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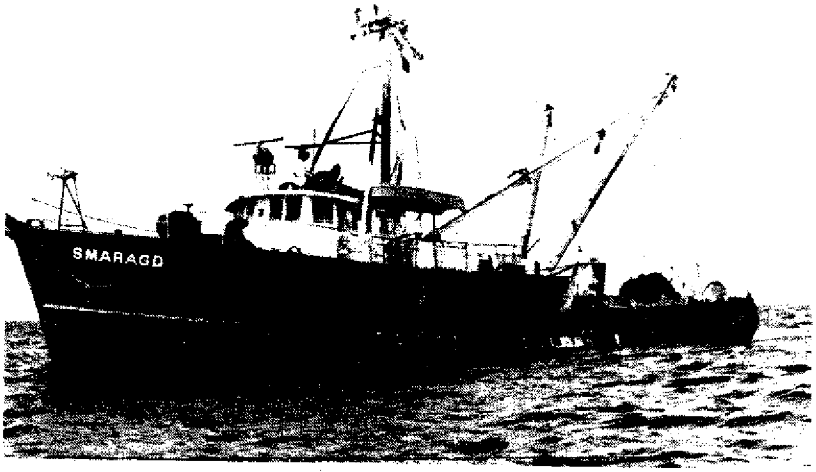
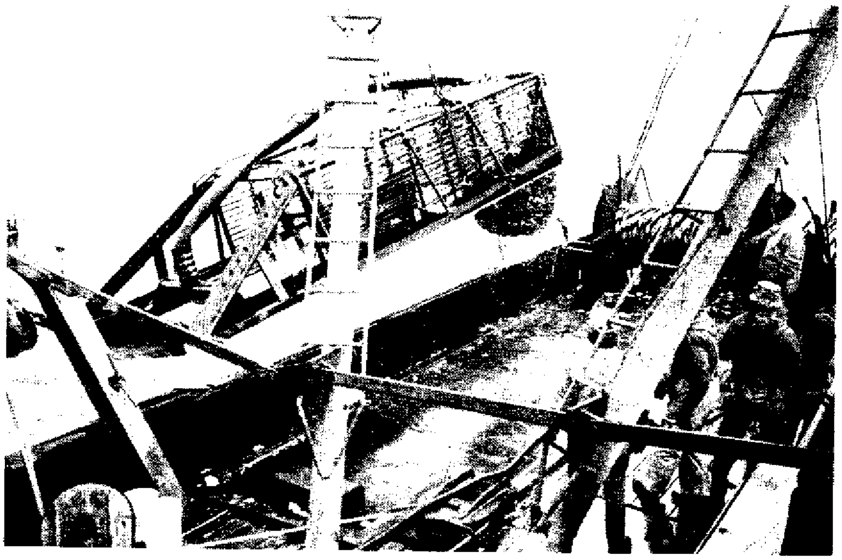


THE PINKNECK CLAM *SPISULA POLYNYMA* IN THE EASTERN BERING SEA

Growth, Mortality, Recruitment and Size at Maturity



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H. M. Feder, A. J. Paul
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Sea Grant Report No. 78-2
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THE PINKNECK CLAM *SPISULA POLYNYMA* IN THE EASTERN BERING SEA

GROWTH, MORTALITY, RECRUITMENT AND SIZE AT MATURITY

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J. R. Moore
Director, IMS

COVER PHOTOS: The F/V *Smaragd* equipped with a modified East Coast hydraulic clam dredge (center), hauls up a wealth of pinkneck clams during a 1977 exploratory cruise on the eastern Bering Sea. (Photos courtesy of the National Marine Fisheries Service.)

ABSTRACT

Specimens of *Spisula polynyma* were collected in the summer of 1977 from the eastern Bering Sea for a study of growth, mortality, recruitment, and size and age at sexual maturity. The aging technique utilized was the annular method. A one-way analysis of variance was used to test the integrity of age classes as defined by counts of annuli.

Annual increases in shell length were typically 7 to 16 mm. The majority, 77%, of the clams were 9 years of age or older. The preponderance of older clams in samples was due to gear bias. The 12 year olds were the first year class to be fully retained by the dredge. The largest clam was 135 mm long and 14 years old. The oldest clams were 16 years old. Specimens were available from three stations. Clams from stations H-15-2 and Dublin Bay had similar growth rates while those from F-13-2 averaged 3 to 9 mm larger.

Growth histories of 15 year classes were determined by measuring the lengths of every annulus. The mean lengths of annuli 1 through 4 exhibited ranges of 1 through 5 mm while variations in mean lengths of annuli 5 through 11 ranged from 5 through 10 mm.

Two methods were used to calculate mortality rates for age classes 12 through 16. The estimated rates of natural mortality for these year classes were 9%, 27%, 40%, 67% and 100% respectively. The mortality rate estimations were utilized to estimate the number of individuals at age 12 for year classes 13 through 16. Calculations suggest that recruitment for these age classes was relatively stable.

The 7-year-old clams, 69 mm mean length, were the first year class where the majority of individuals were sexually mature. All older and larger clams had well developed gonads.

ACKNOWLEDGEMENTS

The authors wish to thank Max Hoberg for his assistance with the collection of the material on board the F/V *Smaragd*. We also wish to thank the crew and scientific personnel of the National Marine Fisheries Service and Alaska Department of Fish and Game for their aid in the collections, Phyllis Shoemaker for her assistance in the laboratory, Ana Lea Vincent for drafting, and Carol Bennie for typing. This report is the result of research sponsored by the Alaska Sea Grant Program, cooperatively supported by NOAA Office of Sea Grant, Department of Commerce, under Grant SG 04-8-M01-49 and by the University of Alaska with funds appropriated by the State of Alaska. This study was partially supported under Contract 03-5-022-56 between the University of Alaska and NOAA, Department of Commerce, through the Outer Continental Shelf Environmental Assessment Program to which funds were provided by the Bureau of Land Management, Department of Interior.

