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**KACHEMAK BAY LITTLENECK CLAM ASSESSMENTS  
1996-1997**

By

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and

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## ABSTRACT

During the spring and summer of 1996 and 1997, the Alaska Department of Fish and Game (ADF&G) conducted quadrat surveys to estimate density, abundance, and biomass of Pacific Littleneck clams *Protothaca staminea* at commercially important beaches in Kachemak Bay, Alaska. The minimum legal size is 38 mm (1 1/2 in). A random sample design was applied at Chugachik Island with 33 quadrats (0.5 m x 0.5 m) dug in 1996 and 40 dug in 1997. Clam densities in 1996 were 63.3 legal and 25.0 sublegal clams/m<sup>2</sup>. This was an 87% increase in legal and a 29% increase in sublegal clam densities from the 1995 survey. Estimated abundance was 3,875,708 ±473,375 legal and 1,529,494 ±1,413,135 sublegal clams in 1996, with a biomass of 102,474 kg of legal and 13,444 kg of sublegal clams. Legal clam density in 1997 declined 5% to 60.2 clams/m<sup>2</sup> and sublegal density declined 11% to 22.4 clams/m<sup>2</sup>. Estimated abundance at Chugachik Island in 1997 was 3,687,491 ±851,102 legal and 1,372,090 ±533,545 sublegal clams, with a biomass of 89,237 kg of legal and 10,977 kg of sublegal clams.

Ismailof Island was surveyed in 1996 with a stratified systematic design using nine 0.5 m x 0.5m and seven 0.25m x 0.5m quadrats. Relative to the previous survey in 1994, the 1996 of legal clam density increased 35% to 104.5 clams/m<sup>2</sup> and sublegal clam density decreased 29% to 68.3 clams/m<sup>2</sup>. Estimated population abundance was 187,738 ±129,379 legal and 134,175 ±140,530 sublegal clams with a biomass of 3,477 kg of legal and 1,190 kg of sublegal clams. The 1997 Ismailof Island survey used a systematic design digging 32 quadrats (0.5m x 0.5m). Legal clam density declined 44% to 59.5 clams/m<sup>2</sup> and sublegal clam density declined 73% to 18.5 clams/m<sup>2</sup> in 1997. Estimated abundance was 141,089 ± 50,567 legal and 43,868 ± 16,938 sublegal clams with a biomass of 2,935 kg of legal and 368 kg of sublegal clams.

In 1996, 58 quadrats (0.5m x 0.5m) were dug from 4 sites on the west side of Sadie Cove using a systematic survey design. Mean density among all sites at West Sadie Cove was 26.4 legal and 21.0 sublegal clams/m<sup>2</sup>. This was a 29% reduction in legal clam density and a 28% increase in sublegal clam density from the 1995 survey. East Sadie Cove was sampled for the first time in 1997; 99 (0.5m x 0.5m) quadrats were systematically dug from 6 sites where commercial harvests had occurred. Mean density for all East Sadie Cove sites was 23.0 legal and 24.7 sublegal clams/m<sup>2</sup>.

## INTRODUCTION

Hardshell clams have been an important component of the recreational and commercial fisheries in Kachemak Bay (Trowbridge et al. 2000). The commercial fishery dates to the 1940s when butter clams *Saxidomus giganteus* were sold in canned and fresh markets, although these harvests were not well documented. Sales of canned clams contaminated with paralytic shellfish poisoning from Southeast Alaska led to a market collapse in the late 1950s (Paul & Feder 1976). A commercial Pacific littleneck *Protothaca staminea* fishery began in 1986 when the Alaska Department of Environmental Conservation (DEC) certified the Chugachik Island beach for commercial harvest (Gustafson 1996). As commercial harvests increased, DEC expanded certified areas to include Halibut Cove, Jakolof Bay, and Kasitsna Bay in 1988, and Tutka Bay in 1990. In December 1994, DEC certified all waters south of a line from the north end of Chugachik Island to Gull Island to Barabara Point, with the exception of: 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 (Figure 1). Bear Cove was closed conditionally from May 1 to September 30.

Commercial hardshell clam harvests ranged from 6,569 to 32,245 kg (14,449 to 71,025 lb) during 1986 to 1997 and the number of participants ranged from 2 to 33 permit holders (Table 1). The hardshell clam fishery targeted littleneck clams except in 1989 when 6,060 kg (13,348 lb) of butter clams were sold as otter food. Recent littleneck clam harvests included 24,254 kg (53,524 lb) taken by 15 diggers in 1996 and 14,323 kg (31,549 lb) taken by 51 diggers in 1997.

Conservation measures adopted into regulation by the Alaska Board of Fisheries in 1990 included a minimum size of 38 mm (1 ½ in) for littleneck clams and 63 mm (2 ½ in) for butter clams. In 1994 the board adopted, as amended in 1997, regulations that included the following provisions:

1. Kachemak Bay contains five subdistricts (Figure 1);
2. Subdistricts are divided into 2 groups that open on alternate years;
3. Sites of high historic recreational use are closed to commercial digging;
4. Weekends are closed to commercial digging from 11:00 p.m. Friday to 1:00 a.m. Monday during the high recreational use period of May 15 to September 15;
5. April 1 registration deadline;
6. Temperature-dependent, 48-hour openings from November 1 to March 15; and
7. 40,000 lb (18,144 kg) guideline harvest divided into quarterly allocations.

In 1992, the Alaska Department of Fish and Game (ADF&G) initiated assessment surveys of Pacific littleneck clams in DEC certified areas within Kachemak Bay. The surveys examined changes in the density, abundance, biomass, and age composition of clam populations at beaches with commercial harvests (Gustafson 1995, 1996). Survey objectives were to:

1. measure changes in density (clams/m<sup>2</sup>), abundance, and biomass of legal and sublegal clams over time;

2. compile baseline data for age composition, growth rate and recruitment to legal size of littleneck clams; and
3. determine the abundance of sublegal clams missed by not washing substrate through screens.

This paper summarizes results of littleneck clam surveys at Chugachik Island, Ismailof Island, and Sadie Cove in 1996 and 1997 (Figure 1).

## METHODS AND STUDY AREAS

### *Field Techniques*

Surveys were conducted on tides forecast to recede to at least the -0.5 m (- 1.5 ft) tide level. Arrival at the study site was scheduled for 2 hours prior to low slack tide. Sampling lasted through the minus tide and until the water rose to the +1.4 m (+4.0 ft) tide level. If multiple sites were sampled during a tide, the first site was surveyed as the tide receded, and the second site surveyed as the tide rose. In many areas, the uppermost elevation of littleneck clam habitat abutted a blue mussel *Mytilus edulis* bed. Some study areas, such as Ismailof Island or Chugachik Island, were sampled during one or more tides by available personnel. However, for larger study areas, such as Sadie Cove, sample sites were selected systematically, or with a random number generator, prior to the survey.

Clam density, abundance, and biomass were estimated from sample quadrats established by one of the following methods. In random placement, we divided the entire study area into enumerated survey plots and used a random number generator to select sample plots prior to the survey. For systematic placement of quadrats, upon arriving at the study site, We divided the length of the site into equally spaced transects established perpendicular to the water line; the number of transects depended upon the number of field staff. Placement of the initial transect from the edge of the site was determined with a random number generator. Quadrats were then systematically dug along the transect at approximately 20 to 50 cm (1-2 ft) elevation intervals throughout the elevation of littleneck clam distribution. Thus, systematic placement involved a 2-stage systematic design.

A plastic pipe square was used to dig a consistent size quadrat. Unless otherwise specified, all quadrats had inside dimensions of 0.5 m x 0.5 m (19.6 in x 19.6 in). Using a clam fork (4 prong garden rake), all substrate from inside the quadrat was removed to a depth of 20 to 34 cm (8.0 to 13.0 in) or deeper until littleneck and butter clams were no longer found. As the substrate was removed, all observed clams were placed in a bucket or bag. The substrate was then raked back into the hole and examined for any clams missed during the initial excavation. Bags of clams were labeled and frozen for later lab analysis.

The number of quadrats used to sample a particular beach site depended upon the size of the beach, the beach slope, the lowest elevation to which the tide would recede, the number of field personnel available, and the ease of digging in a substrate. A greater proportion of rocks to sand often increases the difficulty of digging a particular site. Quadrat sample size also depended upon anticipated clam density because a minimum sample size of clams was needed to obtain a specified precision when determining clam age composition. Thompson (1987) calculated a maximum sample size of 403 was needed from a population of multiple age groups to estimate age proportions within 5% of their true population proportions 90% of the time. However, this maximum sample size assumes perfect age readability. To accommodate unreadable shells, the target sample size was 600 clams per beach.

Quadrat elevation was determined either by using a hand held level and elevation rod to measure height above the water level at a know time, or by recording the time the rising water flooded the quadrat location. Water-level-at-time was later determined from a computer software program.

Laboratory analysis consisted of measuring the shell length (0.1 mm), weighing the whole clam weight (0.1 g), aging the clam (Feder and Paul 1973), and recording the distance to each visible annulus.

### Chugachik Island

Chugachik Island is located at the head of Kachemak Bay near Bear Cove (Figure 1). During low tides, a semicircular beach is exposed between the mainland and the southeast side of the island. Most commercial littleneck clam harvests from Chugachik Island occur in the -1.5 m to +1.2 m (-5.0 to +4.0 ft) tide level and below a large blue mussel bed containing several small stream drainages. The beach of primary clam habitat is an average of 550 m long and 190 m wide. The substrate is composed of a mixture of sandy-mud and 1-8 cm (1/2 to 3 in) diameter gravel. Total clam habitat was estimated to cover 61,254 m<sup>2</sup> (15.1 acres; Gustafson 1995).

The general distribution of clams at Chugachik Island was known from previous studies (Gustafson 1995, 1996). Quadrats were selected using a random number generator and were dug until at least 600 littleneck clams were obtained. The number of personnel available to conduct the survey varied between years. The 1996 survey was conducted June 3 and 5 on -1.6 m and -1.2 m (-5.25 and -4.08 ft) tides using 33 randomly selected quadrats (Figure 2).

To determine how many clams are missed by not screening substrate (Feder and Paul 1973), a non-random transect was established between the blue mussel and low water during the 1996 survey. Four quadrats were dug approximately evenly separated between the -0.9 m and 1.6 m (-3.0 ft and 5.1 ft) tidal elevations. Clams recovered during the initial substrate removal and sorting were bagged. The removed substrate was then washed with water through a 6 mm-mesh screen, and then through a 3-mm mesh screen. Clams retained by the 6-mm and 3-mm mesh screens were pooled and bagged by quadrat. Clams from the screening study were not used for density, abundance, and biomass calculations.

The 1997 survey was conducted May 7 and 8 during  $-1.5$  m and  $-1.4$  m ( $-4.8$  ft and  $-4.5$  ft) tides. Using a random survey design similar to the 1996 survey, 40 randomly selected quadrats were dug (Figure 3).

### Ismailof Island

Ismailof Island is located northeast of the Homer Spit with the study site on the southeast tip of the island (Figures 1 and 4). The southern boundary at the DEC closure line is composed of a steeply-sloped rock mass that opens to a flat beach composed of a mixture of small rocks (1-8 cm diameter), sand, and shell debris. The north end of the beach contains larger rocks (1-25 cm diameter) mixed with sand, mud and shell debris. The beach in the 1996 survey measured 125 m long and from 11 to 20 m wide and had an estimated total clam habitat of  $1,863$  m<sup>2</sup>. In the 1997 survey more transects were set on the north end increasing the area of clam habitat to  $2,371$  m<sup>2</sup>.

The Ismailof Island beach was surveyed on June 6, 1996 during a  $-0.8$  m ( $-2.6$  ft) tide. Numerous depressions and substrate piles on a  $7.5$  m x  $75.0$  m rectangular portion of the beach indicated previous intense harvesting activity. Only moderate digging activity was indicated on the remaining beach. Initially, nine  $0.5$  m x  $0.5$  m quadrats were systematically dug at 25 m intervals at elevations within the  $-0.7$  m to  $0.9$  m ( $-2.3$  ft to  $+2.9$  ft) tide levels. Because this approach did not sample the area of intensive digging, the beach was stratified into a  $1,300$  m<sup>2</sup> stratum of moderate digging activity and a  $563$  m<sup>2</sup> stratum of intensive digging activity. To decrease sampling time in the presence of the advancing tide, the quadrat size was reduced in the intensively dug stratum. Seven  $0.5$  m x  $0.25$  m quadrats were systematically dug at 12.5 m intervals in the area of intensive digging.

In 1997, the Ismailof Island beach was surveyed July 24 during a  $-0.7$  m ( $-2.2$  ft) tide. Nine transects were established, with six transects placed at 12.5 m intervals on the southern end, and three transects placed 25 m apart at the northern end. The initial starting point was randomly determined by randomly choosing a between 0 and 12.5. Three to five standard quadrats were dug in each transect.

### Sadie Cove

Sadie Cove is located south of the Homer spit on the south side of Kachemak Bay (Figure 1). The cove is characterized by steep beaches with a variety of sizes of gravel and rock substrate. The 1996 survey was conducted on May 4 and 5 during  $-1.2$  and  $-1.3$  m ( $-3.9$  and  $-4.2$  ft) tides on the west shore of Sadie Cove. Fifty-eight quadrats were dug at four sites surveyed in 1994 and 1995 (Figure 5). At each site, three transects were established at 25 m to 50 m intervals, with three to six quadrats on each transect. Mean width of clam habitat, extending from the mussel beds to the waterline, was 9.9 m during the 1993 to 1996 surveys. Because clams are assumed to occur along the entire  $9,106$  m (5.7 miles) length of the west shore of Sadie Cove, the estimated clam habitat is  $90,149$  m<sup>2</sup>.

Whole weights were not estimated for clams sampled from Sadie Cove in 1996. However, regression of whole weight on shell length using data from the 1993-1995 Sadie Cove surveys resulted in the following predictive equations (unpublished data):

$$\begin{aligned} \text{legal clam weight} &= 1.83 \text{ shell length} - 55.63; r^2 = 0.95; n = 3 \text{ years and} \\ \text{sublegal clam weight} &= 0.46 \text{ shell length} - 5.21; r^2 = 0.95, n = 3 \text{ years.} \end{aligned}$$

The east shore of Sadie Cove was surveyed during July 21-23, 1997 on -1.5 m to -1.2 m (-4.8 ft to -3.8 ft) tides (Figure 5). Six sites were sampled near locations where commercial harvests were reported in 1996. At each site, three to six transects were established at 25 m to 50 m intervals, and two to five quadrats were dug on each transect for a total of 99 quadrats. Based on an east shoreline length of 9,654 m, and mean transect length of 14.2 m, total clam habitat was estimated to be 137,301 m<sup>2</sup>.

### *Analytical Methods*

Legal littleneck clam abundance ( $N_i$ ) and variance ( $s_i^2$ ) was estimated for each sampling location using:

$$N_i = \frac{A \times c_i}{a} \tag{1}$$

$$s_i^2 = \left(\frac{A}{a}\right)^2 \times s_c^2 \tag{2}$$

where

- $c_i$  = the mean number of legal clams per quadrat in a sampling area,
- $A$  = the total area (m<sup>2</sup>) of clam habitat,
- $a$  = a scaling factor for the area dug within a quadrat, either 0.250 m<sup>2</sup> or 0.125 m<sup>2</sup>, and
- $s_c^2$  = the variance of legal clams per quadrat at a survey site.

