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ABSTRACT

Population studies of the Pacific razor clam *Siliqua patula* were conducted on the eastside beaches of Cook Inlet during the summer of 1992. Aerial surveys revealed that the two most popular beaches, Clam Gulch and Ninilchik, received 25% and 59%, respectively, of the overall digger effort during 1992. Age-4 clams provided the largest proportion of the harvest on both Clam Gulch and Ninilchik beaches (30% and 67%, respectively). Abundance of clams at Clam Gulch, estimated by catch-at-age analysis, declined during the late 1970s to a low of 2.0 million in 1981. The population has increased since then to an estimated 8.8 million clams in 1991. Recent-year population estimates from catch-at-age analysis are considered unreliable, and this last estimate will likely decrease with additional data. Estimated total abundance of clams on the Ninilchik Beach study area from onsite sampling was 3,051,291. Estimated exploitation of clams on this beach during 1991 was 18%.

KEY WORDS: Cook Inlet, razor clam, *Siliqua patula*, harvest, participation, population estimate, exploitation, catch-at-age analysis.

INTRODUCTION

Kenai Peninsula beaches along the east side of Cook Inlet provide the largest sport fishery for the Pacific razor clam *Siliqua patula* in Alaska (Mills 1992). This fishery is confined primarily to an 80.4 km (50 mile) section of beach bounded by the Kasilof River to the north and the Anchor River to the south (Figure 1). The Alaska Department of Fish and Game (ADF&G) began monitoring this clam population in 1965 following the 1964 earthquake that caused subsidence of beaches in the Cook Inlet area (Nelson *Unpublished*).

The eastside Cook Inlet beach was divided into six separate beach areas for study purposes. Initial studies included creel surveys, digger distribution surveys and length-at-age analysis (Nelson *Unpublished*). Beginning in 1977, harvest and participation have been estimated from the annual Statewide Harvest Study (Mills 1979-1992).

Marked increases in both harvest and participation occurred in the late 1960s and early 1970s. Since 1974, increases have been gradual and participation has averaged 29,254 digger-days annually with a high of 32,500 days in 1986. Annual harvests since 1974 have averaged 962,416 clams with the greatest harvest of 1,171,000 occurring in 1988 (Figure 2).

Although there have been only moderate increases in harvest since 1977, the distribution of effort has changed dramatically. Clam Gulch and Ninilchik beaches have consistently provided the greatest proportion of the total harvest. Clam Gulch contributed more than 70% of the harvest on eastside beaches in the late 1970s, but digger effort shifted in the 1980s and Ninilchik Beach has produced the greatest proportion of the overall harvest since 1986 (Figure 3). This shift is probably due to a decline in mean size of clams available for harvest at Clam Gulch and increasing numbers of clams of a larger size on Ninilchik Beach. Mean length-at-age increases incrementally from the northern to the more southern beaches (Athons 1992).

Regulations governing this fishery are minimal. The daily bag limit is the first 60 clams dug and an Alaska sport fishing license is required for all persons 16 years of age or older. The fishery currently seems well within sustainable bounds (Nelson 1993). However, large harvests combined with shifts in digger concentrations led managers to seek methodology that would forecast the effect of harvest on future abundance.

In 1987, ADF&G contracted Dr. Terrance Quinn with the University of Alaska, Juneau to further analyze existing data and to develop methods to estimate abundance. Clam density was estimated directly by pumping sample plots to census abundance within a known area. Sample plots were selected with a stratified-random design and density results applied to the beach area to estimate abundance. Age-specific harvest data were modeled using catch-at-age analysis to develop estimates of abundance-at-age and exploitable abundance-at-age. Szarzi (1991) documented this work, including data analysis for 1988 and 1989.

Athons (1992) presented stock assessment data for 1990 and 1991 and updated the catch-at-age analysis for Clam Gulch. The objectives of this report are to present the 1992 stock assessment data and to update catch-at-age analysis.

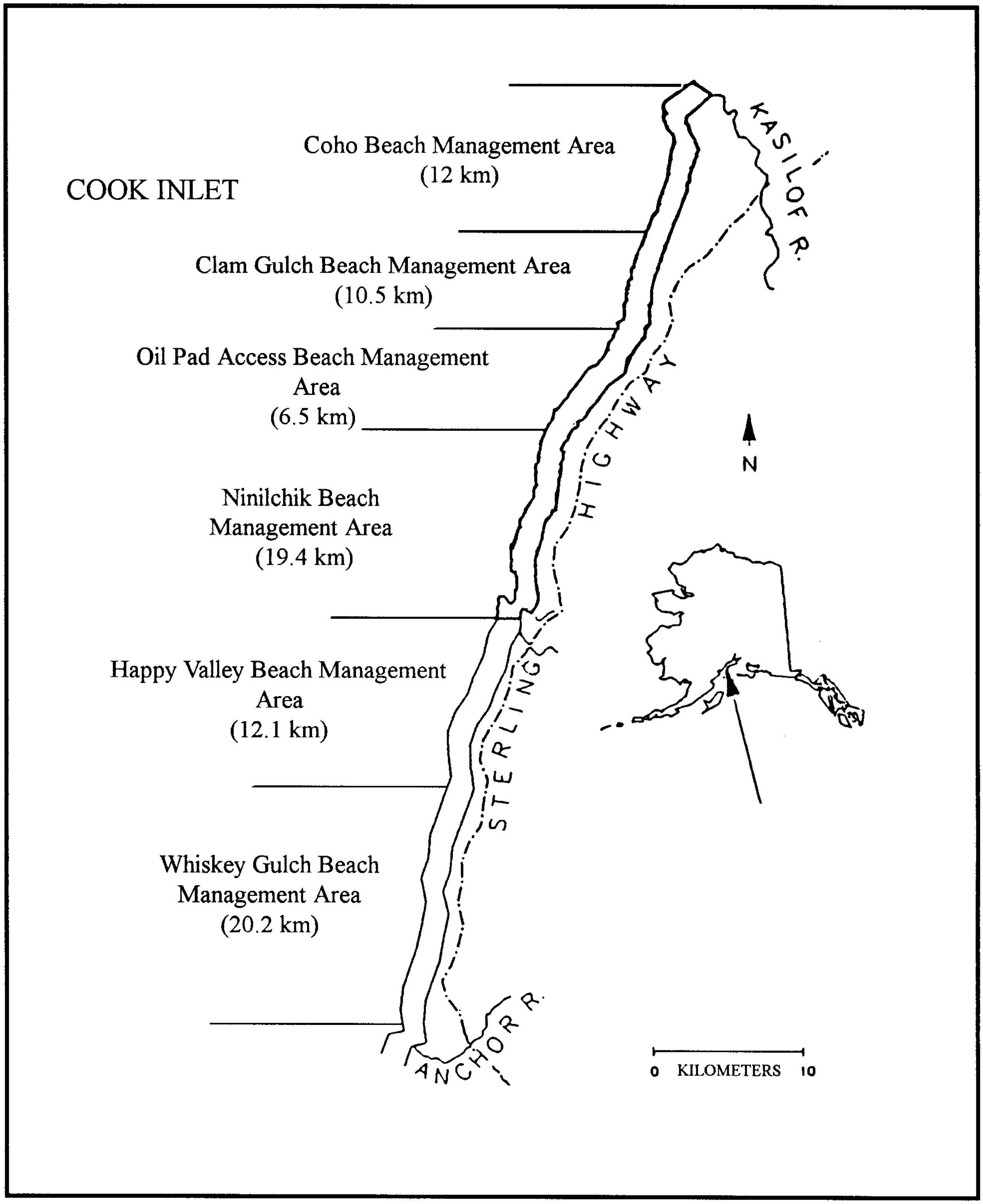

Figure 1. Eastside beaches, Cook Inlet, Alaska.

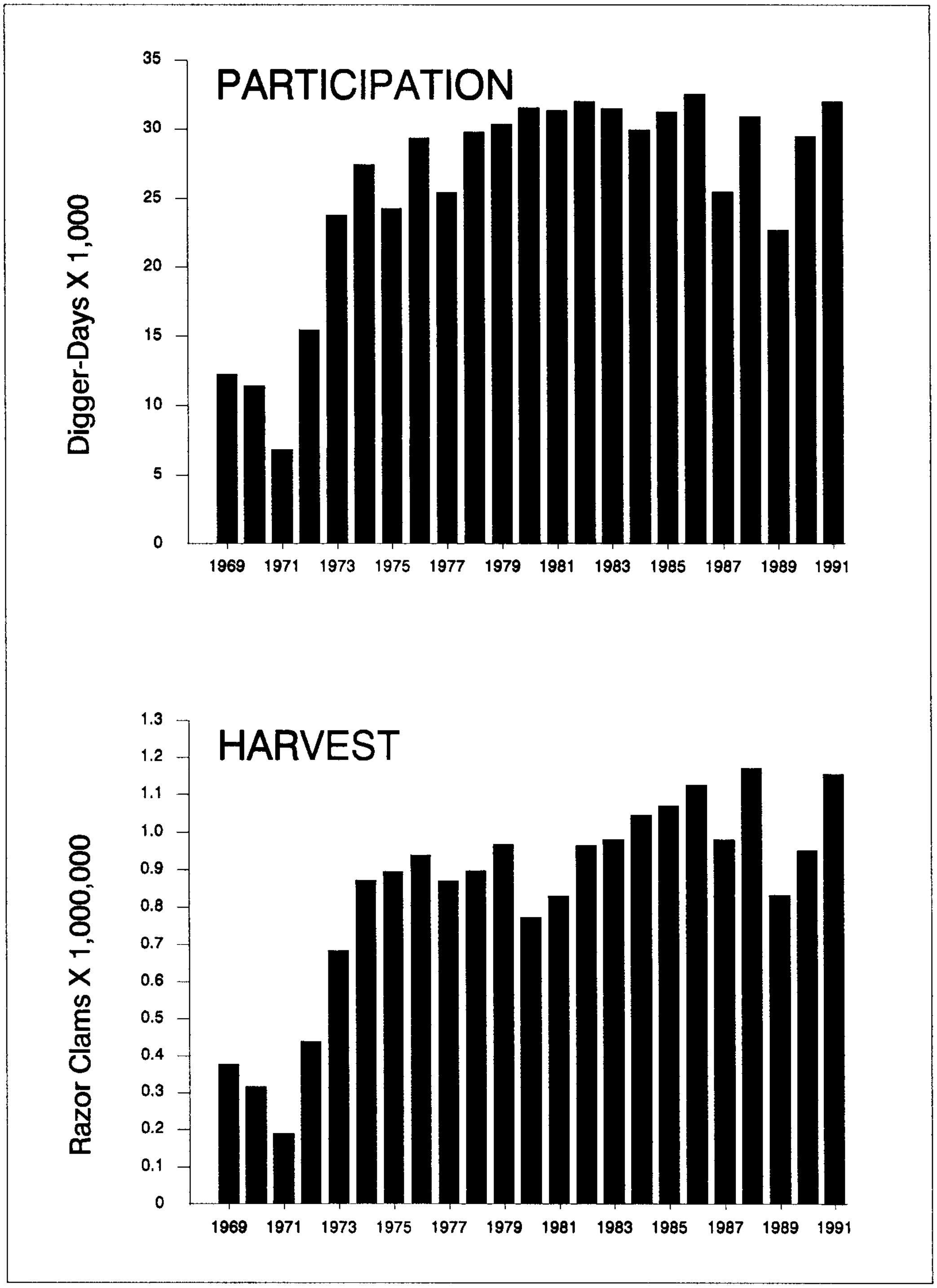

Figure 2. Historical harvest and participation in the recreational razor clam fishery on Cook Inlet eastside beaches, 1969-1991.

