

ALASKA DEPARTMENT OF FISH AND GAME
DIVISION OF COMMERCIAL FISHERIES

COOK INLET AREA

KACHEMAK BAY LITTLENECK CLAM ASSESSMENTS, 1990-1994



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INTRODUCTION

In 1992 the department began conducting clam surveys for Pacific littleneck clams (*Protothaca staminea*) at Alaska Department of Environmental Conservation (DEC) certified beaches in Kachemak Bay of the Southern District in the Cook Inlet Management Area (Figure 1). The surveys were designed to assess the impact of the commercial clam fishery on DEC certified beaches of Chugachik Island, Jakolof Bay, Tutka Bay and Halibut Cove. Sadie Cove was also surveyed to collect baseline data prior to DEC certification.

Fishery History

There was some commercial harvest of hardshell clams prior to statehood, however specific catch data are not available. Prior to harvesting clams for human consumption, an area must be certified for water quality by the DEC in accordance with the National Shellfish Sanitation Program. Additionally DEC used lot sampling to test for the presence of paralytic shellfish poisoning. The post-statehood commercial hardshell clam fishery began in 1986 when Chugachik Island near Bear Cove was certified by DEC (Kimker 1994). Since then Halibut Cove, Jakolof Bay (June, 1988), Kasitsna Bay (June, 1988), and Tutka Bay (September, 1990) have been certified. In December 1994 DEC drew a line from the 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.

The generic term hardshell clams refers to Pacific littleneck and butter clams (*Saxidomus giganteus*). With the exception of 1989

when most of the clams harvested were sold for sea otter food for a rehabilitation project resulting from the Exxon Valdez oil spill, the majority of the harvest was Pacific littleneck clams sold for human consumption. The harvests have ranged from 6,600 to almost 29,000 kg (14,500 to 64,000 lb). The number of participants has increased from 2 to 33 permit holders.

The littleneck clam harvest came from three statistical areas 241-14, 241-15 and 241-16 in the Southern District of the Cook Inlet Management Area (Table 1). Since the beginning of the fishery the majority of the commercial catch and effort has been at Chugachik Island, the only DEC certified beach in statistical area 241-14. The littleneck clam harvest from Chugachik Island has ranged from 5,545 to 20,118 kg (12,214 to 44,313 lb) and averaged 9,500 kg (21,000 lb).

Additional harvest came from Jakolof, Tutka, and Kasitsna Bays in statistical area 241-16. Jakolof Bay was certified in 1988 and the littleneck clam harvest has increased from 1,173 kg (2,584 lb) in 1989 to a high of 8,419 kg (18,544 lb) in 1992. The Jakolof Bay harvest has averaged 4,767 kg (10,500 lb). Tutka was certified in September 1990. The first documented harvest was in 1991 when 9 diggers made 28 landings with a resulting harvest of 8,865 kg (19,527 lb) of littleneck clams. The harvest declined in 1992 when 8 diggers made 25 landings harvesting 3,444 kg (7,586 lb) of littleneck clams.

In 1994 the first commercial harvest from Halibut Cove (statistical area 241-15) was approximately 2,700 kg (6,000 lb) of Pacific littleneck clams.

Conservation measures for the fishery are: a minimum size of 38 mm (1 1/2 in) for littleneck and 63 mm (2 1/2 in) for butter clams adopted by the Alaska Board of Fisheries in 1990. 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.
2. The subdistricts would be opened to fish on alternate years.
3. Areas were permanently closed to commercial fishing within the subdistricts.
4. Weekends, between 11:00 p.m. Friday and 1:00 a.m. Monday, are 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).

Surveys Goals

Surveys for Pacific littleneck were conducted at the following DEC certified areas: Chugachik Island (1992-94), Jakalof Bay (1992-93), Tutka Bay (1990, 1992-93), Halibut Cove (1994) and non-certified (prior to December 1994) Sadie Cove (1993-94).

The objectives of the surveys were as follows:

1. Measure the change in relative density (clams per square meter) of legal and sublegal clams over time.

2. Estimate the legal and sublegal littleneck clam segments of the population and determine how it changes over time.
3. Obtain littleneck clams for shell length frequency to determine if there is a reduction in numbers and size of legal clams.
4. Compile baseline data for age and growth of littleneck clams.

METHODS

Field Methods

Surveys were conducted on minus tides. Arrival at the beach or bay was scheduled for two 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. Therefore, depending on the magnitude of the tide, surveys ranged from 6:30 a.m. to 2:00 p.m. and lasted up to 4 hours.

Sampling was based on the number of littleneck clams present within a quadrat. Quadrats were randomly selected and dug at one or more sites in Chugachik, Jakolof, Tutka (1992 and 1993), and Sadie Cove surveys. Sites were selected by the appearance of good littleneck clam habitat or commercial digging activity. In the Ismailof Island and 1990 Tutka surveys the quadrats were systematically selected. A plastic pipe square 0.5 meter by 0.5 meter inside dimensions (19 5/8 by 19 5/8 in) was used to aid in the digging of 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 25 to 31 cm (10 to 12 in) or somewhat deeper if littlenecks clams were still found.

As the substrate was removed, all littleneck clams were placed in a bucket or bag. Subsequently the substrate was raked back into the hole while looking 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.

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

Since Chugachik Island, Jakolof Bay, Tutka Bay, Halibut Cove and Sadie Cove differ in character, the specific methodology used for estimating the area of clam habitat will be described by area in the results section.

Analytical Methods

Relative density measurements were made by pooling all the quadrats' clams within an area, e.g., Chugachik, to get the mean number of legal, sublegal, and total clams per quadrat. The mean was multiplied by four to expand the 0.25 square meter quadrat to one square meter.

Population estimates were made by multiplying the mean number of clams per square meter by the area of clam habitat, to give the number of clams in a specific area. The number of legal and sublegal were multiplied by the average weight of the respective size group to give a population estimate in pounds contained within an area (Appendix A).

To determine if there was a reduction or change in the average shell length of legal and sublegal littleneck clams over time, from a specific area, the null hypothesis was tested with the F test statistic.

RESULTS

Chugachik Island

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 south southeast side of the island during a low tide. Most of the harvest from Chugachik comes 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 long (between the mussel bed and the -5.0 ft tide line) and averages 190 meters in width between the island and mainland. The substrate is composed of a mixture of 1 to 8 cm (1/2 to 3 in) 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 two or three small streams.

The area of clam habitat was determined by interviewing some of the experienced clam diggers. The mussel beds and unproductive areas were removed from the area calculations. The area of clam habitat was measured with a planimeter from a United States Department of Interior, Geological Survey, Seldovia (C-3) NW Quadrangle, Alaska-Kenai Peninsula Borough, 1:25 000-scale Series (Topographic) map enlarged with a copying machine. The resultant Chugachik Island clam habitat area was estimated to be 61,254 square meters (15.1 acres).

Chugachik 1992 Survey Results

Chugachik Island beach was sampled on a -1.6 m (-5.25 ft) low tide on July 2, 1992. Figure 2 shows the location of the 12 quadrats sampled. The mean number of littlenecks was 67.2 legal and 50.4 sublegal clams per square meter. The total mean number of clams was 117.6 clams per square meter. The population estimate was 4,124,406 legal, 3,083,096 sublegal and totalling 7,207,502 clams. From the laboratory measurements the average weight of legal clams and sublegal was 27.5 g and 7.6 g, respectively. This yielded a population estimate of 113,468 kg (249,929 lb) of legal clams and 23,416 kg (51,576 lb) of sublegal clams (Table 2).

Chugachik 1993 Survey Results

On May 6, 1993, the Chugachik Island beach was surveyed on a -1.6 m (-5.25 ft) tide. Sixteen randomly selected quadrats were dug (Figure 3; Table 3). The mean number of legal littlenecks was 41.0 clams per square meter. The mean number of sublegal littlenecks was 48.8 clams per square meter. The total mean number of clams for all sizes was 89.8 clams per square meter. The population estimate was 2,511,396 legal clams, 2,986,111 sublegal clams, yielding a total population estimate of 5,497,507 littleneck clams. The average weight from laboratory measurements was 30.0 grams for legal size clams and 9.4 grams for sublegals. This yielded a population estimate of 75,3426 kg (165,951 lb) of legal littleneck clams and 28,069 kg (61,827 lb) of sublegal littleneck clams.

Chugachik 1994 Survey Results

The 1994 survey was conducted on April 27 and 29. Thirty-three randomly selected quadrats were dug (Figure 4; Table 4). On April 27, during a -1.7 m (-5.7 ft) tide, 22 quadrats were dug. In order to obtain at least 400 littleneck clams for age frequency

analysis, 11 more quadrats were dug on April 29. The data from all 33 quadrats were used for the population estimates. The mean number of legal littlenecks was 36.4 clams per square meter. There was a mean of 42.8 sublegal clams per square meter. The mean number of all sizes of littleneck clams was 79.2 per square meter. The population estimate was 2,227,402 legal and 2,628,335 sublegal yielding a total of 4,855,737 littleneck clams. The average weight of the legal clams was 26.8 g, resulting in a population estimate of 59,694 kg (131,485 lb) of littleneck clams. The average weight of the sublegal clams was 8.4 g, yielding a population estimate of 22,078 kg (48,630 lb) of littleneck clams.

Shell Length Frequency 1992-94

Shell lengths in 1992 through 1994 surveys ranged from 14 mm to 64 mm. There was a reduction in the legal percentage from 1992 to 1994. Legal clams were 56.7 percent of the 1992 survey, 45.1 percent of the 1993 survey and 45.2 percent of the 1994 survey. Sublegal clams were 43.3 percent of the 1992 survey, 54.9 percent of the 1993 survey and 54.8 percent of the 1994 survey (Figure 5). The average shell lengths of the legal clams between 1992 and 1994 were 47.0, 46.8, and 46.2 mm, respectively. The average legal shell lengths were not significantly different ($F = 1.058$, $F_{.05} = 3.00$, $P < 0.05$, $df_{\text{between groups}} = 2$, $df_{\text{within groups}} = 646$ or ∞). The average shell lengths of the sublegals between 1992 and 1994 were 30.5, 31.3 mm. and 31.1 mm, respectively. The sublegal average size were also the same ($F = 1.249$, $F_{.05} = 3.00$, $P < 0.05$, $df_{\text{between groups}} = 2$, $df_{\text{within groups}} = 657$ or ∞).

Age Frequency

Only clams from the 1992 and 1994 surveys were aged. There were clams from age 3 to 14 in the 1992 survey and age 3 to 14+ in the 1994 survey. In both years age 6 was the most numerous age class (Figure 6). Age 1 and 2 clams were not collected in the survey.

Feder and Paul (1973), Nickerson (1977) and 1990 Tutka Bay survey removed and washed the substrate from the quadrats through small meshed screens. This procedure was not followed during the current surveys due to time constraints and man power necessary to wash substrate. As a result age 1 and 2 clams were not found.

Jakolof Bay

Survey Area Description

Jakolof Bay is located south of Homer and east of Seldovia Bay (Figure 1). The entrance is narrow with fairly steep east side beaches composed of numerous coarse angular rocks with average sizes ranging from less than 2 cm to 16 cm. The west side beaches are less steep. Moving south on the west side, the beaches flatten out more at the southwest end near the air strip. A gravel bar or "island" forms at the head of the bay on a low tide of -0.9 m (-3.0 ft). The substrate was 2.5 to 5.0 cm with small rocks and sandy mud between the large rocks. The area around the island was a soft eelgrass mud flat that looked like poor littleneck habitat.

Jakolof Methods

Jakolof Bay was stratified to estimate littleneck clam population abundance in the DEC certified area. The strata were east side, west side, and the island. Stratification was based on the difference in beach slope length (water edge to mussel beds) for both the east and west side strata. The island stratum was separated out due to the -0.9 m (-3. ft) elevation and large size of clams reported by commercial fishermen. In each stratum 1 to 5 sites were sampled with 2 to 16 quadrats dug per site.

The area of clam habitat was determined by measuring the perimeter of the shoreline for east and west sides of Jakolof Bay with a map

measurer. This gave the beach width for the east and west side strata. At each site, the slope length of beach was measured by pacing the distance between the water line and blue mussels (3 paces = 2 m). Pacing was used for length measurements to expedite the survey with the limited manpower. The slope lengths from all sites were pooled together from the 1992 and 1993 surveys by the east and west strata to give the average slope length. The east side had a perimeter measurement of 1,750 meters (1.1 miles) with an average slope length of 9 meters, resulting in a estimated clam habitat area of 15,750 square meters (3.9 acres). The west side had a perimeter measurement of 2,500 meters (1.5 miles) and an average slope length of 31 meters, yielding an estimated clam habitat area of 77,500 square meters (19.1 acres).

The "island" stratum was measured by pacing the length and taking a width every 50 paces. The island was 160 meters long and varied from 13 to 37 meters wide resulting in an estimated area of 3,630 square meters (0.8 acres).

The stratified population estimate was calculated by stratum using the mean number of clams per square meter, by size group (legal, sublegal and total). The product was multiplied by the area of the stratum yielding an estimated number of clams in the stratum. The average weight of the legal and sublegal clams in a stratum was multiplied by the population estimate of the stratum, giving the estimated biomass, by size group, for each stratum. The results from each stratum were added together to give the population estimate for the DEC certified area in Jakolof Bay (Appendix B).

1992 Jakolof Bay Survey

Jakolof was first sampled on July 1, 1992 on a 1.5 m (-5.0 ft) tide. A total of 4 sites were sampled by digging 24 quadrats in four sites (Figure 7). Three sites (1a, 3a, and 4a) were on the east side of Jakolof Bay and one site (2a) was on the west side

near the old landing strip. Sites 1a and 4a were steep beaches composed of 10 cm and smaller coarse rocks with mud and sand between the rocks, with many clam spouts. Site 3a was a poor site with soft mud between the rocks. Site 2a was less steep than the other sites with kelp covering about 40 percent of the beach.

On August 28, 1992 a survey at the head of Jakolof Bay was conducted on a -1.2 m (-3.8 ft) low tide. Sites 1b and 2b were dug at the head of Jakolof Bay. Site 1b on the northeast side of Jakolof Bay was steep, composed of coarse 10 cm and smaller rock with sand and mud between rocks. Two quadrats were dug in site 1b. At the "island" (site 2b) 16 quadrats were sampled.

Data were pooled from the July 1 and August 28 surveys for the relative density, population estimates (numbers and pounds), length frequency, and age for 1992.

The "island" stratum had 25.8 legal, 0.5 sublegal and a total of 26.3 clams per square meter. The population estimate was 93,473 legals and 1,815 sublegals giving a total of 95,288 clams. The average weight of legal clams from the island was 38.0 g. This yielded a biomass estimate of 3,552 kg (7,824 lb) of legal clams. The average weight of the sublegals was 9.3 grams yielding a biomass estimate of 17 kg (37 lb) (Table 5).

The east side stratum had a mean of 21.0 legals and 3.5 sublegals resulting in a total of 24.5 clams per square meter. The population estimate was 82,688 legals and 13,781 sublegals totalling 96,469 clams. The average weight for the legal clams from the east strata was 31.4 g resulting in a population estimate of 2,596 kg (5,719 lb) of clams. The sublegal segment had an average weight of 8.5 g giving a population estimate of 117 kg (258 lb) (Table 6).

The west stratum had a mean of 18.0 legals and 2.8 sublegals yielding a total of 20.8 clams per square meter. The population estimate was 1,395,000 legals and 217,000 sublegals totalling 1,612,000 clams. The average weight of the legal clams was 31.4 g yielding a population estimate of 43,803 kg (96,482 lb). The sublegal clams had an average weight of 8.5 g yielding a population estimate of 1,845 kg (4,063 lb) (Table 7).

The mean number of clams for all the Jakolof Bay DEC certified area were 22.1 legals and 2.2 sublegals totalling 24.3 clams per square meter (Table 7).

The stratified population estimate for the DEC certified beaches in Jakolof Bay was 1,571,161 legal and 232,596 sublegal clams. The biomass population estimate was 49,951 kg (110,025 lb) of legal and 1,979 kg (4,358 lb) of sublegal clams (Table 7).

1993 Jakolof Bay Survey

The 1993 Jakolof Bay survey was conducted on June 2 through 4, on low tides measuring -0.9, -1.2 and -1.4 m (-2.82, -3.92 and -4.46 ft). Over the course of the 3 days, 5 sites were surveyed on the east side stratum with 2 to 7 quadrats dug per site. The west side stratum had 5 sites sampled with 5 to 8 quadrats dug per site. The "island" stratum had 16 quadrats (Figure 8).

The "island" stratum had a mean of 19.0 legals and 1.3 sublegals resulting in 20.3 total clams per square meter. The population estimate was 68,970 legals and 4,538 sublegals totalling 73,508 clams. The average weight of the legal clams was 35.7 g giving a population estimate of 2,462 kg (5,423 lb). The sublegal average weight was 9.8 g giving an average weight of 44 kg (98 lb) (Table 8).

The east side stratum had a mean of 24.4 legals and 9.5 sublegals resulting in a total of 33.9 clams per square meter. The population estimate was 384,000 legals and 150,000 sublegals yielding a total of 534,000 clams. The average weight for the legal clams was 24.5 g equalling a population estimate of 9,408 kg (20,722 lb) of clams. Sublegal clams averaged 9.1 g resulting in a population estimate of 1,365 kg (3,007 lb) (Table 9).

The west side strata had a mean of 17.9 legals and 10.5 sublegals yielding 28.4 total clams per square meter. The population estimate was 1,385,313 legals and 813,750 sublegals totalling 2,199,063 clams. The average weight of the legal clams was 26.9 g giving a population estimate of 37,265 kg (82,081 lb) of clams. The average weight of sublegal clams was 7.1 g yielding a population estimate of 5,778 kg (12,726 lb) (Table 10).