This variance was calculated as if simple random sampling had been applied in all surveys. Even though systematic sampling and stratified systematic sampling were used to collect littleneck clams at Ismailof Island and Sadie Cove, the abundance and variance estimates described above are thought to be conservative and probably overestimate the true variance compared to a strict random design. Abundance and variance of sublegal clams was calculated in the same manner as for legal clams.

Finite population correction was not included in the variance estimate of abundance because the sampling fraction of quadrats was less than 1% at sampling locations. Cochran (1977) pointed out that finite population corrections can generally be ignored if the sampling fraction does not exceed 5% and for many purposes if the fraction is less than 10%.

The 95% confidence interval (CI) was calculated using:

$$N_i \pm t_{(1-\alpha/2, n-1)} SE \quad , \quad (3)$$

where  $SE$  (standard error) is estimated as the square root of the variance and  $t$  is the  $1-\alpha/2$  value of the Student's  $t$  distribution with  $n-1$  degrees of freedom.

Relative precision (RP) was calculated for all estimates from the upper and lower 95% confidence bounds of the population estimate using,

$$RP = \frac{Upper\ bound - Lower\ bound}{N_i} \quad (4)$$

The same equations were used to estimate abundances, variances and confidence intervals of sublegal clams. Clam population abundance was estimated by adding the estimates of legal and sublegal clams together.

To simplify data analysis, and because the abundance and biomass of clams older than age 14 was typically less than 0.5%, clams older than age 14 were summarized as a single class, age 15+.

Mean annual recruitment was calculated in three steps; using survey data was from 1992 to 1997 for Chugachik (Gustafson 1996), and 1996 and 1997 for Ismailof Island. First,  $L_a$ , the percent abundance of legal clams at age, was estimated by pooling age frequency data among years as in

$$L_a = \frac{\sum_{y=1}^J l_{ay}}{\sum_{y=1}^J t_{ay}} \quad (5)$$

where  $l_{ay}$  is the number of legal clams, and  $t_{ay}$  is the total number of clams, at age class  $a$  in year  $y$ . Second,  $R_a$ , mean recruitment to age  $a$ , was calculated as the difference in percent abundance of legal clams between adjacent age classes by

$$R_a = L_a - L_{a-1} \quad (6)$$

Mean population recruitment among years was calculated as the sum of mean recruitment among all ages.

Recruitment biomass was estimated as the product of mean recruitment abundance and mean clam weight at recruitment to legal size. Mean recruit clam weight was approximated using age-at-length and weight-at-length data. Clams recruit to legal size at 38.0 mm. Gustafson (1995) determined the mean age of recruitment among survey years to be age 7 for littleneck clams at Chugachik Island. Because clams grew an average of 3.9 mm between age 7 and age 8, it was assumed that clams between 38.0 and 41.9 mm shell length represented new recruits. Individual clam weights were only available for 1997. Available data was pooled to determine mean

weight of clams in the 38.0 to 41.9 mm size increment. Multiplying estimated clam abundance by mean recruitment clam weight yielded recruitment biomass.

## RESULTS

### *Chugachik Island*

#### 1996 Survey

A total of 728 littleneck clams, comprised of 522 legal (72%) and 206 sublegal clams, were removed in the 1996 survey. Mean density was 63.3 legal and 25.0 sublegal clams/m<sup>2</sup>, totaling 88.3 clams/m<sup>2</sup> (Table 2). Estimated population abundance, with 95% CI, was 3,875,708  $\pm$ 473,375 legal and 1,529,494  $\pm$ 1,413,135 sublegal clams, totaling 5,405,202  $\pm$ 1,886,510 littleneck clams. Estimated biomass was 102,474 kg (225,713 lb) legal and 13,444 kg (29,613 lb) sublegal clams.

#### 1996 Screening Study

A total of 97 littleneck clams were removed from the four quadrats in the 1996 Chugachik Island screening study. Only 13 clams (13.4%), comprising 2.8% (2 of 71) of all legal clams and 42.3% (11 of 26) of all sublegal clams were missed by not washing the substrate through screens. The age composition of the clams retained by the screens was:

<u>Age</u>	<u>Number</u>	<u>Age</u>	<u>Number</u>
1	2	6	1
2	3	8	1
3	3	10	1
5	2		

#### 1997 Survey

The 826 littleneck clams removed during the 1997 Chugachik survey were comprised of 602 legal (73%) and 224 sublegal clams. Mean density was 60.2 legal and 22.4 sublegal clams/m<sup>2</sup>, totaling 82.6 clams/m<sup>2</sup> (Table 3). Estimated population abundance, with 95% CI, was 3,687,491  $\pm$ 851,102 legal and 1,372,090  $\pm$ 533,545 sublegal clams totaling 5,059,581  $\pm$ 1,384,647. Estimated biomass was 89,237 kg (196,558 lb) legal clams and 10,977 kg (24,178 lb) sublegal clams.

## Size, Age, and Recruitment

Clam shell length at Chugachik Island in 1996 ranged from 6.0 mm to 64.0 mm; mean length was 42.3 mm (Figure 6). Shell length in 1997 ranged from 11.0 mm to 64.0 mm; mean length was 41.8 mm in 1997. Clam age at Chugachik Island in 1996 ranged from 2 to 15+ years, with age-9 clams, the 1987 cohort, comprising 22% of the sampled population and being the most abundant age class (Figure 7). Clam age in 1997 ranged from 1 to 14 years, with age-9 clams, the 1988 cohort, comprising 22% of the observed population and being the most abundant age class.

Among 1992-1997 survey years, mean recruitment by age class increased from 1.1% of the abundance of age-5 clams to 46.5% of age-7 clams (Table 4). Recruitment then decreased to 1.1% of age-10 clams. No new recruitment was indicated prior to age 5 or older than age 10. Estimated population recruitment for 1997 was 614,869 clams.

Gustafson (1995) previously modeled clam growth at Chugachik Island using a Von Bertalanffy curve. At age 7 the growth increment was 3.91 mm. Multiplying the estimated number of clams by age class with the average weight of legal clams from the age class between 38.1 mm and 42.01 mm resulted in a recruitment biomass of 8,437 kg (19,278 lb; Table 4).

## *Ismailof Island*

### 1996 Survey

A total of 389 littleneck clams, comprised of 208 legal (53%) and 181 sublegal clams, were dug in the moderately harvested stratum. Resultant densities were 92.4 legal and 80.4 sublegal clams/m<sup>2</sup>, totaling 172.8 clams/m<sup>2</sup>. Estimated population abundance, with 95% CI, in the moderately harvested area was 120,178  $\pm$ 76,087 legal and 104,578  $\pm$ 80,797 sublegal clams, totaling 224,756  $\pm$ 156,884 clams (Table 5). Estimated biomass was 2,174 kg (4,789 lb) legal and 930 kg (2,048 lb) sublegal clams.

The intensively harvested stratum yielded 151 littlenecks, comprised of 105 legal (70%) and 46 sublegal clams. Mean densities were 120.0 legal and 52.6 sublegal clams/m<sup>2</sup>, totaling 172.6 clams/m<sup>2</sup> (Table 6). The population abundance estimate, with 95% CI, was 67,560  $\pm$ 53,292 legal clams and 29,598  $\pm$ 59,733 sublegal clams, totaling 97,158  $\pm$ 113,025 clams. Estimated biomass was 1,303 kg (2,871 lb) legal and 260 kg (574 lb) sublegal clams.

Estimated population abundance among strata in 1996 was 187,738  $\pm$ 129,379 legal and 134,175  $\pm$ 140,530 sublegal clams, totaling 321,913  $\pm$ 269,909 clams, with a biomass of 3,477 kg (7,659 lb) legal and 1,190 kg (2,621 lb) sublegal clams (Table 6).

## 1997 Survey

A total of 624 clams, comprised of 476 legal (76%) and 148 sublegal clams, were dug in the 1997 Ismailof survey. Clam densities were 59.5 legal and 18.5 sublegal clams/m<sup>2</sup>, totaling 78.0 clams/m<sup>2</sup> (Table 7). Estimated abundance, with 95% CI, was 141,089  $\pm$ 50,567 legal and 43,868  $\pm$ 16,938 sublegal clams, totaling 184,958  $\pm$ 67,505 clams. Estimated biomass was 2,935 kg (6,464 lb) legal and 368 kg (812 lb) sublegal clams.

## Size, Age, and Recruitment

Shell length of littleneck clams from the 1996 Ismailof survey ranged from 10 to 56 mm. (Figure 8). Mean length was 37.7 mm in the moderately harvested stratum and 40.4 mm in the intensively harvested stratum, and 38.5 mm among strata (Figure 8). Clam ages in 1996 ranged from 1 to 11 years, with age-7 clams, the 1989 cohort, comprising 28% of the clams observed and being the most abundant cohort (Figure 9). Age distributions of the moderately and intensively harvested strata were not significantly different ( $\chi^2 = 12.208$ , 10 d.f.,  $\alpha=0.05$ ). When samples were pooled among strata, ages 5 and 6 comprised 18% to 22% of clams aged, ages 8 and 9 each comprised between 6% to 16% of the samples, and the remaining age classes contributing less than 5% of the samples.

In 1997, clam length at Ismailof Island ranged from 12 mm to 62 mm; mean clam length was 41.3 mm (Figure 8). Clam ages in 1997 ranged from 1 to 12 years. Age-8 clams, the 1989 cohort, were the most abundant clams in 1997 and comprised 26% of all aged clams (Figure 9).

A Von Bertalanffy growth equation fit to the 1996 survey data predicted littleneck clams reach legal size at 6 to 7 years (Figure 10). The same model fit to the 1997 data predicted that legal size was reached at 5 to 6 years (Figure 11).  $L_{\infty}$  was predicted to be 64.4 mm from the 1996 samples and 68.6 mm from the 1997 samples.

Clams in 1996 first recruited to legal size at age 5 with full recruitment by age 8 (Table 8). Clam samples from 1997 first recruited to legal size at age 4 with full recruitment by age 8. Only two years of age data were available to estimate recruitment to legal size among years at Ismailof Island. Mean recruitment among years was 13% of estimated total abundance; no recruitment was indicated prior to age 4 or older than age 8. Mean recruitment increased from 5.4% of the abundance of age-4 clams to 37.7% of age-6 clams and 32.8% of age-7 clams. Mean recruitment then decreased to 9.2% of age-8 clams. Less than 0.1% of clams younger than age 4 or older than age 8 were new recruits.

Estimated population recruitment to legal size in 1996 was 42,617 clams with a 631 kg (1,389 lb) biomass based on a mean weight of 14.8 g per recruit (Table 8). Population recruitment in 1997 was estimated to be 25,684 clams with a biomass of 396 kg (871 lb); mean recruit weight in 1997 was 15.4 g.

## *Sadie Cove*

### 1996 Sadie Cove West Shore

A total of 688 littleneck clams, comprised of 383 legal (56%) and 305 sublegal clams, were dug from the four sites on the west shore of Sadie Cove in 1996 (Figure 5). Mean clam density at site 1 was 13.0 legal and 7.3 sublegal clams/m<sup>2</sup>, totaling 20.3 clams/m<sup>2</sup>. Estimated clam abundance, with 95% CI, for site 1 was 22,100 ±19,681 legal and 12,467 ±14,010 sublegal clams, totaling 34,567 ± 33,691 clams (Table 9). Clam densities at site 2 were 29.0 legal and 13.3 sublegal clams/m<sup>2</sup>, totaling 42.3 clams/m<sup>2</sup> (Table 10). Estimated abundance, with 95% CI, for site 2 was 58,725 ±49,565 legal and 27,000 ±37,134 sublegal clams, totaling 85,725 ±86,699 clams. Site 3 clam densities were 33.6 legal and 2.8 sublegal clams/m<sup>2</sup>, totaling 36.4 clams/m<sup>2</sup> (Table 11). Estimated abundance, with 95% CI, at site 3 was 94,918 ±34,390 legal and 7,965 ±6,730 sublegal clams, totaling 102,883 ±41,120 clams. Clam density at site 4 was 26.8 legal and 54.4 sublegal clams/m<sup>2</sup>, totaling 81.2 clams/m<sup>2</sup> (Table 12). Estimated abundance, with 95% CI, at site 4 was 38,626 ±19,244 legal and 78,268 ±58,329 sublegal clams, totaling 116,894 ±77,573 clams. Estimated abundance, with 95% CI, for pooled sites on the west shore of Sadie Cove was 214,369 ±122,879 legal and 125,700 ±116,203 sublegal clams, totaling 340,069 ±239,082.

Mean estimated densities among sites on the west shore of Sadie Cove were 26.4 legal and 21.0 sublegal clams/m<sup>2</sup>, totaling 47.4 clams/m<sup>2</sup> (Table 13). Extrapolating this density to the estimated total clam habitat of 90,149 m<sup>2</sup> resulted in a potential population abundance, with 95% CI, of 2,381,177 ±636,569 legal and 1,896,238 ±1,142,114 sublegal clams, totaling 4,277,415 ±1,778,683 clams. Although clam weights were not measured from Sadie Cove in 1996, regression of shell length resulted in a mean weight of 29.2 g for legal clams and a 8.4 g for sublegal clams. Estimated biomass was 69,530 kg (153,151 lb) of legal and 15,928 kg (35,085 lb) of sublegal clams on the west shore of Sadie Cove.

Clam shell length at the west shore of Sadie Cove in 1996 ranged from 10 mm to 69 mm and mean length was 38.6 mm (Figure 12). No clams were aged from the 1996 West Sadie Cove survey.

### 1997 Sadie Cove East Shore

The 1997 survey on the east shore of Sadie Cove yielded 1,180 littleneck clams, comprised of 569 legal (48%) and 611 sublegal clams. Mean clam densities at site 5 were 5.5 legal and 21.5 sublegal clams/m<sup>2</sup>, totaling 27.1 clams/m<sup>2</sup> (Table 14). Estimated abundance, with 95% CI, at site 5 was 5,538 ±5,454 legal and 21,538 ±17,558 sublegal clams, totaling 34,567 ±23,012 clams. Mean clam densities at site 6 were 2.2 legal and 3.1 sublegal clams/m<sup>2</sup>, totaling 5.3 clams/m<sup>2</sup> (Table 15). Estimated site 6 abundance, with 95% CI, was 1,454 ±1,955 legal and 2,077 ±3,597 sublegal clams, totaling 3,531 ±5,552 clams. Mean clam densities at site 7 were 32.0 legal and 35.8 sublegal clams/m<sup>2</sup>, totaling 67.8 clams/m<sup>2</sup> (Table 16). Estimated abundance, with 95% CI, at site 7 was 60,000 ± 56,917 legal and 67,105 ± 51,822 sublegal clams, totaling 127,105 ± 108,739 clams. Clam mean densities at site 8 were 18.4 legal and 15.0 sublegal clams/m<sup>2</sup>,

totaling 33.4 clams/m<sup>2</sup> (Table 17). Estimated abundance, with 95% CI, at site 8 was 35,328 ±23,130 legal and 28,800 ±28,562 sublegal clams, totaling 64,128 ±51,692 clams. Mean clam densities at site 9 were 49.1 legal and 54.0 sublegal clams/m<sup>2</sup>, totaling 103.1 clams/m<sup>2</sup> (Table 18). Estimated abundance, with 95% CI, at site 9 was 229,840 ±122,050 legal and 252,720 ±121,315 sublegal clams, totaling 482,560 ±243,365 clams. Clam density at site 10 was 19.8 legal and 10.8 sublegal clams/m<sup>2</sup>, totaling 30.6 clams/m<sup>2</sup> (Table 19). Estimated site 10 abundance, with 95% CI, was 37,443 ±26,243 legal and 20,380 ±16,737 sublegal clams, totaling 57,823 ±42,980 clams.