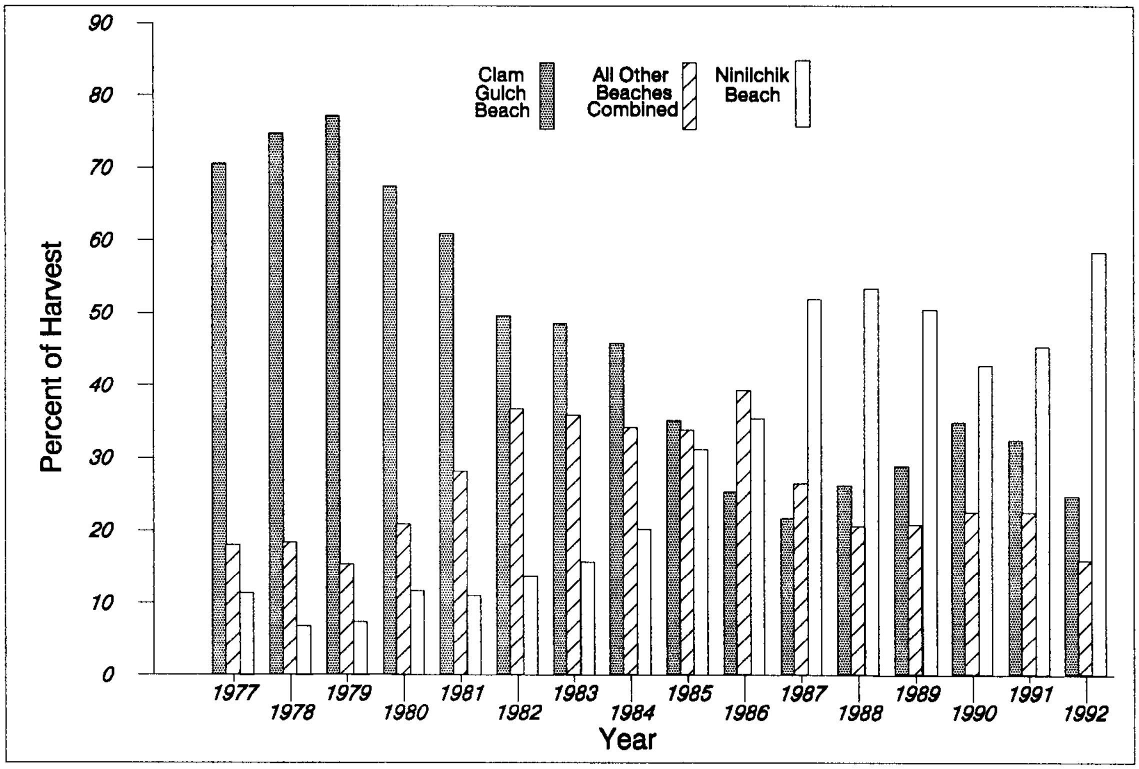

Figure 3. Historical proportions of razor clams harvested by beach area in the recreational fishery on Cook Inlet eastside beaches, 1977-1992.

Abundance estimates for the Ninilchik Beach study area are also presented for 1989-1992.

The 1992 project had three objectives:

1. estimate the proportion of digger effort and harvest of razor clams by beach area,

2. estimate the harvest and mean length of razor clams by age at three selected beaches, and

3. estimate the population density of razor clams on a section of the Ninilchik Beach.

The first two objectives permitted estimating age-specific harvests by beach, which were used to update the catch-at-age analysis for Clam Gulch Beach.

METHODS

Study Design

The initial 2-year study of razor clams on the Kenai Peninsula provided two major products (Szarzi 1991). First, methodology along with estimates of mean density (number per m^2) and total population abundance were documented. These data allowed estimation of exploitation. Second, estimating age and length composition by beach provided the basis for catch-at-age analysis of the Clam Gulch Beach population. The database required for the catch-at-age analysis included harvest and age composition by beach area, auxiliary information on fishing mortality, and initial estimates of natural mortality (Szarzi 1991, Deriso et al. 1985, 1989).

To develop this database, the stock assessment program was designed to estimate three parameters. First, diggers were counted by aerial surveys to apportion digger effort by beach. These data were then applied to estimates of total harvest from Mills (1979-1992) to estimate harvest by beach. Second, sampling conducted to estimate the age and length composition of the clam population at specific beaches allowed estimating age-specific harvest by beach. Third, surveys conducted to estimate clam density by beach were expanded by beach area to estimate total abundance by beach. Estimates of age-specific abundance and harvest provided estimates of fishing mortality. Finally, these three parameters provided the input for the catch-at-age analysis.

Estimation of Digger Effort and Harvest by Beach

Counts of diggers were collected as a stratified, two-stage sampling design with high-low tides (-1.0 ft to -3.0 ft) and low-low tides (<-3.0 ft) as the two strata, flights as the primary units, and diggers as the secondary units. Flights were not chosen randomly, but were spread out through time in a natural progression. During each flight, diggers were counted and the location by beach of every digger was recorded. Beach was an attribute in this situation, not a sampling stage. The multinomial proportions were calculated and combined across the primary units and then the strata.

In 1992, 29 tides between early May and the middle of August were between -1.0 ft and -3.0 ft and 19 tides were lower than -3.0 ft. Over the summer, a total of 13 flights was conducted: seven in the strata between -1.0 ft and -3.0 ft, and six in the strata lower than -3.0 ft. Based on data from previous years, we expected this sample to provide estimates of the proportion of diggers within 30 percentage points of their true value 95% of the time for Clam Gulch and Ninilchik beaches. These two beaches represent over 65% of the diggers observed.

The aerial surveys originated at Anchor River within ± 15 minutes of low water at Deep Creek and proceeded north. As it was impossible to distinguish diggers from non-diggers, all persons associated with digging activity were counted, including those traveling along the beach on all-terrain vehicles. Persons in highway vehicles and those associated with commercial fishing activities were not included.

Success rate of diggers varied by beach. Thus, equal numbers of diggers counted on different beaches may not result in the same number of clams harvested. A harvest success rate (I_b) of either 1.0 or 0.5 was assigned to each beach based on historical information. Digger counts for each beach were multiplied by the harvest success rate to give adjusted digger counts:

$$d_{tbk} = I_b A_{tbk} , \tag{1}$$

where:

d_{tbk} = the adjusted digger count from flight k on beach b in tidal stratum t,

I_b = the harvest success rate for beach b, and

A_{tbk} = the number of diggers counted during flight k on beach b in tidal stratum t.

The relative effort on each beach in each flight was estimated by:

$$\hat{r}_{tbk} = \frac{d_{tbk}}{d_{tk}} , \tag{2}$$

where:

$\hat{r}_{tbk}$ = the relative effort during flight k on beach b in tidal stratum t,

d_{tk} = the total adjusted digger count for flight k in tidal stratum t,

= $\sum_{b=1}^{n} d_{tbk}$, and

n = the total number of beaches.

Average relative effort on beach b in tidal stratum t ($\bar{r}_{tb}$) was calculated, incorporating the sample weights (w_{tk}) that adjust the proportions for different numbers of diggers during different flights, as:

$$\bar{r}_{tb} = \frac{\sum_{k=1}^{c_t} w_{tk}\hat{r}_{tbk}}{c_t}, \tag{3}$$

where:

w_{tk} = the sample weight of flight k in tidal stratum t,

$= \frac{d_{tk}}{\bar{d}_t}$,

$\bar{d}_t = \frac{\sum_{k=1}^{c_t} d_{tk}}{c_t}$, and

c_t = the number of flights in tidal stratum t.

Average relative effort on beach b ($\bar{r}_b$) was then calculated, incorporating the sample weights (W_t) that adjust the proportions for different number of tides in each tidal stratum:

$$\bar{r}_b = \sum_{t=1}^{2} W_t\bar{r}_{tb}, \tag{4}$$

where:

W_t = the sample weight for tidal stratum t,

$= \frac{m_t}{\sum_{t=1}^{2} m_t}$, and

m_t = the number of tides in tidal stratum t.

The estimated harvest by beach (H_b) and its variance were:

$$\hat{H}_b = \bar{r}_b\hat{H}, \tag{5}$$

where:

$\hat{H}$ = the estimate of harvest for razor clams between Kasilof and Anchor Point from the statewide postal harvest survey (Mills 1992), and (Goodman 1960)

$$\hat{V}[\hat{H}_b] = \left\{ \bar{r}_b^2 \hat{V}[\hat{H}] + \hat{H}^2 \hat{V}[\bar{r}_b] - \hat{V}[\hat{H}]\hat{V}[\bar{r}_b] \right\} , \qquad (6)$$

where:

$V[\hat{H}]$ = the variance of the statewide postal survey estimate (from Michael Mills, Alaska Department of Fish and Game, Anchorage, personal communication), and

$$\hat{V}[\bar{r}_b] = \sum_{t=1}^{2} W_t^2 \hat{V}[\bar{r}_{tb}] . \qquad (7)$$

There was a good chance that the number of diggers was related to the size of the minus tide. Since heights of tides occur in cycles, and selection of flights is not random but "pseudo-systematic," numbers of diggers (sample weights) were probably cyclic; therefore, we used a systematic variance equation (Wolter 1985) to estimate the variance of r_{tb}:

$$\hat{V}[\bar{r}_{tb}] = \left[1 - \frac{c_t}{m_t}\right] \left[\frac{\sum_{k=2}^{c_t} (w_{tbk}^2 r_{tbk} - w_{tb(k-1)}^2 r_{tb(k-1)})^2}{2c_t^2(c_t-1)} \right] . \qquad (8)$$

Estimation of Age and Length Composition and Age-Specific Harvest by Beach

Age and size composition of the harvest were estimated by hand digging clams at specific beaches in a manner and at locations within each beach that simulated an average clam digger. All clams dug were retained regardless of size or condition.

