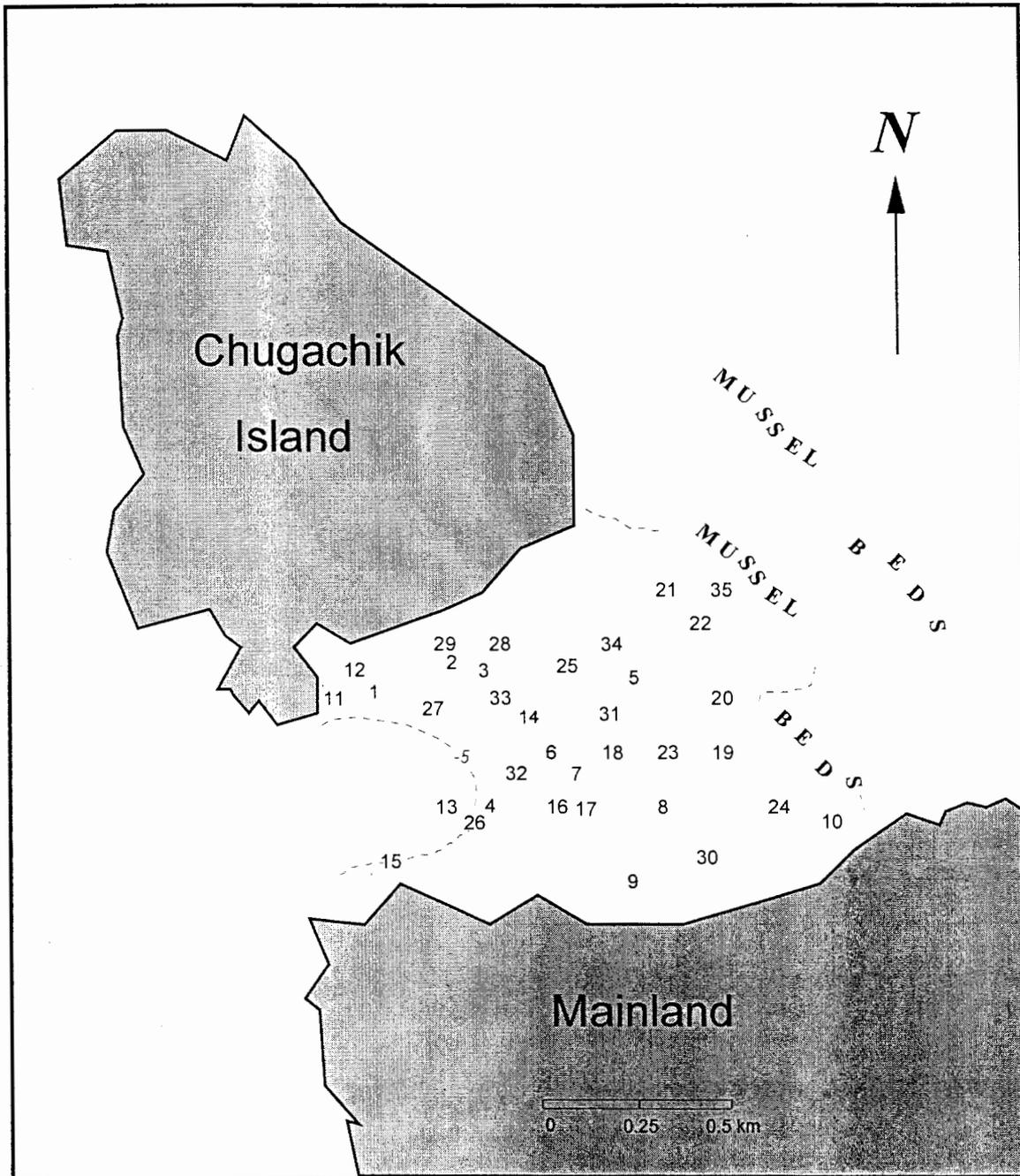


Figure 3. Location of the quadrats dug during the April 17 & 19, 1995 Chugachik Island survey.