Estimated clam densities pooled among sites on the east shore were 23.0 legal and 24.7 sublegal clams/m<sup>2</sup>, totaling 47.7 clams/m<sup>2</sup>. Abundance among pooled sites was 369,603 ±235,749 legal and 392,621 ±239,590 sublegal clams, totaling 762,224 ±475,339 clams. The potential population abundance, with 95% CI, was 3,156,544 ±1,113,564 legal and 3,389,540 ±1,122,292 sublegal clams, totaling 6,546,084 ±2,235,856 clams, with a biomass of 71,654 kg (157,827 lb) of legal clams and 25,422 kg (55,994 lb) of sublegal clams (Table 20).

Shell length of littleneck clams from the east shore of Sadie cove survey ranged from 9.8 mm to 58.9 mm and averaged 36.1 mm. (Figure 13). Clam ages ranged from 1 to 13 years (Figure 13). Age 7 was the most abundant cohort and comprised 15% of all clams aged. Recruitment to legal size occurred as early as age 4 with full recruitment by age 11

## DISCUSSION

### *Chugachik*

Littleneck clam density at Chugachik Island declined from 117.6 clams/m<sup>2</sup> in 1992 to 53 clams/m<sup>2</sup> in 1995, increased to 88.3 clams/m<sup>2</sup> in 1996, then decreased to 82.6 clams/m<sup>2</sup> in 1997 (Table 21). Mean density of legal clams declined 50% from 1992 to 1995, and then increased approximately 80% to densities observed in the 1996 and 1997 surveys. Mean density of sublegal clams declined 62% from 1992 to 1995 before increasing approximately 20% to densities observed in the 1996 and 1997 surveys. This was a relatively modest increase when compared to the increase in legal clam density. Density of sublegal clams has remained relatively low since the 1995 survey, suggesting that true recruitment of age-1 clams or settlement of age-0 clams was low. It is also possible that some environmental conditions may favor settlement at particular portions of the study area. For example, wind and wave conditions during settlement might direct spat of a cohort in a specific direction, resulting in a somewhat patchy distribution for that cohort. In these cases, even though the Chugachik surveys used a random sample design in all years, the effect on population estimation of the relatively small sample size of 12 quadrats in 1992 is unknown. The 40 quadrats sample in 1997 was the most effort expended in the history of the Chugachik Island surveys and likely provided better coverage of the available clam habitat (Figure 3).

Results of the screening study indicated that legal clams are relatively well sampled but that sublegal clams may be underestimated by up to 40% because the substrate was not washed through mesh screens. Although the precision of the abundance estimate for sublegal clams may be greatly improved by washing, the total number of quadrats that could be sampled would be reduced considerably. In the time it took two samplers to dig, screen, and wash the four experimental quadrats, a third sampler had dug and sorted eight quadrats without washing. With the variability of the clam distribution, it is important to sample the maximum number of quadrats in order to estimate the legal production rather than getting a precise estimate of the sublegal component of the clam population.

Additional aspects of survey selectivity at Chugachik Island from 1992 through 1996 have been examined through an age-structured model (Bechtol and Gustafson 1998). This model should be updated with more current survey data. Through a selectivity curve, the model can accommodate undersampling of sublegal clams.

### Size and Age Distributions

Shell lengths at Chugachik Island from 1992 through 1997 ranged from 7 mm to 66 mm (Figure 6). Mean annual length ranged from 38.0 mm in 1994 to 42.3 mm in 1996. Sublegal clams comprised less than half of the estimated clam population in all years except 1993-1994 when legal clams comprised only 46% of the estimated population. Sublegal clams comprised less than 30% of the population in 1996 and 1997.

Littleneck clam age at Chugachik Island during 1992-1997 ranged from 1 to 16 years old. Age 6 was the most abundant clam from 1992 to 1994 (Figure 7). The 1987 cohort, which had been the most abundant clam as age 6 in 1993, was also the most abundant clam as age 8 in 1995 and age 9 in 1996. In all surveys, legal size was attained as early as age 5 and as late as age 10, with the exception of 1992 and 1996 when all clams reached legal size by age 9.

Recruitment to legal size was estimated to be 679,628 clams in 1996 and 614,869 clams in 1997 (Table 4). The average recruitment has been 10% of the total abundance of littleneck clam estimated at Chugachik Island. Between 1992 and 1997 recruitment ranged from 6% to 13% and averaged 10% of the estimated abundance of all clams in the population. Commercial harvest guidelines for future seasons should be based on population trends as indicated by surveys in preceding years. The harvest guideline for 1999, the next scheduled Chugachik Island commercial opening, should depend upon results of the 1998 survey. In the absence of sublegal clams, we recommend the harvest not exceed 50% of the estimated recruitment.

### *Ismailof Island*

Littleneck clam shell length during 1994-1997 ranged from 9 to 61 mm. Density of legal clams in the 1996 survey increased 35% from the previous survey in 1994, whereas density of sublegal clams decreased 29% from the 1994 survey (Table 21). Total clam density decreased by <1%.

One objective of the 1996 survey was to determine if the 1996 commercial fishery, which was conducted prior to survey, substantially reduced the legal clam population. Although the 1994 survey used a sample size of only eight quadrats, the 1996 survey did not detect a decline in the relative density of legal clams following the 1996 fishery. The 1996 commercial clam harvest was 1,128 kg (2,485 lb). Using mean legal clam weight of 18.6 g from the 1996 survey (Table 6), the estimated harvest abundance was 60,647 clams. Adding these animals to survey abundance produced an estimate of 248,385 legal clams prior to the fishery. Thus, the fishery harvested 24% of the legal clams, and 143% of the new recruits estimated to be available following the fishery.

The survey effort of 32 quadrats at Ismailof Island in 1997 was the most in the history of the survey (Table 21). Relative to the 1996 density estimates, the 1997 survey showed legal clams declined 43%, sublegal clams declined 73%, and the aggregate population abundance declined 55%. Commercial removals are not believed to have directly caused this decline because this area was closed to commercial digging between the 1996 and 1997 surveys. Epidemic mortality has been documented for hardshell clams exposed to extreme freezing conditions (Bower 1992), and it is possible that freezing conditions during low tides increased mortality during the winter of 1996-1997. As qualitative evidence, more shell debris was observed on the beach in 1997 than in 1994 or 1996. Also, a greater number of dead clams with empty shells still attached by the ligament were found while digging the quadrats in 1997. The declines in clam density, particularly for sublegal clams, may also indicate poor reproductive success. Regardless, future recruitment to legal size is likely to be poor. Therefore, a guideline harvest range not to exceed 1,000 lb is recommended for the 1998 commercial harvest at Ismailof Island.

### *Sadie Cove*

Although efforts to sample Sadie Cove have increased, the extent of site-specific differences in clam densities throughout this area remains poorly understood. Apparent changes in littleneck clam densities among years may be due to differences in both habitat and harvest history of the sampled sites rather than change in the true population. Estimated population abundance and biomass for both the west and east sides of Sadie Cove are given only to indicate potential production, but with the understanding that unsampled areas may have different clam densities. Very conservative harvest guidelines are recommended for this area until additional sites are sampled with a random survey design. A random design for survey site selection will improve the likelihood of sampling a wide range of habitats with potentially different clam densities.

### *West Shore*

Between the 1995 and 1996 surveys of the west shore of Sadie Cove, density of legal clams declined 29%, and density of sublegal clams increased 28% (Table 21). Total clam density declined 12% from 1995 to 1996, continuing a decreasing trend since 1993. However, because survey sites were not the same between years, and a systematic sample design was applied, direct comparisons may be misleading. Littleneck clam shell lengths ranged from 3.9 mm to 69.2 mm,

and mean length ranged from 37.0 mm to 41.9 mm, during the 1993 to 1996 surveys (Figure 12). Legal clam contribution ranged from 44.0% to 79.5% of total clam abundance during 1993 to 1996. A substantial reduction in the abundance of sublegal clams in 1995 was not apparent in the 1996 survey.

## East Shore

Clam densities on the east shore of Sadie Cove in 1997 were similar to densities on the west shore of Sadie Cove in previous years (Table 21). The 1997 survey was directed at locations of previous commercial harvests. The numbers of transects and quadrats used for the 1997 survey represented was the most effort applied in clam surveys of Sadie Cove.

### *Survey Approach*

The ultimate goal of these surveys is to provide estimates of biomass and abundance to be used in management for long-term sustained yield from littleneck clam resource of Kachemak Bay. The survey design has evolved over time to better achieve this goal. Under the current management strategies, a given area is only opened to commercial digging on alternate years. To complement this management approach, an area is surveyed on a year when no commercial digging occurs and allowing the standing stock to be assessed the year prior to potential commercial digging. In addition, the beds at Ismailof Island and Chugachik Island are now being surveyed annually to generally treat these as long-term index sites for Kachemak Bay. Greater efforts have also been made to standardize the survey design. With one exception, all areas will be sampled with a multistage systematic design. The exception is Chugachik Island, a beach that is adapted well to a totally random design because the available habitat is well defined. These survey approaches will provide a better representation of clam habitat and clam availability in Kachemak Bay because some of the less productive habitats will also be included in future surveys. In addition, the number and variety of areas that are surveyed within Kachemak Bay are being increased in an effort to better represent the available resource. Finally, a conservative harvest approach is applied. This approach involves establishing commercial harvest caps, based on a maximum 10% commercial exploitation rate, for individual embayments. Hoenig (1983) developed an empirical method to estimate natural mortality of a species based on the maximum age observed in the population. The maximum observed age of 16 years for littleneck clams in Kachemak Bay results in an estimated instantaneous natural mortality rate of 26%. Thus, a harvest rate of 10% is substantially less than the estimated natural mortality and should be sufficient to also accommodate recreational removals.

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Table 1. Commercial harvest and effort and sport and personal use harvests of hardshell clams from the Southern District, Cook Inlet Management Area, 1986-1997.

Year	Permits Fished	Landings	Commercial Harvest (lb)				Total Recreational Harvest (lb) <sup>a/</sup>
			Pacific Littlenecks	Butter Clams	Cockles	Total	
1986	5	18	17,303	0		17,303	171,802
1987	8	69	12,214	206	2,347	14,767	137,097
1988	2	32	14,449	0	0	14,449	214,311
1989	9	41	2,584	13,675 <sup>b/</sup>	3,581 <sup>c/</sup>	19,840	128,937
1990	19	62	35,744	0	0	35,744	87,278
1991	19	78	47,486	85	0	47,571	89,046
1992	21	117	54,631	0	0	54,631	84,210
1993	33	159	63,676	0	0	63,676	70,975
1994	32	104	44,291	0	0	44,291	112,481
1995	21	93	66,723	4,267	(confidential)	71,025	168,232
1996	25	102	53,524	233	0	53,757	142,809
1997	15	63	31,549	0	0	31,549	121,584
Average	18	80	37,511	1,679	542	39,732	137,701

<sup>a/</sup> Nicky Szarzi, ADF&G Homer, AK, personal communication.

<sup>b/</sup> Includes 13,348 pounds sold as otter food as a result of Exxon Valdez oil spill.

<sup>c/</sup> Includes 1,982 pounds sold as otter food as a result of Exxon Valdez oil spill.

Table 2. Estimated abundance by quadrat and estimated population abundance and biomass of Pacific littleneck clams at Chugachik Island, 1996.

Quadrat Number	Elevation (m)	Clam Abundance		
		Legal	Sublegal	Total
1	1.33	8	21	29
2	1.32	1	0	1
3	0.93	1	0	1
4	0.86	29	6	35
5	0.70	22	0	22
6	0.68	3	6	9
7	0.58	6	1	7
8	0.55	11	7	18
9	0.52	7	5	12
10	0.52	42	9	51
11	0.46	10	7	17
12	0.43	2	0	2
13	0.33	31	4	35
14	0.12	9	3	12
15	0.08	51	5	56
16	0.02	24	5	29
17	0.00	32	14	46
18	-0.17	6	6	12
19	-0.17	43	17	60
20	-0.20	41	11	52
21	-0.50	14	8	22
22	-0.55	26	24	50
23	-0.75	9	1	10
24	-0.79	12	4	16
25	-0.82	6	3	9
26	-0.91	19	6	25
27	-0.94	8	4	12
28	-1.08	6	5	11
29	-1.12	12	4	16
30	-1.21	10	5	15
31	-1.24	6	5	11
32	-1.28	8	8	16
33	-1.57	7	2	9
Total		522	206	728

1996 Chugachik Population Estimates

	Legal	Sublegal	Total
Mean number of clams/quadrat	15.8	6.2	22.1
Mean number of clams/m <sup>2</sup>	63.3	25.0	88.3
Total area considered (m <sup>2</sup> )	61,254	61,254	61,254
Estimated clam abundance	3,875,708	1,529,494	5,405,202
95% confidence interval	±473,375	±1,413,135	±1,886,510
Relative precision	0.12	0.92	0.35
Average clam weight (g)	26.4	8.8	21.4
Population biomass (kg)	102,474	13,444	115,918
Population biomass (lb)	225,713	29,613	255,326

Table 3. Abundance by quadrat and estimated population abundance and biomass of Pacific littleneck clams at Chugachik Island, 1997.

Quadrat Number	Elevation (m)	Clam Abundance		
		Legal	Sublegal	Total
1	1.5	0	0	0
2	0.7	5	0	5
3	0.7	20	7	27
4	0.6	9	1	10
5	0.4	18	10	28
6	0.4	11	35	46
7	0.3	4	1	5
8	0.3	8	2	10
9	0.2	27	5	32
10	0.2	39	5	44
11	0.2	25	7	32
12	0.1	24	1	25
13	0.0	39	2	41
14	0.0	20	13	33
15	0.0	6	4	10
16	0.0	30	9	39
17	0.0	33	2	35
18	-0.1	18	4	22
19	-0.2	16	3	19
20	-0.2	12	9	21
21	-0.2	9	7	16
22	-0.4	16	0	16
23	-0.7	9	0	9
24	-0.7	28	4	32
25	-0.7	14	0	14
26	-0.7	19	5	24
27	-0.8	28	19	47
28	-0.8	26	20	46
29	-0.8	1	2	399
30	-0.8	22	10	32
31	-0.9	0	2	2
32	-1.1	7	3	10
33	-1.1	0	0	0
34	-1.2	2	4	6
35	-1.2	23	3	26
36	-1.3	1	1	2
37	-1.3	18	17	35
38	-1.4	1	0	1
39	-1.5	0	1	1
40	-1.5	14	6	20
Total		602	224	826

1997 Chugachik Population Estimates

	Legal	Sublegal	Total
Mean number of clams/quadrat	15.1	5.6	20.7
Mean number of clams/m <sup>2</sup>	60.2	22.4	82.6
Total area considered (m <sup>2</sup> )	61,254	61,254	61,254
Estimated clam abundance	3,687,491	1,372,090	5,059,581
95% confidence interval	±851,102	±533,545	±1,384,647
Relative precision	0.23	0.39	0.27
Average clam weight (g)	24.2	8.0	19.8
Population biomass (kg)	89,237	10,977	100,214
Population biomass (lb)	196,558	24,178	220,736

Table 4. Estimated annual recruitment to legal size at Chugachik Island based on mean recruitment abundance among years 1992 to 1997.