Samples were dug at Clam Gulch Beach between 0.4 km (0.25 mi) south to 0.8 km (0.5 mi) north of the access road. At Oil Pad Access Beach, half the specimens were taken from the northern end and the other half from the southern end of the beach. Half of the Ninilchik Beach sample came from the Ninilchik bar. The second half of the Ninilchik sample was dug on the beach north of the Ninilchik River and was aged separately. Additionally, small samples taken from Cohoe Beach were added to the long term database.

In 1992, more than 300 clams were dug from the Clam Gulch, Oil Pad Access, and Ninilchik beaches with a target of 300 usable specimens (Szarzi 1991). After removing the body from the shell, the shell was separated into two halves, with one half retained for analysis. Shells were soaked in a 50% household bleach solution until most of the periostracum was removed but the heavy layers along the annuli remained. The bleach solution was then poured off and the shells dried for aging and measuring. Shells were aged as described by Nelson (*Unpublished*). Total length (along the greatest longitudinal axis) and length at last annulus were measured using Mitutoyo Digimatic Calipers® and input directly into a Lotus spreadsheet.

To estimate the harvest by age class, the proportion of clams in age class a on beach b (p_{ab}) was estimated by:

$$\hat{p}_{ab} = \frac{n_{ab}}{n_{tb}} , \qquad (9)$$

where:

n_{ab} = the number of clams sampled in age class a from beach b, and

n_{tb} = the total number of clams in the sample from beach b.

The variance of the proportion was estimated by:

$$\hat{V}[\hat{p}_{ab}] = \frac{\hat{p}_{ab}(1-\hat{p}_{ab})}{n_{tb} - 1} . \qquad (10)$$

Harvest by age class for beach b was estimated by:

$$\hat{H}_{ab} = \hat{p}_{ab}\hat{H}_b , \qquad (11)$$

with variance (Goodman 1960):

$$\hat{V}[\hat{H}_{ib}] = \hat{p}^2_{ab}\hat{V}[\hat{H}_b] + \hat{H}^2_b\hat{V}[\hat{p}_{ab}] - \hat{V}[\hat{p}_{ab}]\hat{V}[\hat{H}_b]. \qquad (12)$$

Estimation of Abundance and Fishing Mortality

Population size has been estimated for Ninilchik Beach since 1989 (Szarzi 1991, Athons 1992). The Ninilchik Beach was divided into two areas: a 4.2 km (2.6 mi) area north of Ninilchik River and a 1.6 km (1.0 mi) area south of the river. The southern area was further divided into three equal sections and the northern area into five equal sections. At least one transect was sampled in each section and, as one additional day was available for sampling, a northern section chosen at random contained a second transect.

Ninilchik Beach sections were stratified into 15.2 m (50 ft) strips parallel to the shoreline (Figure 4). Transects went perpendicular to the shoreline and were sampled across these strata, with one site sampled on the transect in each stratum. Transect locations were randomly chosen within each beach section. Transect locations north of the Ninilchik River were located by starting where the beach access road enters the beach at Lehmans Point and proceeding south the selected distance. Transect locations on the beach lying south of the Ninilchik River were located by starting at the pilings at the

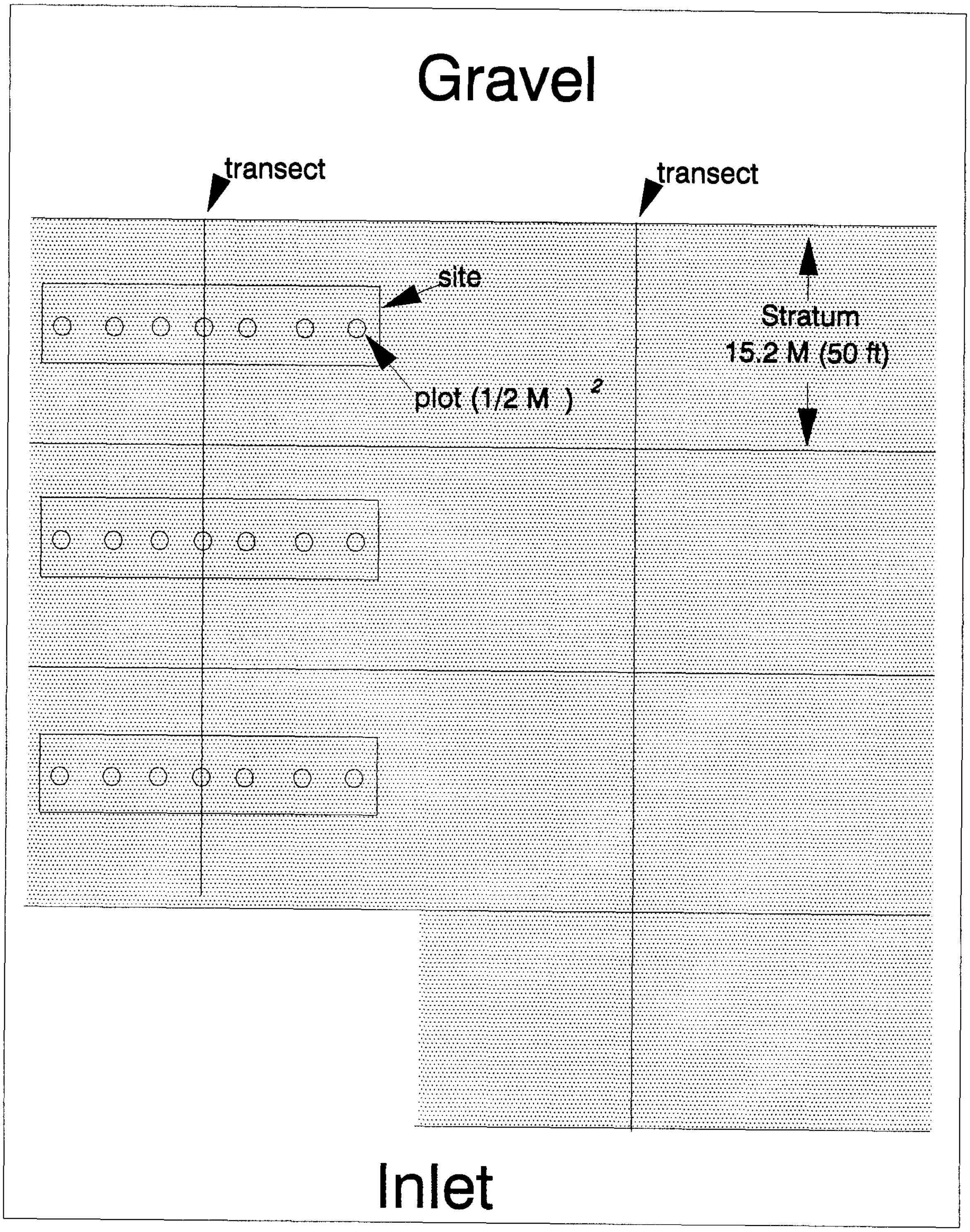

Figure 4. Diagrammatic example of sampling transect for razor clam abundance estimate on Ninilchik Beach, 1992.

high tide line approximately 182 m (200 yards) south of the Ninilchik River and proceeding south in the same manner. Transects began at the gravel edge located high up on the beach and extended out to the extreme low tide line. For most transects, the first site to be sampled was chosen randomly in the first 30.5 m-45.7 m (100 ft-150 ft), although some transects started within the first 15.2 m. Samples were then taken systematically every 15.2 m down the transect as far as the tide would allow.

Up to seven 0.5 m^2 plots were sampled at each sampling site. The number of plots sampled per site and transect length were dependent on the tidal range, the rate at which the tide fell, and the beach substrate. The three transects south of the Ninilchik River extended from 305 m to 457 m (1,000 ft to 1,500 ft) with 16 to 28 sites sampled per transect. The transects north of the Ninilchik River extended from 122 m to 320 m (400 ft to 1,050 ft) with 6 to 19 sites sampled per transect. The beach area north of the river has a steeper gradient than the area south of the river, and less beach area was exposed north of the river.

Sampling equipment consisted of a 4-cycle Honda pump with 30 m of cotton fire hose on the outlet side and 12 m of plastic hosing on the inlet side (Szarzi 1991). The outlet hose had a metal tube or "wand" attached to direct the flow of water into the substrate enclosed by a 0.5 m^2 sampling ring (Figure 5). The wand was repeatedly inserted into the substrate inside the sample ring (plot) as far as the wand would penetrate. The stream of water loosened the substrate in the plot such that all clams within the plot were flushed to the surface. The sampling was considered complete when the entire area was fluid and no clams had surfaced for approximately 1 minute. A hand-held net with 2 mm mesh was used to strain the loosened substrate in search of small clams not readily visible. All clams were measured and then released. An attempt was made to pump seven plots at each site before following the tide out 15.2 m to the next site. Due to rapidly dropping tides, there were times when entire sites were bypassed on the ebb tide. A marker was left in the sand at each site where less than seven samples were obtained with as many of the remaining plots as possible being collected as the incoming tide flooded the beach. Distance from the gravel's edge along the transect and the length of each clam from each plot pumped were recorded in a field notebook and later entered into a data file.

The abundance of clams on the Ninilchik Beach study area was estimated using a stratified three-stage design (Cochran 1977). The estimate was for clams larger than 80 mm which are considered exploitable (Szarzi 1991). To allow comparison among years, abundance estimates included only the first 183 m (600 ft) of sections north of the river and 396 m (1,300 ft) of sections south of the river.