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INTRODUCTION

The pinkneck or redneck clam, *Spisula polynyma*, is a large bivalve found in intertidal and subtidal Alaskan waters. The extent of this resource in Alaska is unknown; however, a cooperative survey by the University of Alaska, National Marine Fisheries Service, Alaska Department of Fish and Game, and private interests have located populations with commercial potential in the eastern Bering Sea. Previous literature on *S. polynyma* is restricted to a geographic study by Chamberlin and Stearns (1963) and a report on growth and size-weight relationships of intertidal pinknecks in Prince William Sound (Feder *et al.*, 1976). Growth data are also available for subtidal Cook Inlet clams (Feder *et al.*, 1978). No published work is available on the biology of subtidal Bering Sea pinkneck clams. The major objectives of this report are to provide information on growth rates, growth history, mortality, recruitment, and size and age at maturity for pinkneck clams from the eastern Bering Sea.

METHODS

Specimens were collected in July and August 1977 from the F/V *Smaragd* with a modified East Coast hydraulic clam dredge. The diameter of the rings in the retaining bag was 75 mm (3"). Specimens from three stations (H-15-2: 57°10'N, 158°51'W; F-13-2: 56°36'N, 159°56'W; Dublin Bay: 54°42'N, 164°43'W) with large numbers of pinknecks, were selected for study (Fig. 1). The shell lengths of 2,617 clams were measured to the nearest millimeter, and a subsample of 652 collected for aging. Age was determined by counting annuli, a series of closely spaced concentric growth lines that are the result of slow winter shell growth (see Paul and Feder, 1973). Growth history was determined for all aged clams by measuring the shell length at each annulus. Shell

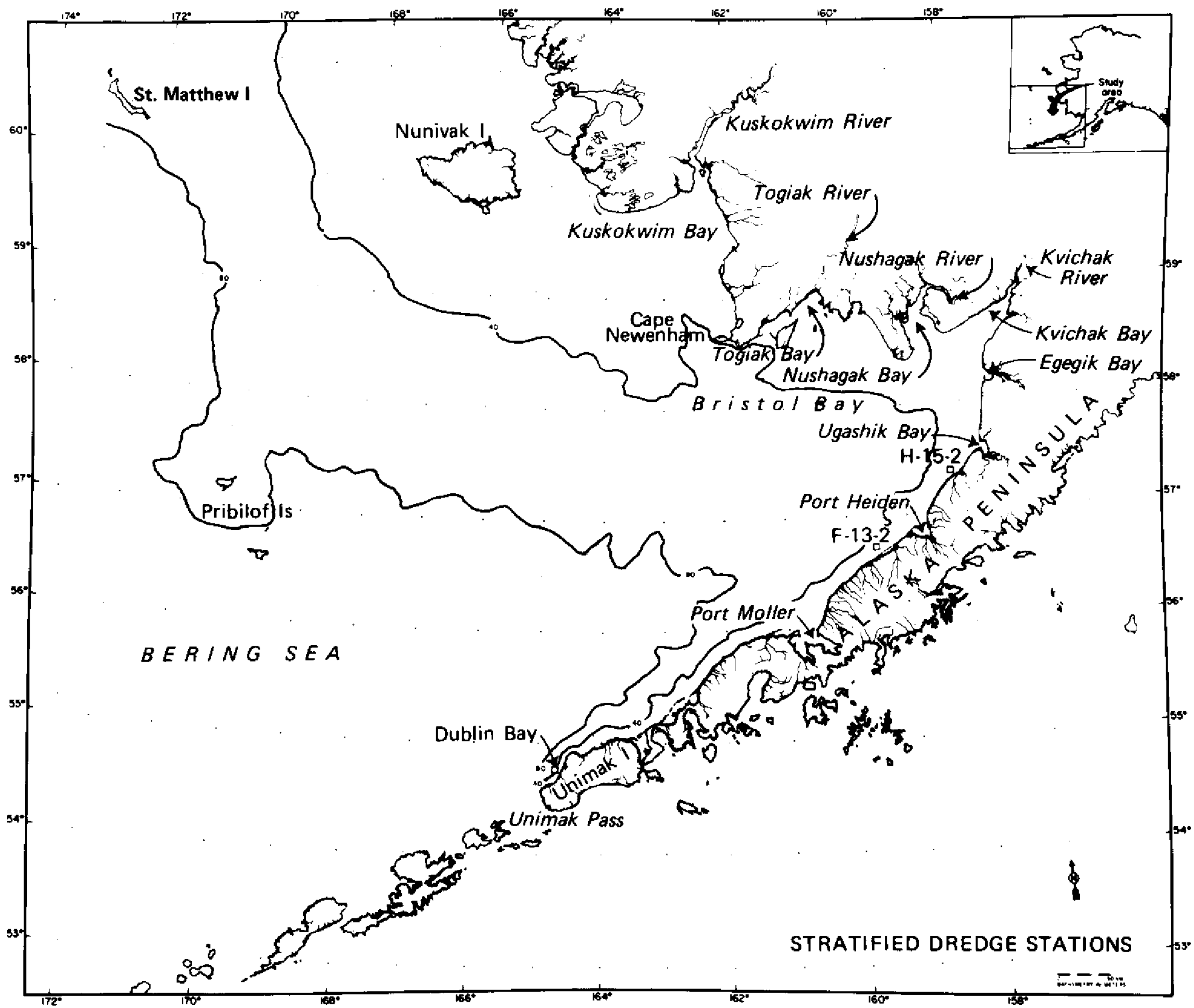

Figure 1. Map of sampling area showing stations H-15-2, F-13-2, and Dublin Bay.

width, the distance from the umbo to the closest point to the margin, was measured to determine which age classes were fully retained by the mesh of the dredge.