<u>A. Mean Recruit Abundance by Age Class</u>											
Age (years)	1	2	3	4	5	6	7	8	9	10	11
% Recruits	0.0	0.0	0.0	0.0	1.1	7.2	46.5	36.3	7.7	1.1	0.0

<u>B. Estimated Annual Recruitment.</u>						
Year	Estimated Population Abundance	Estimated Recruitment Abundance	Percent Recruits	Mean Recruit Weight (g) <sup>a/</sup>	<u>Recruitment Biomass</u> (kg) (lb)	
1992	7,207,502	806,899	11%	16.0	12,910	29,747
1993	5,497,507	425,337	8%	14.9	6,338	14,603
1994	4,855,737	288,013	6%	16.5	4,752	10,950
1995	3,262,213	354,115	11%	16.4	5,807	13,381
1996	5,405,201	679,628	13%	16.6	11,282	25,995
1997	5,059,581	614,869	12%	15.5	9,530	20,991
Average	4,474,392	452,696	10%	16.0	8,437	19,278

<sup>a/</sup> Mean Recruit Weight - Mean weight of clams that were 38.1 mm to 42.0 mm in shell length.

Table 5. Abundance by quadrat and estimated population abundance and biomass of Pacific littleneck clams at the Ismailof Island moderately harvested stratum, 1996.

Transect	Elevation (m)	Quadrat	Clam Abundance		
			Legal	Sublegal	Total
1	0.22	T1	8	61	69
2	0.98	R7	45	30	75
2	0.62	R6	14	4	18
2	0.28	R1	46	39	85
3	0.87	T9	7	13	20
3	0.64	T8	8	6	14
3	-0.49	T2	26	4	30
4	-0.54	R2	4	1	5
5	-0.71	T3	50	23	73
Total			208	181	389

1996 Ismailof Population Estimates – Moderately Harvested Stratum

	<u>Legal</u>	<u>Sublegal</u>	<u>Total</u>
Mean number of clams/quadrat	23.1	20.1	43.2
Mean number of clams/m <sup>2</sup>	92.4	80.4	172.8
Total area considered (m <sup>2</sup> )	1,300	1,300	1,300
Estimated clam abundance	120,178	104,578	224,756
95% confidence interval	±76,087	±80,797	±156,884
Relative precision:	0.63	0.77	0.70
Average clam weight (g)	18.1	8.9	13.8
Population biomass (kg)	2,174	930	3,104
Population biomass (lb)	4,789	2,048	6,836

Table 6. Abundance by quadrat and estimated population abundance and biomass of Pacific littleneck clams at the Ismailof Island heavily harvested stratum, 1996.

Transect	Quadrat	Elevation (m)	Legal	Sublegal	Total
A	T6	-0.26	26	39	65
B	R4	-0.30	2	0	2
B	R5	0.13	15	1	16
C	T4	-0.49	18	0	18
C	T5	-0.12	4	2	6
D	R3	-0.69	36	3	39
D	T7	0.08	4	1	5
Total			105	46	151

1996 Ismailof Population Estimate - Heavily Harvested Stratum

Mean number of clams/quadrat	15.0	6.6	21.6
Mean number of clams/m <sup>2</sup>	120.0	52.6	172.6
Total area considered (m <sup>2</sup> )	563	563	563
Population abundance for high stratum	67,560	29,598	97,158
95% confidence interval for high stratum	±53,292	±59,733	±113,025
Relative precision	0.79	2.02	1.16
Average clam weight (g)	19.3	8.8	16.1
Population biomass (kg) for high stratum	1,303	260	1,563
Population biomass (lb) for high stratum	2,871	574	3,445

1996 Ismailof Population Estimate - Pooled Strata

	<u>Legal</u>	<u>Sublegal</u>	<u>Total</u>
Population abundance	187,738	134,175	321,913
95% confidence interval	±129,379	±140,530	±269,909
Relative precision	0.69	1.05	0.84
Mean clam weight (g)	18.6	8.9	14.6
Population biomass (kg)	3,477	1,190	4,667
Population biomass (lb)	7,659	2,621	10,280

Table 7. Pacific littleneck clam abundance by quadrat and estimated population abundance and biomass at Ismailof Island, 1997.

Transect	Quadrat	Elevation (m)	Legal	Sublegal	Total
1	1	1.92	0	2	2
	3	1.04	8	2	10
	5	0.37	3	3	6
2	7	-0.29	7	0	7
	2	1.34	7	3	10
	4	0.82	7	3	10
	6	0.12	68	16	84
3	8	-0.49	17	4	21
	1	2.10	0	0	0
	3	1.16	1	1	2
4	5	0.03	22	2	24
	7	-0.43	9	2	11
	2	1.46	19	5	24
5	4	0.52	9	4	13
	6	-0.27	5	0	5
	CC	2.10	0	1	1
	T	1.04	10	4	14
6	HH	-0.03	44	3	47
	QQ	1.55	0	11	11
	AA	0.49	40	5	45
7	G	-0.52	15	1	16
	8	-0.12	8	0	8
	9	0.12	7	4	11
	10	0.37	31	11	42
8	11	0.55	3	0	3
	9	-0.24	8	1	9
	10	0.37	31	6	37
9	11	0.55	11	3	14
	M	-0.24	31	3	34
	C	0.40	23	16	39
	F	0.58	25	19	44
	0	0.91	7	13	20
Total			476	148	624

1997 Ismailof Island Population Estimate

	<u>Legal</u>	<u>Sublegal</u>	<u>Total</u>
Mean number of clams/ quadrat	14.9	4.6	19.5
Mean number of clams/m <sup>2</sup>	59.5	18.5	78.0
Total area considered (m <sup>2</sup> )	2,371	2,371	2,371
Estimated clam abundance	141,089	43,868	184,958
95% Confidence Interval	±50,567	±16,938	±67,505
Relative precision	0.36	0.39	0.37
Average clam weight (g)	20.8	8.4	17.9
Population biomass (kg)	2.935	368	3.303
Population biomass (lb)	6.464	812	7.276

Table 8. Estimated recruitment to legal size for littleneck clams at Ismailof Island, 1996 and 1997.

A. Mean Recruit Abundance by Age Class

Age (years)	1	2	3	4	5	6	7	8	9	10	11
% Recruits	0.0	0.0	0.0	5.4	14.9	37.7	32.8	9.2	0.0	0.0	0.0

B. Estimated Recruit Abundance and Biomass by Survey Year

Year	Clam Abundance		Percent Recruits	Mean Recruit Weight <sup>a/</sup> (g)	Recruitment Biomass	
	Population	Recruitment			(kg)	(lb)
1996	321,913	42,617	13%	14.8	631	1,389
1997	184,958	25,684	14%	15.4	396	871
Mean	253,436	34,151	13%	15.0	513	1,130

<sup>a/</sup> Legal clams measure  $\geq 38$  mm shell length.

Table 9. Pacific littleneck clam abundance by quadrat and estimated abundance at site 1 on the west shore of Sadie Cove, 1996.

<u>Transect</u> <sup>a/</sup>		Elevation (m)	Legal	Sublegal	Total
Number	Length (m)				
1	24	1	0	0	0
		2	0	0	0
		3	0	0	0
		4	0	0	0
2	23	1	3	1	4
		2	1	0	1
		3	1	2	3
		4	2	0	2
3	21	1	5	1	6
		2	9	5	14
		3	15	11	26
		4	3	2	5
<b>Total</b>			<b>39</b>	<b>22</b>	<b>61</b>

Sadie Cove West Shore, Site 1, Population Estimate

	<u>Legal</u>	<u>Sublegal</u>	<u>Total</u>
Mean clams/quadrat	3.3	1.8	5.1
Mean clams /m <sup>2</sup>	13.0	7.3	20.3
Area considered (m <sup>2</sup> )	1,700	1,700	1,700
Estimated clam abundance	22,100	12,467	34,567
95% confidence interval	±19,681	±14,010	±33,691
Relative precision	0.89	1.12	0.98

<sup>a/</sup> Transects spaced 25 m apart.

Table 10. Pacific littleneck clam abundance by quadrat and estimated abundance at site 2 on the west shore of Sadie Cove, 1996.

<u>Transect</u> <sup>a/</sup>		Quadrat	Elevation (m)	Legal	Sublegal	Total
Number	Length (m)					
7	7	1	0.10	0	0	0
		2	0.18	0	2	2
		3	0.49	0	0	0
		4	1.41	5	1	6
		5	1.99	4	1	5
5	10	1	0.20	32	26	58
		2	0.79	17	1	18
		3	1.81	14	1	15
4	10	1	0.00	0	2	2
		2	0.09	2	4	6
		3	0.61	9	1	10
		4	1.81	4	1	5
Total				87	40	127

Sadie Cove West Shore, Site 2, Population Estimate

	<u>Legal</u>	<u>Sublegal</u>	<u>Total</u>
Mean clams/quadrat	7.3	3.3	10.6
Mean clams /m <sup>2</sup>	29.0	13.3	42.3
Area considered (m <sup>2</sup> )	2,025	2,025	2,025
Estimated clam abundance	58,725	27,000	85,725
95% confidence interval	±49,565	±37,134	±86,699
Relative precision:	0.84	1.38	1.01

<sup>a/</sup> Transects spaced 25 m apart.

Table 11. Pacific littleneck clam abundance by quadrat and estimated abundance at site 3 on the west shore of Sadie Cove, 1996.

<u>Transect</u> <sup>a/</sup>		Elevation				
Number	Length (m)	Quadrat	(m)	Legal	Sublegal	Total
8	19.0	1	1.21	3	0	3
		2	0.52	13	3	16
		3	-0.09	10	0	10
		4	-0.22	9	0	9
		5	-0.68	0	1	1
		6	-1.25	2	0	2
9	18.8	1	1.53	1	1	2
		2	0.93	8	1	9
		3	0.47	17	0	17
		4	0.11	13	0	13
		5	-0.49	12	1	13
		6	-1.28	2	0	2
10	16.8	1	0.99	1	0	1
		2	0.87	9	0	9
		3	0.13	10	0	10
		4	-0.13	15	4	19
		5	-1.26	18	1	19
Total				143	12	155

Sadie Cove West Shore, Site 3, Population Estimate

	<u>Legal</u>	<u>Sublegal</u>	<u>Total</u>
Mean clams/quadrat	8.4	0.7	9.1
Mean clams /m <sup>2</sup>	33.6	2.8	36.4
Area considered (m <sup>2</sup> )	2,821	2,821	2,821
Estimated clam abundance	94,918	7,965	102,883
95% confidence interval	±34,390	±6,730	±41,120
Relative precision	0.36	0.85	0.40

<sup>a/</sup> Transects 8-10 spaced 35 m apart with 50 m spacing on either end of transects 8 and 10.

Table 12. Pacific littleneck clam abundance by quadrat and estimated abundance at site 4, and estimated clam abundance for pooled sites, on the west shore of Sadie Cove, 1996.

<u>Transect</u> <sup>a/</sup>		Quadrat	Elevation (m)	Legal	Sublegal	Total
Number	Length (m)					
11	13	1	-0.40	8	9	17
		2	-0.16	2	12	14
		3	0.07	11	26	37
		4	0.57	23	20	43
		5	1.14	12	6	18
		6	1.55	0	0	0
12	12	1	-0.91	2	7	9
		2	-0.28	3	77	80
		3	0.35	15	42	57
		4	0.50	12	13	25
		5	1.28	2	1	3
		6	1.57	1	1	2
13	11	1	-0.94	1	0	1
		2	-0.31	12	3	15
		3	0.45	1	6	7
		4	0.88	3	1	4
		5	1.25	6	7	13
Total				114	231	345

Sadie Cove West Shore, Site 4, Population Estimate

	<u>Legal</u>	<u>Sublegal</u>	<u>Total</u>
Mean clams/quadrat	6.7	13.6	20.3
Mean clams /m <sup>2</sup>	26.8	54.4	81.2
Area considered (m <sup>2</sup> )	1,440	1,440	1,440
Estimated clam abundance	38,626	78,268	116,894
95% confidence interval	±19,244	±58,329	±77,573
Relative precision:	0.50	0.75	0.66

<sup>a/</sup> Transects spaced 25 m apart.

Table 13. Potential Pacific littleneck clam abundance and biomass for the west shore of Sadie Cove, 1996

Sadie Cove West Shore, Pooled Sites			
	<u>Legal</u>	<u>Sublegal</u>	<u>Total</u>
Total Abundance	383	305	688
Mean clams/quad	6.6	5.3	11.9
Mean clams /m <sup>2</sup>	26.4	21.0	47.4
Total Area Considered (m <sup>2</sup> )	7,986	7,986	7,986
Estimated abundance all sites	214,369	125,700	340,069
95% confidence interval	±122,879	±116,203	±239,082
Relative precision:	0.57	0.92	0.70

Sadie Cove West Shore Potential Population (including unsampled areas)			
	<u>Legal</u>	<u>Sublegal</u>	<u>Total</u>
Total area considered	90,149	90,149	90,149
Potential clam abundance	2,381,177	1,896,238	4,277,415
95%confidence interval	±636,569	±1,142,114	±1,778,683
Relative precision	0.27	0.60	0.42
Estimated clam weight (g)	29.2	8.4	20.0
Potential biomass (kg)	69,530	15,928	85,458
Potential biomass (lb)	153,151	35,085	188,236

Table 14. Pacific littleneck clam abundance by quadrat and estimated abundance and biomass at site 5 on the east shore of Sadie Cove, 1997.

<u>Transect</u>		Quadrat	Elevation (m)	Legal	Sublegal	Total
Number	Length (m) <sup>a</sup>					
1	8	101	-0.09	0	0	0
		102	-0.85	0	1	1
2	10	103	0.24	0	0	0
		104	-0.73	0	1	1
3	12	105	-0.09	0	5	5
		106	-0.61	0	27	27
4	10	107	-1.19	1	9	10
		108	-0.03	2	6	8
5		109	-0.84	4	4	8
		110	-1.28	0	2	2
		111	0.03	7	6	13
		112	-1.07	4	9	13
		113	-1.34	0	0	0
<u>Total</u>				18	70	88

Sadie Cove East Shore, Site 5, Population Estimate

	<u>Legal</u>	<u>Sublegal</u>	<u>Total</u>
Mean clams/quadrat	1.4	5.4	6.8
Mean clams /m <sup>2</sup>	5.5	21.5	27.1
Area considered (m <sup>2</sup> )	1,000	1,000	1,000
Estimated clam abundance	5,538	21,538	27,076
95% confidence interval	±5,454	±17,558	±23,012
Relative precision:	0.99	0.82	0.85
Average clam weight (g)	23.2	4.9	8.6
Biomass (kg)	128	106	234
Biomass (lb)	283	232	515

Table 15. Pacific littleneck clam abundance by quadrat and estimated abundance and biomass at site 6 on the east shore of Sadie Cove, 1997.