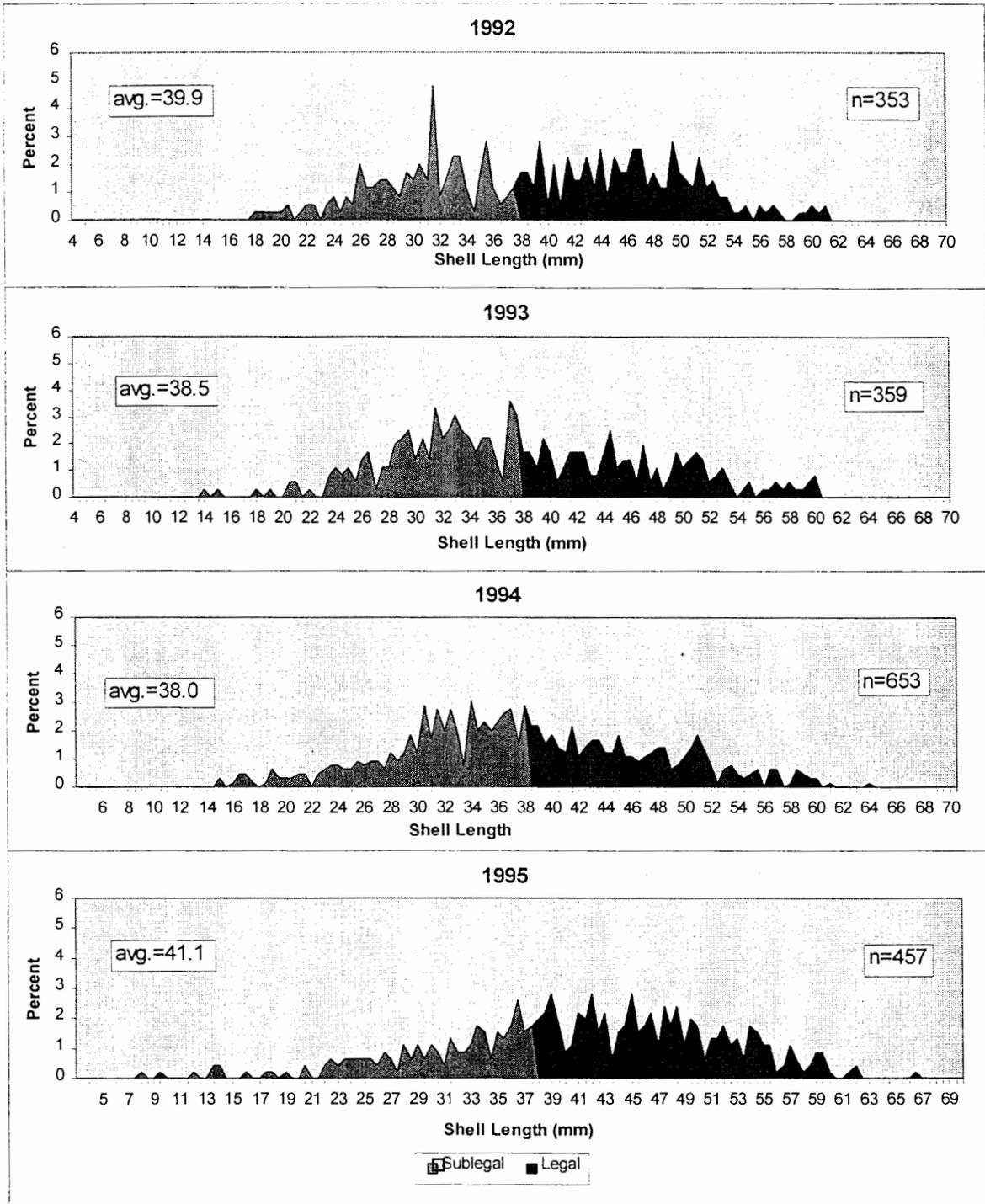


Figure 4. Percent shell length frequency of Pacific littleneck clams dug at Chugachik Island, 1992 to 1995.