Unaged clams, for which only length data were available, were assigned to the age class which had a mean shell length closest to their own length. These converted data, in addition to specimens actually aged, were used in mortality and recruitment observations (a total of 2617 clams). Mortality rates were calculated by determining the percent annual decrease in specimens of a given age and applying the technique of Gruffydd (1974). The latter technique, developed to determine mortality in scallops, assumes that although recruitment varies from year to year in a given spot, overall recruitment to a large area is fairly constant. With this assumption, the total number of specimens from several hauls in a large area were plotted against age on semi-log paper. The curves thus calculated eliminate the effect of uneven recruitment apparent in individual samples. Utilizing the number of individuals estimated from the curve rather than the actual catch, the percent mortality (Z) is estimated using the expression, $Z = \frac{N_t - N_{t+1}}{N_t} \times 100$; where N = number of clams and t = time. The mortality curve shown in Figure 9 was drawn freehand, and the assumption was made that all age classes with shell widths greater than 75 mm were fully retained by the dredge. The number of clams in each age class was utilized to examine recruitment. Initial year class strengths were estimated by applying mortality calculations to each age group in the age structure tables. Recruitment estimations were restricted to age classes with shell widths larger than 75 mm.

Histological examinations of the gonads of 70 clams were made to determine size at maturity. The gonadal mass of each clam was removed and preserved in 10% formalin. A cube of preserved gonadal tissue was removed from the mid-lateral portion of the visceral mass for the preparation of slides. The tissue was dehydrated in alcohol, cleared in xylene, embedded in paraffin, sectioned at 10, 20 and 30 microns, and stained with Ehrlich's hematoxylin (Davenport, 1960).

RESULTS AND DISCUSSION

Aging

Annuli are formed during the winter when increases in shell size are negligible and growth at the shell margin consists of a series of closely spaced concentric lines. Spring growth results in a progressively increasing distance between these lines; as summer progresses the distance between these lines gradually decreases again until a new annulus is formed the following winter. True annuli extend from the umbo anteriorly and merge with the hinge structure posteriorly. False checks may also appear as an aggregation of fine concentric lines; however, such checks fail to merge dorsally (Paul and Feder, 1973).

Annuli, as defined above, were generally distinct, and three biologists who independently aged clams for this project achieved similar results. Since annuli have not been validated in the field for *Spisula polynyma*, the validity of the annular aging method was examined with a standard one-way analysis of variance (Snedecor, 1956). Individual shell lengths within each age class from the three stations and all specimens together were used as a basis for comparison. The calculated F ratio indicates that, in general, age classes as defined by shell lengths are statistically distinguishable (α = 0.01; N = 652, Tables 1-3, 5). The graphical method of Hubbs and Hubbs (1953) further illustrates the integrity of the age classes with the failure of any of the standard errors of the mean to overlap even when sample sizes are small (Figs. 2-5).

Table 1. Mean shell length for age classes of *Spisula polynyma* from Station F-13-2 in the southeastern Bering Sea, and an analysis of variance of shell lengths for the various annular age classes. N = number of clams, MSL = mean shell length (mm), sd = standard deviation (mm), AI = annual increase in shell length (mm), R = range (mm)

Age	N	MSL	sd	AI	R
0	0	-	-	-	-
1	0	-	-	-	-
2	4	12.0	1.4	-	11-14
3	9	28.0	6.3	16.0	16-34
4	42	35.1	5.8	7.1	24-46
5	39	47.6	4.9	12.5	37-59
6	15	56.7	6.1	9.1	49-67
7	14	71.7	7.5	15.0	59-80
8	14	81.7	5.2	10.0	73-94
9	31	87.7	6.6	6.0	70-103
10	41	97.9	7.9	10.2	80-121
11	48	102.2	7.1	4.3	84-118
12	40	111.4	7.0	9.2	98-128
13	27	118.9	6.3	7.5	107-130
14	14	125.1	5.5	6.2	113-135
15	1	119.0	0	-	119
16	1	127.0	0	-	127
Total	340				

Analysis of Variance

Source of Variation	Degrees of Freedom	Mean Square	F ratio	Significant Difference ($\alpha = 0.01$)
Sample means	1	304,287.480		
Individuals	337	57.329	5,307.756	Yes

Table 2. Mean shell length for age classes of *Spisula polynyma* from Station H-15-2 in the southeastern Bering Sea, and an analysis of variance of shell lengths for the various annular age classes. N = number of clams, MSL = mean shell length (mm), sd = standard deviation (mm), AI = annual increase in shell length (mm), R = range (mm).

Age	N	MSL	sd	AI	R
0	-	-	-	-	-
1	0	-	-	-	-
2	0	-	-	-	-
3	0	-	-	-	-
4	0	-	-	-	-
5	0	-	-	-	-
6	2	63.0	4.2	-	60-66
7	0	-	-	-	-
8	2	66.0	1.4	-	65-95
9	7	85.3	10.0	19.3	72-100
10	17	92.9	7.3	7.6	84-118
11	30	101.5	8.3	8.6	89-117
12	45	107.1	6.9	5.6	93-126
13	32	111.5	5.1	4.4	102-120
14	17	118.0	5.3	6.5	110-125
15	2	125.5	9.2	7.5	114-132
16	0	-	-	-	-
Total	154				

Analysis of Variance

Source of Variation	Degrees of Freedom	Mean Square	F ratio	Significant Difference ($\alpha = 0.01$)
Sample means	1	14,489.153		
Individuals	153	52.614	275.387	Yes

Table 3. Mean shell length for age classes of *Spisula polynyma* from Station Dublin Bay in the southeastern Bering Sea, and an analysis of variance of shell lengths for the various annular age classes. N = number, MSL = mean shell length (mm), sd = standard deviation (mm), Al = annual increase in shell length (mm), R = range (mm).