<u>Transect</u>		Quadrat	Elevation (m)	Legal	Sublegal	Total
Number	Length (m)					
1	9	114	-0.76	4	8	12
		115	-0.30	0	1	1
		116	0.12	0	0	0
		117	0.52	0	0	0
2	8	118	-0.76	2	0	2
		119	-0.09	0	0	0
		120	0.15	0	0	0
3	7	121	-0.85	0	0	0
		122	-0.43	0	0	0
4	12	123	-0.40	1	1	2
		124	0.06	0	0	0
		125	0.49	0	0	0
		126	0.61	0	0	0
Total				7	10	17

Sadie Cove East Shore, Site 6, Population Estimate

	<u>Legal</u>	<u>Sublegal</u>	<u>Total</u>
Mean clams/quadrat	0.5	0.8	1.3
Mean clams /m <sup>2</sup>	2.2	3.1	5.3
Area considered (m <sup>2</sup> )	675	675	675
Estimated clam abundance	1,454	2,077	3,531
95% confidence interval	±1,955	±3,597	±5,552
Relative precision	1.35	1.73	1.57
Average clam weight (g)	21.3	7.6	13.2
Biomass (kg)	31	16	47
Biomass (lb)	68	35	103

Table 16. Pacific littleneck clam abundance by quadrat and estimated abundance and biomass at site 7 on the east shore of Sadie Cove, 1997.

<u>Transect</u>		Quadrat	Elevation (m)	Legal	Sublegal	Total
Number	Length (m)					
1		127	1.55	0	0	0
		128	1.16	0	0	0
		129	0.34	0	0	0
2	21	130	2.19	0	0	0
		131	0.61	2	2	4
		132	-0.37	2	1	3
		133	-0.98	0	3	3
3	21	134	1.86	0	0	0
		135	0.55	28	39	67
		136	-0.24	8	22	30
		137	-0.73	13	23	36
4	17	138	0.85	6	3	9
		139	0.06	66	49	115
		140	-0.64	2	2	4
		141	-1.25	0	5	5
5	16	142	0.64	14	1	15
		143	0.09	5	6	11
		144	-0.52	6	14	20
		145	-1.04	0	0	0
<b>Total</b>				152	170	322

Sadie Cove East Shore, Site 7, Population Estimate

	<u>Legal</u>	<u>Sublegal</u>	<u>Total</u>
Mean clams/quadrat	8.0	8.9	16.9
Mean clams /m <sup>2</sup>	32.0	35.8	67.8
Area considered (m <sup>2</sup> )	1,875	1,875	1,875
Estimated clam abundance	60,000	67,105	127,105
95% confidence interval	±56,917	±51,822	±108,739
Relative precision:	0.95	0.77	0.86
Average clam weight (g)	21.5	9.3	15.1
Biomass (kg)	1,290	624	1,914
Biomass (lb)	2,841	1,375	4,216

Table 17. Pacific littleneck clam abundance by quadrat and estimated abundance and biomass at site 8 on the east shore of Sadie Cove, 1997.

<u>Transect</u>		Quadrat	Elevation (m)	Legal	Sublegal	Total
Number	Length (m)					
1	11	146	-0.67	0	0	0
1		147	-0.27	7	3	10
1		148	0.21	0	0	0
1		149	0.88	0	0	0
2	15	150	0.67	14	27	41
2		151	-0.15	20	25	45
2		152	0.79	12	2	14
2		153	1.16	5	4	9
3a	14	154	-0.40	14	9	23
3a		155	0.00	10	4	14
3a		156	0.46	10	0	10
3a		157	0.98	0	0	0
3	13	158	-0.58	0	0	0
3		159	0.27	0	0	0
3	11	160	0.61	0	1	1
4a		161	-0.43	0	0	0
4a		162	-0.21	0	0	0
4a		163	0.06	0	0	0
4		164	-0.70	0	0	0
4		165	0.34	0	0	0
Total				92	75	167

Sadie Cove East Shore, Site 8, Population Estimate

	<u>Legal</u>	<u>Sublegal</u>	<u>Total</u>
Mean clams/quadrat	4.6	3.8	8.4
Mean clams /m <sup>2</sup>	18.4	15.0	33.4
Area considered (m <sup>2</sup> )	1,920	1,920	1,920
Estimated clam abundance	35,328	28,800	64,128
95% confidence interval	±23,130	±28,562	±51,692
Relative precision	0.66	0.99	0.81
Average clam weight (g)	24.0	7.2	16.4
Biomass (kg)	848	207	1,055
Biomass (lb)	1,868	457	2,324

Table 18. Pacific littleneck clam abundance by quadrat and estimated abundance and biomass at site 9 on the east shore of Sadie Cove, 1997.

<u>Transect</u>		Quadrat	Elevation (m)	Legal	Sublegal	Total
Number	Length (m) <sup>a</sup>					
1	27	166	0.91	2	0	2
1		167	0.40	9	6	15
1		168	-0.21	12	5	17
1		169	0.76	2	0	2
2	18	170	0.98	12	7	19
2		171	0.37	38	1	39
2		172	-0.40	20	36	56
2		173	-0.88	0	10	10
3	29	174	0.94	33	24	57
3		175	0.46	3	35	38
3		176	-0.06	39	27	66
3		177	-0.52	11	30	41
3		178	-0.85	0	2	2
4	30	179	1.49	2	3	5
4		180	1.13	3	2	5
4		181	0.43	24	12	36
4		182	-0.09	9	30	39
4		183	-0.91	2	13	15
<b>Total</b>				<b>221</b>	<b>243</b>	<b>464</b>

Sadie Cove East Shore, Site 9, Population Estimate

	<u>Legal</u>	<u>Sublegal</u>	<u>Total</u>
Mean clams/quadrat	12.3	13.5	25.8
Mean clams /m <sup>2</sup>	49.1	54.0	103.1
Area considered (m <sup>2</sup> )	4,680	4,680	4,680
Estimated clam abundance	229,840	252,720	482,560
95% confidence interval	±122,050	±121,315	±243,365
Relative precision:	0.53	0.48	0.50
Average clam weight (g)	23.0	8.1	15.2
Biomass (kg)	5,286	2,047	7,333
Biomass (lb)	11,644	4,509	16,153

Table 19. Pacific littleneck clam abundance by quadrat and estimated abundance and biomass at site 10 and pooled among sites on the east shore of Sadie Cove, 1997.

<u>Transect</u>		Quadrat	Elevation (m)	Legal	Sublegal	Total
Number	Length (m) <sup>a</sup>					
1a	11	184	0.09	0	3	3
1a		185	0.34	1	0	1
1a		186	0.82	7	1	8
1	17	187	-0.43	8	5	13
1		188	-0.15	23	15	38
1		189	0.55	17	2	19
1		190	1.13	2	1	3
2	10	191	0.09	1	0	1
2		192	0.43	4	2	6
3	10	193	-0.12	3	10	13
3		194	0.58	6	1	7
3		195	0.94	0	0	0
4	9	196	0.46	0	1	1
4		197	0.76	3	1	4
5	8	198	0.18	4	1	5
5		199	1.01	0	0	0
<u>Total</u>				79	43	122

Sadie Cove East Shore, Site 10, Population Estimate

	<u>Legal</u>	<u>Sublegal</u>	<u>Total</u>
Mean clams/quadrat	4.9	2.7	7.6
Mean clams /m <sup>2</sup>	19.8	10.8	30.6
Area considered (m <sup>2</sup> )	1,896	1,896	1,896
Estimated clam abundance	37,443	20,380	57,823
95% confidence interval	±26,243	±16,737	±42,980
Relative precision	0.70	0.82	0.74
Average clam weight (g)	22.2	8.1	17.2
Biomass (kg)	831	165	996
Biomass (lb)	1,831	364	2,195

Abundance Estimates Pooled Among Sites, Sadie Cove East Shore

	<u>Legal</u>	<u>Sublegal</u>	<u>Total</u>
Estimated clam abundance	369,603	392,621	762,224
95% confidence interval	±235,749	±239,590	±475,339
Relative precision	0.64	0.61	0.62
Biomass (kg)	8,415	3,008	11,423
Biomass (lb)	17,535	6,773	24,308

Table 20. Pacific littleneck clam potential production abundance and biomass on the east side of Sadie Cove pooling sampled sites and unsampled area, 1997.

	Legal	Sublegal	Total
Total	569	611	1180
Mean number of clams/quadrat	5.7	6.2	11.9
Mean number of clams/m <sup>2</sup>	23.0	24.7	47.7
Total area considered (m <sup>2</sup> )	137,301	137,301	137,301
Potential abundance	3,156,544	3,389,540	6,546,084
Sample quadrats	99	99	99
95% confidence interval	±1,113,564	±1,122,292	±2,235,856
Relative precision	.35	.33	.34
Average clam weight (all east side sites)	22.7	7.5	14.8
Potential biomass (kg)	71,654	25,422	97,076
Potential biomass (lb)	157,827	55,994	213,821

Table 21. Results from the ADF&G Pacific littleneck clam surveys in DEC certified areas of Kachemak Bay, 1990 to 1997.

Clam Subdistrict	Bay or Area Year	Sample Effort		Clams /m <sup>2</sup>			Survey Design
		Sites	Quadrats	Legal	Sublegal	Total	
1	Chugachik						
	1992	1	12	67.2	50.4	117.6	Randomly selected
	1993	1	16	41.0	48.8	89.8	"
	1994	1	33	36.4	42.8	79.2	"
	1995	1	35	33.8	19.4	53.2	"
	1996	1	33	63.3	25.0	88.3	"
	1997	1	40	60.2	22.4	82.6	"
2	Ismailof Island						
	1994	1	8	77.6	96.4	174.0	2-Stage Systematic
	1996 Med. Density	1	9	92.4	80.4	172.8	2-Stage Systematic
	1996 High Density	1	7	120.0	52.6	172.6	2-Stage Systematic
	1996 Total	1	16	104.5	68.3	172.8	Stratified/Systematic
	1997	1	32	59.5	18.5	78.0	2-Stage Systematic
3a	Sadie Cove (east shore)						
	1997	6	99	23.0	24.7	47.7	2-Stage Systematic
3b	Sadie Cove (west shore)						
	1993	2	17	27.6	35.2	62.8	2-Stage Systematic
	1994 <sup>a/</sup>	4	24	35.2	27.6	62.8	"
	1995 <sup>b/</sup>	4	27	36.9	16.4	53.3	"
	1996 <sup>c/</sup>	4	58	26.4	21.0	47.4	"
	Tutka (west shore)						
1990 <sup>d/</sup>	1	24	24.8	36.8	61.6	2-Stage Systematic	
3a & 3b	Tutka (east & west shores, multiple sites)						
	1992	8	39	16.8	2	18.8	Random/ Systematic
	1993	4	22	13.6	4.8	18.4	Random/ Systematic
4	Jakolof (bay wide estimate)						
	1992	6	42	22.1	2.2	24.3	Random/ Systematic
	1993	11	53	26.2	10.4	36.6	Random/ Systematic

<sup>a/</sup> The legal component may be comparable.

<sup>b/</sup> In 1994 2 sites were the same as in 1993 and 2 were different.

<sup>c/</sup> The 1995 sites were different from previous years.

<sup>d/</sup> Substrate was washed through small screens in 1990 survey only.

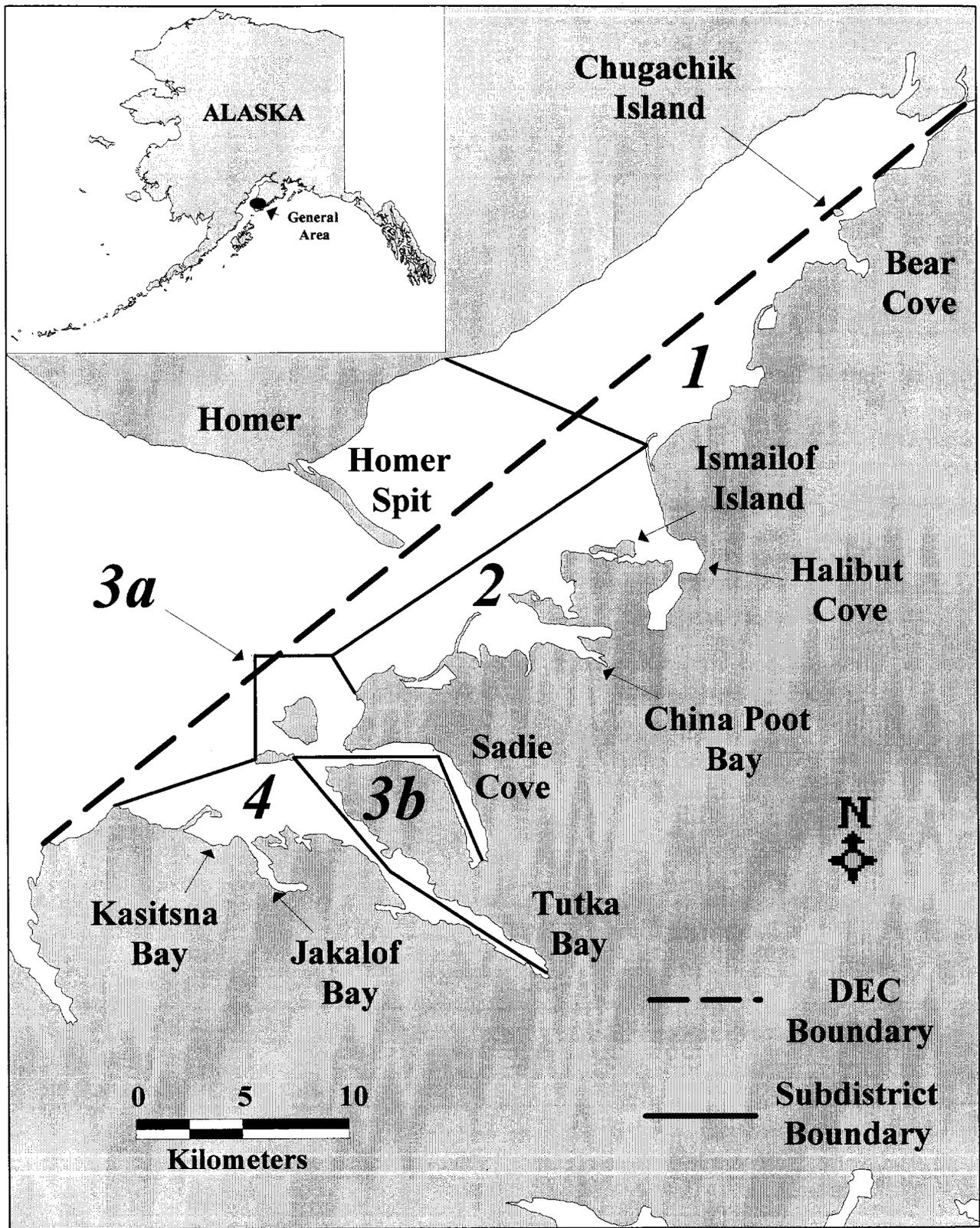


Figure 1. ADF&G hardshell clam survey sites and subdistricts for the commercial harvesting of clams and mussels in Kachemak Bay, Southern District, Cook Inlet Management Area.