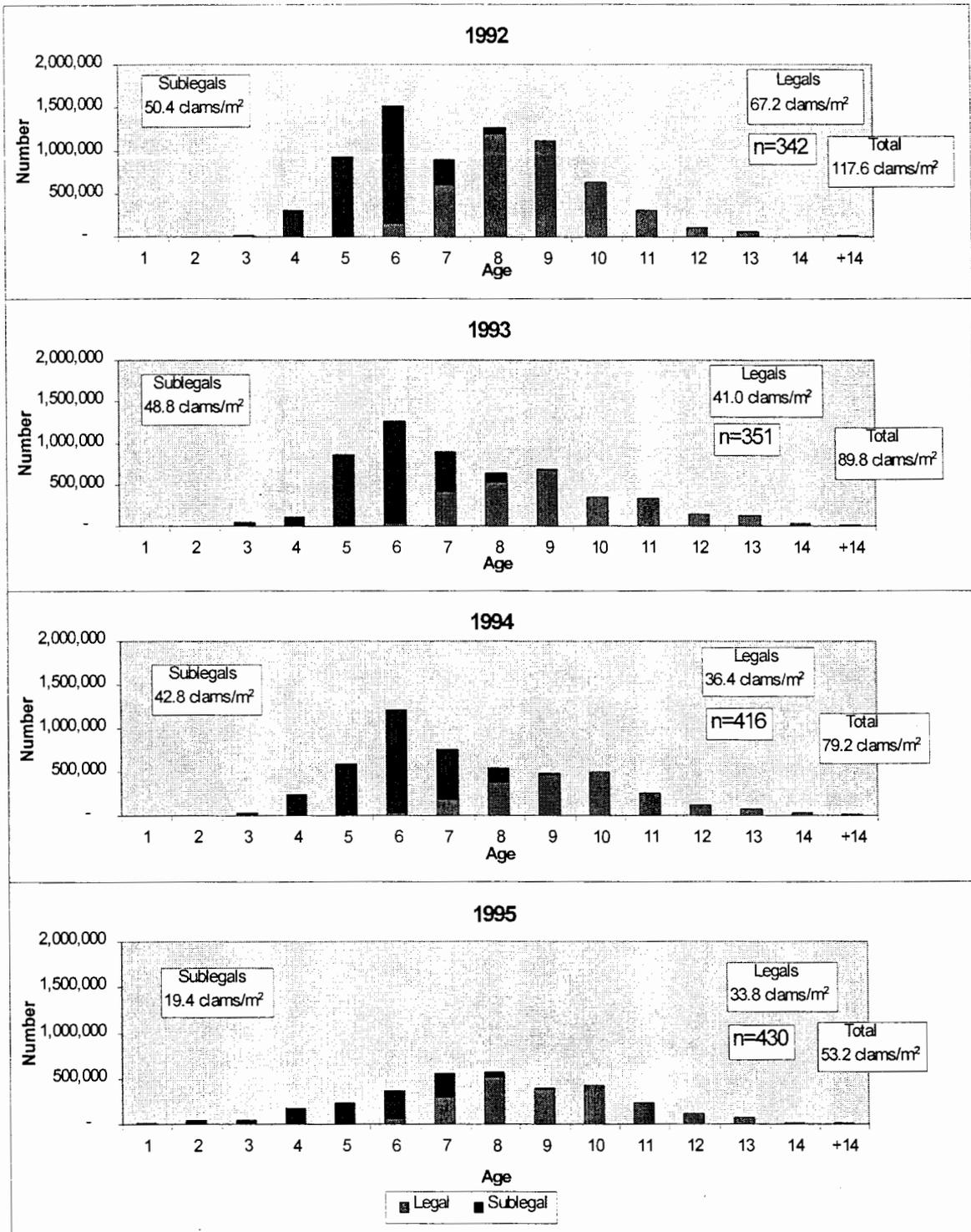
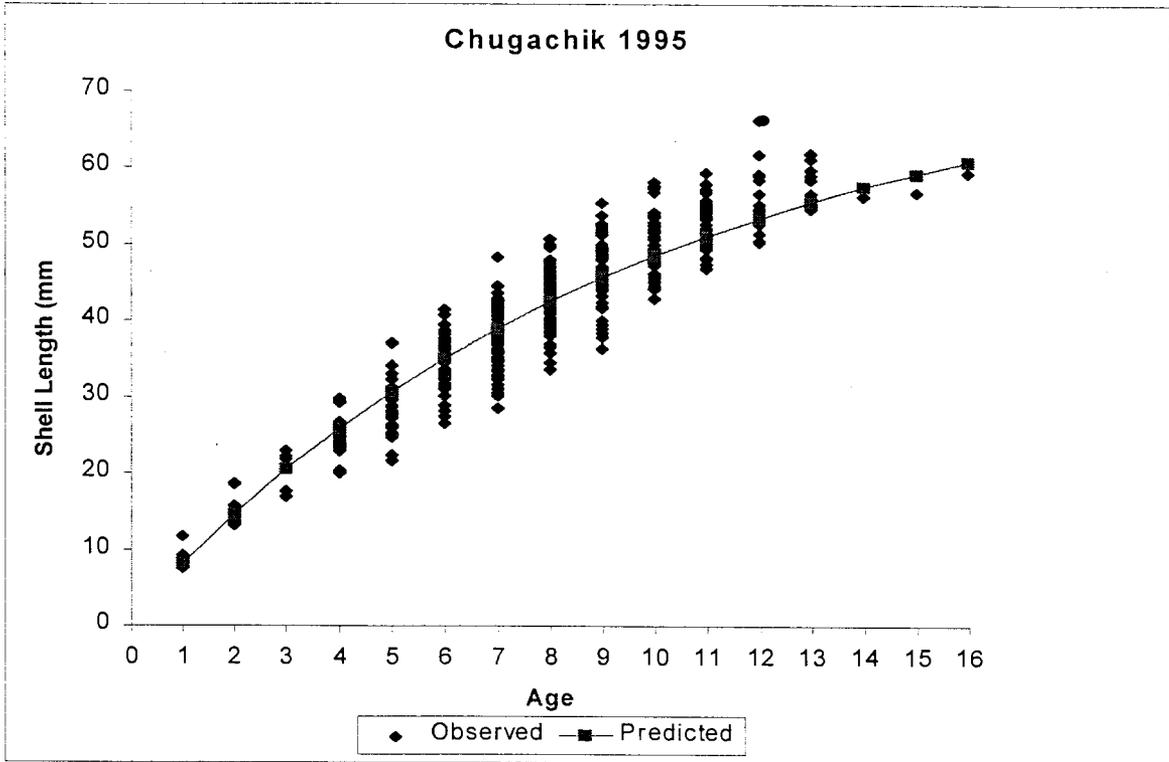


Figure 5. Estimated number of Pacific littleneck clams by age class from 1992 through 1995, Chugachik Island survey.



Age	Predicted shell length (mm)	Growth increment (mm)
1	8.14	8.14
2	14.68	6.53
3	20.57	5.89
4	25.89	5.32
5	30.69	4.80
6	35.02	4.33
7	38.93	3.91
8	42.45	3.53
9	45.63	3.18
10	48.50	2.87
11	51.09	2.59
12	53.43	2.34
13	55.54	2.11
14	57.44	1.90
15	59.16	1.72
16	60.70	1.55

Figure 6. Von Bertalanffy's length-age model for Pacific littleneck clams at Chugachik where $L_{(\infty)} = 75.0$, $K = 0.10$, $t_{(0)} = -0.12$, $SS = 33.75$ and $n = 430$.