The mean density per plot at site j on transect i of beach stratum e was estimated by:

$$\bar{y}_{eij} = \frac{\sum_{k=1}^{n_{eij}} y_{eijh}}{n_{eij}} , \qquad (13)$$

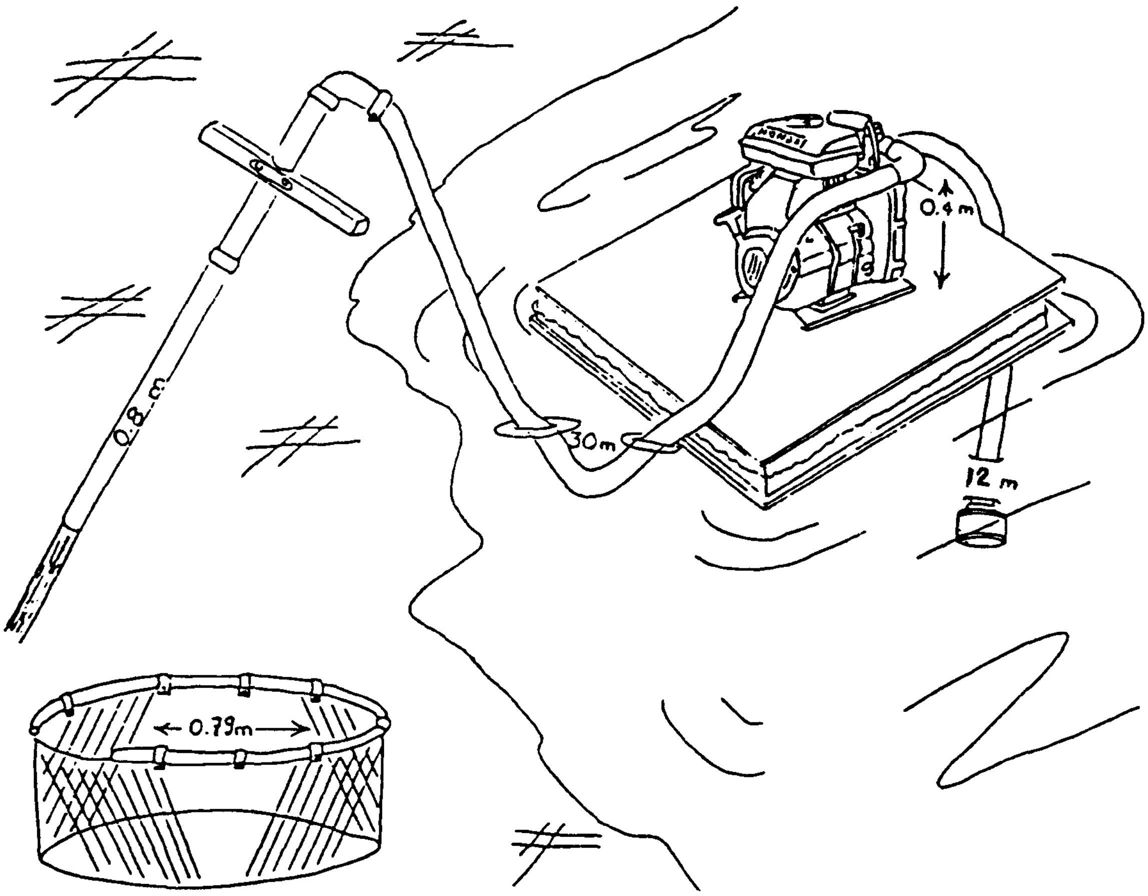

Figure 5. Sampling ring and pumping apparatus used for razor clam field sampling.

where:

$\bar{y}_{eij}$ = the mean density of clams per 0.5 m^2 at site j on transect i of stratum e,

y_{eijh} = the number of clams in plot h at site j on transect i of stratum e, and

n_{eij} = the number of plots sampled at site j on transect i of stratum e.

The variance of mean density among plots within a beach stratum was estimated by:

$$s^2_{eij} = \frac{\sum_{i=1}^{n_e} \sum_{j=1}^{n_{ei}} \sum_{h=1}^{n_{eij}} (y_{eijh} - \bar{y}_{eij})^2}{n_e \, n_{ei} \, n_{eij}(n_{eij}-1)} , \quad (14)$$

where:

n_{ei} = the number of sites sampled in stratum e on transect i (always one in this study), and

n_e = the number of transects in stratum e.

Note that, since only one site is sampled on each transect within a stratum, the among site variance (s^2_{ei}) is 0, and the mean density per site ($\bar{y}_{ei}$) is equivalent to the mean density per plot at the one site sampled.

The mean density per transect of beach stratum e was estimated by:

$$\bar{y}_e = \frac{\sum_{i=1}^{n_e} \bar{y}_{ei}}{n_e} = \frac{\sum_{i=1}^{n_e} \bar{y}_{eij}}{n_e} , \quad (15)$$

where:

$\bar{y}_{ei}$ = the mean density per 0.5 m^2 per site for transect i in beach stratum e.

The variance among transects within stratum e was estimated by:

$$s^2_e = \frac{\sum_{i=1}^{n_e} (\bar{y}_{ei} - \bar{y}_e)^2}{n_e(n_e-1)} = \frac{\sum_{i=1}^{n_e} (\bar{y}_{eij} - \bar{y}_e)^2}{n_e(n_e-1)} . \quad (16)$$

The number of clams in each stratum was calculated as:

$$\hat{N}_e = 2A_e\bar{y}_e , \quad (17)$$

where:

$\hat{N}_e$ = the abundance of clams ≥ 80 mm in stratum e, and

A_e = the area of stratum e in m^2 .

Note that the samples were taken in 0.5 m^2 plots, so the mean density is multiplied by 2 to give density per m^2.

The abundance of clams on the entire beach was the sum of the number of clams in each beach stratum:

$$\hat{N} = \sum_{e=1}^{n_u} \hat{N}_e. \tag{18}$$

The variance of the abundance was estimated by:

$$V[N] = 4 \sum_{e=1}^{n_u} A^2_e \; [(1-f_1)s_e^2 + f_1(1-f_2)\; s^2_{ei} + f_1 f_2(1-f_3)\; s^2_{eij}] \; , \tag{19}$$

where:

n_u = the total number of beach strata,

f_1 = the finite population correction factor for the number of transects sampled in a stratum relative to the total possible transects (n_e/N_e),

f_2 = the finite population correction factor for the number of sites sampled along a transect relative to the total possible sites along a transect (n_{ei}/N_{ei}), and

f_3 = the finite population correction factor for the number of plots sampled per site relative to the total possible plots to sample at a site (n_{eij}/N_{eij}).

At Ninilchik Beach in 1992, nine transects were sampled (n_e = 9). The Ninilchik Beach study area is 5.8 km long, and transects are 5.53 m wide, thus the total number of possible transects (N_e) is 5,800/5.53 = 1049. The width of one site sampled on a transect in a 15.2 m wide beach stratum (n_{ei}) was 0.79 m, giving the total number of possible sites to sample (N_{ei}) = 15.2/0.79 = 19. Finally, we ignored the correction factor for plots within a site by assuming $f_3 \approx 0$, recognizing that we may have overestimated the size of the third term in the variance of N.

Annual exploitation was computed by dividing the total estimate of harvest by beach by the total estimate of abundance by beach. Survey estimates of exploitation rates were converted to instantaneous fishing mortality by solving the Baranov catch equation (Deriso et al. 1989) for fishing mortality using abundance estimates from the density samples.

Catch-at-Age Analysis

Catch-at-age analysis was performed using the CAGEAN model (Deriso et al. 1985, 1989) as applied by Szarzi (1991) for razor clams at Clam Gulch Beach during 1977-1989. Inputs into the model were: (1) harvest by age for Clam Gulch Beach, (2) instantaneous fishing mortality, and (3) natural mortality. Estimation of the first two parameters is described above. Natural mortality was estimated at 0.125 by Quinn and Jones (1989).

Presentation of the results from the output of CAGEAN include: (1) estimates of total abundance by age, and (2) estimates of harvestable abundance by age. Szarzi (1991) estimated that minimum length-at-recruitment into the fishery was 80 mm. CAGEAN output provided estimates of the fraction of each age class recruited to the fishery.

RESULTS

Estimation of Digger Effort and Harvest by Beach

Aerial survey counts of clam diggers on eastside beaches during 1992 ranged from 133 to 1,962 (Appendix A1). Ninilchik Beach received the largest proportion of digger effort during both 1991 and 1992 (44.7% and 58.8%, respectively) and the greatest harvest of clams. Clam Gulch provided the second largest proportion of effort (32.9% and 24.8%, respectively) (Table 1). Clam Gulch historically provided the largest proportion of the harvest, averaging 46.6% since 1977 (Table 2). Note that before 1990, the effort surveys were not weighted by tidal height and in some years only three surveys were flown. Ninilchik Beach, which contributed less than 100,000 clams to the total harvest in the late 1970s, surpassed Clam Gulch in 1986 and has provided an estimated 398,755 to 624,607 clams annually since then (Table 3).

Estimation of Age and Length Composition and Age-Specific Harvest by Beach

Age class composition of all razor clams sampled on eastside Cook Inlet beaches in 1992 ranged from 2 to 12 years (Table 4). Age 4 was the dominant age class on both Clam Gulch (29.8%) and Ninilchik (66.7%) beaches. Age-4 clams from Clam Gulch Beach also attained the ≥ 80 mm size at which clams are vulnerable to the fishery (Szarzi 1991) while harvestable size was attained at age 3 for clams at Ninilchik Beach (Table 4). Major year classes have historically first been prominent in the Clam Gulch fishery at age 4 or 5 and in the Ninilchik fishery at age 3 or 4 (Tables 5 and 6).

Reproductive success is variable on eastside Cook Inlet beaches and major year classes may be followed in historic age composition tables. The 1977 year class at Clam Gulch first entered the fishery as age 3 in 1980 and was the dominant year class from 1981-1984 (Table 5). The prominence of a year class at Ninilchik was most readily apparent for the 1981 year class which was dominant from 1984-1987 (Table 6).

Age composition of the harvest in 1991 was estimated for Cohoe, Clam Gulch, Oil Pad, and Ninilchik beaches, and for the density study area on Ninilchik Beach (Table 7). Harvest was apportioned to ages 4 and older on Cohoe and Clam Gulch beaches, and to ages 3 and older on Oil Pad and Ninilchik beaches.