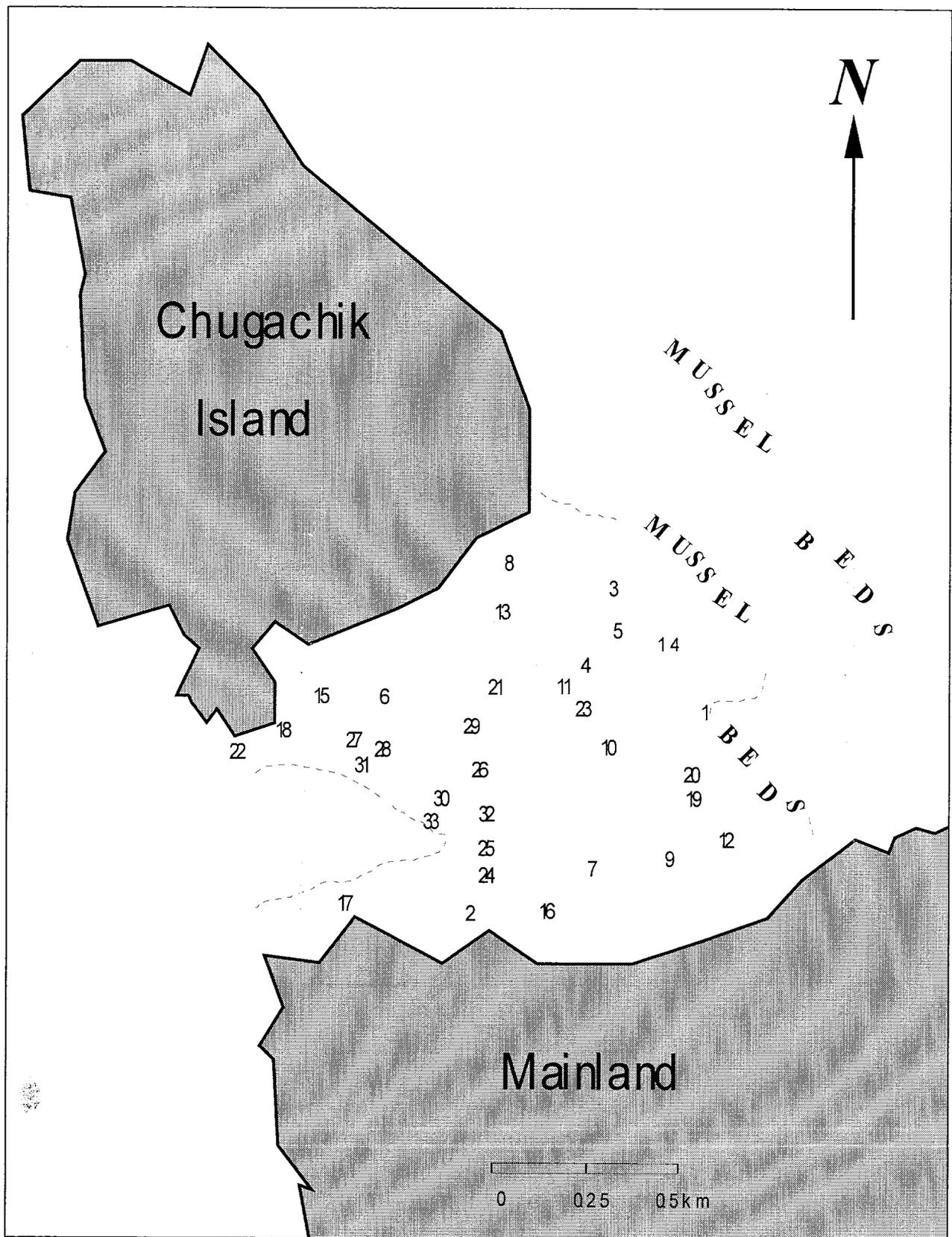


Figure 2. Sample quadrat placement at Chugachik Island, June 3 and 4, 1996.

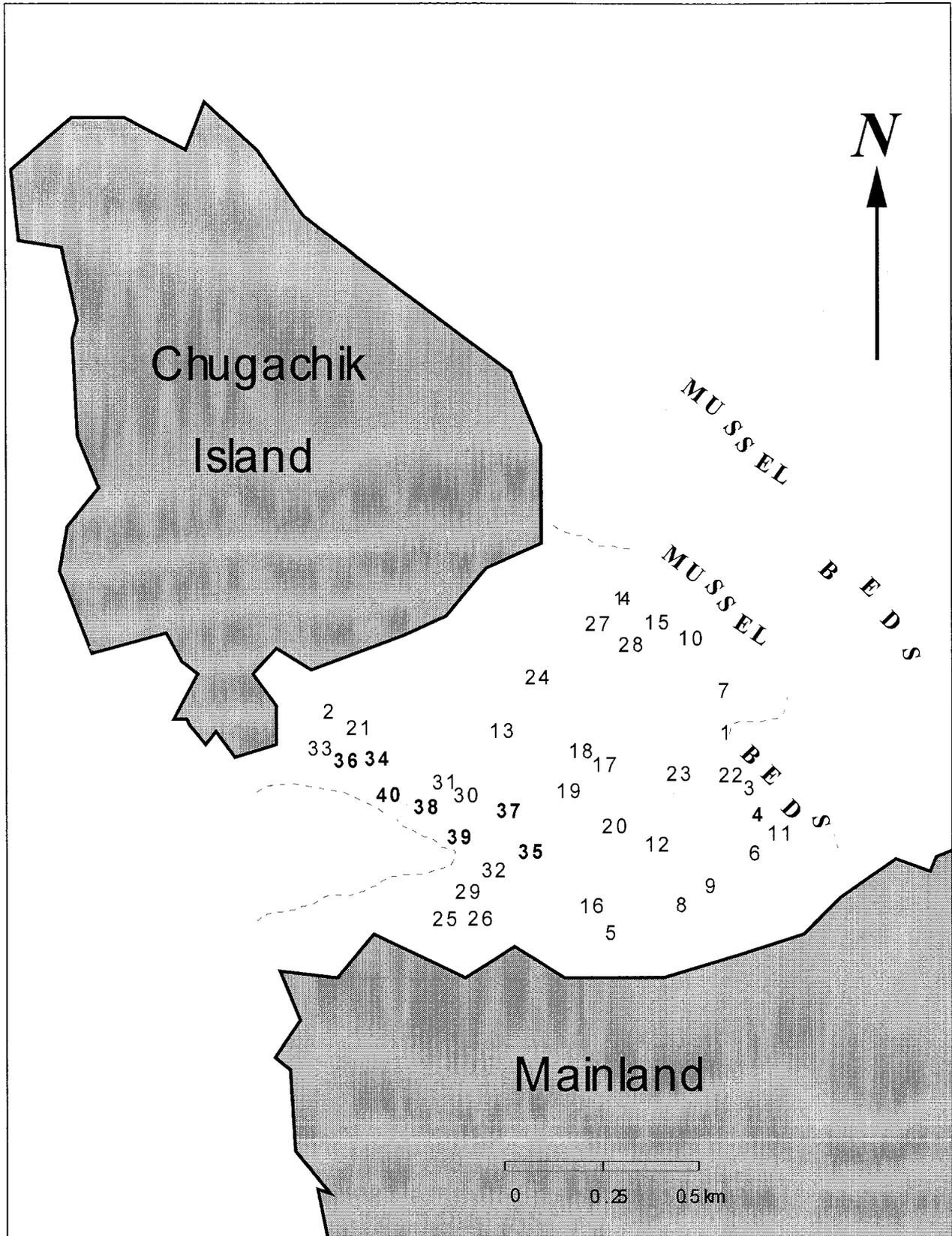


Figure 3. Sample quadrat placement at Chugachik Island, May 7 and 8, 1997.

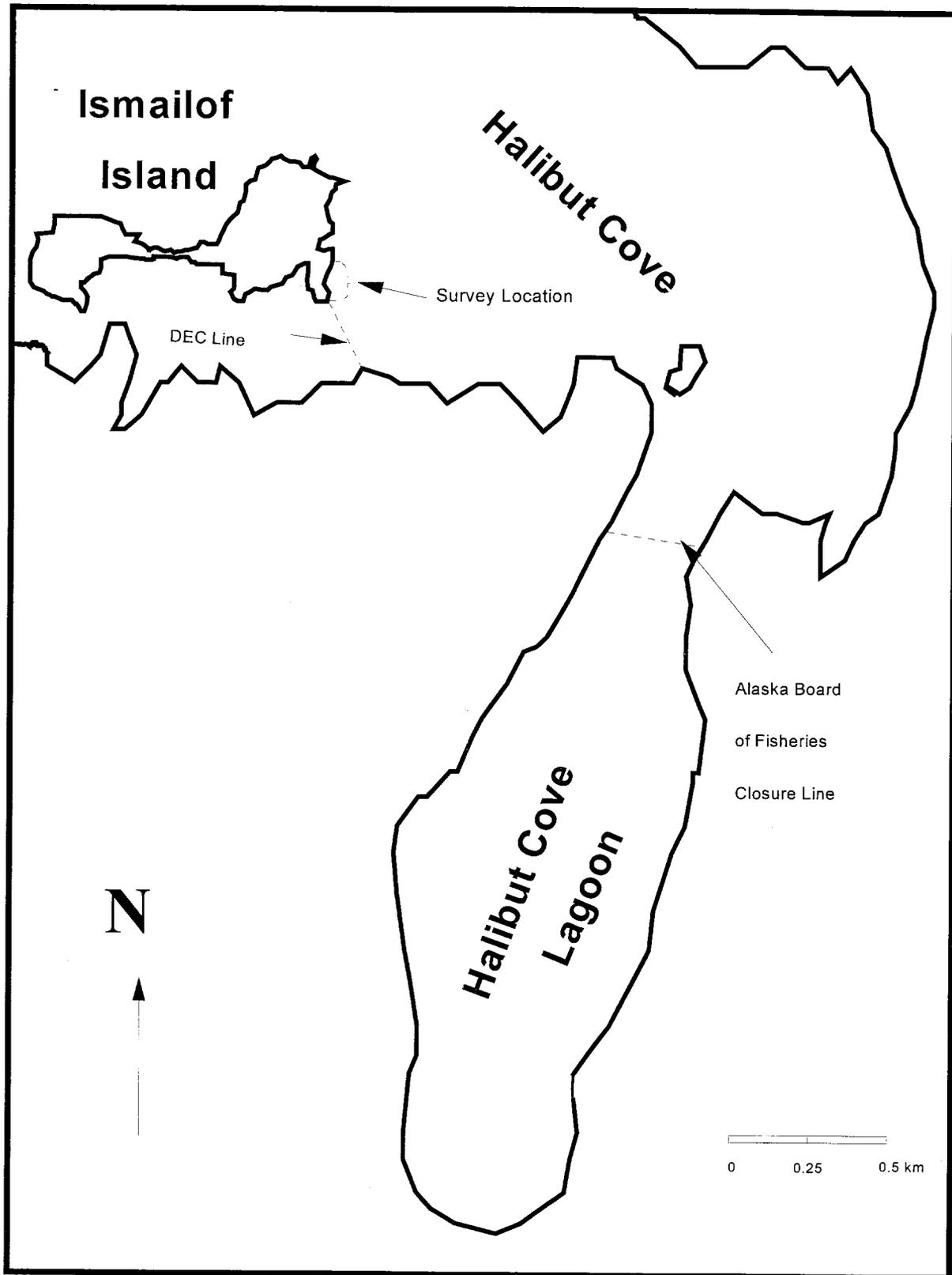


Figure 4. Ismailof Island survey beach and commercial harvest closure lines around Halibut Cove.

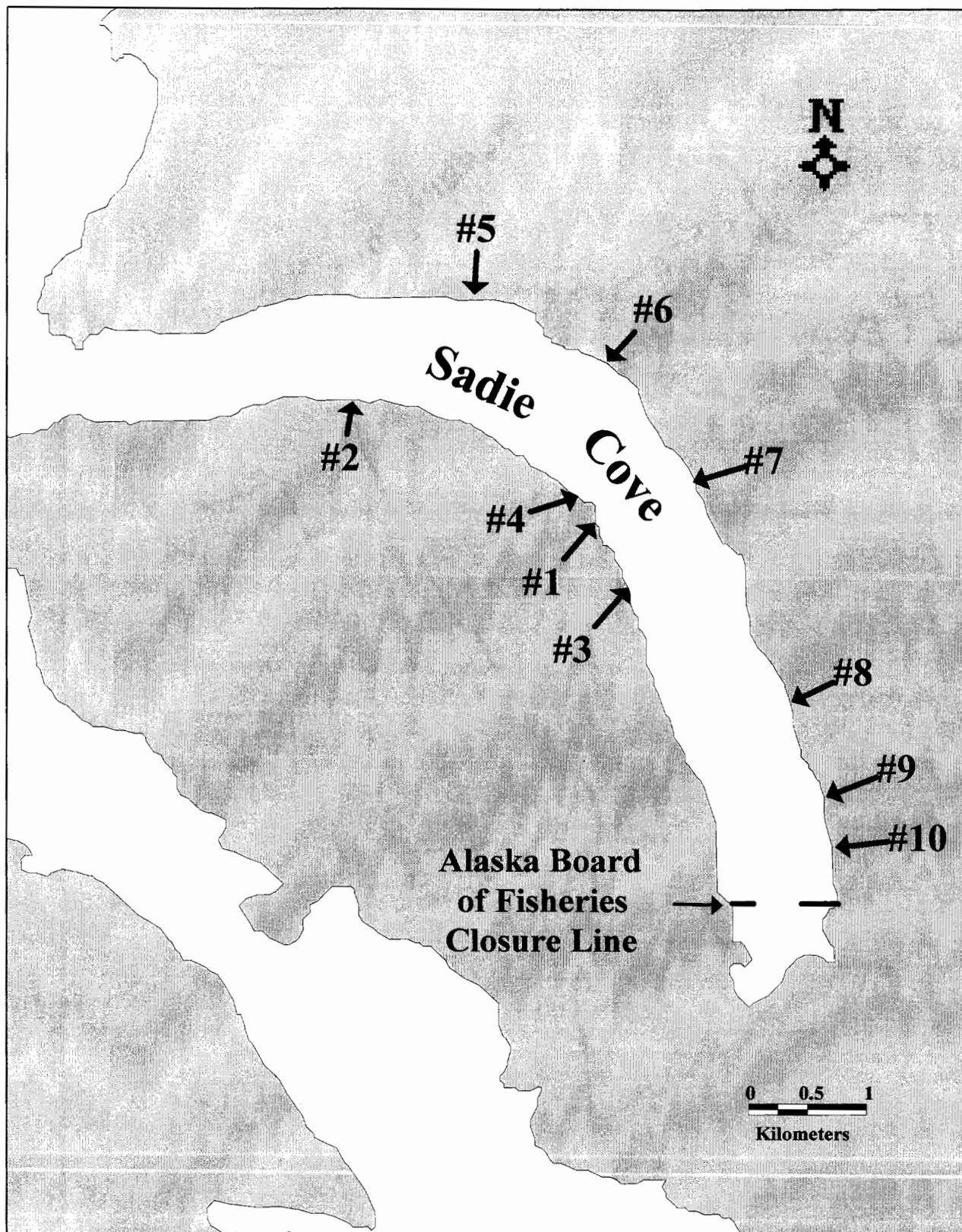


Figure 5. Sites 1-4 along the west shore of Sadie Cove surveyed May 4 and 5, 1996 and sites 5-10 along the east shore of Sadie Cove surveyed July 21-23, 1997.