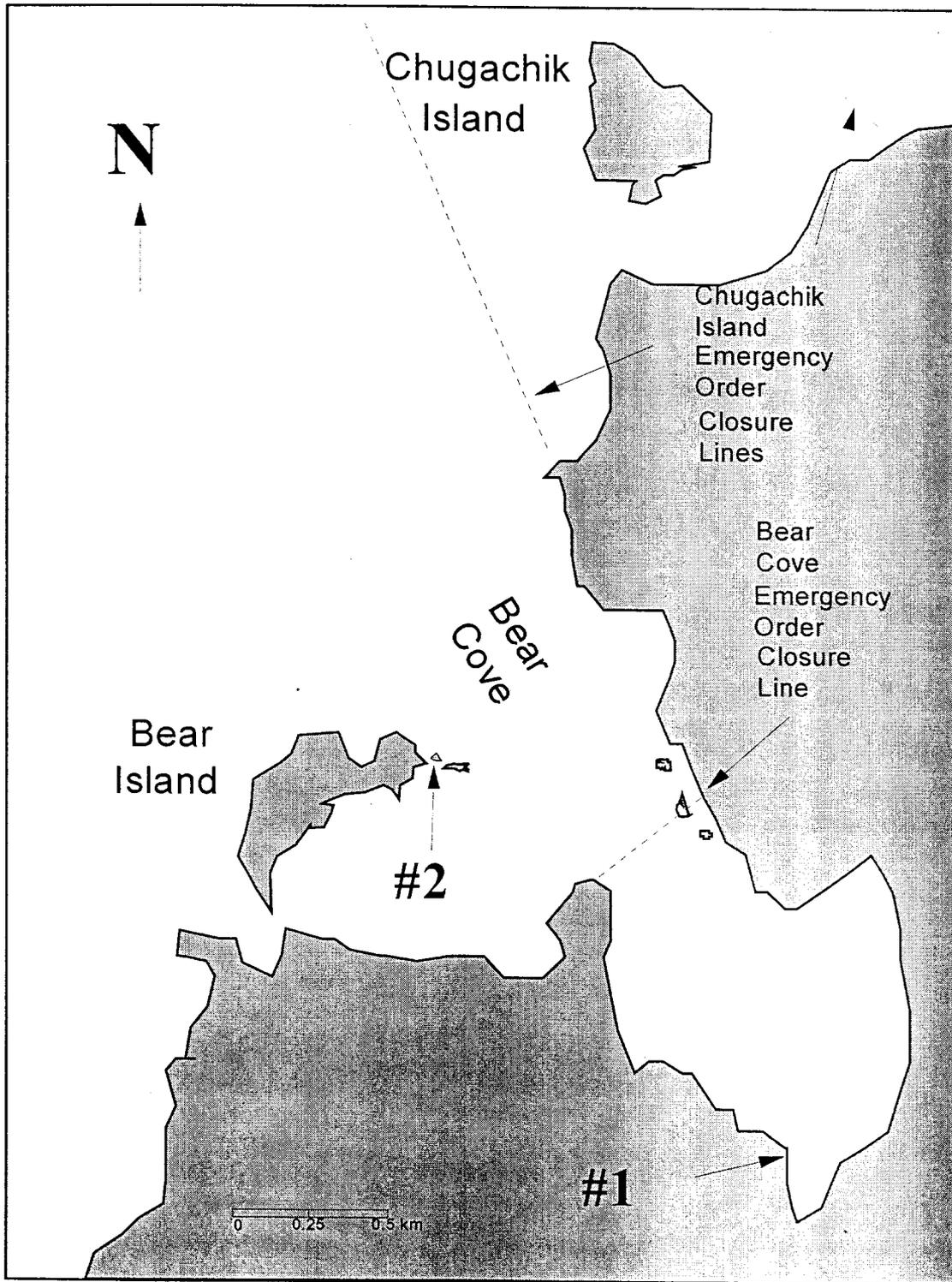


Figure 7. Location of sites #1 (closed) and #2 (open) dug in the Bear Cove survey, April 20, 1995, after the close of the commercial fishery.