Age	N	MSL	sd	Al	R
0	0	-	-	-	-
1	0	-	-	-	-
2	0	-	-	-	-
3	0	-	-	-	-
4	0	-	-	-	-
5	0	-	-	-	-
6	0	-	-	-	-
7	1	71.0	0	-	71
8	1	73.0	0	2.0	73
9	9	83.3	7.3	10.3	70-91
10	37	90.9	6.7	7.6	70-106
11	49	98.8	6.4	7.9	81-111
12	36	104.3	6.6	5.5	88-118
13	12	109.3	5.9	5.0	98-116
14	2	114.0	4.2	4.7	111-117
15	0	-	-	-	-
16	0	-	-	-	-
Total	147				

Analysis of Variance

Source of Variation	Degrees of Freedom	Mean Square	F ratio	Significant Difference (α = 0.01)
Sample means	1	6,613.437		
Individuals	144	40.282	164.180	Yes

Table 4. A comparison of mean shell lengths (mm) for *Spisula polynyma* and age from three stations in the southeastern Bering Sea. Data are provided only for age classes having ten or more individuals.

Age	F-13-2	H-15-2	Dublin Bay
0			
1			
2			
3			
4	35.1		
5	47.6		
6	56.7		
7	71.7		
8	81.7		
9	87.7		
10	97.9	92.9	90.9
11	102.2	101.5	98.8
12	111.4	107.1	104.3
13	118.9	111.5	109.3
14	125.1	118.0	
15			
16			

Table 5. Mean shell length for age classes of *Spisula polynyma* from three stations in the southeastern Bering Sea, and an analysis of variance of shell lengths for the various annular age classes. N = number of clams, MSL = mean shell length (mm), sd = standard deviation (mm), Al = annual increase in shell length (mm), R = range (mm).

Age	N	MSL	sd	Al	R
0	0	-	-	-	-
1	0	-	-	-	-
2	4	12.0	1.4	-	11-14
3	9	28.0	6.3	16.0	16-34
4	42	35.1	5.8	7.1	24-46
5	39	47.6	4.9	12.5	37-59
6	18	57.1	6.2	9.5	49-67
7	18	68.9	9.2	11.8	59-80
8	18	78.4	8.0	9.5	65-95
9	51	85.3	8.2	6.9	70-103
10	95	94.3	8.0	9.0	70-121
11	129	100.5	7.4	6.2	81-118
12	121	107.7	7.4	7.2	88-128
13	71	114.0	6.9	6.3	98-130
14	34	120.6	6.5	6.6	110-135
15	3	123.3	7.5	2.7	114-132
16	1	127.0	0	3.7	127
Total	652				

Analysis of Variance

Source of Variation	Degree of Freedom	Mean Square	F ratio	Significant Difference (α = 0.01)
Sample means	1	388,052.254		
Individuals	650	62.902	6,169.164	Yes