The legal population estimate for all Jakolof Bay strata was 1,838,283 clams weighing 49,135 kg (108,227 lb). The sublegal population estimate was 968,288 clams weighing 7,187 kg (15,831 lb) (Table 10).

Shell Length Frequency

The shell length of all clams dug in the 1992 Jakolof survey ranged from 19.2 to 63.3 mm with an average 47.2 mm. Legal clams comprised 91.6 percent of the clams dug. The legal clams average shell length was 48.5 mm. Sublegals were 8.4 percent of the clams dug. The average length of the sublegals was 32.1 mm (Figure 9).

In 1993, Jakolof survey shell length ranged from 11.4 to 61.5 mm. The average shell length of all clams was 41.9 mm. The legal clams were 70.8 percent of the clams dug and the average shell length was 47.1 mm. Sublegal clams were 29.2 percent of the total and the average shell length was 29.1 mm (Figure 9).

Between the 1992 and 1993 survey, the small reduction in the average legal shell length from 48.5 to 47.1 was statistically significant ($F = 8.83$, $F_{.05} = 3.84$, $P < 0.05$, $df_{\text{between groups}} = 1$, $df_{\text{within groups}} = 553$ or ∞). Although the sublegal average shell length was large from 32.1 to 29.1 mm. The reduction in average length was not significant ($F = 3.38$, $F_{.05} = 3.84$, $P < 0.05$, $df_{\text{between groups}} = 1$, $df_{\text{within groups}} = 151$ or ∞) (Note the F test was rechecked to verify the results).

Age Frequency

Only 247 clams were aged from the 1992 survey and 119 from the 1993 survey. The average age declined from age 9 in 1992 to age 8 in the 1993 survey. In 1992, clams first were legal size at age 5 and were fully recruited by age 10. In 1993, clams were first legal size at age 6 and fully recruited at age 11 (Figure 10).

Tutka Bay

Survey Area Description

Tutka Bay is the next large bay east of Jakolof Bay, past Little Jakolof and Little Tutka Bays. There are numerous beaches on the east and west side of the bay and a large beach forms at the entrance to Tutka Bay Lagoon. Most of the beaches are steep. The substrate on some beaches varies from a mixture of small rocks (1 to 2 cm and smaller), sand, and shells to others that are composed of large rocks and a mixture of clay, sand, and mud.

Tutka Methods

Population estimates were not done in Tutka Bay due to the limited number of sights sampled in 1990, 1992, and 1993. The shoreline inside the DEC certified area of Tutka Bay was measured with a map

measurer and found to be 30,820 meters, (19 miles). However, slope length measurements were not conducted in enough locations to determine the area of clam habitat. Therefore, only the mean legal and sublegal clams per square meter will be presented.

In 1990, as part of the Exxon Valdez Oil Spill studies, Tutka Bay was surveyed inside the DEC certified area at site A north of the entrance to Tutka Bay Lagoon (Trowbridge, ADF&G, P.O. Box 669, Cordova, AK 99574-0669, personal communication)(Figure 11). Three transects were set perpendicular to the shoreline.

To determine the location of the first quadrat, a small trench was dug toward the waterline starting at a tide height of +2.4 m (8 ft). At the occurrence of the first clam, 8 quadrats were dug systematically in the transect between highest tide elevation and the lowest tide height that was possible to dig. The quadrat sampling consisted of removing all substrate from a 0.5 x 0.5 meter (19 1/2 by 19 1/2 inches) quadrat. Sifting the substrate through a 6 mm (1/4 inch) and 3 mm (1/8 inch) screens with the aid of a portable pump and a shower head. Since the substrate was washed through screens, all or most of the smaller clams were found. In the surveys conducted after 1990, the substrate was not washed through screens and some of the smaller sublegal clams were missed due to their size. Therefore, the sublegal component of the data were not comparable to the other data sets.

Surveys conducted in 1992 and 1993 sampled 4 to 8 sites. The sites were selected based on appearance of good littleneck clam habitat and evidence of commercial harvest. The quadrats were randomly chosen by tossing the pipe quadrat between the waterline and the blue mussel beds. The substrate excavated within the quadrat was not washed through screens.

1990 Tutka Survey

The survey was conducted on June 24, 1990 on a -1.6 m (-5.3 ft) tide. Twenty-four quadrats were dug in the 3 transects at site A (Figure 11). There were 24.8 legals and 36.8 sublegals totalling 61.7 clams per square meter (Table 11).

1992 Tutka Survey

The survey was conducted on July 31, 1992 on a - 1.5 m (-4.9 ft) tide. Thirty-nine quadrats were dug at 8 sites with 2 to 8 quadrats dug per site (Figure 11). There was a mean of 16.6 legals and 2.1 sublegals yielding 18.7 total clams per square meter (Table 12).

1993 Tutka Survey

On May 7, 1993 Tutka was surveyed during a -1.6 m (-5.2 ft) tide. Twenty-two quadrats were dug at 4 sites with 4 to 8 quadrats dug at each site (Figure 12). There was a mean of 13.6 legals and 4.8 sublegals giving a total of 18.4 clams per square meter (Table 13).

Shell Length Frequency

The 1990 shell lengths ranged from 5.5 to 56.8 mm and averaged 34.2 mm. The legal sized clams were 40.4 percent and averaged 46.1 mm. The sublegal size were 59.6 percent of the clams and averaged 34.2 mm (Figure 13).

In 1992 the shell length ranged from 31.5 to 64.5 mm. The legal clams were 89 percent of the clams and averaged 46.7 mm. The sublegals were 11 percent of the clams and averaged 35.6 mm (Figure 13).

The 1993 shell length ranged from 15.3 to 59.3 mm. The average for all sizes was 42.3 mm. The legals were 73.3 percent of the clams and averaged 47.4 mm. The sublegal clams were 26.7 percent of the clams and averaged 29.4 mm (Figure 13).

The average size of the legals was the same between the 1990, 1992, and 1993 surveys ($F = 1.76$, $F_{.05} = 3.00$, $P < 0.05$, $df_{\text{between groups}} = 2$, $df_{\text{within groups}} = 351$ or ∞). The average sublegal sizes were different between surveys ($F = 10.02$, $F_{.05} = 3.00$, $P < 0.05$, $df_{\text{between groups}} = 2$, $df_{\text{within groups}} = 262$ or ∞).

Age Frequency

The 1990 ages ranged from 1 to 14. Age 5 was the dominant age class encompassing over 20 percent of the clams. Age 4 and 6 were over 10 percent of the clams aged. The clams began reaching legal size at age 5 and by age 9 all clams were legal size (Figure 14).

In the 1992 survey, clams ranged from age 4 to 14. The dominant age class was age 8 followed by age 9 and 10. Similar to 1990, clams began to reach legal size at age 5, and by age 9 all clams were legal size.

The 1993 survey clams ranged from age 3 to 13. Age 9 was the dominant age class. Ages 6, 7, and 11 were also strong age groups.

Halibut Cove

Survey Area Description

Halibut Cove is located east southeast of the Homer Spit. The DEC certified area is bounded by a line from the north by the marker light on Ismailof Island, east to the mainland. The western boundary is the southeastern tip of Ismailof Island south to the

mainland (Figure 15). Halibut Cove Lagoon was closed by the Board of Fisheries in 1994. The majority of the commercial harvest has come from Ismailof Island.

There are 3 beaches located on Ismailof Island. Beach A was surveyed on the south end of Ismailof Island. The beach was 155 meters long (north to south). The north end was 87 meters long by 5 meters wide (from large boulders in mussel beds to waterline). The substrate was larger angular rocks. The south end was 68 meters long by 11 meters wide (waterline to +1.5 m (5.0 ft) elevation). The substrate was composed of smaller rocks and sand. The total area for beach A was 1,183 square meters (0.3 acres). Beach A is 1/3 to 1/4 of the area of littleneck clam habitat for the DEC approved area on Ismailof Island.

Beach B at the north end of Ismailof was 217 meters long and 7 meters wide (2,702 square meters). The area between beach A and B forms a cove which appeared to be good littleneck clam habitat. Although it was not measured, it is likely to be as large as beach B because it is less steep (ie. wider) than beach B. Therefore, the total area of clam habitat on Ismailof Island is estimated to be 8,000 to 10,800 square meters.

Halibut Cove Methods and Results

On August 23, 1994, during a -0.4 m (-1.4 ft) tide, 8 quadrats were dug on Ismailof Island location A (Figure 15). The quadrats were selected in a systematic manner. Quadrats were dug every 20 paces. In order to complete the survey in the time available spacing was expanded to every 30 paces. Each successive quadrat was dug a foot higher in elevation. The mean density of legal clams was 77.5 per square meter. There were 96.5 sublegal clams per square meter and a total of 174 clams per square meter. This yields a population estimate of 91,683 legals and 114,160 sublegals totalling 205,843 clams for beach A on Ismailof Island. When

expanded by the average weight of legals (22.7 g) and sublegals (8.8 g), the resultant population estimate was 2,081 kg (4,584 lb) of legal clams and 1,005 kg (2,213 lb) of sublegal clams (Table 14).

If the densities of the other areas of Ismailof Island were similar to beach A, the legal clam total biomass estimate would be 8,308 kg (18,300 lb).

Shell Length Frequency

The clam shell length ranged from 17.6 to 55.9 mm. The legals composed 44.3 percent of the clams and the average shell length was 44.9mm. The sublegal component was 55.7 percent of the clams dug. The average shell length of the sublegal clams was 31.8 mm (Figure 16).

Sadie Cove

Survey Area Description

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, typically smaller with less mud than substrate found in Jakolof Bay. The west side of the bay was sampled on the south side of the alluvial fan peninsula at the bend of the bay (site 1a) and south of the bend in 1993 (site 2a) (Figure 17). In 1994, both sides of the alluvial fan peninsula were sampled (sites 1b and 2b). Also in 1994, the south side of the bay was sampled between the entrance of the bay and the alluvial fan peninsula (sites 3b and 4b).

The west side was 9,106 meters (5.7 miles) in length. The average slope length of the sites sampled in 1993 and 1994 was 7 meters.

This give an estimated clam habitat of 63,742 square meters (15.8 acres).

Since no sites were dug on the east side of Sadie Cove, a population estimate was made only for the west side.

1993 Sadie Cove Survey Results

On June 4, 17 quadrats were dug on a -1.4 m (-4.5 ft) tide at two sites (1a and 2a). At site 1a, 7 quadrats were dug. Ten quadrats were dug at site 2b (Figure 17). The mean numbers were 27.6 legals and 35.2 sublegals totalling 62.8 clams per square meter (Table 15). The population estimate for the west side was 1,769,778 legals and 2,234,720 sublegals yielding a total of 4,004,498 clams. The average weight of the legal clams was 24.5 g resulting in a population estimate of 43,360 kg (95,506 lb) of clams. The average weight of the sublegal clams was 9.1 g giving a population estimate of 20,336 kg (44,793 lb).

1994 Sadie Cove Survey Results

The 1994 Sadie Cove survey was conducted on September 6 and 7 on two -0.6 m (-2.0 and -1.9 ft) tides. During the 2 days, 24 quadrats were dug at 4 sites (1b, 2b, 3b and 4b) (Figure 17). The means were 35.2 legals, and 27.6 sublegals totalling of 62.8 clams per square meter (Table 16). The population estimate for the west side of Sadie Cove was 2,236,434 legal and 1,755,637 sublegal clams. The average weight of the legal clams was 27.5 g yielding a population estimate of 61,502 kg (135,467 lb). The sublegal clams average weight was 9.1 g resulting in a population estimate of 15,976 kg (35,190 lb).

Shell Length Frequency

The 1993 shell length ranged from 10.5 mm. to 53.9 mm. The average size for all clams was 37.0 mm. Legals were 45.4 percent of the clams and the shell length averaged 43.9 mm. The sublegals composed 54.6 percent and shell length averaged 31.3 mm. The 1994 shell length ranged from 4.0 mm to 60.8 mm. The average for all clams was 39.0 mm. The legal component of the clams was 56.9 percent and average shell length was 45.2 mm. The sublegal clams were 43.1 percent of the clams. The average size was 30.6 mm (Figure 18). The average legal shell length was different between 1993 and 1994 ($F = 7.20$, $F_{.05} = 3.84$, $P < 0.05$, $df_{\text{between groups}} = 1$, $df_{\text{within groups}} = 398$ or ∞). The sublegal average shell length between 1993 and 1994 were the same ($F = 1.40$, $F_{.05} = 3.84$, $P < 0.05$, $df_{\text{between groups}} = 1$, $df_{\text{within groups}} = 430$ or ∞).

DISCUSSION

Chugachik

The relative density of legal clams declined from 67.2 to 41.2 to 36.2 clams per square meter from 1992 to 1994 (Table 17). The population estimates of littleneck clams at Chugachik Island has shown a 37 percent decline in number and a 33 percent decline in biomass of the legal segment of the population between the 1992 and 1993 survey. There was an additional 11 percent decline in the number and a 21 percent decline in the biomass of the legals between the 1993 and 1994 survey.

The relative density of sublegals declined from 50.4 to 48.8 to 42.8 clams per square meter. The population estimates showed a 3 percent reduction in the estimated number of clams from the 1992 to the 1993 survey. The downward trend continued with a 12 percent

reduction between the 1993 and 1994 surveys. The biomass of sublegal clams had increased 20 percent between the 1992 and 1993 surveys. The increase in biomass was due to the growth of the sublegal clams. The biomass of sublegals declined 21 percent between the 1993 and 1994 surveys.

For all sizes of littleneck clams, there was a 24 percent reduction in numbers between 1992 and 1993 surveys. The trend continued with a reduction of 13 percent in number of littleneck clams between 1993 and 1994. The biomass estimates for all sizes showed a downward trend, with a 24 percent reduction between the 1992 and 1993 surveys and a 21 percent reduction between the 1993 and 1994 surveys.

In 1992 the commercial harvest was 10.8 percent of the legal population estimate at Chugachik. The 1993 harvest increased to 26.7 percent the legal population estimate. In 1994 the harvest decreased to 20.5 percent of the legal population estimate. The average annual Chugachik harvest between 1992 and 1994 was 14,971 kg (32,757 lb). During that time period the littleneck clam population declined by 33 percent. Harvest rates of 10 to 26.7 percent of the estimated legal population and natural mortality resulted in a 33 percent reduction of the legal population estimates. It appears, therefore, that by reducing the harvest rates the population decline could be reversed.

The average size of the legal clams has remained the same between the 1992 to 1994 surveys. One would expect some change in the average legal size. For example, in the Sadie Cove survey the average legal shell lengths increased, and in the Jakolof Bay survey the legal shell lengths decreased with increases in clam density for both areas. Either uniform recruitment, commercial harvest, or some other unknown mechanism has kept the average shell length stable.

After the April 1994 survey documented the reduction in density of the legal and sublegal segments of the littleneck clam population, the Chugachik area was closed to commercial clam harvest in May 1994.

The Chugachik survey will be conducted again in mid April, 1995. The opening of the area will be dependent upon the survey results.

Jakolof Bay

The relative density of legal clams increased between the 1992 and 1993 survey from 22.0 to 26.2 clams per square meter. The population estimate increased 12 percent from 1.6 to 1.8 million legal clams. During the same time period the legal clam average shell length dropped from 48.6 to 47.1 mm. With the reduction in size and average weight the population estimate showed a slight decline from 49,995 to 49,135 kg (110,025 to 108,227 lb) between 1992 and 1993.

The commercial fishery harvested 16.9 percent of the legal clam population estimate in 1992 and 12.0 in 1993.

The relative sublegal density at Jakolof Bay increased from 2.0 to 10.4 clams per square meter from 1992 to 1993. The population estimate for sublegal clams increased from 0.2 to 1.0 million between 1992 and 1993.

The Jakolof Bay harvest for 1994 was below the six year average of 4,595 kg (10,122 lb). The population estimate of both the legals and sublegals increased between 1992 and 1993. When Jakolof Bay opens in 1996 the harvest should be kept below the historical average and catch rates should be monitored closely.

Tutka Bay

The relative density of legal clams dropped from 16.8 to 13.6 clams per square meter between the 1992 and 1993 surveys. The 1990 survey had a higher density of 24.8 clams per square meter. The 1990 survey was only in one site and the specific site was not sampled in 1992 or 1993, therefore data may not be comparable. In the Tutka Bay sites the legal clam densities were some of the lowest found in Kachemak Bay.

The sublegal densities doubled from 2.0 to 4.8 clams per square meter between the 1992 and 1993 surveys. The 1990 sublegal clam density was 36.8 clams per square meter. The substrate from the quadrats was washed and clams of age 1 through 3 were found. These smaller clams were missed to an unknown percentage in the surveys after 1990. The 1990 sublegal density of age 4 and older was 26.2 clams per square meter.

Since the sites sampled in Tutka Bay had the lowest densities, the harvest should be kept to half the average harvest. A preliminary estimate of clam habitat area would be: east side perimeter equals 17,000 meters (10.6 miles), with an average slope length of 8 meters. (From limited field measurements the east side of Tutka had an average slope length of 8 meters.) This yields an area of 136,000 square meters (33.6 acres). The 1993 relative legal density was 13.6 clams per square meter. This yields 1.8 million legal size clams. The 1993 average weight of the legal clams was 28.4 grams. The resultant population estimate of legal clams was 53,644 kg (118,160 lb). This estimate should be considered as a maximum due to the nature of the method of clam habitat estimation and the limited number sample sites. The harvest should, therefore, be kept low and the catch per unit effort of the clam diggers should be monitored closely.