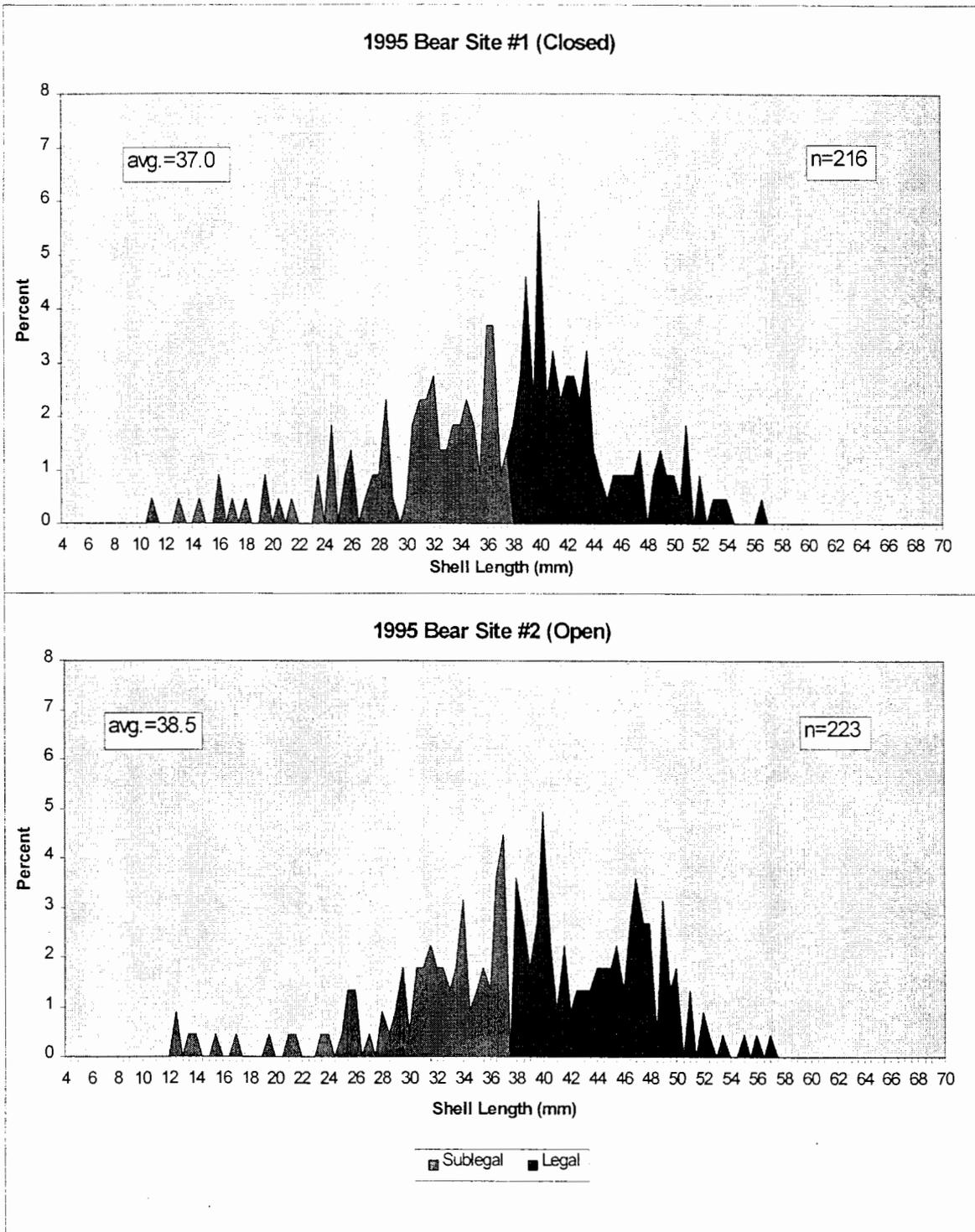


Figure 8. Percent shell length frequency of Pacific littleneck clams dug at Bear Cove site 1(closed) and site 2 (open), April 20, 1995.