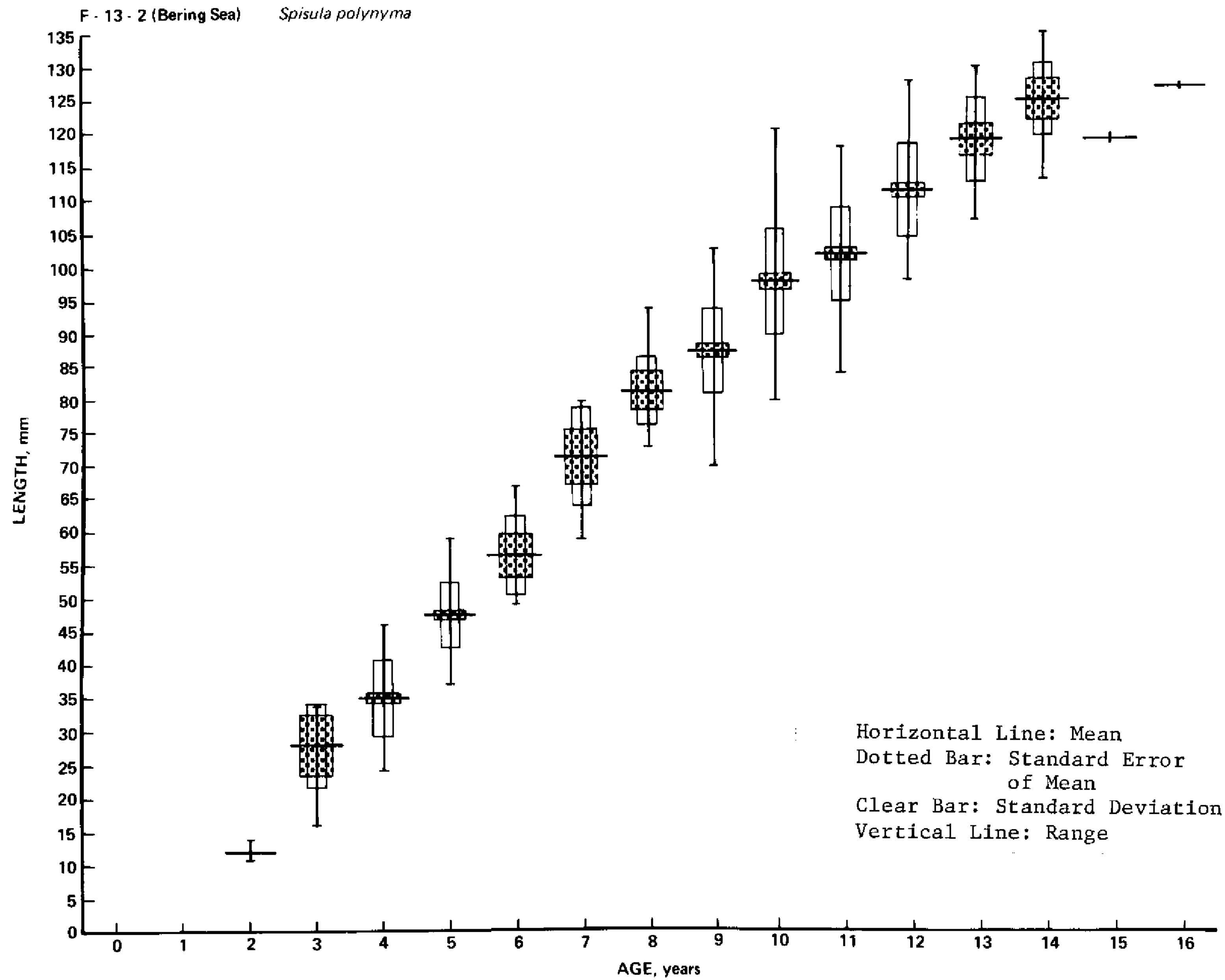

Figure 2. Growth curve for clams from Station F-13-2.

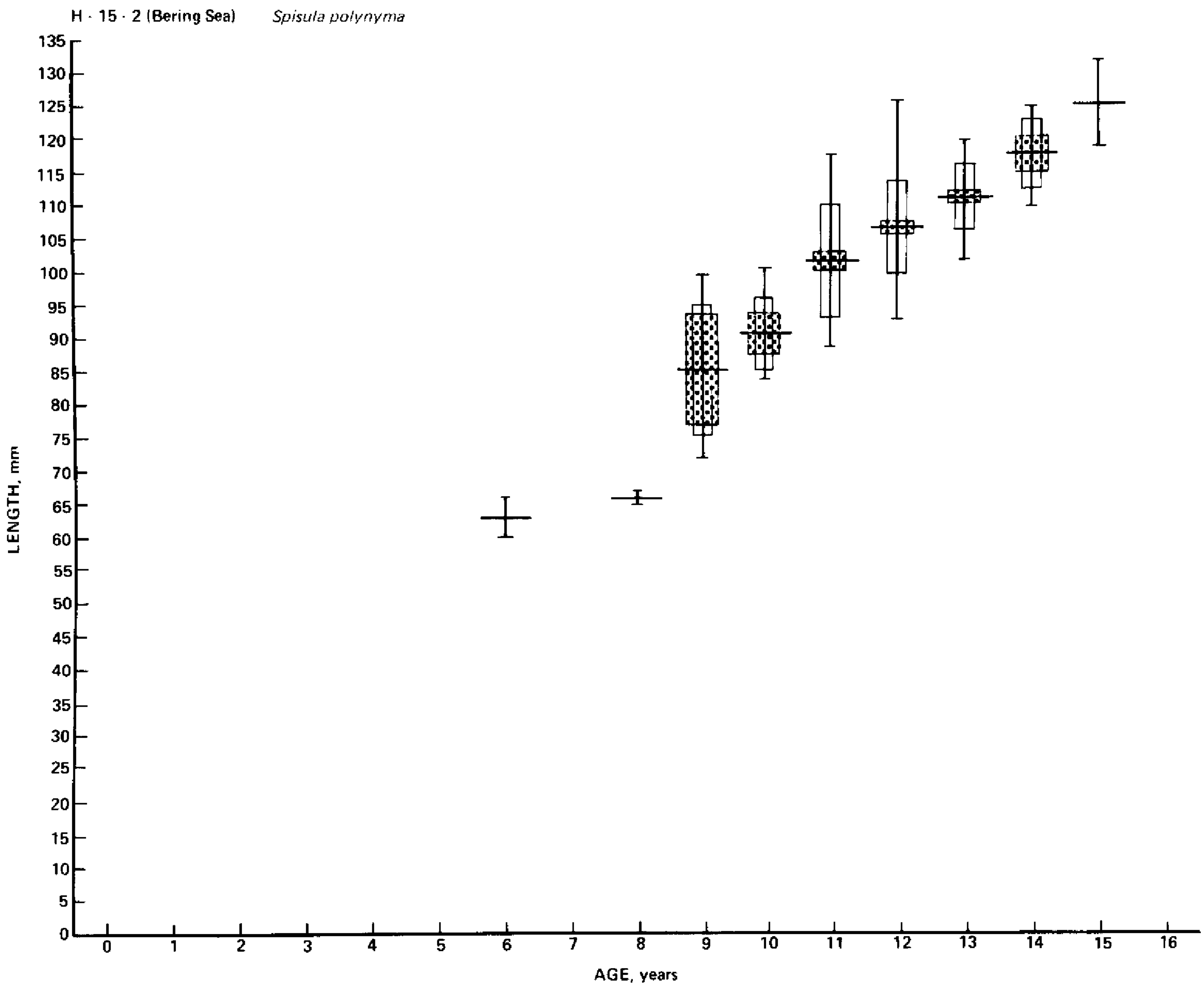

Figure 3. Growth curve for clams from Station H-15-2.