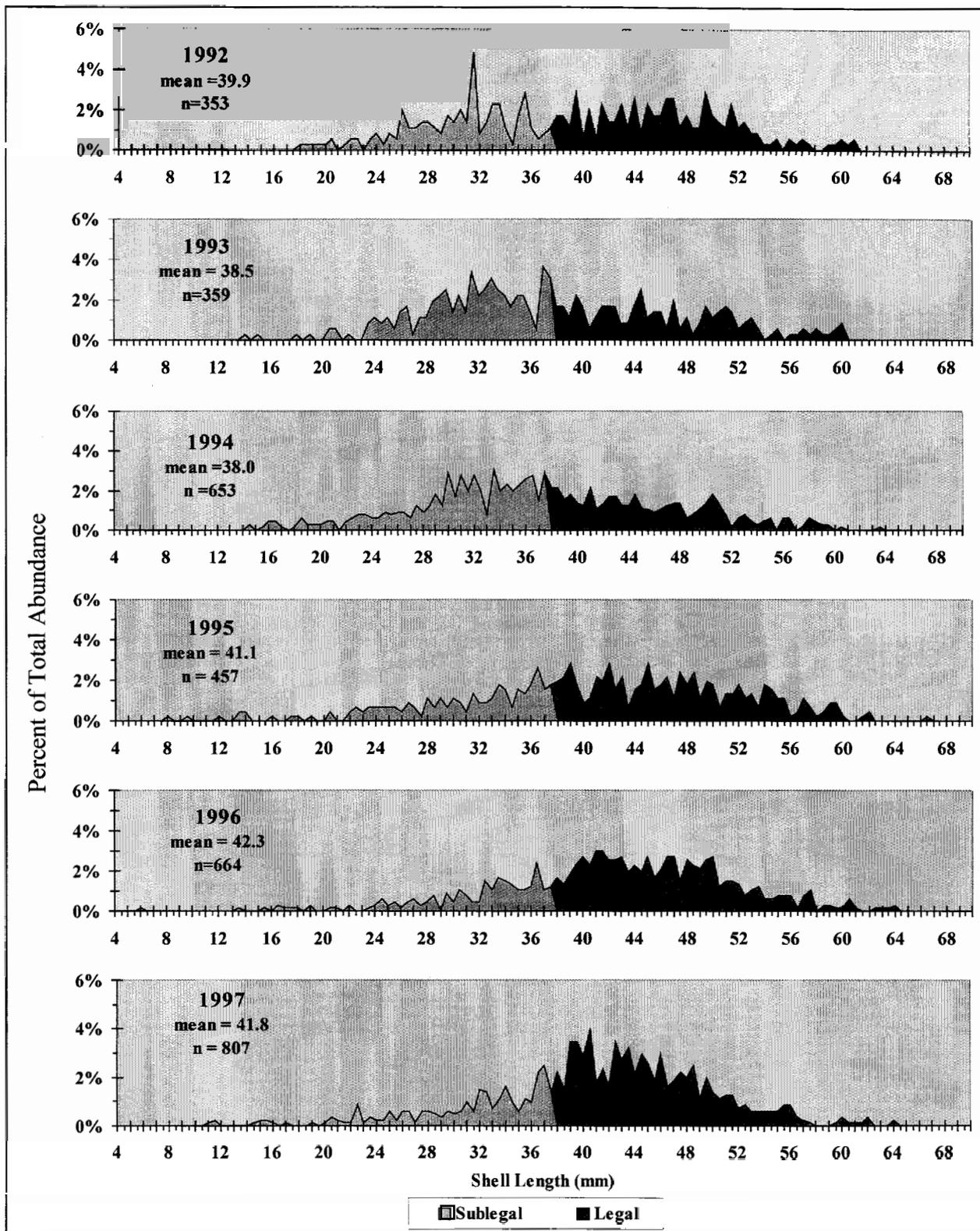


Figure 6. Length frequency distributions of Pacific littleneck clams at Chugachik Island, 1992-1997.

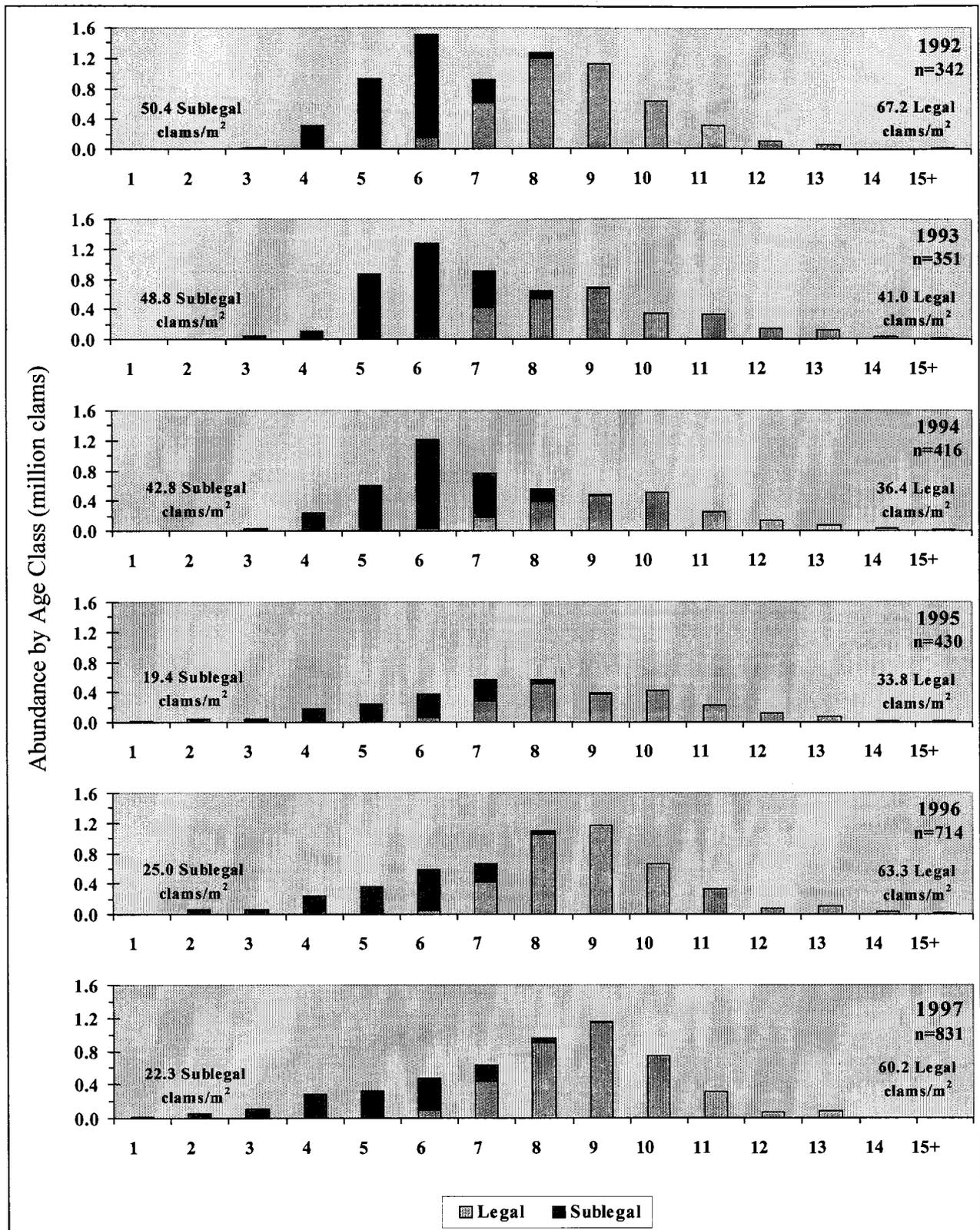


Figure 7. Estimated abundance by age class of Pacific littleneck clams at Chugachik Island, 1992-1997.

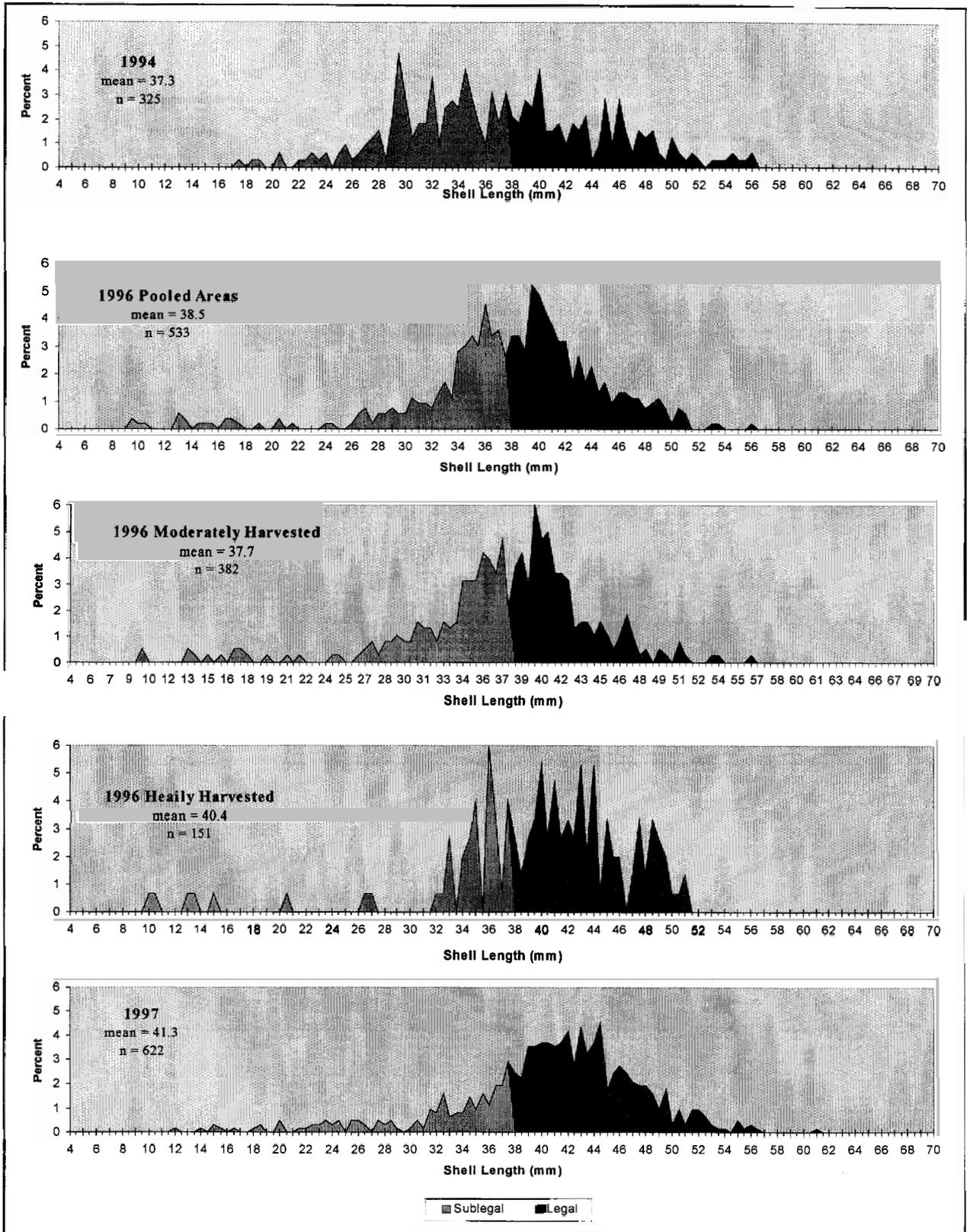


Figure 8. Length frequency distributions of Pacific littleneck clams at Ismailof Island, 1994-1997.

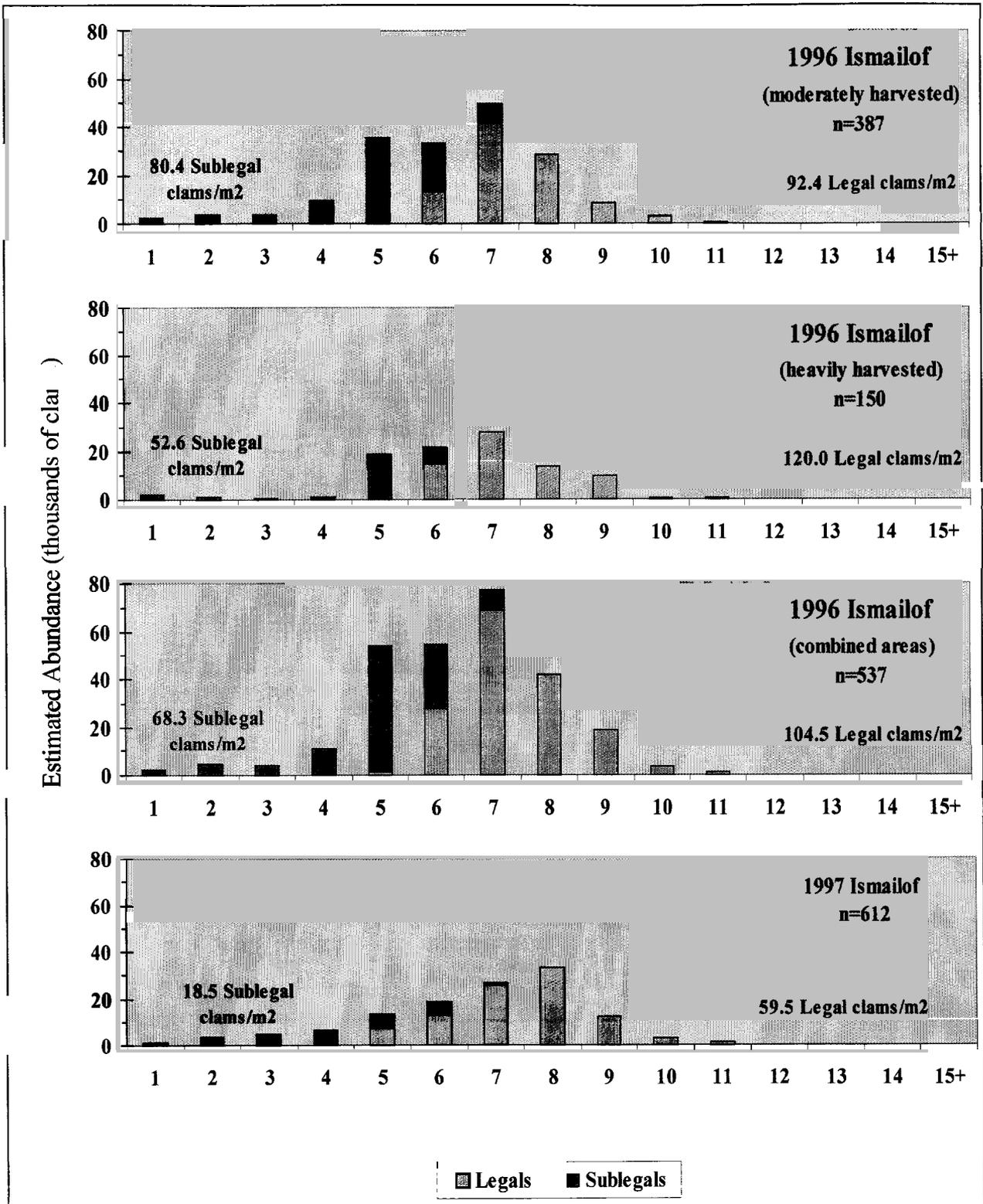


Figure 9. Estimated abundance by age class of Pacific littleneck clams at Ismailof Island, 1996 and 1997.