Halibut Cove (Ismailof Island)

The Ismailof Island survey had relative densities of 77.6 legal and 96.4 sublegal clams per square meter. Of the beaches surveyed in Kachemak Bay, Ismailof beach A has the highest clam density. Beach A is small, and therefore yielded a legal clam population estimate of only 2,081 kg (4,584 lb). If the rest of Ismailof Island had a clam density similar to beach A, the population estimate would be 8,308 kg (18,300 lb). The harvest from Ismailof was 1,855 kg (4,087 lb). In order to protect the high density of clams, the area was closed at the 22 percent harvest level. Sublegal clam numbers were very high and if the future survival of the small clams is high, the area may be able to sustain a 1,400 to 1,800 kg (3,000 to 4,000 lb) harvest on an every other year basis.

Sadie Cove

The sites dug in Sadie Cove had a 21.6 percent increase in legal clam relative density between 1993 and 1994. The sublegal clam segment of the population dropped 21.6 percent in that same time period. For all sizes the population density has remained the same between the two surveys at 62.8 clams per square meter. The population estimates of legal clams for the west side of Sadie Cove were 43,360 and 61,502 kg (95,506 and 135,467 lb) in 1993 and 1994, respectively. Harvest rates should be kept within 10 to 15 percent of the estimated legal population.

Age and Growth

The age and growth information presented in this report is preliminary. More clams need to be aged before any comparison of age and growth from area to area can be made, using growth models such as von Bertalanfy's growth equations. Because growth is variable, more data sets need to be aged before future recruitment

can be calculated for Chugachik or any other areas. In all survey areas legal size is attained as early as age 5 and as late as age 10. Therefore growth is highly variable and slow. In general the surveys have tracked strong year classes of the legal segment of the population. For example, using the Chugachik age data (Figure 6), the 1992 survey peak at age 8 eventually showed as a peak at age 10 in the 1994 survey. The sublegal segment of the population does not track smaller clams (ages 3, 4 and 5) between 1992 and 1994. For example, age 4 in the 1992 survey should have been in similar abundance as age 6 clams found in 1994. Only a small percent of the age 3 and 4 clams were sampled and were most likely missed due to their small size.

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Table 1. Pacific Littleneck clam harvest by DEC certified beach and ADF&G shellfish statistical area, Southern District, Cook Inlet Management Area, from 1986 to 1994.

Year	Sub-stat area 241-14 Chugachik lbs.	Percent of total harvest	Sub-stat area 241-15 Halibut Cove lbs.	Percent of total harvest	Jakolof lbs.	Percent of total harvest	Kasitsna lbs.	Percent of total harvest	Tutka lbs.	Percent of total harvest	Jakolof lbs.	Not specified lbs.	Total lbs.	Percent of total harvest	All Southern District total lbs.
1986	17,303	100													17,303
1987	12,214	100													12,214
1988	14,449	100													14,449
1989	0	0	0	0	2,584	100							2,584	100	2,584
1990	18,956	53	0	0	17,838	50							17,838	50	35,744
1991	15,349	32	0	0	1,184	2	0		19,527	41	560	10,816	32,131	68	47,586
1992	26,971	49	0	0	18,544	34	872	2	7,586	14	0	658	27,660	51	54,631
1993	44,313	70	0	0	12,974	20	597	1	5,737	9			19,308	30	63,621
1994	26,986	61	5,957	13	7,608	17	284	1	3,456	8			11,348	26	44,291
1993 Avg.	18,694	60			10,625		490	2	10,950	35	280	5,737	19,904	64	31,017
1994 Avg.	19,616	60	993	3	10,122	31	438	1	9,077	28			18,478	57	32,491

Note: 1 pound = 0.454 kilograms

Table 2. Number of Pacific littleneck clams by quadrat, and the population estimate statistics from the Chugachik survey, 7/2/92.

	Quadrat	Legals	Sublegals	Total littlenecks
	1	6	5	11
	2	8	7	15
	3	20	15	35
	4	10	20	30
	5	27	44	71
	6	14	7	21
	7	9	22	31
	8	19	0	19
	9	27	6	33
	10	22	3	25
	11	7	14	21
	12	33	8	41
Total	12	202	151	353

	Legals	Sublegals	Total
Mean number of clams per quadrat	16.8	12.6	29.4
Mean number per sq. meter	67.3	50.3	117.7
Total area considered (square meters)	61,254	61,254	61,254
Pop. est. based on all quadrats	4,124,406	3,083,096	7,207,502
Upper Range: (95% CI)	5,390,608	4,740,824	9,390,214
Lower Range: (95% CI)	2,858,205	1,425,368	5,024,791
Percent error	30.7	53.8	30.3
Average weight per clam in grams from laboratory samples	27.5	7.6	18.9
Population est. in kilograms	113,468	23,416	136,437
Population est. in pounds	249,929	51,576	300,523

Table 3. Number of Pacific littleneck clams by quadrat, and the population estimate statistics from the Chugachik survey, 5/6/93.

	Quadrat	Legals	Sublegals	Total littlenecks
	1	1	11	12
	2	15	13	28
	3	12	29	41
	4	14	3	17
	5	11	17	28
	6	11	24	35
	7	13	16	29
	8	24	29	53
	9	12	9	21
	10	2	1	3
	11	10	2	12
	12	6	12	18
	13	10	7	17
	14	11	9	20
	15	10	12	22
	16	2	1	3
Total	16	164	195	359

	Legals	Sublegals	Total
Mean number of clams per quadrat	10.3	12.2	22.4
Mean number per sq. meter	41.0	48.8	89.8
Total area considered (square meters)	61,254	61,254	61,254
Pop. est. based on all quadrats	2,511,396	2,986,111	5,497,507
Upper Range: (95% CI)	3,191,248	4,073,467	7,078,719
Lower Range: (95% CI)	1,831,544	1,898,756	3,916,295
Percent error	27.1	36.4	28.8
Average weight per clam in grams from laboratory samples	30.0	9.4	18.9
Population est. in kilograms	75,342	28,069	103,903
Population est. in pounds	165,951	61,827	228,861

Table 4. Number of Pacific littleneck clams by quadrat, and the population estimate statistics from the Chugachik survey, 4/27 and 4/29/94.

Quadrat	Legals	Sublegals	Total littlenecks
1	0	0	0
2	8	5	13
3	18	26	44
4	9	7	16
5	1	0	1
6	0	0	0
7	2	0	2
8	22	19	41
9	10	2	12
10	7	1	8
11	3	5	8
12	4	2	6
13	21	9	30
14	4	8	12
15	6	0	6
16	3	16	19
17	17	1	18
18	17	10	27
19	28	4	32
20	6	36	42
21	18	60	78
22	3	3	6
23	2	0	2
24	0	1	1
25	6	15	21
26	10	9	19
27	4	24	28
28	4	7	11
29	17	47	64
30	9	12	21
31	22	18	40
32	5	2	7
33	14	5	19
Total	330	354	654

Table 4. Continued.

	Legals	Sublegals	Total
Mean number of clams per quadrat	9.1	10.7	19.8
Mean number per sq. meter	36.4	42.9	79.3
Total area considered (square meters)	61,254	61,254	61,254
Pop. est. based on all quadrats	2,227,402	2,628,335	4,855,737
Upper Range: (95% CI)	2,868,966	3,811,363	6,409,529
Lower Range: (95% CI)	1,585,839	1,445,306	3,301,944
Percent error:	28.8	45.0	32.0
Average weight per clam in grams from laboratory samples	26.8	8.4	16.9
Population est. in kilograms	59,694	22,078	82,062
Population est. in pounds	131,485	48,630	180,753

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Table 5. Number of Pacific littleneck clams by quadrat, and the population estimate statistics from the "Island" stratum, in Jakolof Bay survey, 8/28/92.

Site	Quadrat	Legals	Sublegals	Total littlenecks
2b	1	12	1	13
	2	13	0	13
	3	1	0	1
	4	6	0	6
	5	1	0	1
	6	10	0	10
	7	3	0	3
	8	8	0	8
	9	13	0	13
	10	2	0	2
	11	1	0	1
	12	3	0	3
	13	6	0	6
	14	15	0	15
	15	1	1	2
	16	8	0	8
Total	16	103	2	105

	Legals	Sublegals	Total
Mean number of clams per quadrat	6.4	0.1	6.6
Mean number per sq. meter	25.8	0.5	26.3
Total area considered (square meters)	3,630	3,630	3,630
Pop. est. based on all quadrats	93,473	1,815	95,288
Upper Range: (95% CI)	198,479	9,037	200,577
Lower Range: (95% CI)	(11,534)	(5,407)	(10,002)
Percent error	112.3	397.9	110.5
Average weight per clam in grams from laboratory samples	38.0	9.25	37.4
Population est. in kilograms	3,552	17	3,564
Population est. in pounds	7,824	37	7,850

Table 6. Number of Pacific littleneck clams by quadrat, and the population estimate statistics for the east side stratum of Jakolof Bay in DEC certified area, from surveys conducted 7/1/92 and 8/28/92.

Site	Quadrat	Legals	Sublegals	Total littlenecks
1a	1	6	0	6
	2	11	2	13
	3	5	1	6
	4	9	1	10
	5	2	0	2
	6	4	0	4
3a	1	0	0	0
	2	0	0	0
	3	0	0	0
	4	1	0	1
4a	1	7	3	10
	2	5	1	6
	3	12	4	16
	4	12	2	14
1b	1	9	0	9
	2	1	0	1
Total	16	84	14	98

	Legals	Sublegals	Total
Mean number of clams per quadrat	5.25	0.875	6.125
Mean number per sq. meter	21	3.5	24.5
Total area considered (square meters)	15,750	15,750	15,750
Pop. est. based on all quadrats	82,688	13,781	96,469
Upper Range: (95% CI)	175,177	40,387	209,909
Lower Range: (95% CI)	(9,802)	(12,825)	(16,972)
Percent error	111.9	193.1	117.6
Average weight per clam in grams from laboratory samples	31.4	8.5	28.5
Population est. in kilograms	2,596	117	2,749
Population est. in pounds	5,719	258	6,056

Table 7. Number of Pacific littleneck clams by quadrat, and the population estimate statistics from the west side stratum of Jakolof Bay in DEC certified area from survey conducted 7/1/92, and the total 1992 stratified population estimate for the DEC certified area of Jakolof Bay.

Site	Quadrat	Legals	Sublegals	Total littlenecks
2a	1	3	0	3
	2	8	0	8
	3	0	1	1
	4	3	0	3
	5	2	1	3
	6	7	1	8
	7	5	2	7
	8	7	1	8
	9	3	1	4
	10	7	0	7
Total	10	45	7	52

	Legals	Sublegals	Total
Mean number of clams per quadrat	4.5	0.7	5.2
Mean number per sq. meter	18	2.8	20.8
Total area considered (square meters)	77,500	77,500	77,500
Pop. est. based on all quadrats	1,395,000	217,000	1,612,000
Upper Range: (95% CI)	1,466,600	235,052	1,683,099
Lower Range: (95% CI)	1,323,400	198,948	1,540,901
Percent error	5.1	8.3	4.4
Average weight per clam in grams from laboratory samples	31.4	8.5	28.5
Population est. in kilograms	43,803	1,845	45,942
Population est. in pounds	96,482	4,063	101,194

Table 7. Continued.

Jakolof Bay inside DEC line			
	Legals	Sublegals	Total
Total number of quadrats dug	42	42	42
Mean (all quadrats)	5.52	0.55	6.07
Mean number per sq. meter	22.1	2.19	24.29
Population estimate (number)	1,571,160	232,596	1,803,756
Population estimate (kilograms)	49,951	1,979	52,255
Population estimate (pounds)	110,025	4,358	115,099

-continued-

Table 8. Number of Pacific littleneck clams by quadrat, and the population estimate statistics from the Jakolof Bay survey, "Island" stratum conducted June 2-4, 1992.

Site	Quadrat	Legals	Sublegals	Total littlenecks
7	1	6	0	6
	2	4	0	4
	3	1	0	1
	4	11	0	11
	5	4	2	6
	6	8	0	8
	7	1	0	1
	8	2	0	2
	9	11	0	11
	10	1	0	1
	11	1	0	1
	12	2	2	4
	13	5	0	5
	14	9	1	10
	15	7	0	7
	16	3	0	3
Total	16	76	5	81

	Legals	Sublegals	Total
Mean number of clams per quadrat	4.8	0.3	5.1
Mean number per sq. meter	19.0	1.3	20.3
Total area considered (square meters)	3,630	3,630	3,630
Pop. est. based on all quadrats	68,970	4,538	73,508
Upper Range: (95% CI)	94,225	9,547	98,892
Lower Range: (95% CI)	43,715	(472)	48,123
Percent error	36.6	110.4	34.5
Average weight per clam in grams from laboratory samples	35.7	9.8	34.0
Population est. in kilograms	2,462	44	2,499
Population est. in pounds	5,423	98	5,505

Table 9. Number of Pacific littleneck clams by quadrat, and the population estimate statistics from the Jakolof Bay survey, east side stratum conducted June 2–4, 1993.

Site	Quadrat	Legals	Sublegals	Total littlenecks
6	1	2	1	3
	2	2	0	2
	1	3	0	3
	2	12	2	14
	3	4	0	4
	4	0	1	1
	5	3	0	3
	6	7	1	8
	7	3	1	4
	1	8	2	10
	2	7	0	7
	1	11	9	20
	2	6	0	6
	3	8	4	12
	4	11	2	13
	5	8	3	11
	6	2	7	9
	1	3	7	10
	2	3	8	11
	3	14	0	14
	4	11	2	13
Total	21	128	50	178

	Legals	Sublegals	Total
Mean number of clams per quadrat	6.1	2.4	8.5
Mean number per sq. meter	24.4	9.5	33.9
Total area considered (square meters)	15,750	15,750	15,750
Pop. est. based on all quadrats	384,000	150,000	534,000
Upper Range: (95% CI)	492,086	228,317	668,894
Lower Range: (95% CI)	275,914	71,683	399,106
Percent error	28.1	52.2	25.3
Average weight per clam in grams from laboratory samples	24.5	9.1	15.9
Population est. in kilograms	9,408	1,365	8,491
Population est. in pounds	20,722	3,007	18,702

Table 9. Continued.

	Legals	Sublegals	Total
Site 6			
Mean no. all quadrats	2.0	0.5	2.5
Mean no. per sq. meter	8.0	2.0	10.0
Site 8			
Mean no. all quadrats	4.6	0.7	5.3
Mean no. per sq. meter	18.3	2.9	21.1
Site 9			
Mean no. all quadrats	7.5	1.0	8.5
Mean no. per sq. meter	30.0	4.0	34.0
Site 10			
Mean no. all quadrats	7.7	4.2	11.8
Mean no. per sq. meter	30.7	16.7	47.3
Site 11			
Mean no. all quadrats	7.8	4.3	12.0
Mean no. per sq. meter	31.0	17.0	48.0

-continued-

Table 10. Number of Pacific littleneck clams by quadrat, and the population estimate statistics from the Jakolof Bay survey, west side stratum conducted June 2-4, 1993.

Site	Quadrat	Legals	Sublegals	Total littlenecks
1	1	0	0	0
	2	0	0	0
	3	2	0	2
	4	0	0	0
	5	1	1	2
	6	0	0	0
	7	0	0	0
2	1	5	7	12
	2	5	0	5
	3	7	1	8
	4	13	3	16
	5	8	1	9
	6	5	3	8
	7	8	2	10
	8	7	5	12
3	1	0	0	0
	2	2	0	2
	3	1	0	1
	4	1	0	1
	5	6	1	7
4	1	4	6	10
	2	2	2	4
	3	3	1	4
	4	9	0	9
	5	6	0	6
	6	1	0	1
5	1	10	11	21
	2	6	5	11
	3	7	11	18
	4	2	4	6
	5	8	7	15
	6	14	13	27
Total	32	143	84	227

	Legals	Sublegals	Total
Mean number of clams per quadrat	4.5	2.6	7.1
Mean number per sq. meter	17.9	10.5	28.4
Total area considered (square meters)	77,500	77,500	77,500
Pop. est. based on all quadrats	1,385,313	813,750	2,199,063
Upper Range: (95% CI)	1,967,165	1,166,734	2,989,420
Lower Range: (95% CI)	803,460	460,766	1,408,705
Percent error	42.0	43.4	35.9
Average weight per clam in grams			
from laboratory samples	26.9	7.1	19.5
Population est. in kilograms	37,265	5,778	42,882
Population est. in pounds	82,081	12,726	94,453

Table 10. Continued.

	Legals	Sublegals	Total
Site 1			
Mean no. clams per quadrat	0.4	0.1	0.6
Mean no. per sq. meter	1.7	0.6	2.3
Site 2			
Mean no. clams per quadrat	7.3	2.8	10.0
Mean no. per sq. meter	29.0	11.0	40.0
Site 3			
Mean no. clams per quadrat	2.0	0.2	2.2
Mean no. per sq. meter	8.0	0.8	8.8
Site 4			
Mean no. clams per quadrat	4.2	1.5	5.7
Mean no. per sq. meter	16.7	6.0	22.7
Site 5			
Mean no. clams per quadrat	7.8	8.5	16.3
Mean no. per sq. meter	31.3	34.0	65.3
Jakolof Bay all strata inside DEC line			
	Legals	Sublegals	Total
Total number of quadrats dug	53	53	53
Mean number of clams per quadrat	6.55	2.62	9.17
Mean number per sq. meter	26.19	10.49	36.68
Population estimate (number)	1,838,283	968,288	2,806,570
Population estimate (kilograms)	49,135	7,187	53,872
Population estimate (pounds)	108,227	15,831	118,660

-continued-

Table 11. Number of Pacific littleneck clams by quadrat, and the population estimate statistics from the Tutka Bay survey conducted 6/24/90.