Table 1. Relative percent of the harvest (P_b) and estimated harvest (H_b) of razor clams on Cook Inlet eastside beaches, 1991-1992.[a]

Beach Area	P_b	Relative Success	H_b	Standard Error	95% C.I. Lower	95% C.I. Upper	Relative Precision
1991							
Cohoe	0.6	0.5	6,645	784	5,109	8,181	0.12
Clam Gulch	32.9	1.0	384,093	37,275	311,034	457,152	0.10
Oil Pad Access	15.7	1.0	182,774	15,923	151,565	213,983	0.09
Ninilchik, Lehmans to Access	2.5	1.0	29,526	6,446	16,891	42,160	0.22
Ninilchik, Deep Creek to Lehmans[b]	31.2	1.0	364,425	33,595	298,578	430,272	0.09
Ninilchik Bar	10.9	1.0	127,154	13,922	99,867	154,440	0.11
Happy Valley	5.3	0.5	62,062	6,055	50,195	73,929	0.10
Whiskey Gulch	0.9	0.5	10,109	1,388	7,387	12,830	0.14
Total	100.0		1,166,787	68,194	1,033,127	1,300,447	0.06
1992							
Cohoe	0.3	0.5					
Clam Gulch, Bluff to S. extension Cohoe Lp.	1.3	1.0					
Clam Gulch, Bluff to A frame[b]	16.1	1.0					
Clam Gulch, Tower to Bluff	7.4	1.0					
Oil Pad Access	11.5	1.0					
Ninilchik, Lehmans to Access	2.0	1.0					
Ninilchik, Deep Creek to Lehmans[b]	49.0	1.0					
Ninilchik Bar	7.8	1.0					
Happy Valley	4.1	0.5					
Whiskey Gulch	0.5	0.5					
Total	100.0						

[a] Harvest estimates for the 1992 season will not be available until the fall of 1993.

[b] Study area.

Table 2. Percentage of harvest[a] by beach area in the Cook Inlet eastside beach razor clam fishery adjusted for relative success rate, 1977-1992.

Year	No. of surveys	Beach Area Cohoe	Clam Gulch	Oil Pad	Ninilchik	Happy Valley	Whiskey Gulch
1977	3	2.19	70.58	11.21	11.43	3.10	1.49
1978	9	1.78	74.73	10.37	6.91	4.32	1.89
1979	8	2.49	77.15	7.35	7.46	4.75	0.81
1980	8	1.97	67.45	8.22	11.71	8.33	2.31
1981	9	1.67	60.86	12.80	11.07	10.20	3.40
1982	6	1.19	49.56	10.94	13.71	18.36	6.23
1983	6	1.72	48.46	12.79	15.74	15.01	6.27
1984	6	0.92	45.73	19.48	20.17	10.03	3.67
1985	5	0.87	35.10	17.55	31.14	12.67	2.67
1986	4	1.00	25.32	21.44	35.45	13.31	3.47
1987	3	0.17	21.64	13.14	51.90	9.46	3.68
1988	3	0.75	26.14	4.86	53.33	11.22	3.70
1989	11	0.22	28.80	12.07	50.43	5.71	2.77
1990	12	0.36	34.85	16.07	42.76	4.61	1.36
1991	10	0.57	32.92	15.66	44.66	5.32	0.87
Mean	7	1.19	46.62	12.93	27.19	9.09	2.97
1992	13	0.32	24.83	11.50	58.81	4.11	0.52

[a] Harvest percentage weighted by tidal height beginning in 1990.

Table 3. Estimated harvest by beach area and participation in the Cook Inlet eastside beaches razor clam fishery, 1977-1991.[a]

Year	Beach Area: Cohoe	Clam Gulch	Oil Pad	Ninilchik	Happy Valley	Whiskey Gulch	Total Harvest	Participation (Digger-Days)
1977	19,072	614,943	97,684	99,545	26,979	13,025	871,247	25,393
1978	15,977	670,079	92,959	61,973	38,733	16,946	896,667	29,750
1979	24,023	745,767	71,025	72,070	45,958	7,834	966,677	30,323
1980	15,206	520,484	63,431	90,368	64,300	17,813	771,603	31,494
1981	13,864	504,833	106,130	91,788	84,617	28,206	829,436	31,298
1982	11,519	477,753	105,494	132,170	177,035	60,022	963,994	31,954
1983	16,854	474,312	125,199	154,091	146,868	61,396	978,720	31,470
1984	9,575	477,568	203,475	210,657	104,730	38,301	1,044,307	29,880
1985	9,312	374,943	187,472	332,731	135,327	28,555	1,068,340	31,195
1986	11,261	284,825	241,108	398,755	149,699	39,081	1,124,728	32,507
1987	1,664	211,890	128,687	508,092	92,632	36,055	979,020	25,427
1988	8,807	306,207	56,906	624,607	131,425	43,357	1,171,308	30,905
1989	1,809	239,697	100,401	419,696	47,487	23,065	832,155	22,658
1990	3,388	331,400	152,788	406,603	43,835	12,959	950,974	29,427
1991	6,645	384,093	182,774	521,105	62,062	10,109	1,166,787	31,899
Mean	11,265	441,253	127,702	274,950	90,113	29,115	974,398	29,705

[a] Harvest and digger days of participation determined by Statewide Harvest Study. Harvest by beach is apportioned from aerial surveys and assumes a success rate of 0.5 on the Whiskey Gulch, Happy Valley and Cohoe beaches and 1.0 on all other beaches.

Table 4. Age composition (%), mean length at last annulus formation, and respective standard errors (SE) of razor clams sampled on Cook Inlet eastside beaches, 1992.

		Age Class											
		2	3	4	5	6	7	8	9	10	11	12	Total
Cohoe	n	1	6	97	27	2	3	1					137
	%	0.7	4.4	70.8	19.7	1.5	2.2	0.7	0.0	0.0	0.0	0.0	100
	SE(%)	0.7	1.8	3.9	3.4	1.0	1.3	0.7	0.0	0.0	0.0	0.0	
	Length	30	70	87	101	117	114	122					
	SE(L)		2.0	0.5	0.7	4.0	3.5						
Clam Gulch	n	0	2	102	35	31	15	42	49	59	5	2	342
	%	0.0	0.6	29.8	10.2	9.1	4.4	12.3	14.3	17.3	1.5	0.6	100
	SE(%)	0.0	0.4	2.5	1.6	1.6	1.1	1.8	1.9	2.0	0.6	0.4	
	Length		68	91	104	111	119	123	128	128	135	137	
	SE(L)		1.0	0.6	0.9	1.2	1.7	1.0	0.9	0.8	1.9	1.5	
Oil Pad North	n	0	4	59	31	9	6	48	30	13	1	0	201
	%	0.0	2.0	29.4	15.4	4.5	3.0	23.9	14.9	6.5	0.5	0.0	100
	SE(%)	0.0	1.0	3.2	2.6	1.5	1.2	3.0	2.5	1.7	0.5		
	Length		81	104	113	121	122	131	132	135	132		
	SE(L)		3.1	0.6	0.9	1.7	1.8	0.7	1.8	1.5			
Oil Pad South	n	1	1	98	19	13	3	2	7	2	1	0	147
	%	0.7	0.7	66.7	12.9	8.8	2.0	1.4	4.8	1.4	0.7	0.0	100
	SE(%)	0.7	0.7	3.9	2.8	2.3	1.2	1.0	1.8	1.0	0.7		
	Length	66	99	110	116	124	123	127	137	137	147		
	SE(L)			0.5	1.5	1.1	4.3	4.0	2.6	8.5			
Oil Pad (All samples)	n	1	5	157	50	22	9	50	37	15	2		348
	%	0.3	1.4	45.1	14.4	6.3	2.6	14.4	10.6	4.3	0.6	0.0	100
	SE(%)	0.3	0.6	2.7	1.9	1.3	0.9	1.9	1.7	1.1	0.4	0.0	
	Length	66	84	108	114	123	122	131	133	135	140		
	SE(L)		4.4	0.5	0.8	1.0	1.7	0.7	1.6	1.5	7.5		
Ninilchik Beach	n	5	2	175	22	3	3	9	7	10	2	1	239
	%	2.1	0.8	73.2	9.2	1.3	1.3	3.8	2.9	4.2	0.8	0.4	100
	SE(%)	0.9	0.6	2.9	1.9	0.7	0.7	1.2	1.1	1.3	0.6	0.4	
	Length	70	101	119	127	138	142	144	140	151	145	155	
	SE(L)	3.6	7.0	0.4	1.1	2.9	0.7	2.5	2.3	2.5	3.5		
Ninilchik Bar	n	2	2	104	32	1	1	10	5	8	11	3	179
	%	1.1	1.1	58.1	17.9	0.6	0.6	5.6	2.8	4.5	6.1	1.7	100
	SE(%)	0.8	0.8	3.7	2.9	0.6	0.6	1.7	1.2	1.5	1.8	1.0	
	Length	61	93	117	125	129	130	145	152	152	156	155	
	SE(L)	10.0	3.0	0.6	1.0			1.5	2.2	1.6	1.5	2.0	
Ninilchik (All samples)	n	7	4	279	54	4	4	19	12	18	13	4	418
	%	1.7	1.0	66.7	12.9	1.0	1.0	4.5	2.9	4.3	3.1	1.0	100
	SE(%)	0.6	0.5	2.3	1.6	0.5	0.5	1.0	0.8	1.0	0.9	0.5	
	Length	67	97	119	126	135	139	144	145	151	154	155	
	SE(L)	3.7	3.9	0.3	0.7	3.0	3.1	1.4	2.4	1.5	1.7	1.4	

Table 5. Age composition (%) of razor clams sampled at Clam Gulch Beach, 1969-1992.