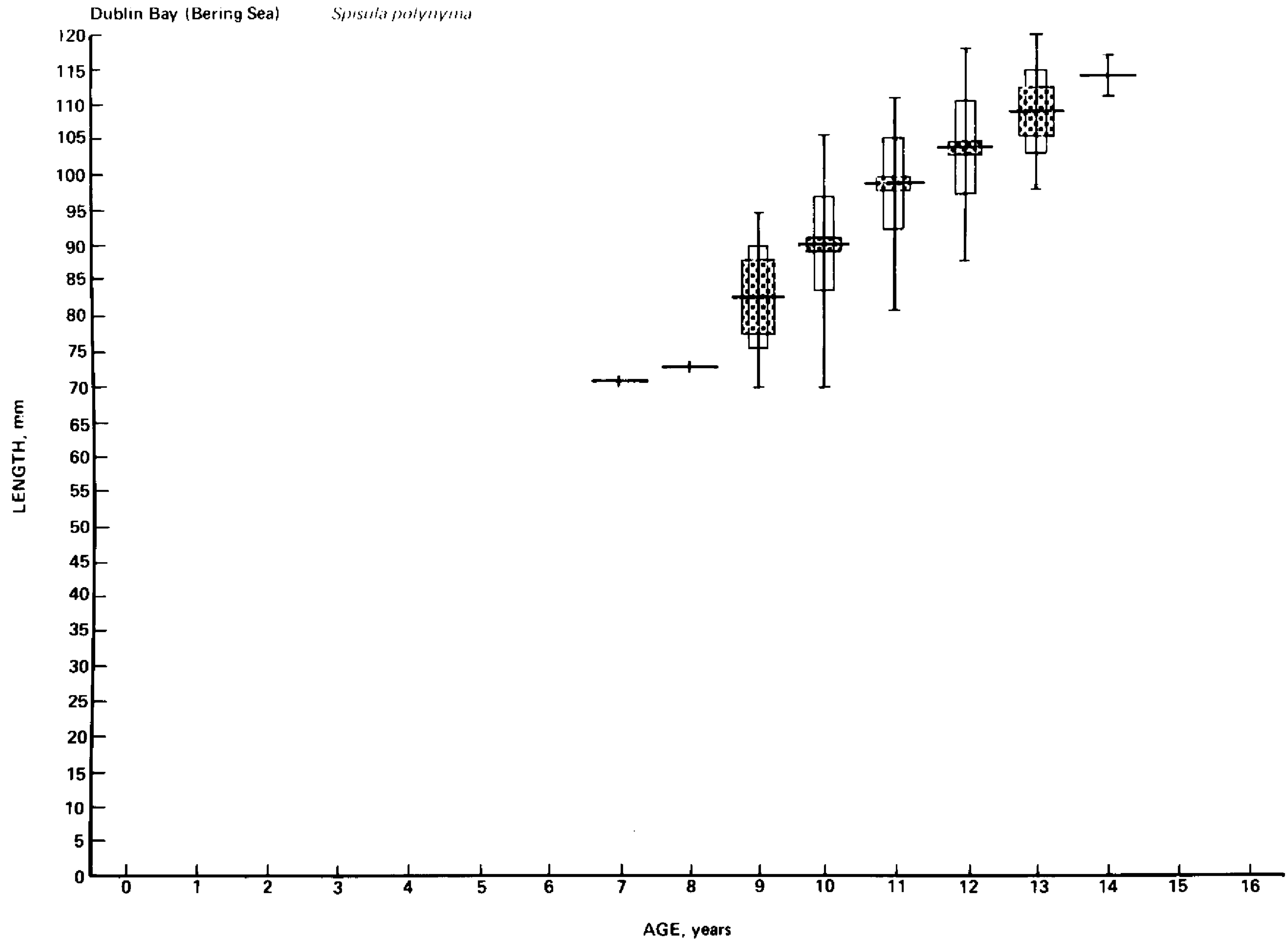

Figure 4. Growth curve for clams from Station Dublin Bay.