Site	Quadrat	Legals	Sublegals	Total littlenecks
1	1	0	8	8
	2	3	5	8
	3	9	17	26
	4	10	15	25
	5	20	24	44
	6	5	8	13
	7	7	4	11
	8	0	0	0
2	1	1	2	3
	2	8	2	10
	3	14	6	20
	4	16	16	32
	5	6	18	24
	6	11	31	42
	7	1	14	15
	8	0	3	3
3	1	0	4	4
	2	0	1	1
	3	6	0	6
	4	12	13	25
	5	11	8	19
	6	8	10	18
	7	1	8	9
	8	0	4	4
Total	39	149	221	370

	Legals	Sublegals	Total
Mean number of clams per quadrat	6.2	9.2	15.4
Mean number per sq. meter	24.8	36.8	61.7
Transect 1			
Mean number of clams per quadrat	6.8	10.1	16.9
Mean number per sq. meter	27.0	40.5	67.5
Transect 2			
Mean number of clams per quadrat	7.1	11.5	18.6
Mean number per sq. meter	28.5	46.0	74.5
Transect 3			
Mean number of clams per quadrat	4.8	6.0	15.0
Mean number per sq. meter	19.0	24.0	60.0

Table 12. Number of Pacific littleneck clams by quadrat, and the population estimate statistics from the Tutka Bay survey conducted 7/31/92.

Site	Quadrat	Legals	Sublegals	Total littlenecks
1	1	0	1	1
	2	9	0	9
	3	0	0	0
	4	0	0	0
	5	0	0	0
	6	0	0	0
2	1	0	0	0
	2	0	0	0
	3	0	0	0
	4	14	0	14
	5	1	0	1
	6	5	0	5
3	1	0	0	0
	2	0	0	0
	3	0	0	0
	4	0	0	0
	5	0	0	0
	6	4	0	4
	7	0	0	0
	8	0	0	0
4	1	1	0	1
	2	8	0	8
	3	1	0	1
	4	8	0	8
5	1	7	0	7
	2	7	0	7
	3	7	0	7
	4	1	0	1
	5	4	1	5
	6	4	1	5
	7	10	0	10
	8	18	1	19
6	1	32	5	37
	2	8	3	11
	3	0	0	0
	4	12	6	18
7	1	0	0	0
8	1	1	1	2
	2	0	1	1
Total	39	162	20	182

Table 12. Continued.

	Legals	Sublegals	Total
Mean number of clams per quadrat	4.2	0.5	4.7
Mean number per sq. meter	16.6	2.1	18.7

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Table 13. Number of Pacific littleneck clams by quadrat, and the population estimate statistics from the Tutka Bay survey conducted 5/7/93.

Site	Quadrat	Legals	Sublegals	Total littlenecks
1	1	0	0	0
	2	0	6	6
	3	0	0	0
	4	2	0	2
	5	0	0	0
	6	0	0	0
2	1	8	1	9
	2	1	0	1
	3	0	0	0
	4	0	0	0
	5	0	0	0
	6	0	0	0
	7	0	0	0
	8	4	0	4
3	1	4	1	5
	2	6	2	8
	3	3	1	4
	4	23	4	27
4	1	6	8	14
	2	1	0	1
	3	11	3	14
	4	5	1	6
Total	22	74	27	101

	Legals	Sublegals	Total
Mean number of clams per quadrat	3.4	1.2	4.6
Mean number per sq. meter	13.5	4.8	18.4
Site 1			
Mean number of clams per quadrat	0.3	1.0	1.3
Mean number per sq. meter	1.3	4.0	5.3
Site 2			
Mean number of clams per quadrat	1.6	0.1	1.8
Mean number per sq. meter	6.5	0.5	7.0
Site 3			
Mean number of clams per quadrat	9.0	2.0	11.0
Mean number per sq. meter	36.0	8.0	44.0
Site 4			
Mean number of clams per quadrat	5.8	3.0	8.8
Mean number per sq. meter	23.0	12.0	35.0

Table 14. Number of Pacific littleneck clams by quadrat, and the population estimate statistics from the Halibut Cove survey on Ismailof Island 8/23/94.

Quadrat	Legal Legals	Sublegal Sublegals	Total littlenecks
1	1	65	66
2	12	11	23
3	15	44	59
4	6	5	11
5	24	4	28
6	49	13	62
7	42	46	88
8	6	5	11
8	155	193	348

	Legal	Sublegal	Total
Mean (all quadrats)	19.4	24.1	43.5
Mean number per sq. meter	77.5	96.5	174.0
Total area considered (square me	1,183	1,183	1,183
Pop. est. based on all quadrats	91,683	114,160	205,842
Upper Range: (95% CI)	149,548	192,318	300,572
Lower Range: (95% CI)	33,817	36,001	111,112
Percent error	63.1	68.5	46.0
Average weight per clam in grams from laboratory samples	22.7	8.8	18.9
Population est. in kilograms	2,081	1,005	3,890

Table 15. Number of Pacific littleneck clams by quadrat, and the population estimate statistics from the Sadie Cove survey conducted 6/4/93.

Site	Quadrat	Legals	Sublegals	Total littlenecks
1a	1	2	18	20
	2	3	15	18
	3	3	8	11
	4	0	20	20
	5	6	44	50
	6	7	10	17
	7	7	17	24
2a	1	11	7	18
	2	19	0	19
	3	29	6	35
	4	0	0	0
	5	0	0	0
	6	14	1	15
	7	12	3	15
	8	3	0	3
	9	0	0	0
	10	2	0	2
Total	17	118	149	267

	Legals	Sublegals	Total
Mean number of clams per quadrat	6.9	8.8	15.7
Mean number per sq. meter	27.8	35.1	62.8
Total area considered (square meters)	63,742	63,742	63,742
Pop. est. based on all quadrats	1,769,778	2,234,720	4,004,497
Upper Range: (95% CI)	2,900,058	2,874,821	5,432,912
Lower Range: (95% CI)	639,498	1,594,618	2,576,083
Percent error	63.9	28.6	35.7
Average weight per clam in grams from laboratory samples	24.5	9.1	15.9
Population est. in kilograms	43,360	20,336	63,672
Population est. in pounds	95,506	44,793	140,246
Site 1a			
Mean number of clams per quadrat	4.0	18.9	22.9
Mean number per sq. meter	16.0	75.4	91.4
Site 2a			
Mean number of clams per quadrat	9.0	1.7	10.7
Mean number per sq. meter	36.0	6.8	42.8

Table 16. Number of Pacific littleneck clams by quadrat, and the population estimate statistics from the Sadie Cove survey conducted 9/6 & 7/94.

Site	Quadrat	Legals	Sublegals	Total littlenecks
1b	1	0	0	0
	2	2	0	2
	3	3	0	3
	4	0	0	0
	5	1	0	1
	6	0	0	0
	7	0	0	0
	8	0	0	0
	9	0	0	0
	10	4	2	6
	11	9	7	16
2b	1	1	0	1
	2	22	14	36
	3	4	4	8
	4	15	19	34
	5	18	7	25
	6	1	0	1
	7	18	12	30
	8	23	23	46
	9	36	10	46
	10	5	10	15
	11	0	0	0
3b	1	58	22	80
	2	9	15	24
	3	16	4	20
	4	0	2	2
	5	0	2	2
4b	1	6	9	15
	2	0	1	1
	3	20	5	25
	4	15	48	63
	5	2	8	10
	6	5	7	12
	7	14	10	24
	8	0	0	0
Total	35	307	241	548

Table 16. Continued

	Legals	Sublegals	Total
Mean number of clams per quadrat	8.8	6.9	15.7
Mean number per sq. meter	35.1	27.5	62.6
Total area considered (square meters)	63,742	63,742	63,742
Pop. est. based on all quadrats	2,236,434	1,755,637	3,992,070
Upper Range: (95% CI)	3,501,620	2,752,281	6,005,807
Lower Range: (95% CI)	971,247	758,992	1,978,333
Percent error	56.6	56.8	50.4
Average weight per clam in grams from laboratory samples	27.5	9.1	19.5
Population est. in kilograms	61,502	15,976	77,846
Population est. in pounds	135,467	35,190	171,466
Site 1b			
Mean number of clams per quadrat	1.7	0.8	2.5
Mean number per sq. meter	6.9	3.3	10.2
Site 2b			
Mean number of clams per quadrat	13.0	9.0	22.0
Mean number per sq. meter	52.0	36.0	88.0
Site 3b			
Mean number of clams per quadrat	16.6	9.0	25.6
Mean number per sq. meter	66.4	36.0	102.4
Site 4b			
Mean number of clams per quadrat	7.8	11.0	18.8
Mean number per sq. meter	31.0	44.0	75.0

Table 17. Results from the ADF&G Pacific littleneck clam surveys in DEC certified areas of Kachemak Bay, 1990 to 1994.

Location year	Number of sites	Number of quadrats dug	Relative density clams/square meter			Population estimate million clams			Average shell length (mm)		Average weight (grams)		Pop. est. pounds of clams			Percent Harvest Legal pop. est.
			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	47.0	30.5	27.5	7.6	249,929	51,576	301,505	10.8
1993	1	16	41.2	48.8	89.6	2.5	3.0	5.5	46.8	31.4	30.0	9.4	165,951	61,827	227,778	26.7
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	20.5
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	16.9
1993	11	53	26.2	10.4	36.6	1.8	1.0	2.8	47.1	29.1	28.9	7.2	108,227	15,831	124,058	12.0
Tutka																
1990 ^{a/}	1	24	24.8	36.8	61.6				46.1	26.1	25.1	5.8				
1992	8	39	16.8	2.0	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																
(small of ls. one beach 1/4 to 1/3 clam habitat)			(No. of clams one beach only)						(Pop. est. 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	22.3
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	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	

^{a/} The 1990 Tutka survey substrate was washed through small screens. The methodology was different than in 1992-94 surveys. The legal component may be comparable.

Note: 1 lb. = 0.454 kg.

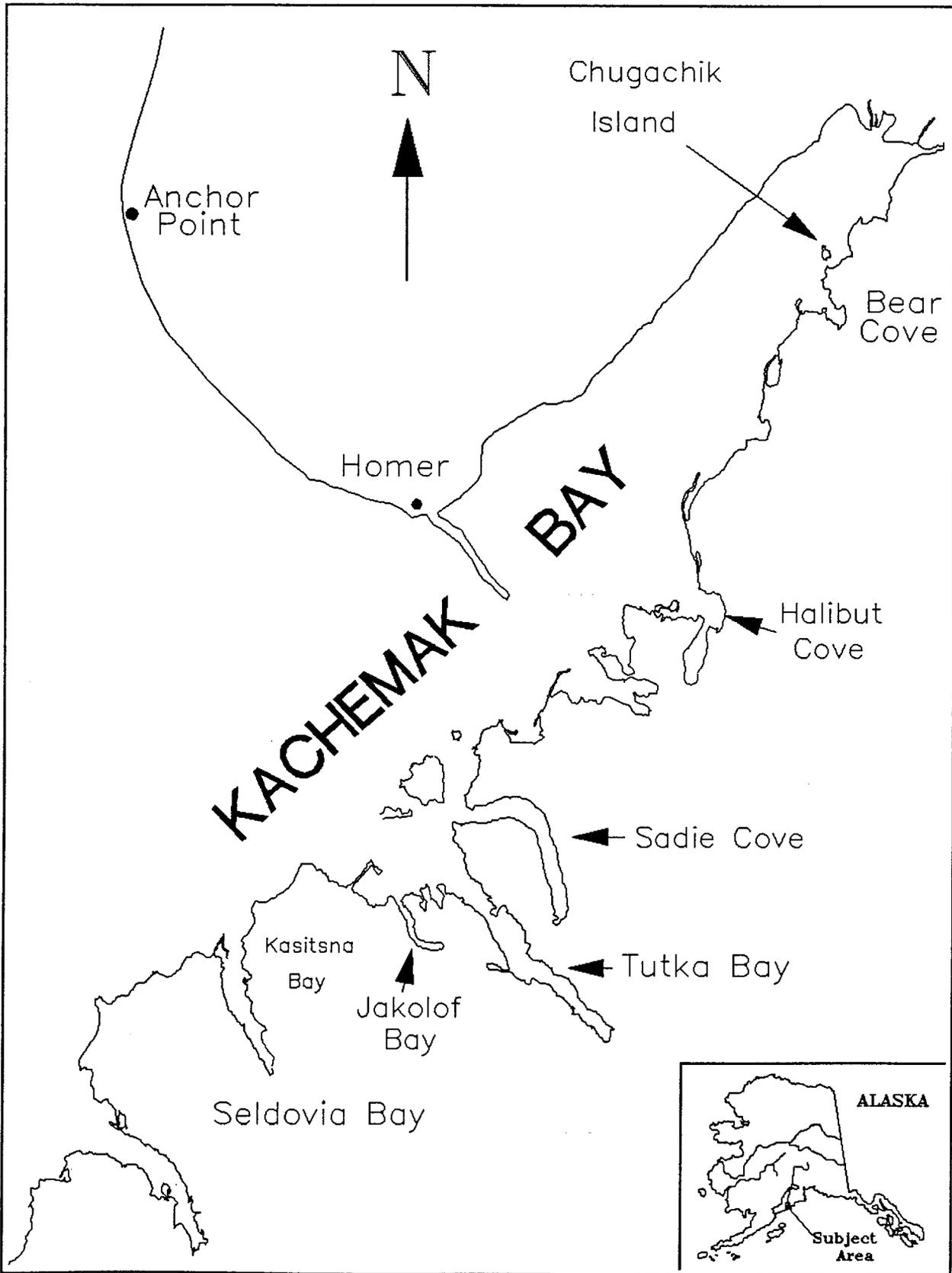


Figure 1. Location of the ADF&G clam survey in the Southern District of the Cook Inlet Management Area, 1990 through 1994.

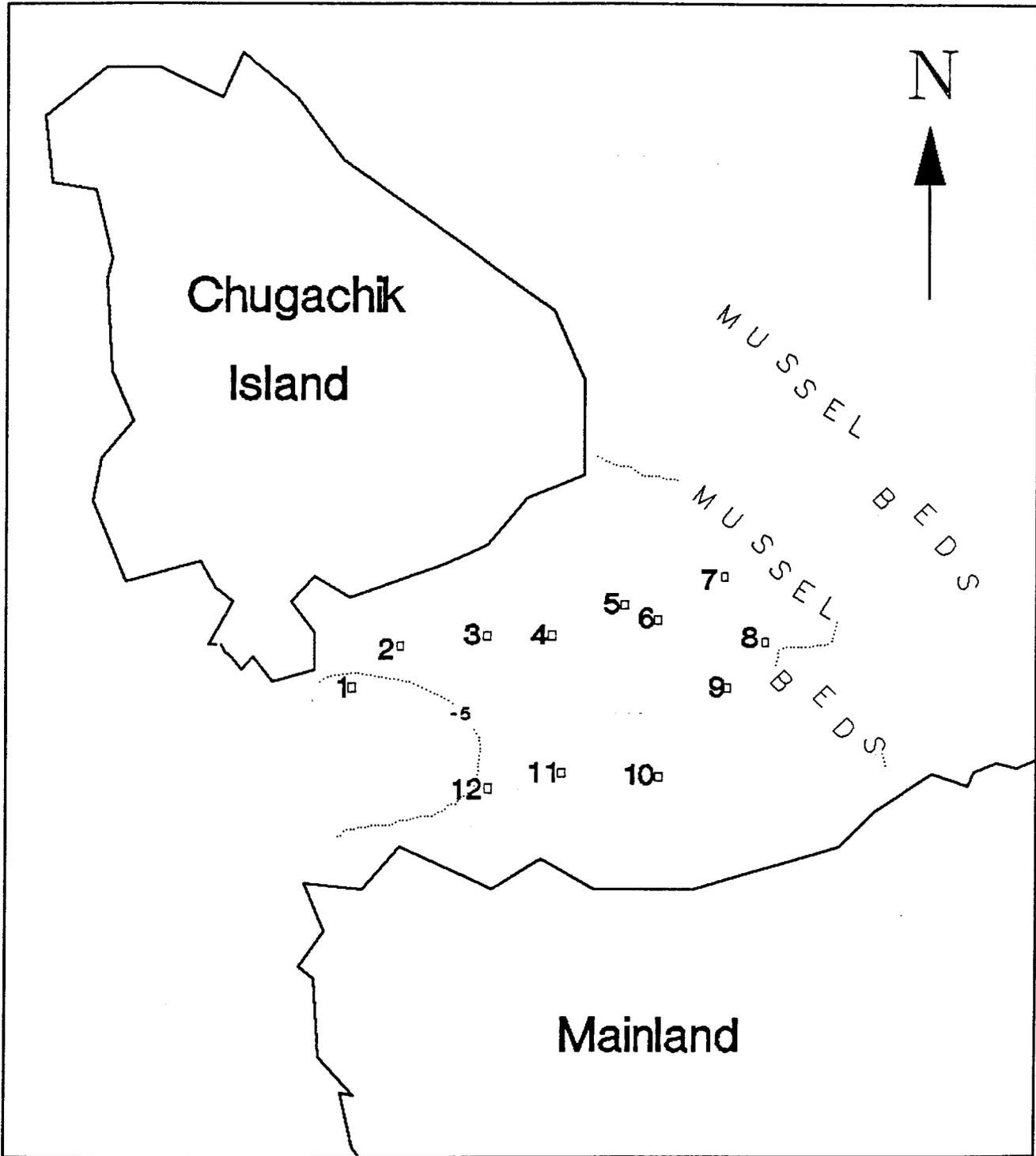


Figure 2. Location of the quadrats dug in the 7/2/92 Chugachik Island survey.