Year	Age Class 1	2	3	4	5	6	7	8	9	10	11	12	13	14	Number Sampled
1969		2.4	5.8	13.6	5.4	36.5	36.3								742
1970			4.1	17.1	15.9	30.5	32.4								655
1971			0.9	28.8	17.6	29.0	20.2	3.5							688
1972				8.4	45.9	19.8	11.5	14.4							715
1973			1.5	2.4	8.6	52.4	23.3	9.2	2.6						824
1974			0.2	1.5	2.3	12.3	43.5	28.3	10.0	1.9					480
1975			0.4	0.6	4.2	5.0	18.6	42.9	19.2	9.1					504
1976				0.4	1.0	7.4	5.9	9.8	14.1	19.9	41.5				744
1977			1.1	3.0	2.0	4.5	5.9	8.8	28.9	45.8					433
1978				1.4	6.1	6.9	8.0	9.6	28.1	39.9					492
1979			0.2	1.5	5.3	5.3	9.5	11.2	30.0	30.0	6.2	0.8			546
1980		0.3	12.4	0.9	5.7	3.4	11.8	12.6	14.9	29.9	7.2	0.9			348
1981			0.4	30.9	14.3	8.5	10.0	7.7	5.8	17.4	4.2	0.8			260
1982		1.5	1.0	23.0	25.5	14.2	10.8	5.9	7.8	8.8	1.0	0.5			204
1983			4.3	5.1	16.3	36.8	17.9	6.8	2.6	7.6	1.7	0.9			116
1984		1.3	2.8	8.7	14.6	10.0	42.6	9.3	6.0	4.0		0.7			150
1985			3.1	7.7	9.2	6.2	30.8	16.9	6.2	12.3	4.6	1.5		1.5	65
1986			4.2	3.2	41.5	8.5	9.6	29.8	2.1	1.1					94
1987			19.3	3.7	18.3	38.6	12.8	6.4	0.9						109
1988				11.6	18.2	42.1	14.9	9.9	3.3						122
1989			2.7	10.7	2.7	24.1	21.4	18.8	11.6	8.0					112
1990	7.7	1.9	5.2	3.2	7.1	5.2	18.1	36.8	11.6	3.2					155
1991			5.3	7.3	5.6	7.6	10.6	32.3	22.1	9.2					303
1992			0.6	29.8	10.2	9.1	4.4	12.3	14.3	17.3	1.5	0.6			342

Table 6. Age composition (%) of razor clams sampled at Ninilchik Beach, 1974-1992.

Year	Age Class 2	3	4	5	6	7	8	9	10	11	12	13	Number Sampled
1974		1.3	1.3	1.3	43.0	21.5	22.2	9.4					149
1977				6.4	3.2	1.6	24.2	32.3	11.3	21.0			62
1978					12.5			37.5	12.5	25.0	12.5		8
1979													
1980		90.0	7.5	2.5									80
1981													
1982		7.5	5.0	3.1	79.5	1.2			2.5		1.2		161
1983	7.9	21.2	46.3	4.0	4.0	16.6							151
1984	1.4	63.0	27.4	6.8	1.4								73
1985		5.9	69.5	11.8	4.7	3.5	2.3	2.3					85
1986		3.4	3.4	48.9	34.1	3.4	5.7		1.1				88
1987		9.9	6.6	2.2	57.1	18.7	4.4	1.1					91
1988													
1989	4.8	0.7	7.6	16.5	6.2	1.4	22.1	24.8	9.7	4.1	1.4	0.7	145
1990	10.0	27.3	9.1	0.9	0.9	12.7	19.1	8.2	8.2	3.6			110
1991	0.7	57.3	8.7	0.7	1.8	8.7	4.7	4.0	9.4	3.3	0.4	0.4	276
1992	1.7	1.0	66.7	12.9	1.0	1.0	4.5	2.9	4.3	3.1	1.0		418

Table 7. Age composition (%), age composition of the harvestable population (%), harvest by age, and respective standard errors (SE) of razor clams on Cook Inlet eastside beaches in 1991.

		Age Class												
		2	3	4	5	6	7	8	9	10	11	12	13	Total
Cohoe	n	1	43	51	6	2	4	3	4	1	0	0	0	115
	%	0.9	37.4	44.3	5.2	1.7	3.5	2.6	3.5	0.9				100
	SE(%)	0.9	4.5	4.7	2.1	1.2	1.7	1.5	1.7	0.9				
	Age 4+(%)			71.8	8.5	2.8	5.6	4.2	5.6	1.4				100
	SE(Age 4+)			5.4	3.3	2	2.8	2.4	2.8	1.4				
	Harvest			4,773	562	187	374	281	374	94				6,645
	SE(H)			666	229	132	187	162	187	94				784
Clam Gulch	n	0	16	22	17	23	32	98	67	28	0	0	0	303
	%		5.3	7.3	5.6	7.6	10.6	32.3	22.1	9.2				100
	SE(%)		1.3	1.5	1.3	1.5	1.8	2.7	2.4	1.7				
	Age 4+(%)			7.7	5.9	8.0	11.1	34.1	23.3	9.8				100
	SE(Age 4+)			1.6	1.4	1.6	1.9	2.8	2.5	1.8				
	Harvest			29,443	22,751	30,781	42,826	131,154	89,666	37,472				384,093
	SE(H)			6,658	5,775	6,826	8,240	16,640	12,929	7,630				37,275
Oil Pad	n	0	28	60	41	12	26	52	34	17	7	2	0	279
	%		10.0	21.5	14.7	4.3	9.3	18.6	12.2	6.1	2.5	0.7		100
	SE(%)		1.8	2.5	2.1	1.2	1.7	2.3	2.0	1.4	0.9	0.5		
	Age 3+(%)		10.0	21.5	14.7	4.3	9.3	18.6	12.2	6.1	2.5	0.7		100
	SE(Age 3+)		1.8	2.5	2.1	1.2	1.7	2.3	2.0	1.4	0.9	0.5		
	Harvest		18,343	39,306	26,859	7,861	17,033	34,065	22,274	11,137	4,586	1,310		182,774
	SE(H)		3,650	5,644	4,519	2,319	3,504	5,186	4,065	2,787	1,754	928		15,923
Ninilchik Beach	n	2	98	15	0	0	0	3	0	1	1	0	0	120
	%	1.7	81.7	12.5				2.5		0.8	0.8			100
	SE(%)	1.2	3.5	3.0				1.4		0.8	0.8			
	Age 3+(%)		83.1	12.7				2.5		0.8	0.8			100
	SE(Age 3+)		3.5	3.1				1.5		0.8	0.8			
	Harvest		327,180	50,079				10,016		3,339	3,339			393,951
	SE(H)		31,503	12,845				5,777		3,339	3,339			34,208
	Study Area		302,658	46,325				9,265		3,088	3,088			364,425
	SE(Area)		30,609	11,936				5,349		3,088	3,088			33,595
Ninilchik Bar	n	0	60	9	2	5	24	10	11	25	8	1	1	156
	%		38.5	5.8	1.3	3.2	15.4	6.4	7.1	16.0	5.1	0.6	0.6	100
	SE(%)		3.9	1.9	0.9	1.4	2.9	2.0	2.1	2.9	1.8	0.6	0.6	
	Age 3+(%)		38.5	5.8	1.3	3.2	15.4	6.4	7.1	16.0	5.1	0.6	0.6	100
	SE(Age 3+)		3.9	1.9	0.9	1.4	2.9	2.0	2.1	2.9	1.8	0.6	0.6	
	Harvest		48,905	7,336	1,630	4,075	19,562	8,151	8,966	20,377	6,521	815	815	127,154
	SE(H)		7,285	2,500	1,156	1,843	4,243	2,642	2,778	4,341	2,350	815	815	13,922
Ninilchik (All samples)	n	2	158	24	2	5	24	13	11	26	9	1	1	276
	%	0.7	57.2	8.7	0.7	1.8	8.7	4.7	4.0	9.4	3.3	0.4	0.4	100.0
	SE(%)	0.5	3.0	1.7	0.5	0.8	1.7	1.3	1.2	1.8	1.1	0.4	0.4	
	Age 3+(%)		57.7	8.8	0.7	1.8	8.8	4.7	4.0	9.5	3.3	0.4	0.4	
	SE(Age 3+)		3.0	1.7	0.5	0.8	1.7	1.3	1.2	1.8	1.1	0.4	0.4	
	Harvest		376,085	57,414	1,630	4,075	19,562	18,167	8,966	23,716	9,859	818	815	521,105
	SE(H)		32,334	13,086	1,156	1,843	4,243	6,353	2,778	5,477	4,083	815	815	36,932

Szarzi (1991) noted that sample sizes for age and length data after 1981 were less than that needed to produce a reliable population estimate. Sample sizes were increased beginning in 1991. Harvest by age data was updated for the catch-at-age analysis at Clam Gulch (Table 8) and for future catch-at-age analysis at Ninilchik (Table 9).

Estimation of Abundance

Estimates of exploitable abundance of clams at Ninilchik Beach from 1989-1992 varied from a low of 483,289 clams in 1989 to a high of 2,938,234 in 1992 (Table 10). In 1989, an estimated 72.7% of these clams were harvested while only 17.8% were harvested in 1991 (the last year for which harvest estimates are available). Estimates of total abundance vary less than those of exploitable abundance, ranging from a low of 1,983,605 to a high of 3,051,291 during those same years. Exploitation rates of the total population were all less than 20%.

Catch-at-Age Analysis

Exploitable abundance of razor clams on Clam Gulch Beach estimated by catch-at-age analysis ranged from 905,362 clams in 1982 to 4,366,446 clams in 1991 (Table 11). The proportion of each partially recruited age class available to the Clam Gulch fishery was estimated at:

Age	Fraction
4	0.0999
5	0.2537
6	0.3696

Age 7 and older clams were fully recruited to the Clam Gulch fishery.

Temporal trends in abundance are evident. Total abundance of razor clams on Clam Gulch Beach declined from 3,471,800 in 1977 to 1,995,642 in 1980 (Table 12). During the period 1981 to 1984, abundance was stable at approximately 2.4 million clams. Abundance has steadily increased since 1985 to approximately 8.8 million clams in 1991.

The absence of data from Ninilchik in 1979, 1981, and 1988 precluded catch-at-age analysis for this beach.

DISCUSSION

Population estimates for Clam Gulch Beach from the CAGEAN analysis approximate estimates presented earlier (Athons 1992). Estimates will continue to change as sampling in future years provides a more complete picture of the strength of cohorts that just entered the fishery. Changes in abundance estimates are therefore expected to be the greatest for the most recent years.

Although the CAGEAN analysis indicates that the clam population at Clam Gulch declined in the early 1980s and has steadily increased since then, caution should be exercised in placing emphasis on specific numbers. Not only were

Table 8. Estimated razor clam harvest by age class from Clam Gulch Beach, 1977-1991.