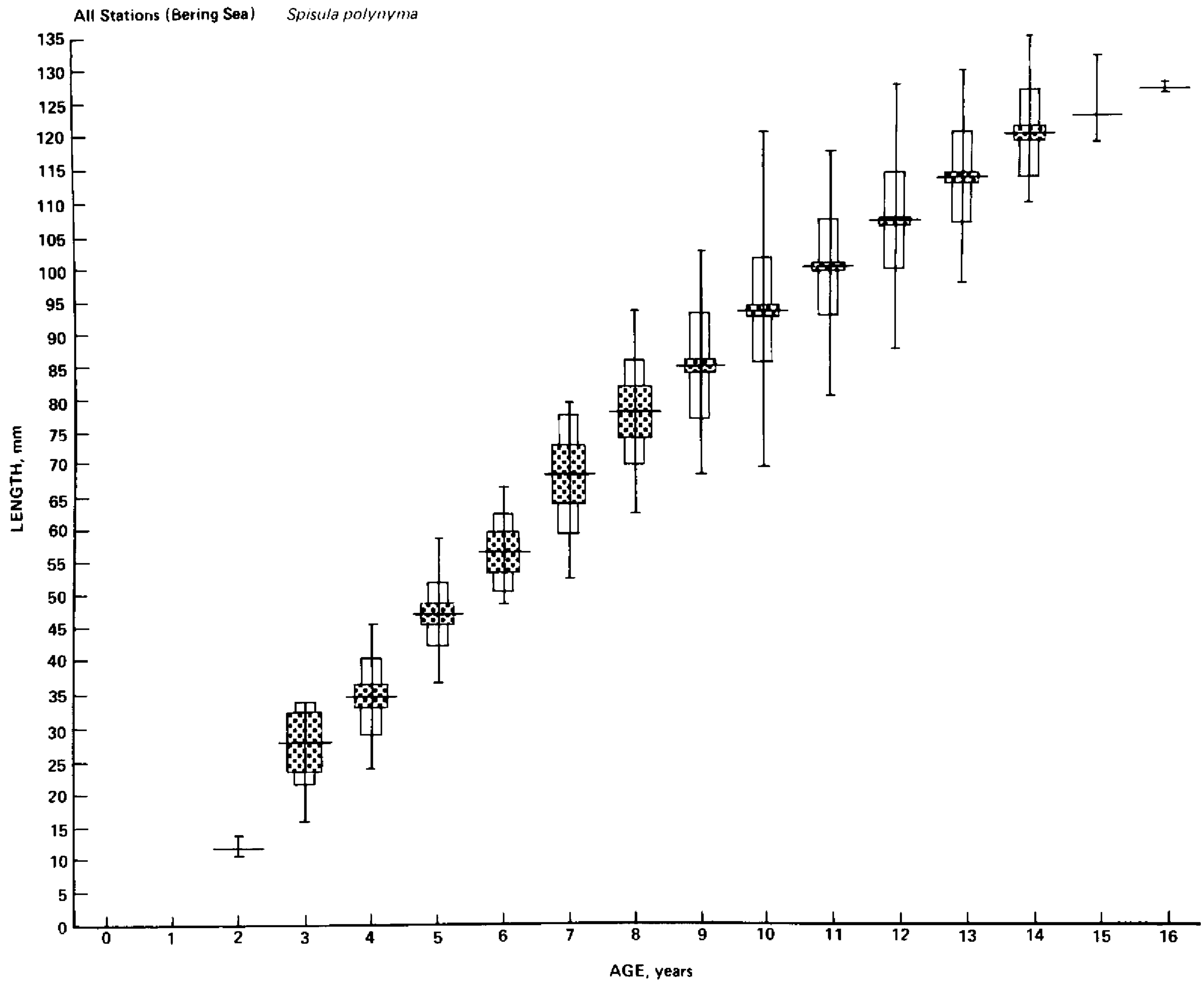

Figure 5. Growth curve for clams from all three stations.

The annular method of aging is reliable for most Alaskan clams because of a strong seasonality of growth. All hard shell Alaska clams in which annuli formations have been studied form a single, readable annulus during the winter (Weymouth *et al.*, 1931; Weymouth and Thompson, 1931; Quayle and Bourne, 1972; Paul and Feder, 1973). Therefore, it is reasonable to assume that pinkneck clams form a single annulus. However, following the growth of marked clams is the only method that will positively validate annulus formation and annual growth. This procedure was not possible in the present investigation, but should be encouraged in future studies.

Age and Growth

A total of 652 *Spisula polynyma* were available for aging. The majority (77%) of the specimens were 9 years old or older. The oldest clam examined was 16 years of age and 127 mm in length. The largest clam was 14 years old and 135 mm long. The annual increase in shell length for all age classes was typically 7 to 16 mm (Tables 1-5; Figs. 2-5). A comparison of size at age for clams from the three study areas is shown in Table 4. The mean shell lengths for clams from Station F-13-2 were between 3 and 9 mm larger than those from Station H-15-2 and Dublin Bay (Table 4; Figs. 2-4).

The vertical columns of the growth history tables (Figs. 6-8) provide information on length at age for 14 or 15 years of growth. Examination of these lengths suggest that growth rates were variable over this period, although much of this variability may be due to small sample size. If comparisons of mean lengths are restricted to values represented by 10 or more measurements, a more dependable estimation of annual variation can be made. The age classes 10 through 14, 4 through 14 and 10 through 12 for Stations

Station F-13-2 (Bering Sea) *Spisula polynyma*

Year Class	*M S L at Annulus 1	M S L at Annulus 2	M S L at Annulus 3	M S L at Annulus 4	M S L at Annulus 5	M S L at Annulus 6	M S L at Annulus 7	M S L at Annulus 8	M S L at Annulus 9	M S L at Annulus 10	M S L at Annulus 11	M S L at Annulus 12	M S L at Annulus 13	M S L at Annulus 14	M S L at Annulus 15	M S L at Annulus 16	Number in Age Class
1																	0
2	7.0	12.0															4
3	9.2	18.2	28.0														9
4	8.0	14.0	23.7	35.1													42
5	8.1	15.0	25.5	36.1	47.6												39
6	7.9	14.8	23.3	35.0	46.1	56.7											15
7	8.5	16.1	25.6	37.8	49.9	60.4	71.7										14
8	8.6	15.7	24.4	34.9	46.9	58.8	70.7	81.7									14
9	9.3	14.6	24.1	34.5	46.0	57.9	68.5	78.7	87.7								31
10	9.2	14.5	22.8	32.8	44.0	55.2	66.7	77.5	87.8	97.9							41
11	9.4	14.8	23.2	31.8	41.8	51.9	63.0	73.1	82.9	93.2	102.2						48
12	9.7	15.9	23.9	32.7	42.1	52.7	63.4	73.7	82.9	92.6	102.7	111.4					40
13	9.1	14.8	23.1	31.5	40.7	52.4	62.4	72.5	82.2	92.1	102.0	111.0	118.9				27
14	9.0	14.2	21.8	30.9	40.9	52.1	61.9	71.5	80.6	89.4	98.4	109.0	118.1	125.1			14
15	8.0	14.0	23.0	29.0	36.0	42.0	45.0	58.0	65.0	74.0	83.0	94.0	105.0	111.0	119.0		1
16	9.0	12.0	18.0	27.0	35.0	46.0	53.0	70.0	79.0	81.0	87.0	95.0	101.0	112.0	119.0	127.0	1
	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	Total
	YEAR OF ANNULUS FORMATION																340

* M S L = Mean Shell Length, mm

Figure 6. Growth history for clams from Station F-13-2.