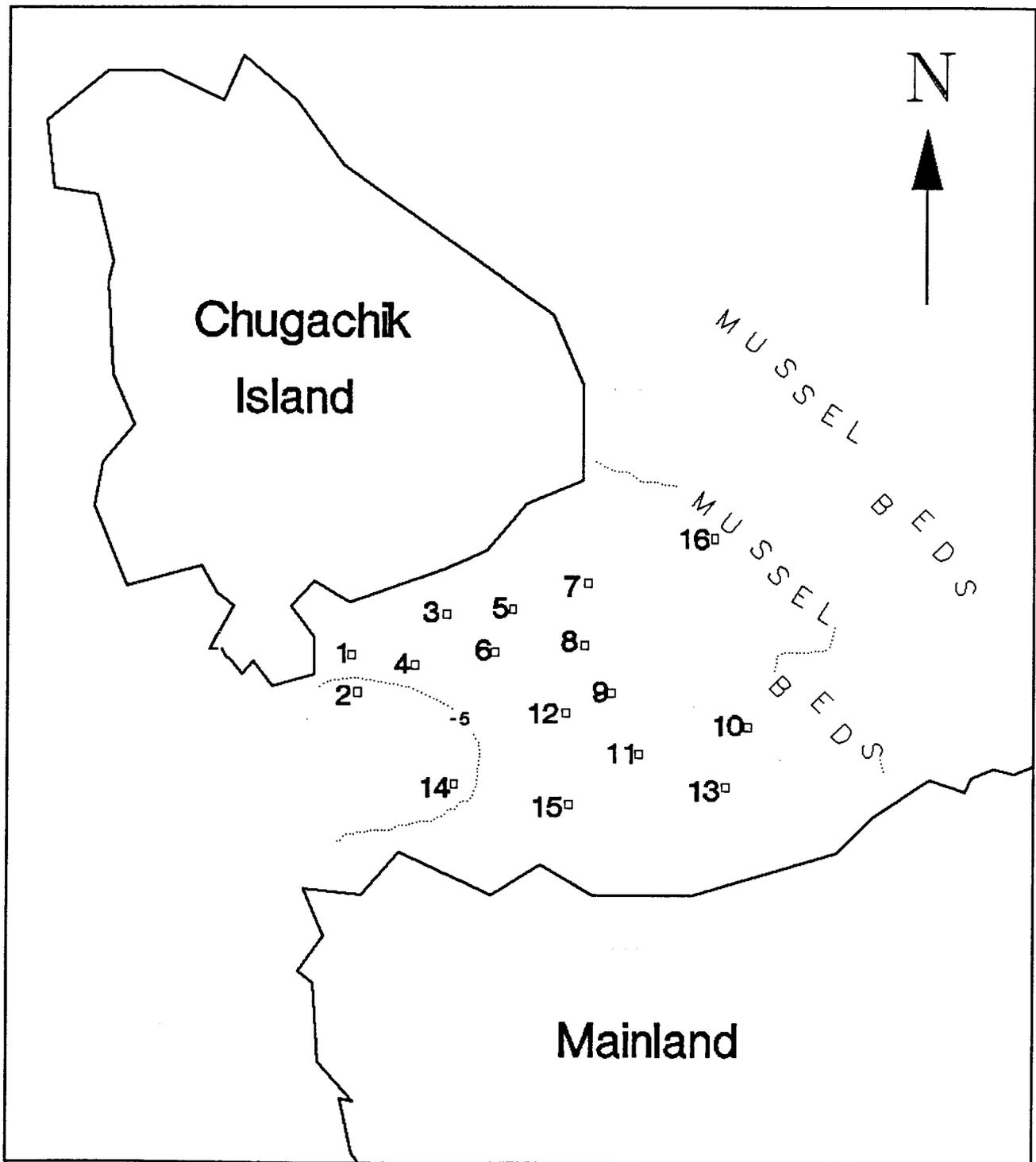


Figure 3. Location of the quadrats dug in the 5/6/93 Chugachik Island survey.

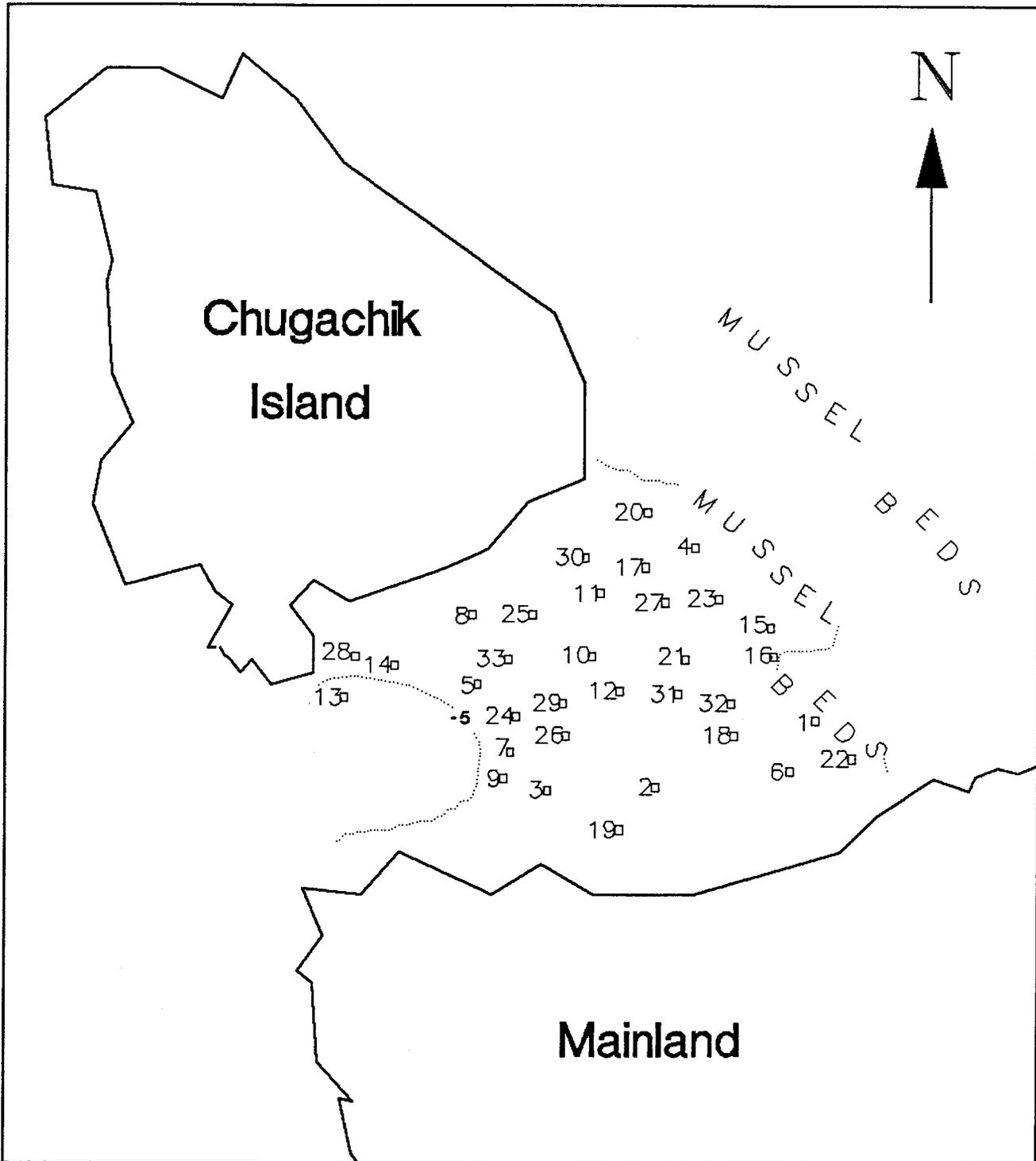


Figure 4. Location of the quadrats dug in the 4/27 & 29/94 Chugachik Island survey.

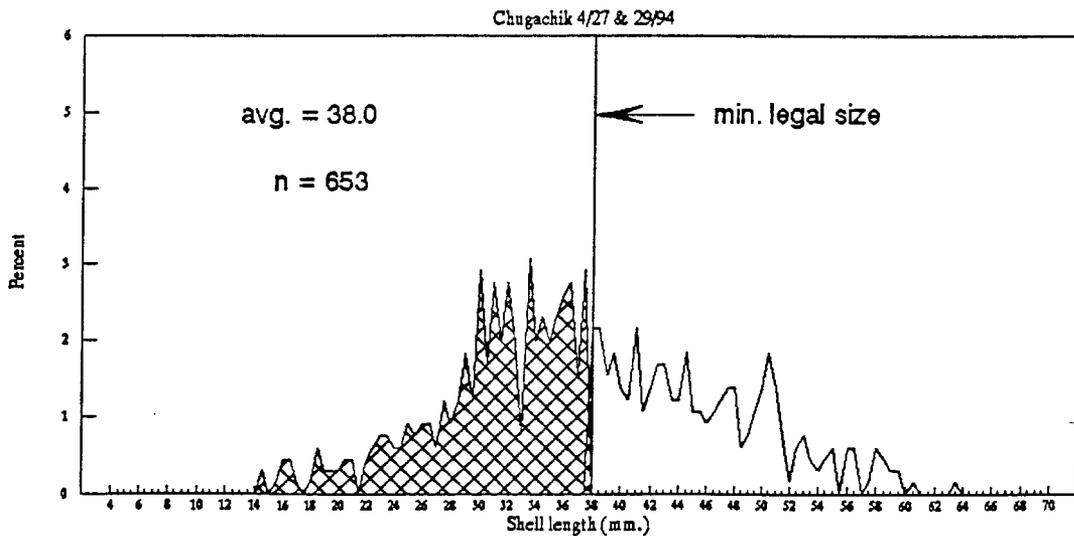
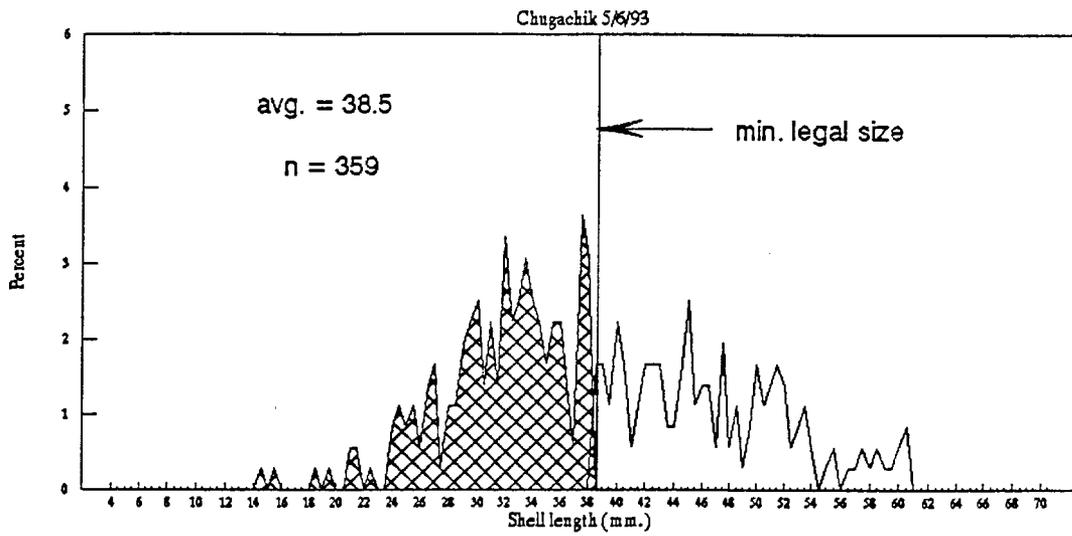
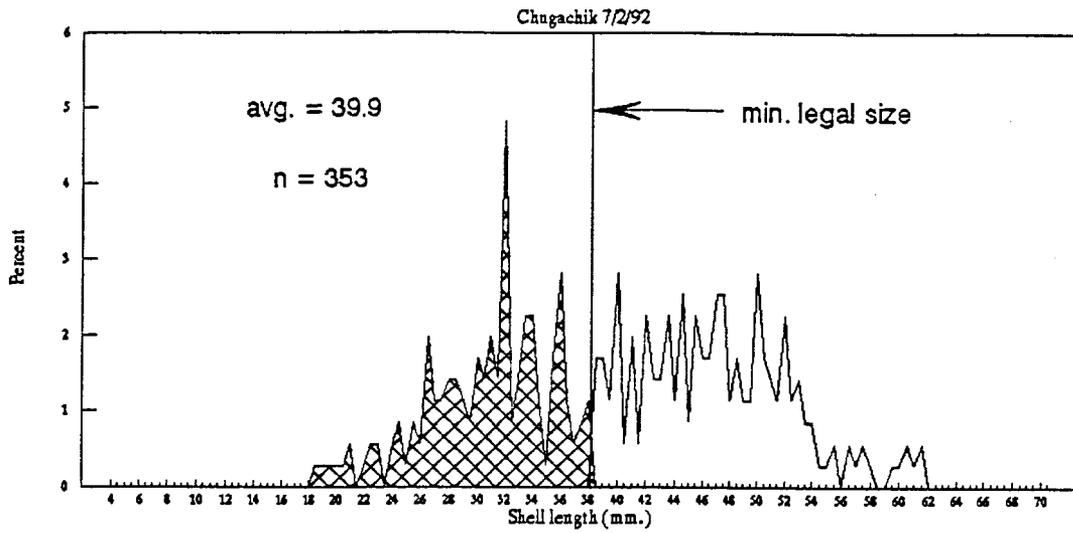


Figure 5. Percent shell length frequency of Pacific littleneck clams dug at Chugachik Island, 1992 to 1994.

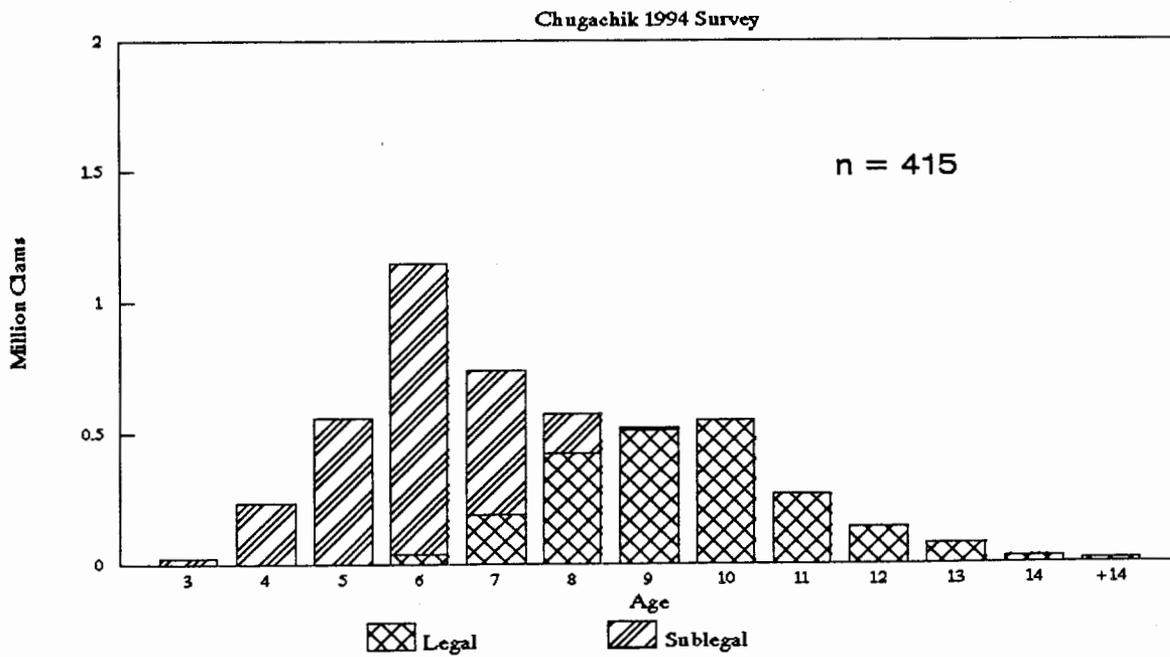
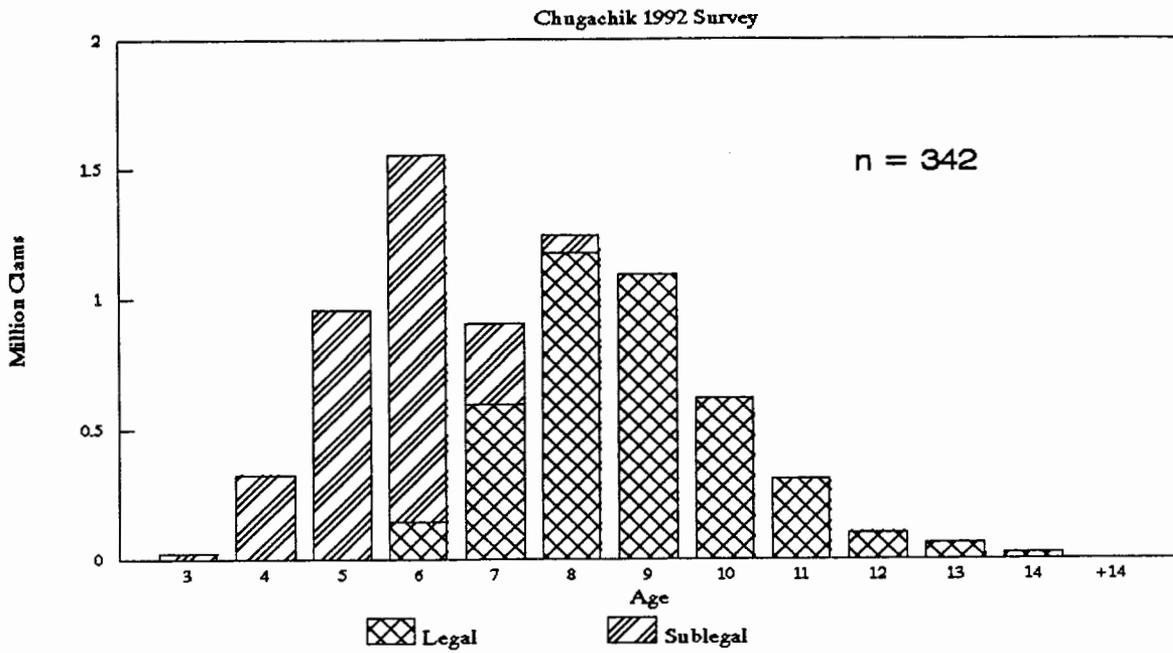


Figure 6. Estimated number of Pacific littleneck clams by age class from the 1992 and 1994 Chugachik Island surveys.