Year	Age Class 4	5	6	7	8	9	10	11+	Total
1977	18,653	12,436	27,980	36,685	54,717	179,695	284,777		614,943
1978	9,381	40,875	46,235	53,606	64,328	188,292	267,362		670,079
1979	11,209	39,605	39,605	70,990	83,693	224,178	224,178	52,308	745,767
1980	5,366	33,984	20,271	70,352	75,121	88,834	178,264	48,292	520,484
1981	156,620	72,481	43,083	50,686	39,028	29,398	88,194	25,343	504,833
1982	112,701	124,951	69,580	52,920	28,910	38,220	43,120	7,350	477,753
1983	25,277	80,787	182,390	88,717	33,702	12,886	37,667	12,886	474,312
1984	43,325	72,706	49,799	212,142	46,313	29,879	19,919	3,486	477,568
1985	29,794	35,598	23,990	119,177	65,393	23,990	47,593	29,407	374,943
1986	9,514	123,385	25,272	28,542	88,599	6,244	3,270		284,825
1987	9,715	48,049	101,350	33,608	16,804	2,363			211,890
1988	35,520	55,730	128,913	45,625	30,314	10,105			306,207
1989	26,359	6,651	59,370	52,719	46,313	28,576	19,708		239,697
1990	12,553	27,617	20,085	70,297	143,105	45,191	12,553		331,400
1991	29,443	22,751	30,781	42,826	131,154	89,666	37,472		384,093

Table 9. Estimated razor clam harvest by age class from Ninilchik Beach, 1977-1991.

Year	Age Class 3	4	5	6	7	8	9	10	11+	Total
1977			6,371	3,185	1,593	24,090	32,153	11,249	20,904	99,545
1978				7,747			23,240	7,747	23,240	61,973
1979										72,070
1980	81,331	6,778	2,259							90,368
1981										91,788
1982	9,913	6,609	4,097	105,075	1,586			3,304	1,586	132,170
1983	35,469	77,464	6,692	6,692	27,773					154,091
1984	134,598	58,540	14,528	2,991						210,657
1985	19,631	231,248	39,262	15,638	11,646	7,653	7,653			332,731
1986	13,558	13,558	194,991	135,975	13,558	22,729		4,386		398,755
1987	50,301	33,534	11,178	290,121	95,013	22,356	5,589			508,092
1988										624,607
1989	3,086	33,505	72,741	27,333	6,172	97,429	109,333	42,763	27,333	419,696
1990	123,213	41,071	4,107	4,107	57,499	86,249	36,964	36,964	16,428	406,603
1991	376,085	57,414	1,630	4,075	19,562	18,167	8,966	23,716	11,489	521,105

Table 10. Population and exploitation estimates of total and exploitable [a] razor clams on the Ninilchik Beach study area, 1989-1992.

Year	Area (m^2)	Population Estimate	SE	Relative Precision[b]	Harvest	Exploitation
Total Abundance:						
1989	1,399,231	1,983,605	412,719	0.27	351,586	17.7 %
1990	1,130,148	2,250,851	412,703	0.24	318,955	14.2 %
1991	1,399,231	2,200,426	371,044	0.22	364,425	16.6 %
1992	1,399,231	3,051,291	777,965	0.33	c	
Exploitable Abundance:						
1989	1,399,231	483,289	108,972	0.29	351,586	72.7 %
1990	1,130,148	677,720	198,198	0.37	318,955	47.1 %
1991	1,399,231	2,048,658	360,725	0.23	364,425	17.8 %
1992	1,399,231	2,938,234	781,655	0.34	c	

[a] Clams 80 mm or greater in length are considered to be harvestable.

[b] 80% confidence interval.

[c] Harvest estimates for 1992 not available until fall of 1993.

Table 11. Abundance by age and year of exploitable razor clams age 4 and older on Clam Gulch Beach estimated by catch-at-age (CAGEAN) analysis for 1977-1991.

Year	Abundance by Age									Standard
	4	5	6	7	8	9	10	11+	Total	Error
1977	58,657	90,467	162,324	399,242	433,315	537,775	718,505	21	2,400,306	769,345
1978	33,461	128,599	110,086	357,694	283,527	307,725	381,909	510,272	2,113,273	612,037
1979	45,630	71,956	149,001	225,859	209,377	165,963	180,128	522,240	1,570,153	416,337
1980	41,391	97,078	81,131	293,800	118,743	110,078	87,254	369,264	1,198,739	282,475
1981	107,968	87,926	109,035	159,079	152,136	61,488	57,001	236,394	971,027	197,194
1982	78,175	226,321	95,473	203,517	72,095	68,948	27,866	132,967	905,362	176,432
1983	52,116	165,493	251,973	184,819	101,797	36,061	34,487	80,447	907,193	204,628
1984	69,784	110,836	186,416	496,152	96,802	53,318	18,888	60,199	1,092,395	262,947
1985	156,356	148,633	125,322	369,095	263,773	51,464	28,346	42,045	1,185,034	313,213
1986	206,663	333,240	168,339	248,735	197,518	141,156	27,540	37,669	1,360,860	371,053
1987	199,881	455,993	412,141	379,821	188,310	149,536	106,865	49,369	1,941,916	501,218
1988	95,677	444,166	574,197	954,609	308,690	153,045	121,532	126,975	2,778,890	703,921
1989	160,522	212,705	559,956	1,332,226	779,406	252,035	124,956	202,898	3,624,704	1,025,192
1990	121,447	355,745	266,019	1,284,131	1,053,955	616,606	199,391	259,373	4,156,667	1,104,253
1991	324,542	269,300	445,548	611,328	1,021,648	838,521	490,569	364,990	4,366,446	1,553,877

Table 12. Abundance by age and year of total razor clams age 4 and older on Clam Gulch Beach estimated by catch-at-age (CAGEAN) analysis for 1977-1991.

Year	Abundance by Age								Total	Standard Error
	4	5	6	7	8	9	10	11+		
1977	587,085	356,649	439,208	399,242	433,315	537,775	718,505	21	3,471,800	851,129
1978	334,902	506,976	297,865	357,694	283,527	307,725	381,909	510,272	2,980,871	648,268
1979	456,701	283,672	403,157	225,859	209,377	165,963	180,128	522,240	2,447,099	442,102
1980	414,273	382,711	219,519	293,800	118,743	110,078	87,254	369,264	1,995,642	331,358
1981	1,080,630	346,630	295,021	159,079	152,136	61,488	57,001	236,394	2,388,380	454,469
1982	782,441	892,224	258,325	203,517	72,095	68,948	27,866	132,967	2,438,384	495,439
1983	521,621	652,423	681,774	184,819	101,797	36,061	34,487	80,447	2,293,430	466,428
1984	698,459	436,949	504,393	496,152	96,802	53,318	18,888	60,199	2,346,160	438,309
1985	1,564,943	585,954	339,089	369,095	263,773	51,464	28,346	42,045	3,244,708	767,023
1986	2,068,454	1,313,731	455,482	248,735	197,518	141,156	27,540	37,669	4,490,287	1,448,274
1987	2,000,574	1,797,659	1,115,147	379,821	188,310	149,536	106,865	49,369	5,787,281	1,660,926
1988	957,611	1,751,032	1,553,629	954,609	308,690	153,045	121,532	126,975	5,927,124	1,578,280
1989	1,606,636	838,548	1,515,096	1,332,226	779,406	252,035	124,956	202,898	6,651,801	1,958,285
1990	1,215,542	1,402,452	719,780	1,284,131	1,053,955	616,606	199,391	259,373	6,751,230	2,363,945
1991	3,248,289	1,061,659	1,205,538	611,328	1,021,648	838,521	490,569	364,990	8,842,540	10,227,898

sample sizes for age composition quite low in the middle years of this analysis, but aerial surveys to apportion harvest by beach were minimal in some years.

Stock assessment for Clam Gulch Beach indicates total and exploitable abundances of clams continue to increase. Exploitable abundance of clams was estimated at greater than 4.3 million in 1991 - up from less than 1 million during the early 1980s. Harvest rates remain less than 10% of the exploitable population.

Estimates of abundance at Ninilchik Beach differ from those in previous reports (Szarzi 1991, Athons 1992) because the approach we used was different. In the previous approach the area physically sampled changed each year, but this difference was not incorporated when estimating abundance. The area used in previous reports to estimate abundance was the area physically sampled the first year of the project. Therefore, annual abundance estimates differed merely due to the area sampled, and comparisons among years were extremely difficult to make. This year we also incorporated finite population correction factors in estimating the variance of abundance to improve (reduce) the variance.

The changes in estimating abundance also made our exploitation rates on the Ninilchik Beach study area greater than those previously reported (Szarzi 1991, Athons 1992). Note that these exploitation rates are biased high and the abundance estimates are biased low because some areas of the beach where harvest occurred were not sampled.

Stock assessment for Ninilchik Beach shows a dramatic increase in clam abundance on the study area for both the total and exploitable populations. Exploitation rates in 1991 for total and exploitable clams were 16.6% and 17.8%, respectively. Exploitation rates for 1992 using a preliminary eastside beach harvest estimate of 1,100,000 clams are 17.7% for total and 18.3% for exploitable abundances.

Resource managers have had few concerns in recent years about the effect of harvest on the Clam Gulch razor clam population. Their lack of concern is further supported by additional clam population growth. Exploitation rates on the exploitable population at Ninilchik Beach in 1989 (73%) and 1990 (47%) suggest that abundance on specific beach locations might be affected by the current levels of harvest. These high exploitation rates, however, correspond to harvest rates of less than 20% of the total population. Managers will become concerned when both total and exploitable harvest rates are high; however when clam populations changed in the past, digger effort shifted to more productive beaches. Additionally, effort is concentrated around a few access points leaving miles of relatively unexploited beach. The accelerated growth rate on the more southern beaches provides clams of a larger size than at Clam Gulch (Figure 6). This is probably the primary factor contributing to the shift of digger effort to the readily accessible Ninilchik Beach. While we assume that the powerful Cook Inlet tides will carry razor clam spawn many miles up and down the eastside beaches, we do not know how important local populations are to the repopulation of specific beaches.