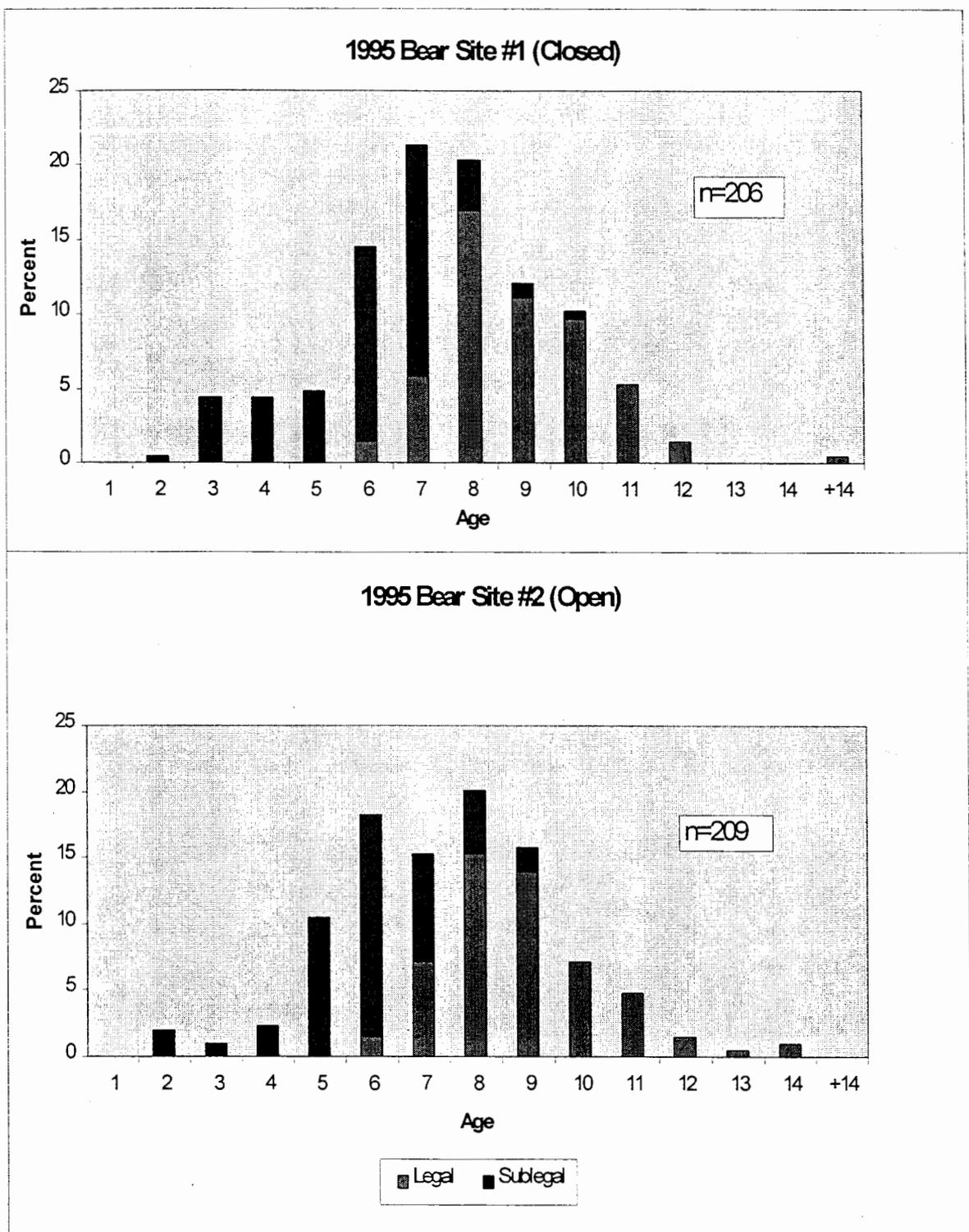


Figure 9. Percent age frequency of Pacific littleneck clams dug at Bear Cove site 1 (closed) and site 2 (open), April 20, 1995.

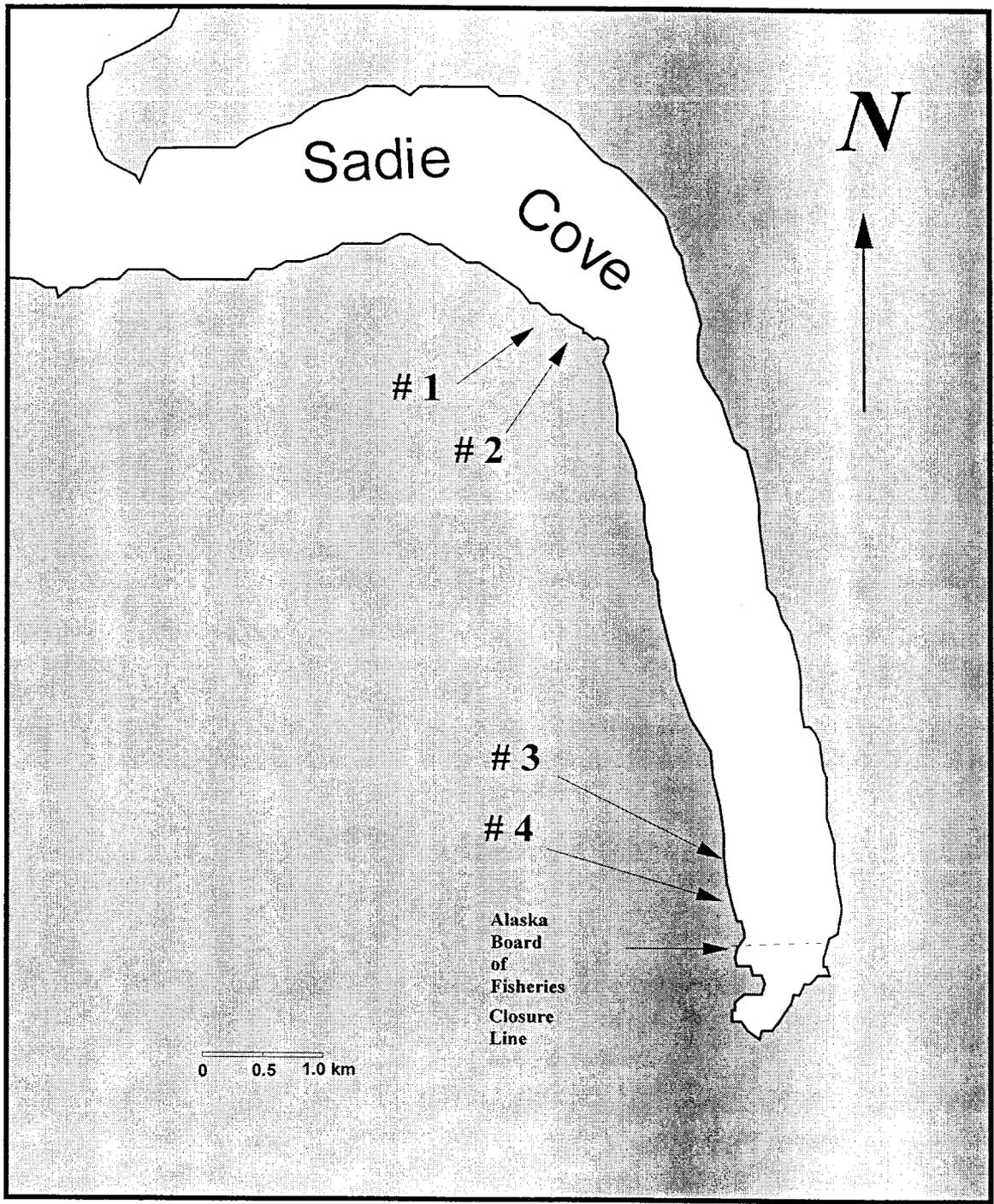


Figure 10. Location of the Sadie Cove sites #1, #2, #3, and #4 dug May 15 & 16, 1995.