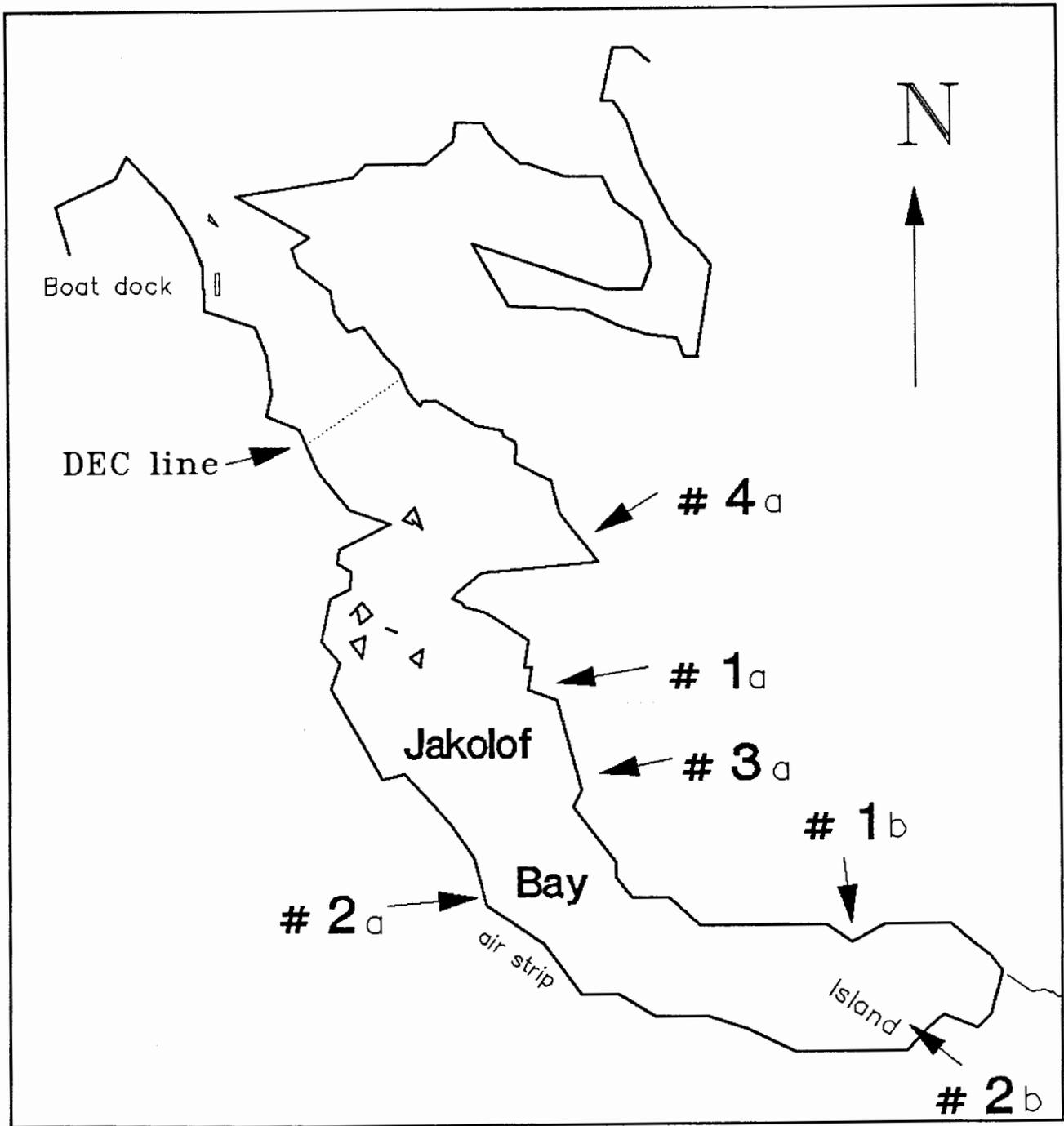


Figure 7. Location of sites #1a, #2a, #3a and #4a dug during a survey conducted on 7/1/1992 and sites #1b, #2b and #3b dug during a survey conducted 8/28/1992.

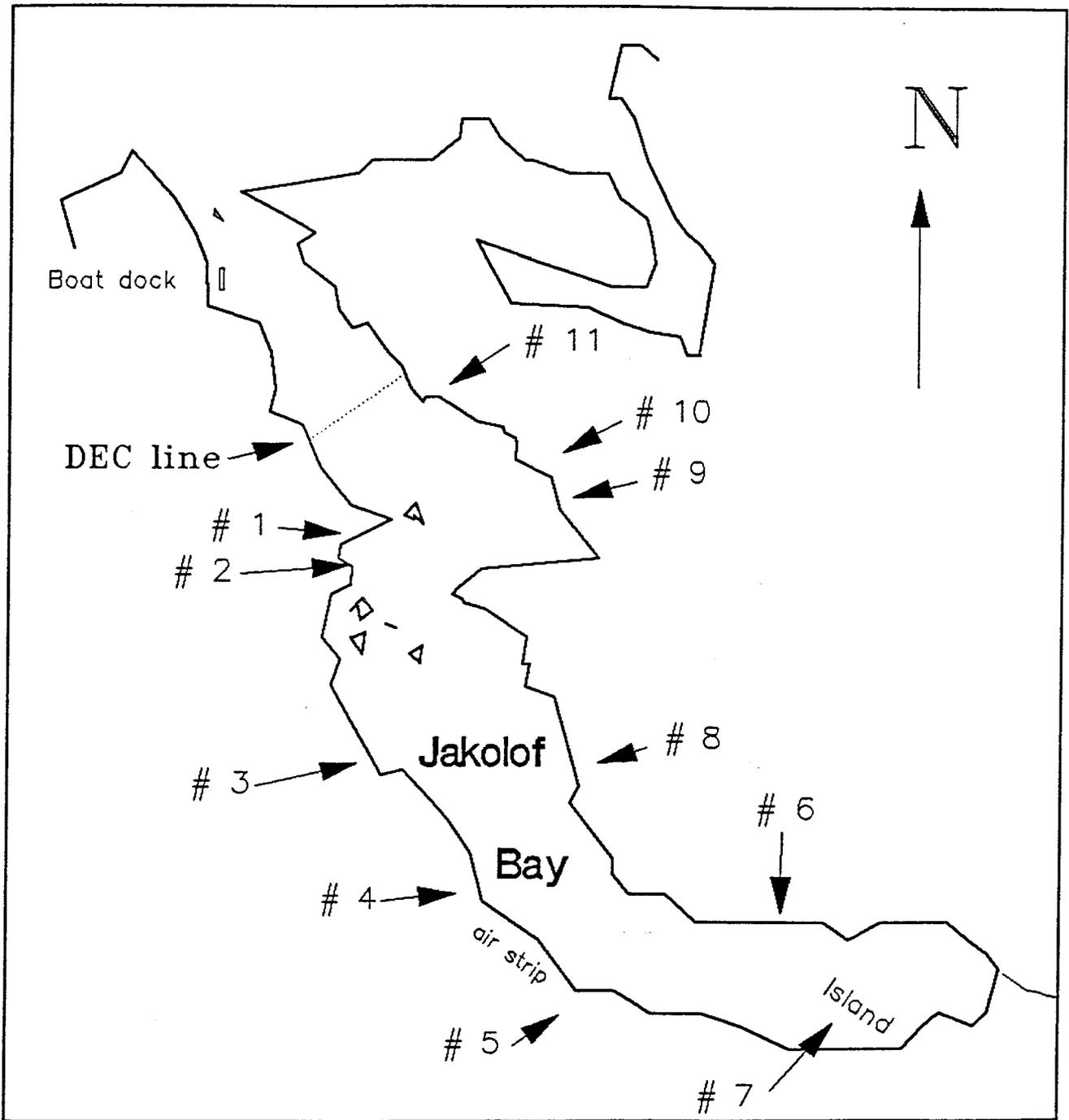


Figure 8. Location of the 11 sites dug in the 6/2 to 4/93 Jakolof Bay survey.

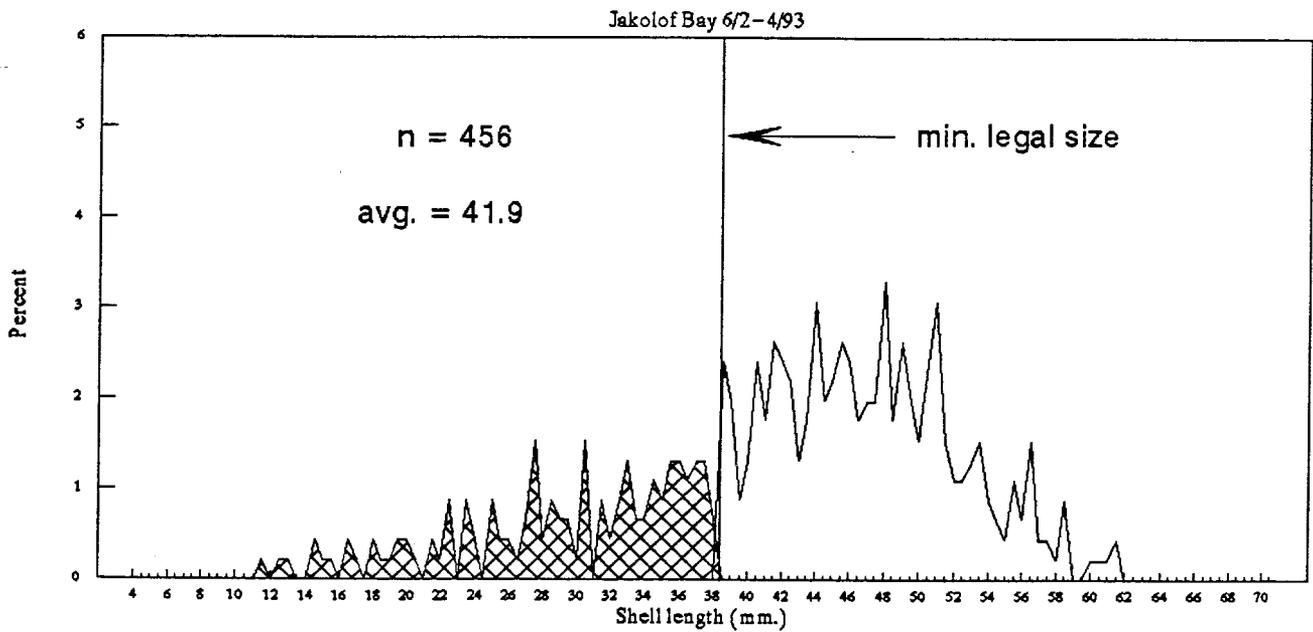
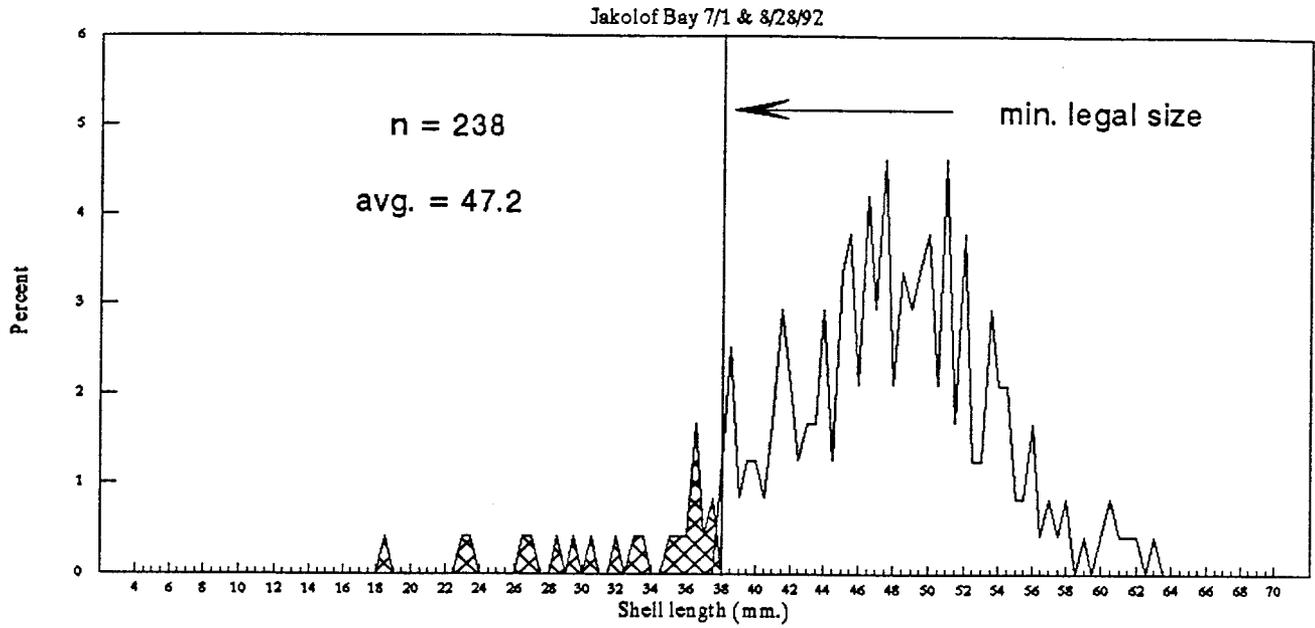


Figure 9. Percent shell length frequency from Pacific littleneck clams dug at Jakolof Bay, 1992 and 1993.

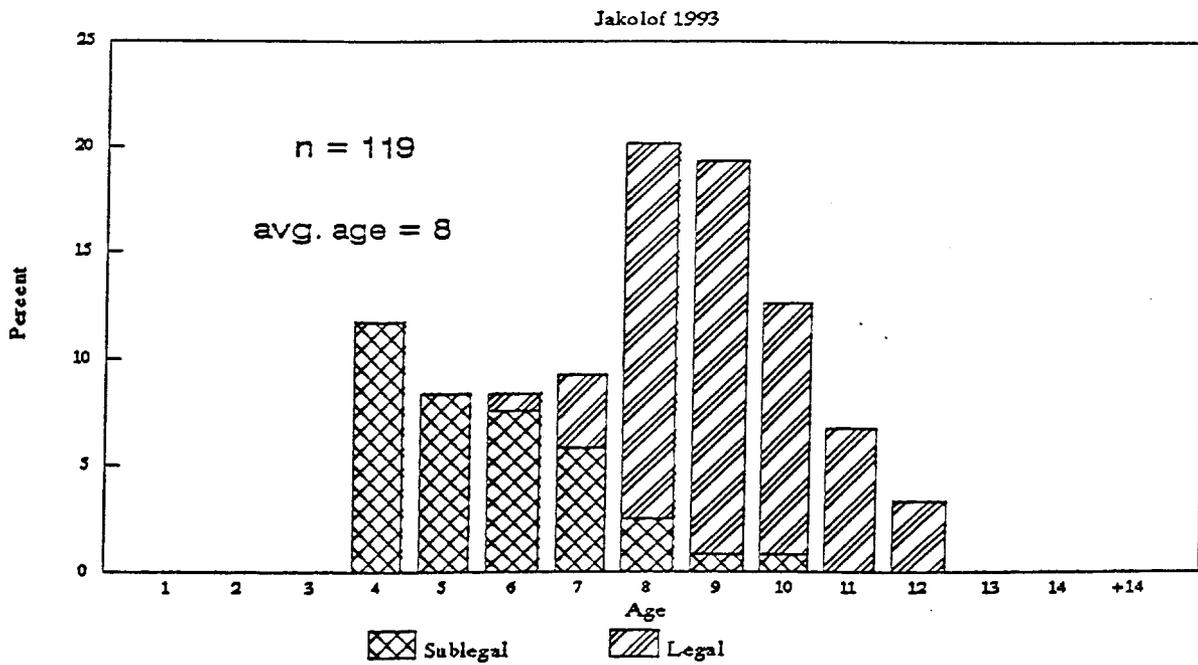
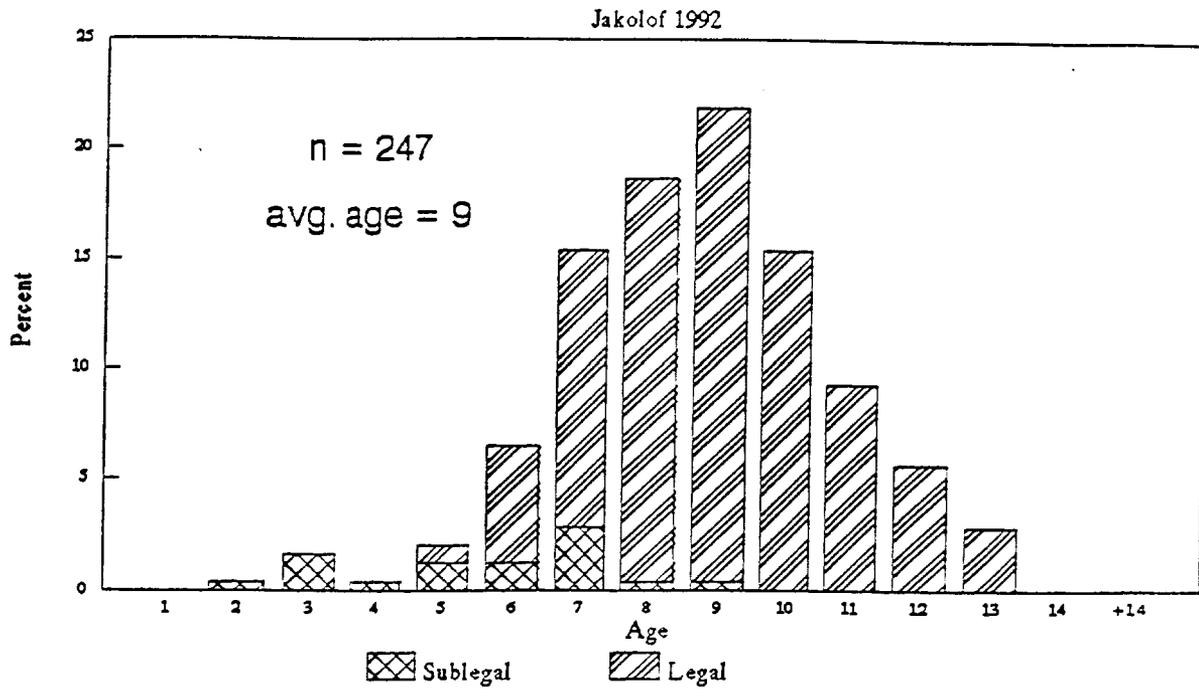


Figure 10. Percent age frequency from Pacific littleneck clams dug at Jakolof Bay, 1992 and 1993.