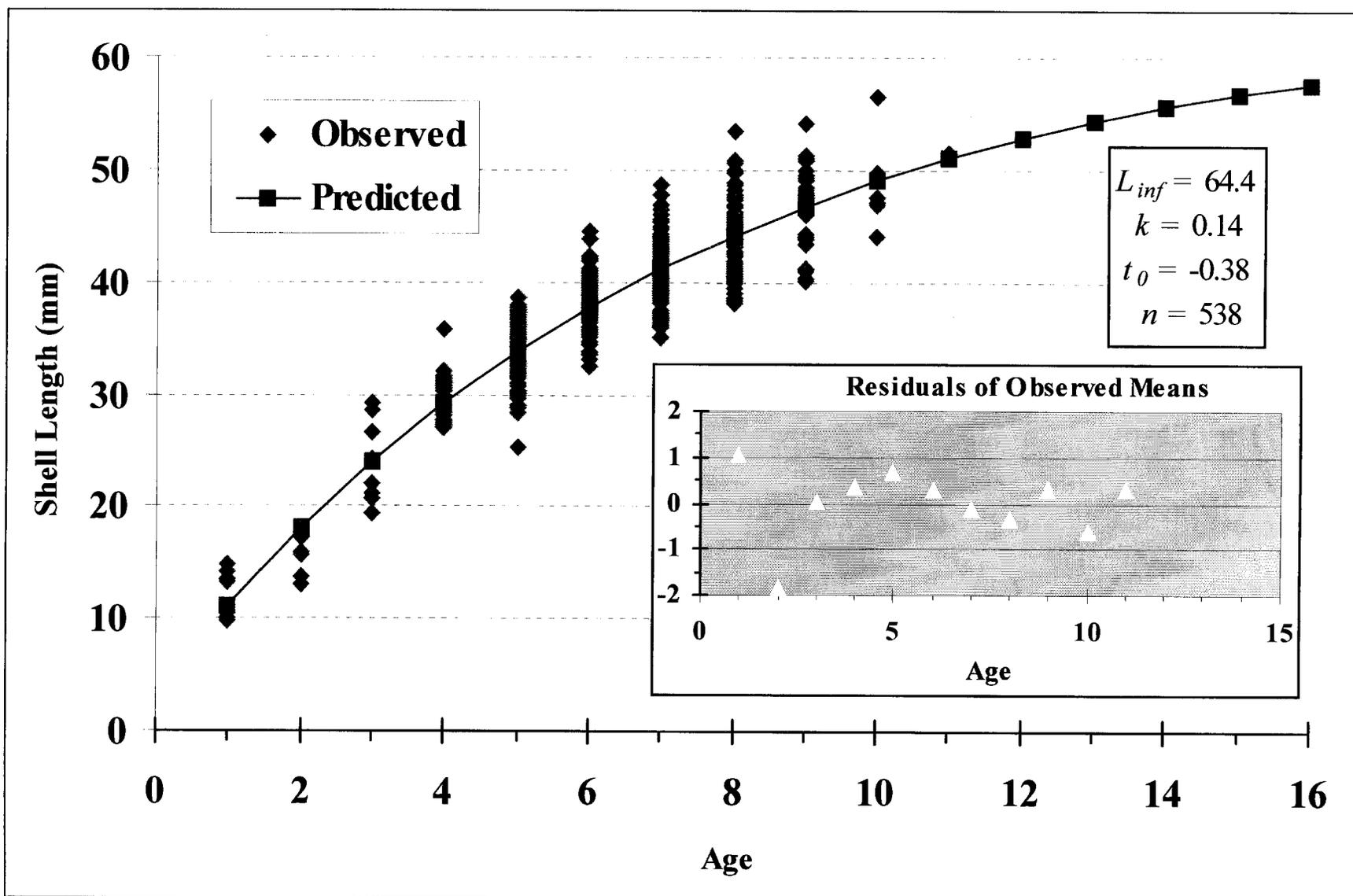


Figure 10. Von Bertalanffy growth model for Pacific littleneck clams at Ismailof Island, 1996.

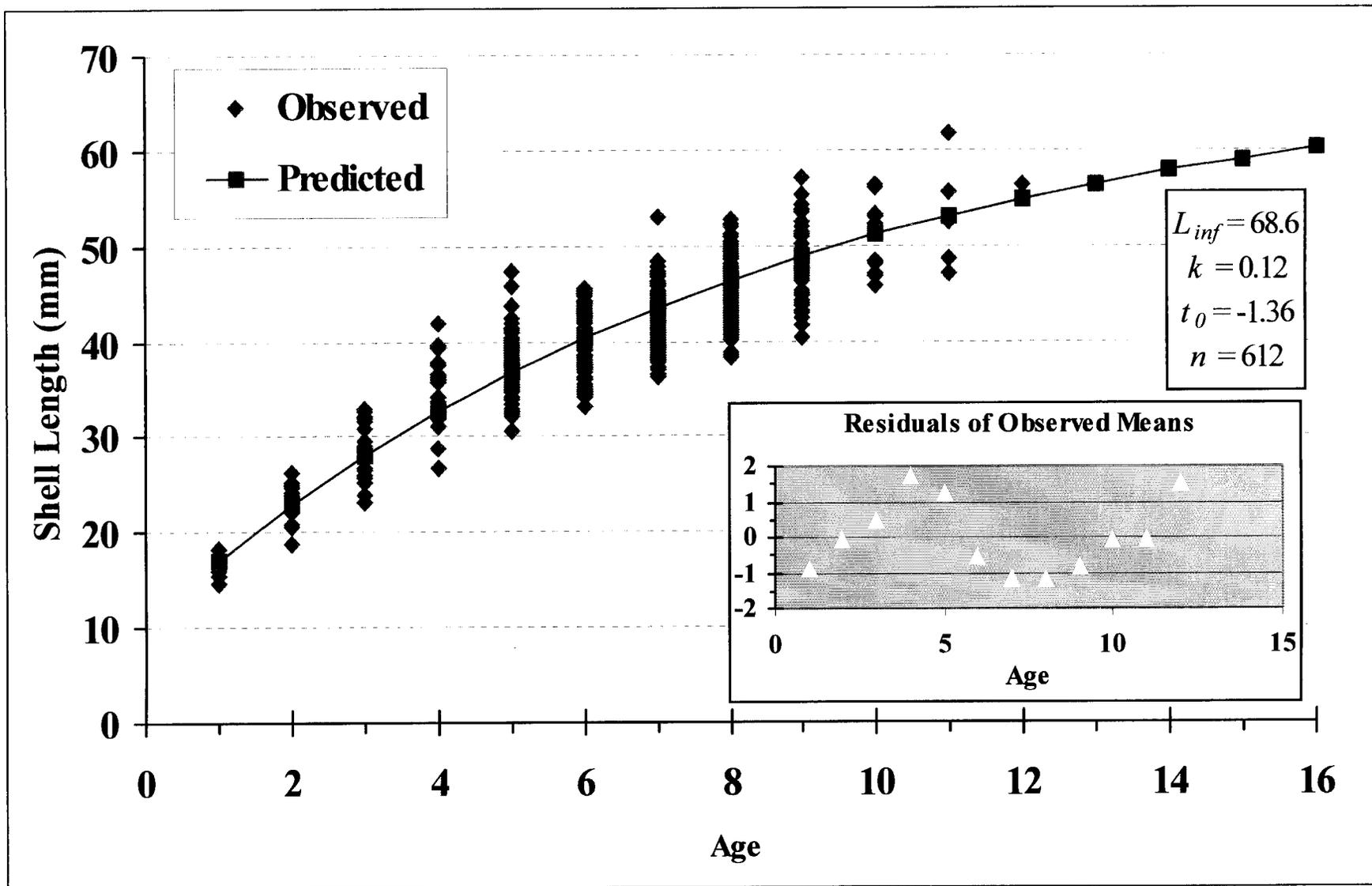


Figure 11. Von Bertalanffy growth model for Pacific littleneck clams at Ismailof Island, 1997.

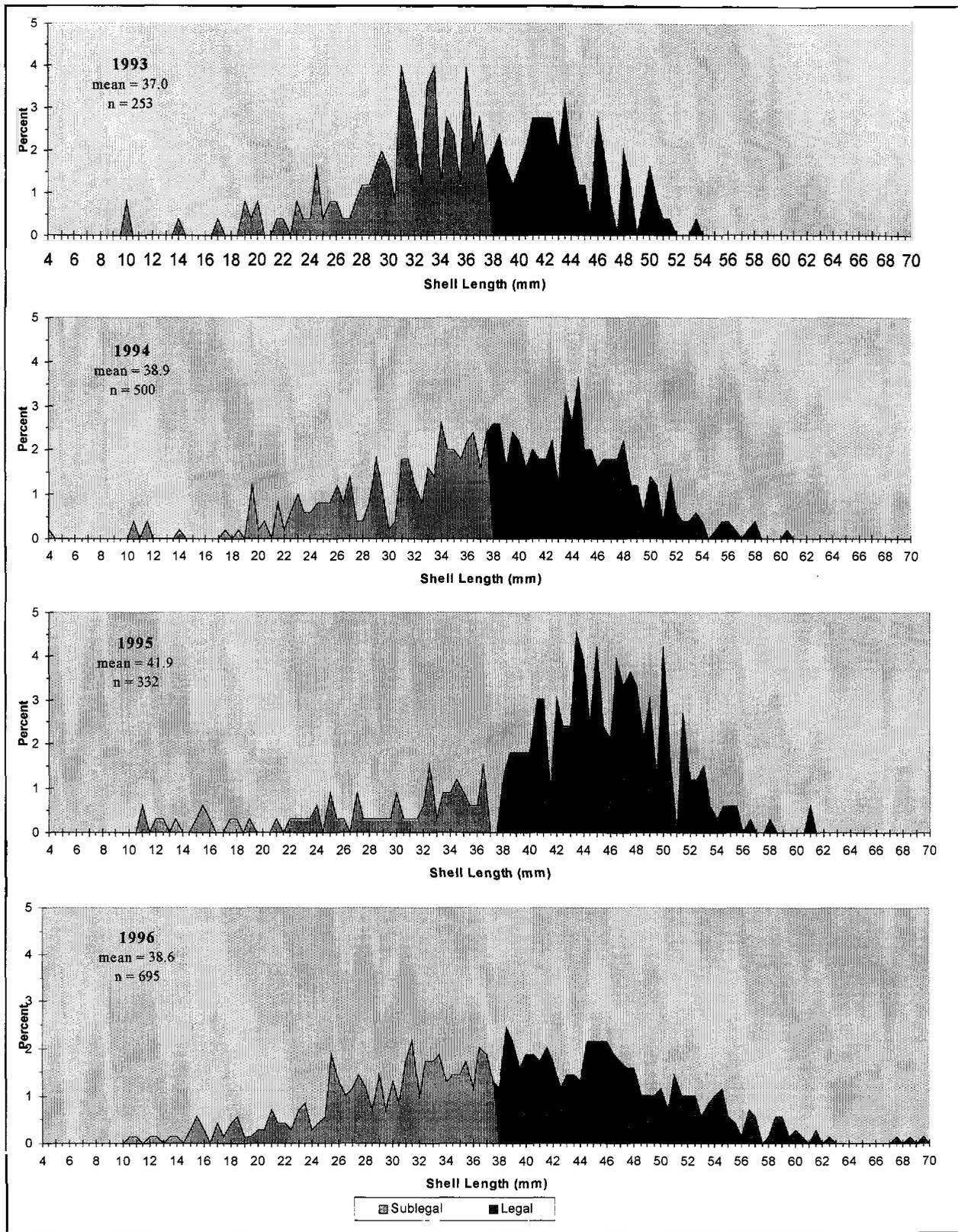


Figure 12. Length frequency distributions of Pacific littleneck clams at West Sadie Cove, 1993-1996.

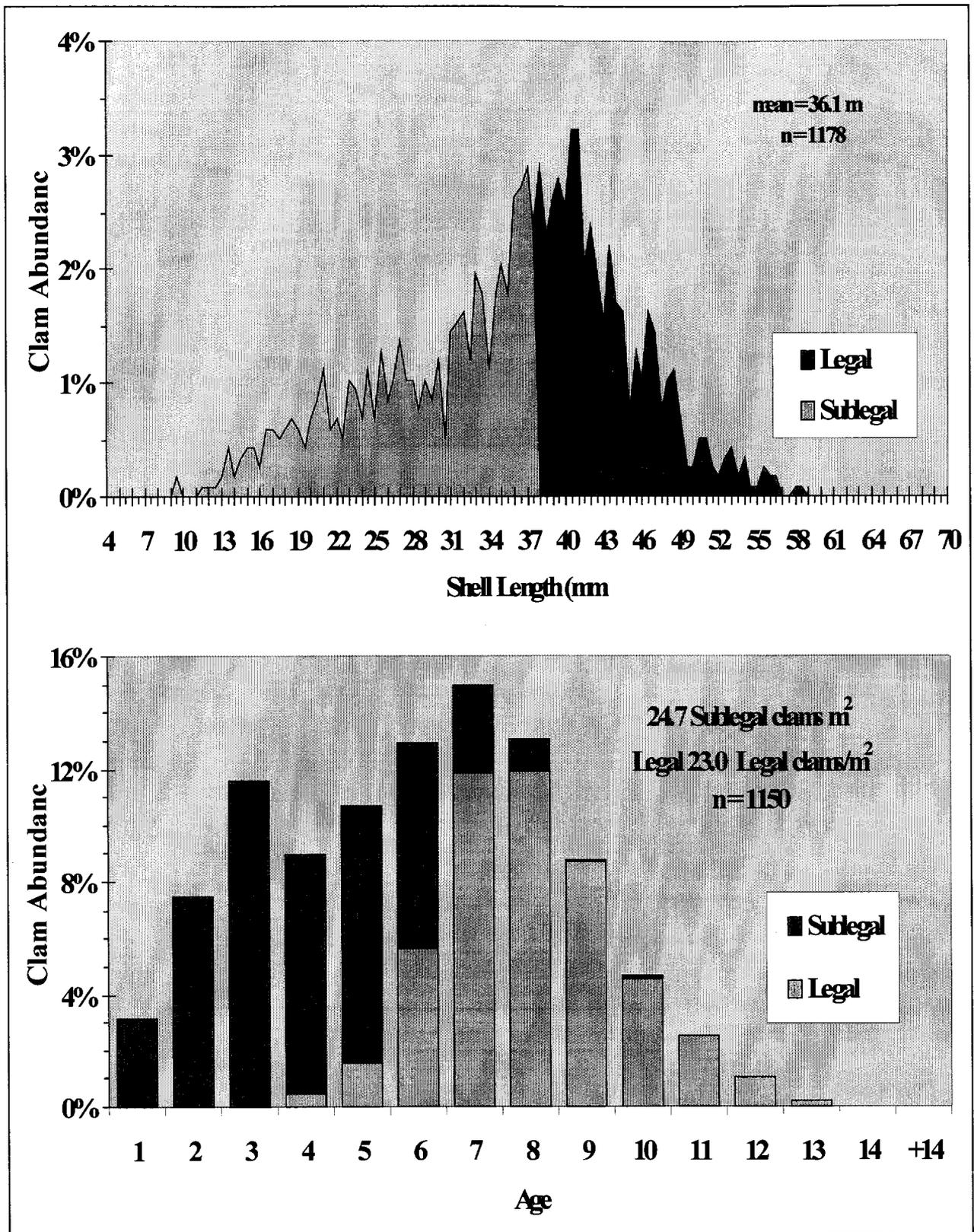


Figure 13. Shell length and age composition of Pacific littleneck clams at East Sadie Cove, 1997.

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