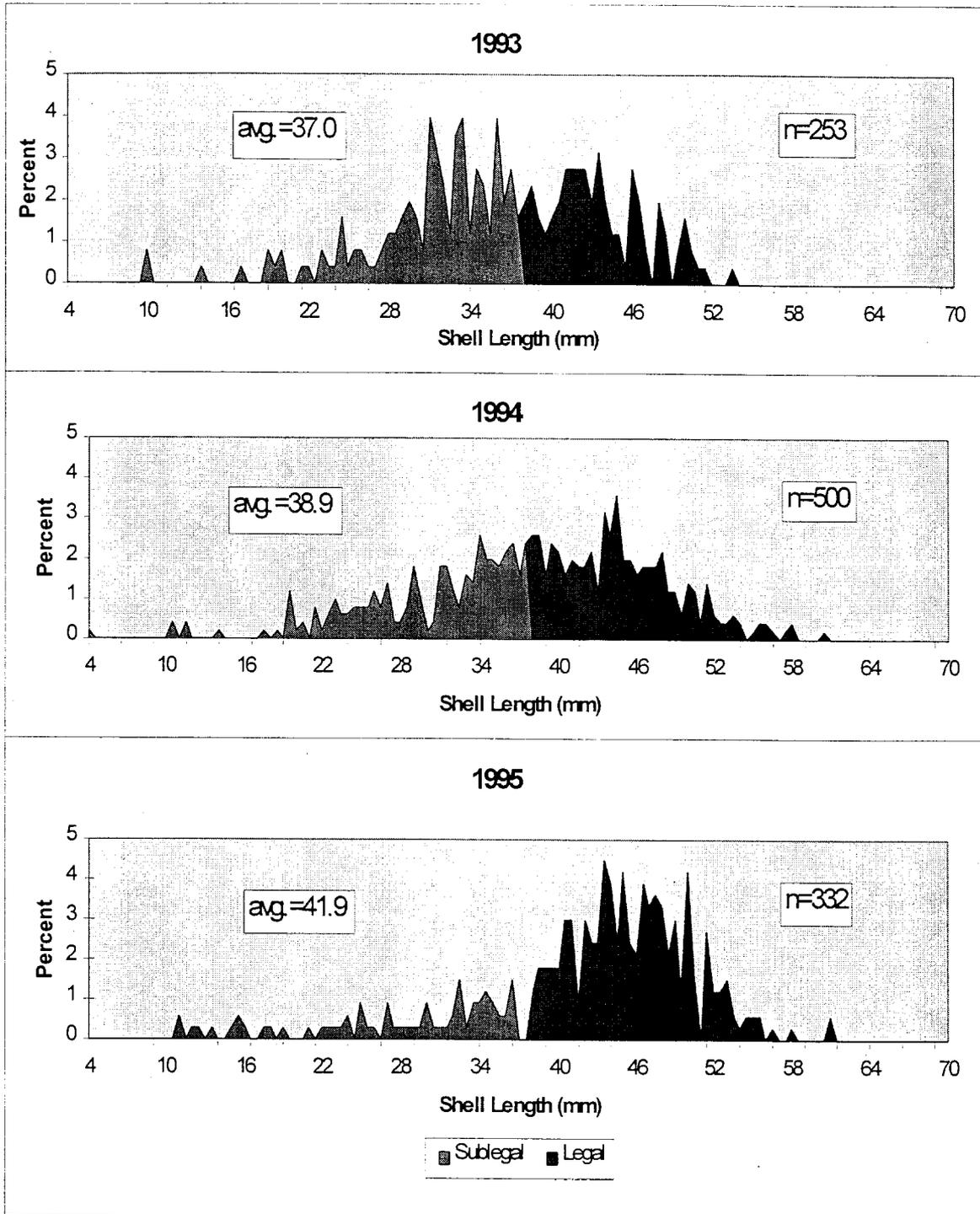


Figure 11. Percent shell length frequency from Pacific littleneck clams dug at Sadie Cove, 1993 to 1995.