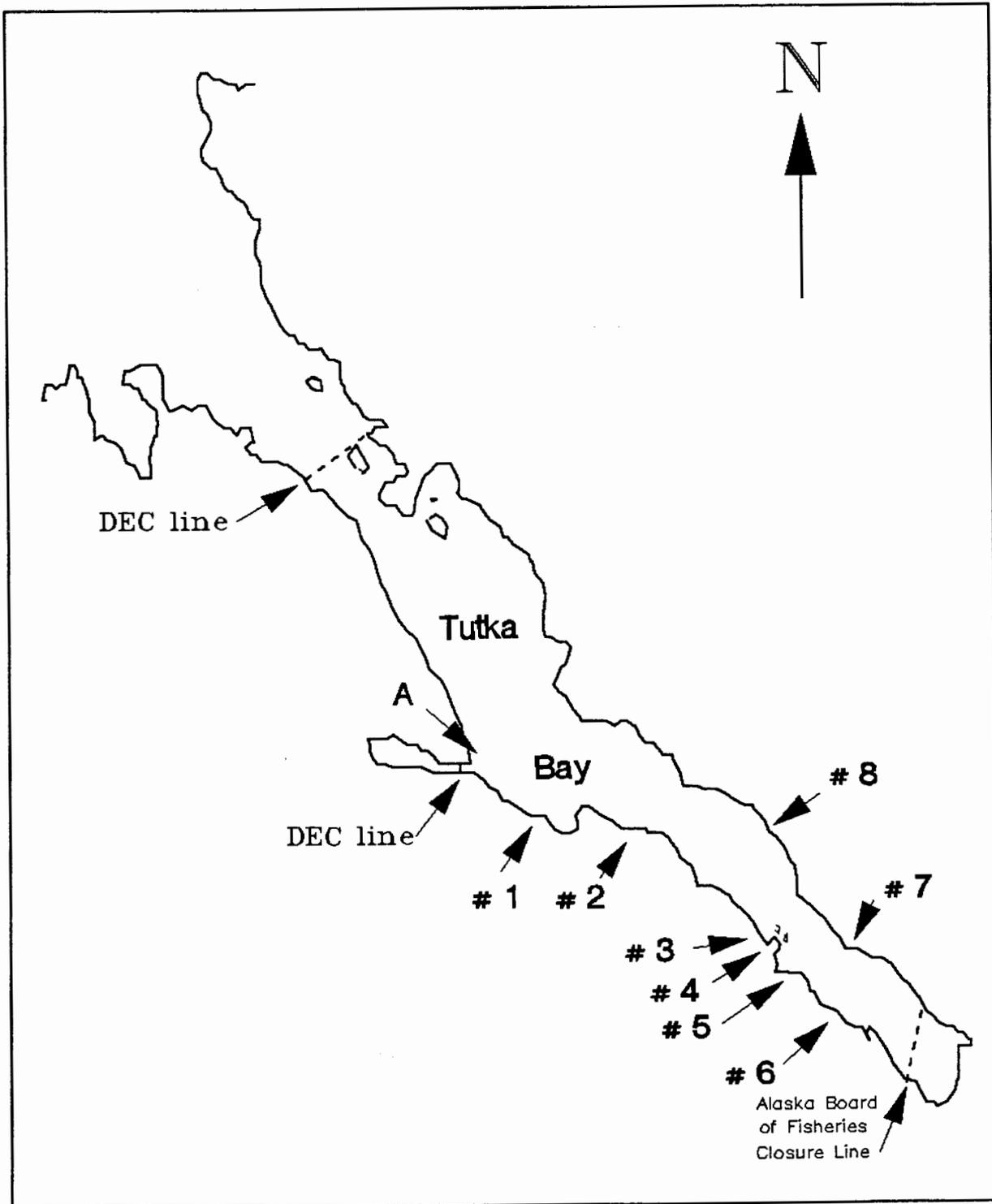


Figure 11. Location of the clam surveys in Tutka Bay conducted 6/24/90 (site A, 3 transects sampled as part of the Exxon Valdez Oil Spill studies) and 7/31/92 (quadrat samples at site #1 through #8).

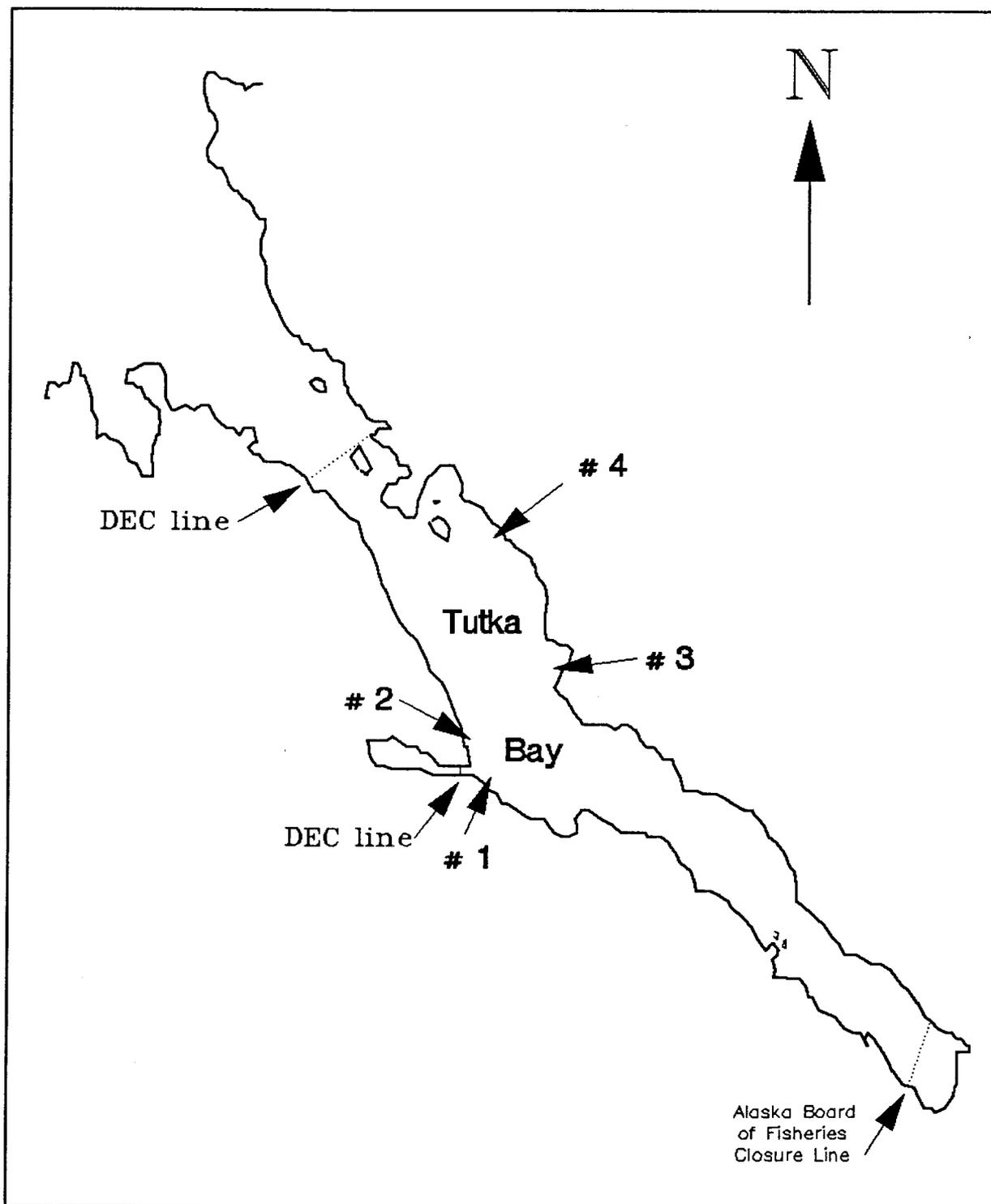


Figure 12. Location of the sites dug in the Tutka Bay survey, 5/7/93.

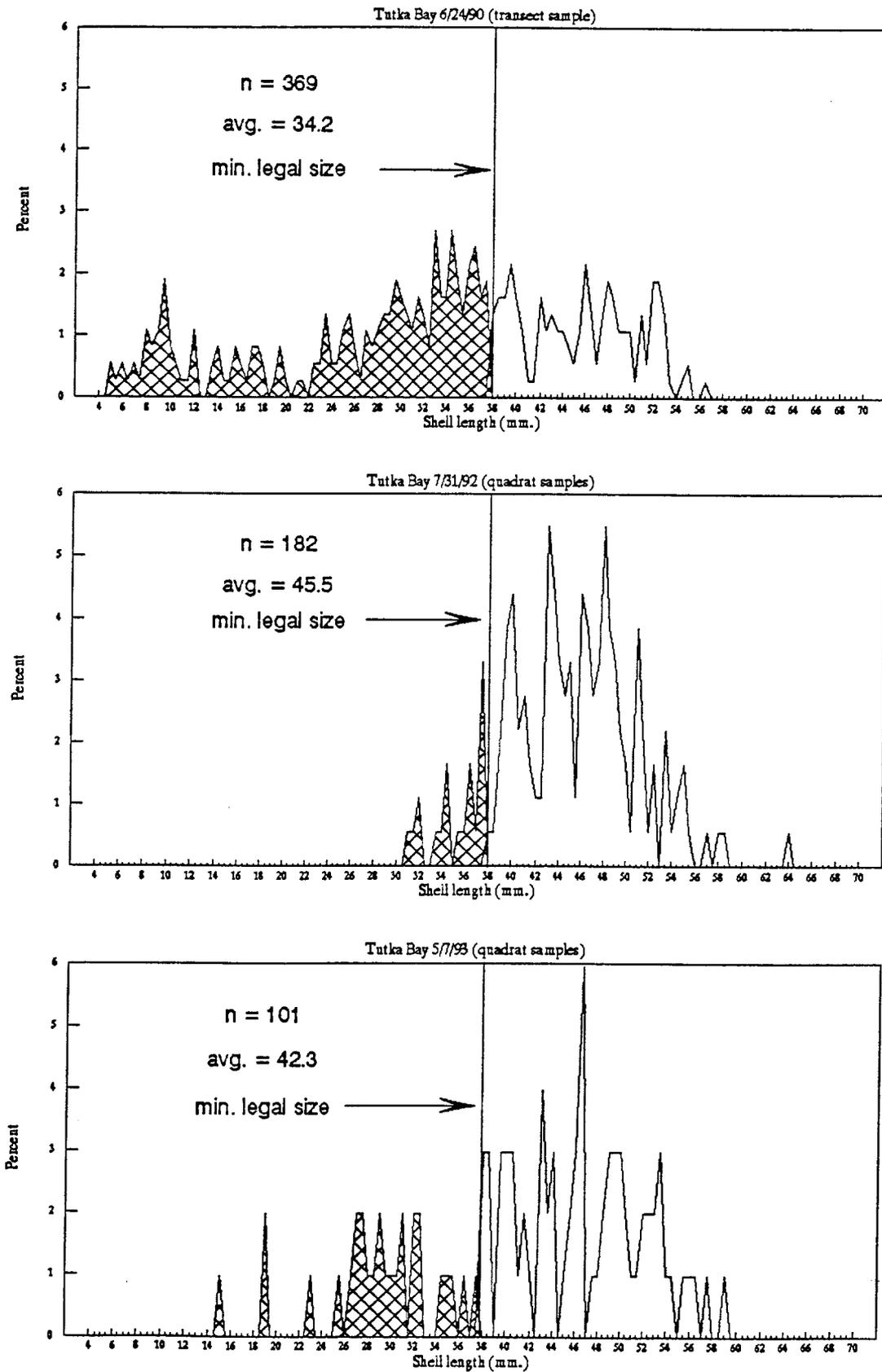


Figure 13. Percent shell length frequency from Pacific littleneck clams dug at Tutka Bay, 1990, 1992, and 1993.

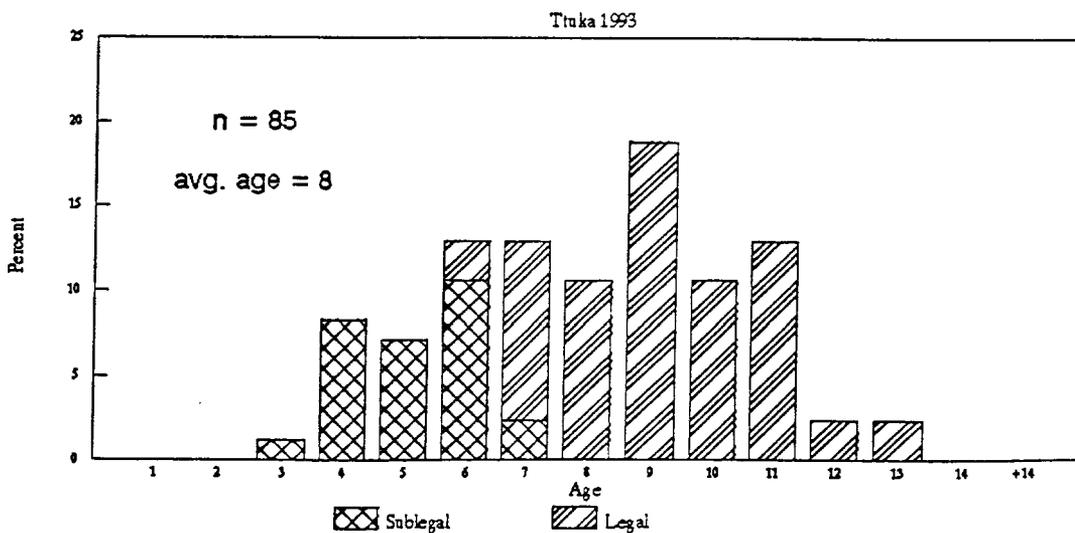
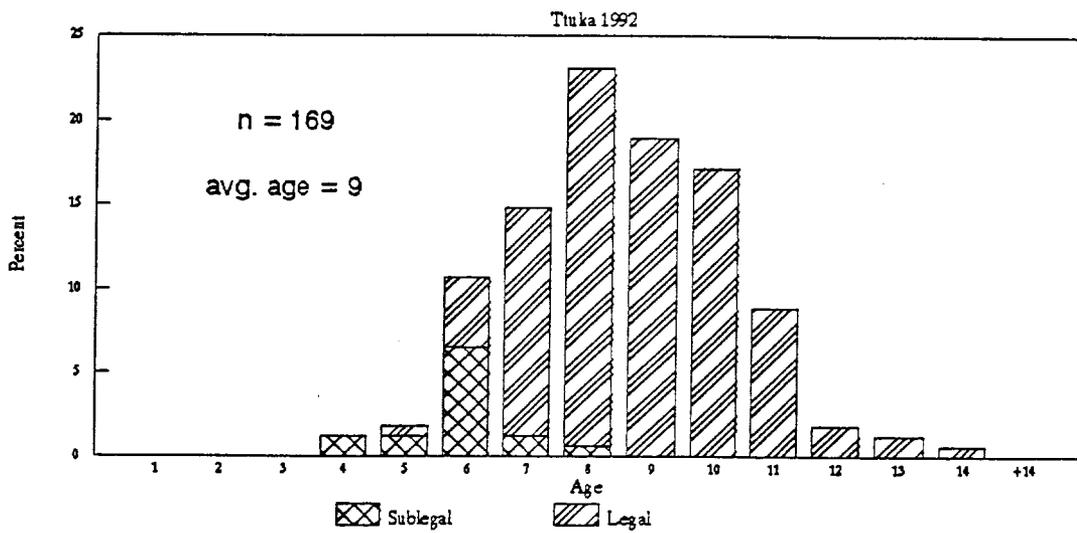
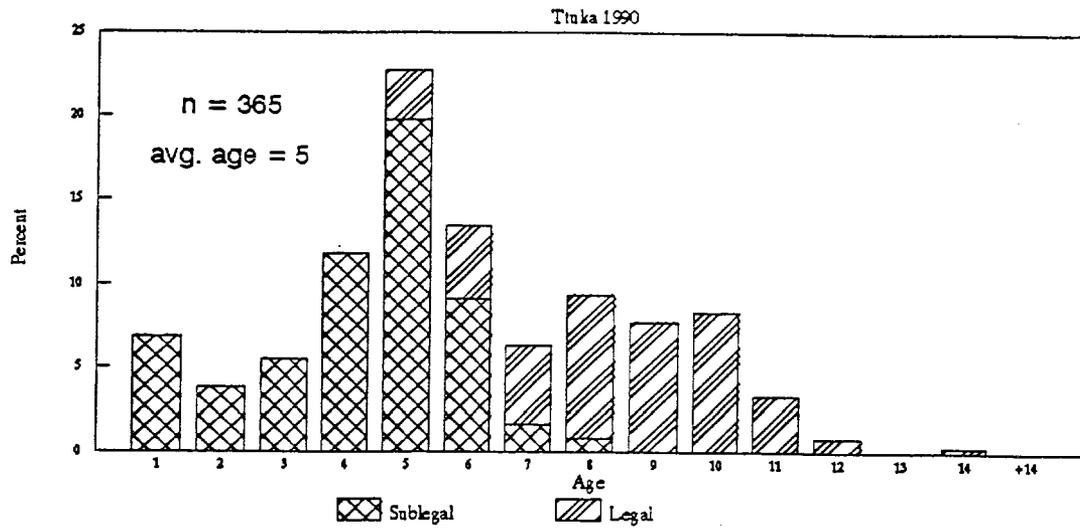


Figure 14. Percent age frequency from Pacific littleneck clams dug at Tutka Bay, 1990, 1992, and 1993.