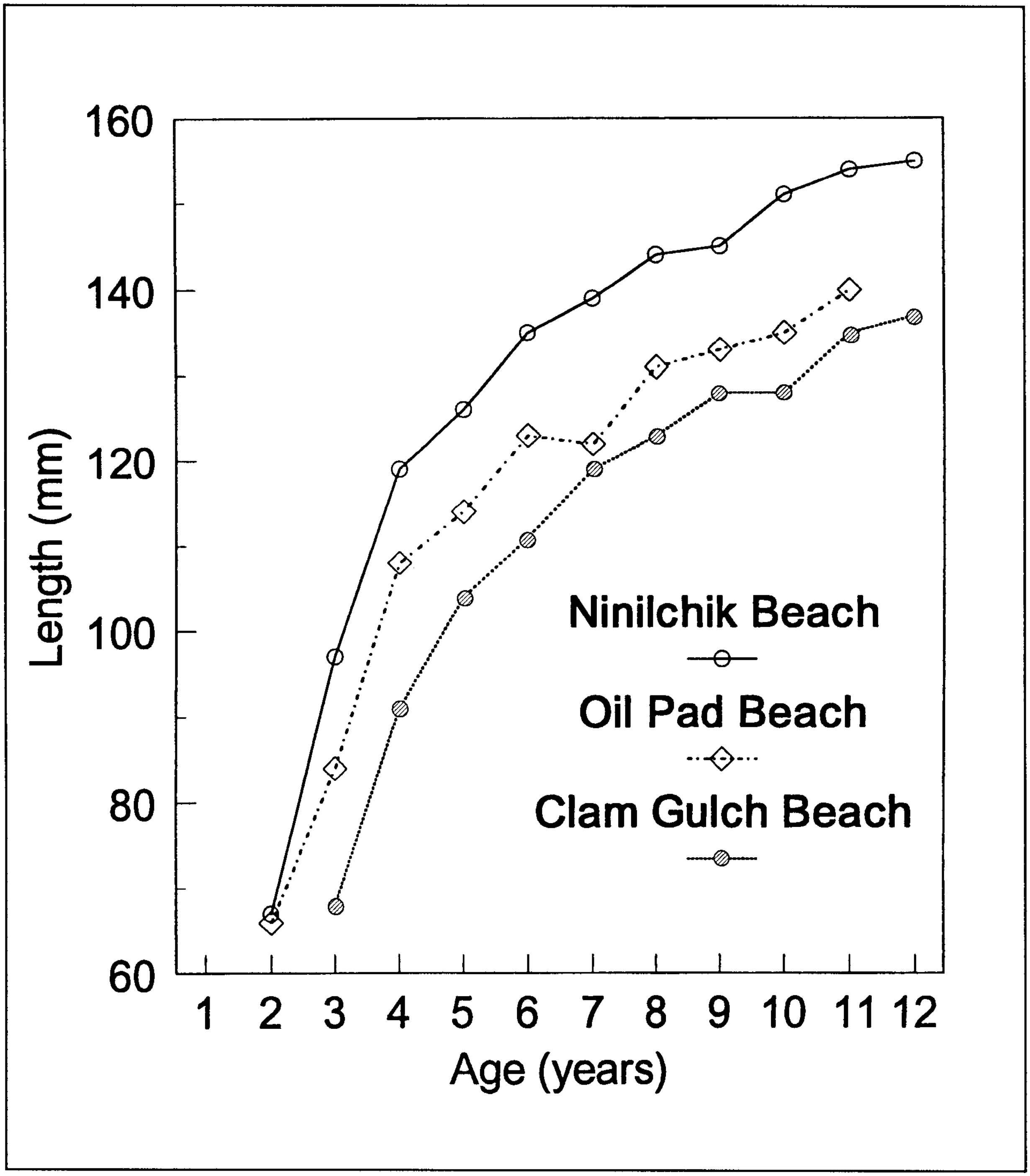

Figure 6. Mean length at age of razor clams sampled from three Cook Inlet eastside beaches, 1992.

RECOMMENDATIONS

As the catch-at-age analysis is based on age composition of harvested razor clams, it is imperative that aging techniques be consistent and desirable that they be accurate. To improve consistency, we saved representative specimens of each year class from the 1991 and 1992 samples, by beach, so that year classes can be compared to samples in subsequent years. Growth rates are variable enough between years that definite patterns do emerge. This proved valuable when analyzing 1992 specimens and this practice should be continued in future years. A study that examines the effects of between-reader and within-reader variability on age structured modeling has been proposed. The primary questions regarding accuracy concern the first 2 years of life. Dependent on the results of the proposed variability study, a life history study that focuses on the early life history of Cook Inlet razor clams should be considered.

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LITERATURE CITED

Athons, D. E. 1992. Harvest distribution, age composition, density, and abundance of razor clams along the eastern beaches of Cook Inlet, 1992. Alaska Department of Fish and Game, Fishery Data Series No. 92-50, Anchorage.

Cochran, W. G. 1977. Sampling techniques, third edition. John Wiley and Sons, New York.

Deriso, R. B., P. R. Neal and T. J. Quinn II. 1989. Further aspects of catch-at-age analysis with auxiliary information. Pages 127-135 *in* R. J. Beamish and G. A. McFarlane, editors. Effects of ocean variability on recruitment and evaluation of parameters used in stock assessment models. Canadian Journal of Fisheries and Aquatic Sciences Special Publication 108.

Deriso, R. B., T. J. Quinn II, and P. R. Neal. 1985. Catch-at-age analysis with auxiliary information. Canadian Journal of Fisheries and Aquatic Sciences 42:815-824.

Goodman, L. A. 1960. On the exact variance of products. Journal of the American Statistical Association 55:708-713.

Mills, M. J. 1979. Alaska statewide sport fish harvest studies. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1978-1979, Project F-9-11, 20 (SW-1-A), Juneau.

_______. 1980. Alaska statewide sport fish harvest studies. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1979-1980, Project F-9-12, 21 (SW-1-A), Juneau.

_______. 1981a. Alaska statewide sport fish harvest studies (1979). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1980-1981, Project F-9-13, 22 (SW-I-A), Juneau.

_______. 1981b. Alaska statewide sport fish harvest studies (1980). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1980-1981, Project F-9-13, 22 (SW-I-A), Juneau.

_______. 1982. Alaska statewide sport fish harvest studies (1981). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1981-1982, Project F-9-14, 23 (SW-1-A), Juneau.

_______. 1983. Alaska statewide sport fish harvest studies (1982). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1982-1983, Project F-9-15, 24 (SW-1-A), Juneau.

_______. 1984. Alaska statewide sport fish harvest studies (1983). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1983-1984, Project F-9-16, 25 (SW-1-A), Juneau.

_______. 1985. Alaska statewide sport fish harvest studies (1984). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1984-1985, Project F-9-17, 26 (SW-1-A), Juneau.

_______. 1986. Alaska statewide sport fish harvest studies (1985). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1985-1986, Project F-10-1, 27 (RT-2), Juneau.

_______. 1987. Alaska statewide sport fisheries harvest report 1986. Alaska Department of Fish and Game, Fishery Data Series No. 2, Juneau.

_______. 1988. Alaska statewide sport fisheries harvest report 1987. Alaska Department of Fish and Game, Fishery Data Series No. 52, Juneau.

_______. 1989. Alaska statewide sport fisheries harvest report 1988. Alaska Department of Fish and Game, Fishery Data Series No. 122, Juneau.

_______. 1990. Harvest and participation in Alaska sport fisheries during 1989. Alaska Department of Fish and Game, Fishery Data Series No. 90-44, Anchorage.

_______. 1991. Harvest and participation in Alaska sport fisheries during 1990. Alaska Department of Fish and Game, Fishery Data Series No. 91-58, Anchorage.

_______. 1992. Harvest, catch and participation in Alaska sport fisheries during 1991. Alaska Department of Fish and Game, Fishery Data Series No. 92-40, Anchorage.

Nelson, D. C. *Unpublished.* A review of Alaska's Kenai Peninsula east side beach recreational razor clam fishery, 1965-1980. Alaska Department of Fish and Game, Division of Sport Fish, Soldotna.

_______. 1993. 1992 Area management report for the recreational fisheries of the Kenai Peninsula. Alaska Department of Fish and Game, Division of Sport Fish, Soldotna.

Quinn, T. J. and N. F. Jones. 1989. Razor clam (*Siliqua patula,* Dixon) investigations on the eastside Cook Inlet beaches. Project Report UAF-JCFOS-8902. Juneau Center for Fisheries and Ocean Sciences, University of Alaska, Fairbanks.

Szarzi, N. J. 1991. Distribution and abundance of the Pacific razor clam, *Siliqua patula* (Dixon), on the east side Cook Inlet beaches. Master's thesis, University of Alaska, Fairbanks.

Wolter, K. M. 1985. Introduction to variance estimation. Springer-Verlag, New York, New York.

APPENDIX A

Razor Clam Digger Counts on Cook Inlet Eastside Beaches, 1992

Appendix A1. Razor clam digger counts on Cook Inlet eastside beaches, 1992.

	Month:	5	5	6	6	6	6	7	7	7	7	7	7	8
	Day:	4	19	4	15	18	29	1	4	15	16	29	30	2
	Time:	11:14	11:53	12:31	10:23	12:10	9:18	10:46	13:00	10:45	11:13	9:45	10:31	12:35
	Tide:	-3.5	-2.1	-3.9	-2.6	-1.3	-2.9	-5.0	-3.2	-1.8	-1.6	-4.1	-4.9	-2.5
1.	Whiskey Gulch													
	Anchor River to Happy Creek	9	0	16	0	0	5	55	26	0	0	10	22	0
2.	Happy Valley													
	Happy Creek to Deep Creek	32	11	19	24	4	48	274	176	17	15	54	168	12
3.	Ninilchik													
	Deep Creek to Set Net Access	222	50	252	187	64	376	1145	681	181	126	555	1071	258
	A. Ninilchik Bar	50	8	22	6	28	18	297	92	5	2	104	337	2
	B. Deep Creek to Lehmans	155	41	219	173	33	338	796	581	171	122	445	716	248
	C. Lehmans to Access	17	1	11	8	3	20	52	8	5	2	6	18	8
4.	Oil Pad Access													
	Set Net Access to Clam Gulch Tower	84	15	47	15	14	78	161	96	54	52	50	115	69
5.	Clam Gulch													
	Tower to S. extension of Cohoe Lp. Rd.	134	58	148	81	51	136	318	214	128	99	98	175	115
	A. Tower to bluff	39	21	55	19	26	22	109	52	47	28	34	65	29
	B. Bluff to A frame	85	32	91	55	25	110	194	122	76	66	56	100	85
	C. A frame to S. Ext.	10	5	2	7	0	4	15	40	5	5	8	10	1
6.	Cohoe													
	S. ext. of Cohoe Lp. Rd to Kasilof R.	2	0	3	1	0	6	9	15	2	5	3	10	0
	Total Diggers	483	134	485	308	133	649	1,962	1,208	382	297	770	1,561	454