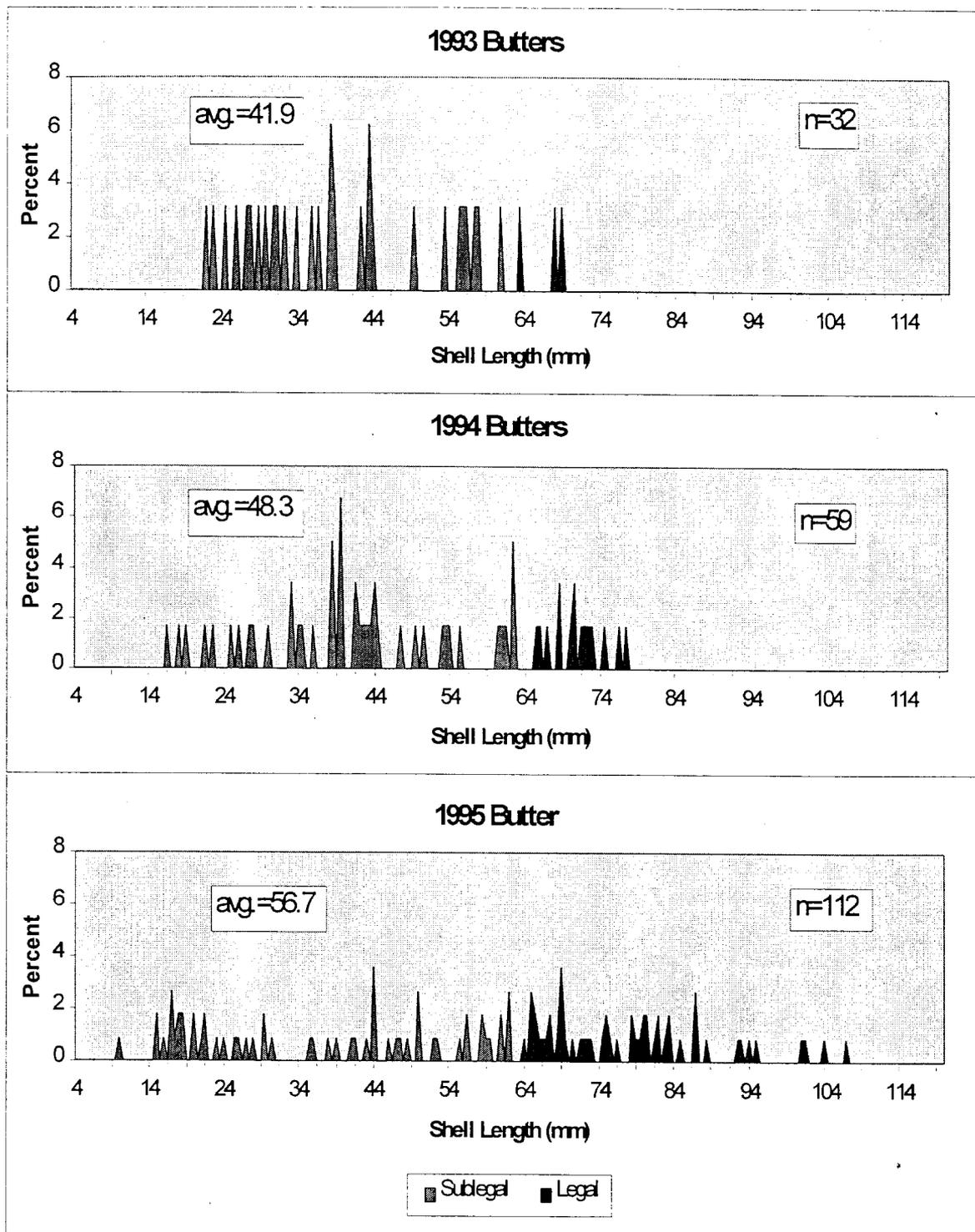


Figure 12. Percent shell length frequency from butter clams dug at Sadie Cove, 1993 to 1995.

Appendix A. Formulas and explanation for calculations of the abundance estimate for Pacific littleneck clams at DEC certified areas of Kachemak Bay, Southern District of the Cook Inlet Management Area.

Mean number of clams per quadrat $\bar{x}_q = \frac{\sum_{i=1}^N x_i}{N}$

Where: x_i = number of clams in quadrat_{*i*}.
 N = number of quadrats dug.

Mean number of clams per square meter = $\frac{\bar{x}_q}{(0.25)} = \bar{X}_m$

Area of a quadrat = $0.5 \times 0.5 = 0.25 \text{ m}^2$

Area of Clam habitat = A

Population estimate (number of clams) = $\bar{X}_m \times A = P_{(n)}$

Sample variance (SV) = $\frac{1}{N-1} \sum_{i=1}^N (x_i - \bar{x})^2$

where x_1, x_2, \dots, x_N are the number of clams per quadrat.

Standard deviation (SD) = \sqrt{SV}

Standard error of the mean (SE) = $\frac{SD}{\sqrt{N}}$

Standard deviation of the population estimate (Sp) = $\left(\frac{A}{0.25}\right) SE$

Percent error = $\frac{1.96 \times SE}{x} \times 100$

Percent error: 1.96 is the value from the normal distribution statistical table giving an approximate 90% confidence interval.

Population estimate (biomass) = $P_{(n)} \times W = P_{(W)}$

Where: W is the average weight of all legal or sublegal clams collected from a specific area, i.e. Chugachik.

Appendix B. Formulas and explanation for calculations for annual recruitment of littleneck clams at Chugachik Island.

1. The average percent abundance of legals by age, \bar{L}_i , class was calculated by pooling 1992 through 1995 age frequency, where:

$$\bar{L}_i = \frac{\sum_{j=1}^4 l_{ij}}{\sum_{j=1}^4 t_{ij}} .$$

Where \bar{L}_i was the average percent number of legals at age i , and l_i was the number of legals at age i for year j , and t_i is the total number of clams at age class i for year j , where $j = 1992$ to 1995 .

2. The average recruitment by age class = $\bar{R}_i = \bar{L}_i - \bar{L}_{(i-1)}$.

3. Annual recruitment = $R_j = \sum (\bar{R}_i \cdot P_{ij})$,

Where P_{ij} is the population estimate for age class i in year j .

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