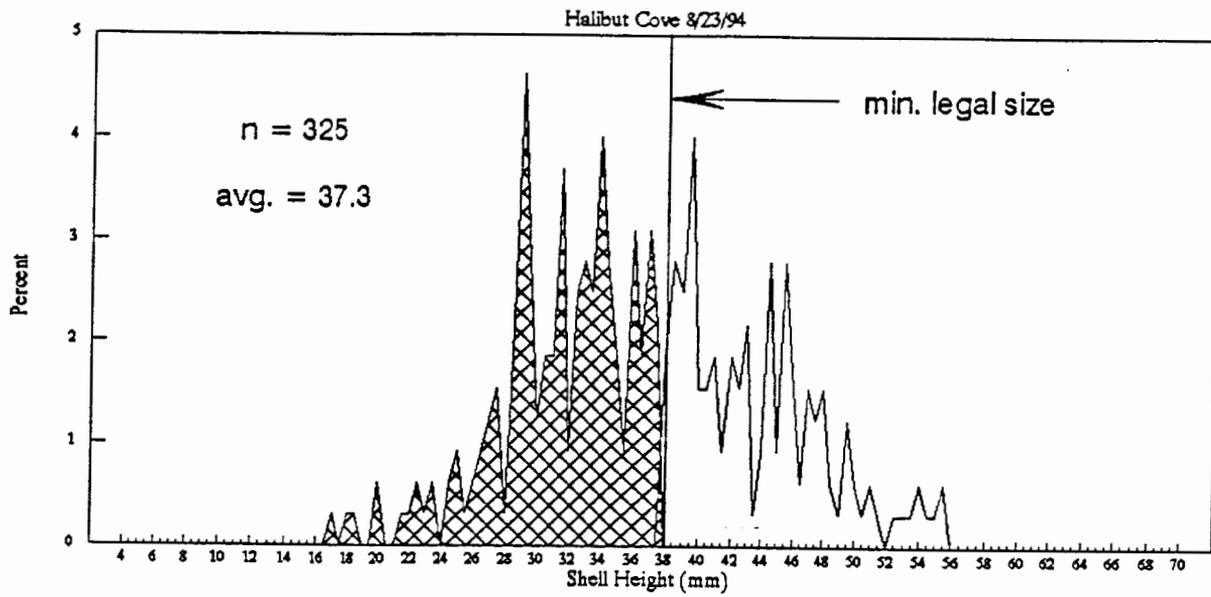


Figure 16. Percent shell length frequency from Pacific littleneck clams dug at Ismailof Island (Halibut Cove), 8/23/94.

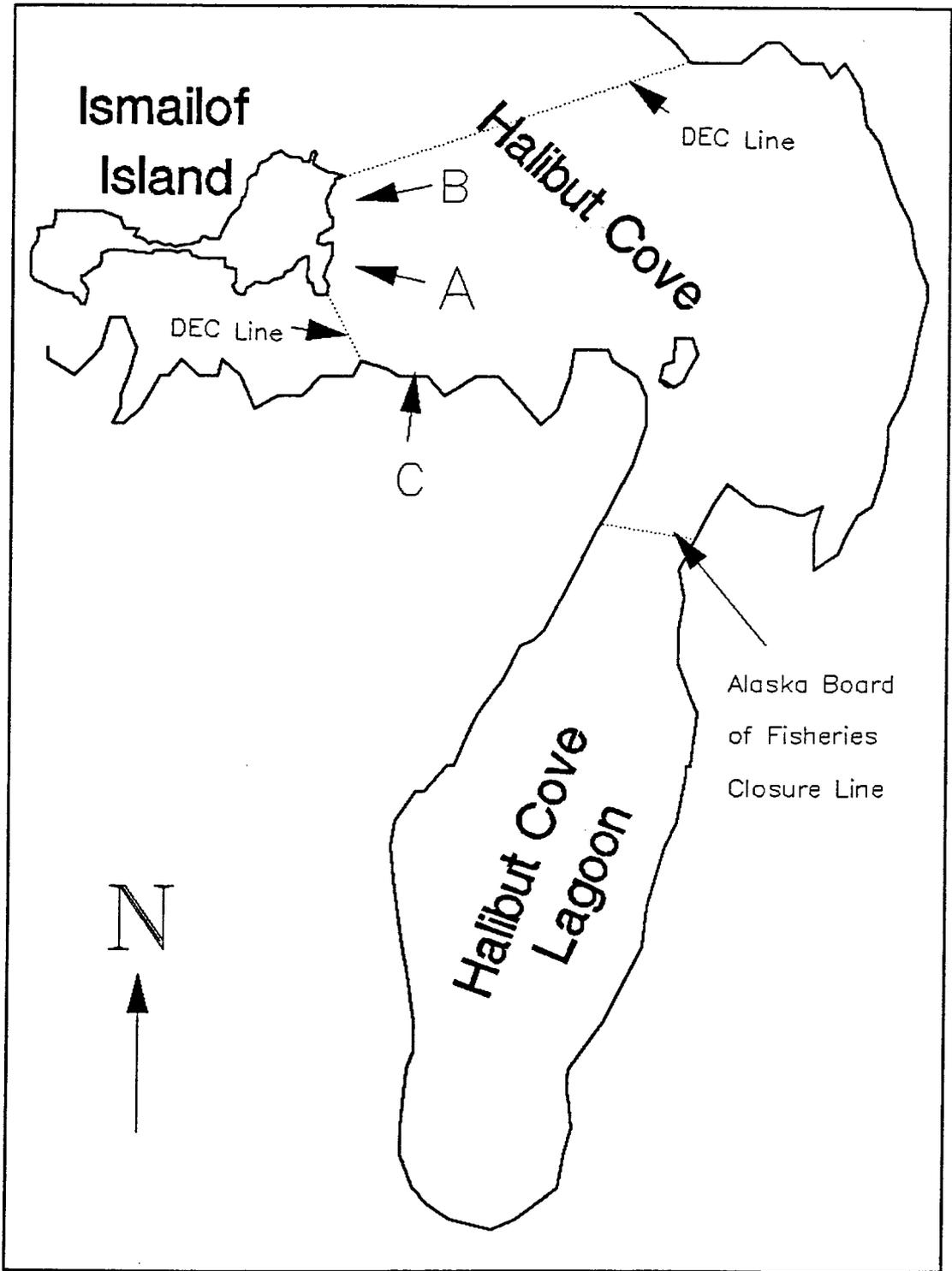


Figure 15. Location of the Halibut Cove clam survey, 8/23/94. Quadrats were dug at beach A. Only area measurements were made at beach B and beach C.

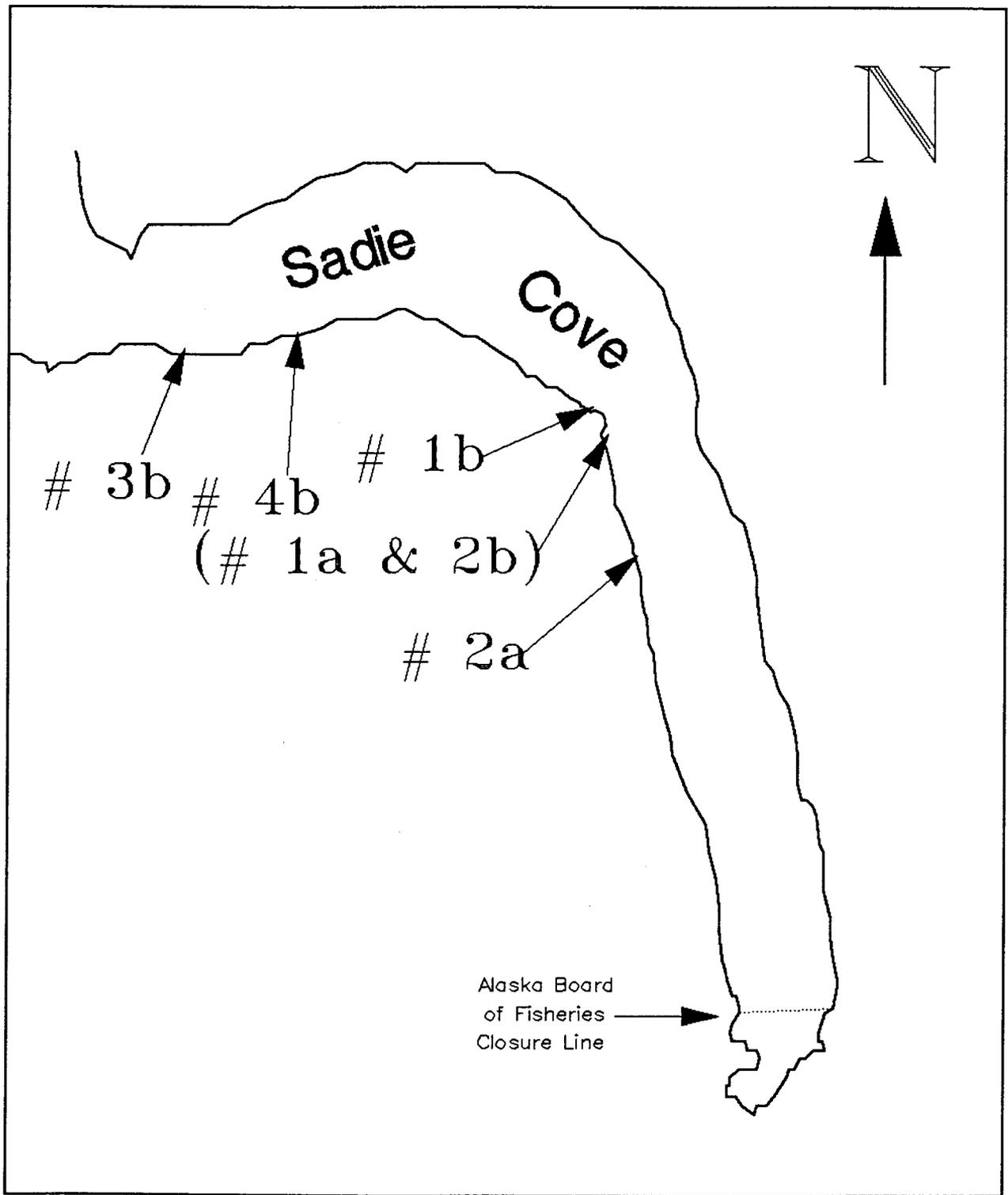


Figure 17. Location of Sadie Cove sites #1a & #2a dug 6/4/93 and sites #1b, #2b, #3b & #4b dug 9/6-7/94.

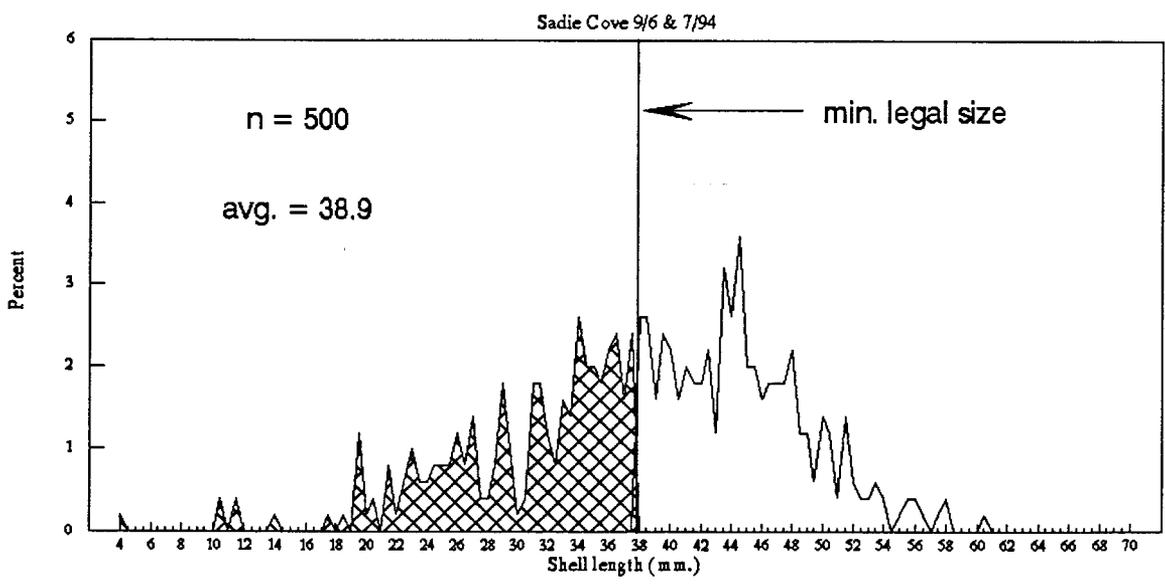
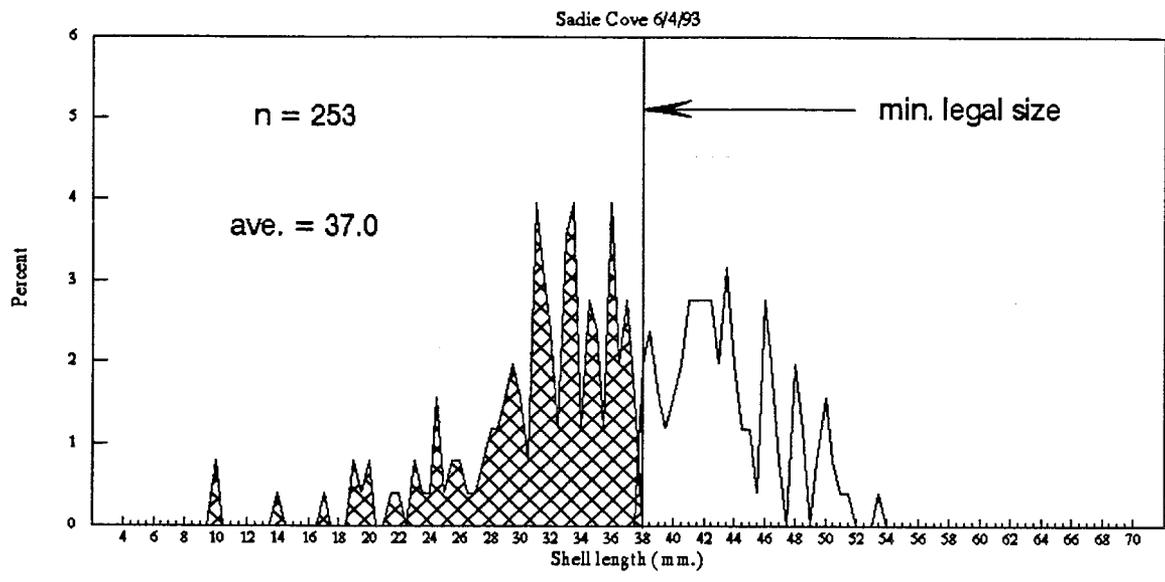


Figure 18. Percent shell length frequency from Pacific littleneck clams dug at Sadie Cove, 1993 and 1994.

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

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

Where: N = number of quadrats dug.

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

Area of a quadrat = 0.5 x 0.5 = 0.25 square meters

Area of clam habitat = A

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

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

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

$$\text{Standard deviation (SD)} = \sqrt{SV}$$

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

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

$$\text{Percent error} = \frac{1.96 \times SE}{\bar{X}} \times 100$$

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

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

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

Appendix B. Formulas and explanations for calculations of stratified abundance estimate and range for Pacific littleneck clams in Jakolof Bay.

Stratified population estimate (P_{sn}) became:

$$P_s = \left(\frac{1}{0.25} \right) \sum_{i=1}^3 A_i \bar{X}_i$$

Where A_i is the area of stratum i in m^2 . The mean clams per quadrat (\bar{X}_i) was estimated from the standardized clams per m^2 (X_{ij}) from each quadrat (j) averaged across the n_i quadrats in stratum i as:

$$\bar{X}_i = \frac{\sum_{j=1}^{n_i} X_{ij}}{n_i}$$

Stratified population estimate_(biomass) (P_{sw}) became:

$$P_{sw} = \frac{1}{0.25} \sum_{i=1}^3 A_i \bar{X}_i W_i$$

Where W_i is the average weight of clams in stratum i .

The standard deviation (SD_p) of the stratified population estimate became:

$$SD_p = \left(\frac{1}{0.25} \right) \sqrt{\sum_{i=1}^3 A_i^2 \frac{S_i^2}{n_i}}$$

Where S_i^2 was:

$$S_i^2 = \frac{\sum_{j=1}^{n_i} (X_{ij} - \bar{X}_i)^2}{(n_i - 1)}$$

Percent error (PE) was estimated as:

$$PE = \frac{1.96 SD_p}{P_s} 100$$

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