Station H-15-2 (Bering Sea) *Spisula polynyma*

Year Class	*M S L at Annulus 1	M S L at Annulus 2	M S L at Annulus 3	M S L at Annulus 4	M S L at Annulus 5	M S L at Annulus 6	M S L at Annulus 7	M S L at Annulus 8	M S L at Annulus 9	M S L at Annulus 10	M S L at Annulus 11	M S L at Annulus 12	M S L at Annulus 13	M S L at Annulus 14	M S L at Annulus 15	Number in Age Class
1																0
2																0
3																0
4																0
5																0
6	9.5	18.0	28.0	40.5	54.5	63.0										2
7																0
8	10.0	15.0	22.5	30.5	37.5	46.0	57.5	66.0								2
9	9.0	15.9	22.4	33.6	43.6	53.1	63.6	74.4	85.3							7
10	9.2	15.2	22.9	32.6	43.1	53.6	63.4	72.9	83.1	92.9						17
11	9.2	15.0	23.1	32.2	42.0	52.0	63.3	73.5	83.5	92.8	101.5					30
12	8.8	14.8	23.0	31.5	40.7	50.4	59.8	69.6	79.4	89.6	99.2	107.1				45
13	9.3	15.1	22.6	31.0	39.4	48.9	58.1	67.6	76.7	85.4	94.7	103.7	111.5			32
14	9.1	14.5	22.5	29.1	37.6	47.5	56.9	66.2	75.0	84.6	92.9	102.2	110.7	118.0		17
15	9.0	16.0	22.5	29.5	38.5	46.0	54.5	62.0	71.0	81.5	92.5	101.5	111.0	118.5	125.5	2
	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	Total
	YEAR OF ANNULUS FORMATION															154

* M S L = Mean Shell Length, mm

Figure 7. Growth history for clams from Station H-15-2.

Station Dublin Bay (Bering Sea) *Spisula polynyma*

Year Class	*M S L at Annulus 1	M S L at Annulus 2	M S L at Annulus 3	M S L at Annulus 4	M S L at Annulus 5	M S L at Annulus 6	M S L at Annulus 7	M S L at Annulus 8	M S L at Annulus 9	M S L at Annulus 10	M S L at Annulus 11	M S L at Annulus 12	M S L at Annulus 13	M S L at Annulus 14	Number in Age Class
1															0
2															0
3															0
4															0
5															0
6															0
7	10.0	17.0	26.0	34.0	44.0	59.0	71.0								1
8	9.0	15.0	21.0	35.0	46.0	54.0	63.0	73.0							1
9	9.2	15.6	23.6	33.0	42.1	52.1	64.0	73.7	83.3						9
10	9.5	15.8	23.5	32.6	42.0	51.6	62.4	72.6	81.8	90.9					37
11	9.2	15.1	22.6	30.9	40.4	50.0	60.4	71.2	81.4	90.9	98.8				49
12	9.1	15.0	21.8	29.8	38.8	48.5	57.7	67.7	77.6	87.0	95.9	104.3			36
13	8.8	14.3	20.8	28.2	36.7	44.6	54.4	64.2	73.6	83.3	92.6	101.6	109.3		12
14	8.5	15.5	21.5	30.0	36.0	48.0	57.5	66.5	72.5	82.0	92.0	102.0	108.5	114.0	2
YEAR OF ANNULUS FORMATION	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	Total 147

* M S L = Mean Shell Length, mm

Figure 8. Growth history for clams from Station Dublin Bay.

H-15-2, F-13-2 and Dublin Bay respectively, all contain 10 or more individuals. Within these groups the mean lengths of annuli 1 through 4 exhibited ranges of 2 to 5 mm while annuli 5 through 11 had variations ranging from 5 to 10 mm (Figs. 6-8). These differences in lengths suggest that the conditions which effect growth vary on an annual basis.

Growth data are available for intertidal *Spisula polynyma* from Prince William Sound (Feder *et al.*, 1976) and subtidal specimens from Cook Inlet (Feder *et al.*, in press). In both of these collections length values for ages 0 through 9 are based on small sample sizes or back-measured lengths; therefore, comparisons in the discussion will be restricted to clams older than age 9. Individuals in the year classes 9 through 12 from all three areas have similar lengths with less than 10 mm difference (Table 6). The lengths of pinkneck clams 13 through 15 years of age from the Bering Sea and Cook Inlet are similar while the Prince William Sound clams appear to grow somewhat faster (Table 6).

Growth data are available for *Spisula solidissima*, a closely related Atlantic species. This clam is generally harvested at a shell length of 127 mm (Yancey and Welch, 1968). The most northerly growth data for this species comes from Prince Edward Island, Canada, where terminal lengths and ages of *S. solidissima* are 127 mm and 11 years, respectively (Kerswill, 1944). This compares with 127 mm length and 16 years for *S. polynyma* in the Bering Sea. *Spisula solidissima* grows more rapidly in the southern portions of its range. For example, surf clams reach 127 mm in shell length in only four or five growing seasons off New Jersey (Yancey and Welch, 1968). Therefore, it is reasonable to assume that the slower growth rates reported for *S. polynyma* are due in part to the lower water temperatures of the Bering Sea.

Table 6. Mean shell length of subtidal Cook Inlet (Feder *et al.*, in press), intertidal Prince William Sound (Feder *et al.*, 1976), and subtidal Bering Sea *Spisula polynyma*. MSL = mean shell length (mm), sd = standard deviation.

Age	Cook Inlet		Prince William Sound		Bering Sea[1]	
	MSL	sd	MSL	sd	MSL	sd
0	5	0	-	-	-	-
1	10	1.2	8	1.3	-	-
2	15	2.2	13	2.3	12	1.4
3	-	-	22	3.3	28	6.3
4	-	-	32	4.0	35	5.8
5	-	-	43	4.8	48	4.9
6	-	-	57	5.7	57	6.2
7	-	-	66	6.3	69	9.2
8	-	-	77	6.5	78	8.0
9	80	5.9	88	6.7	85	8.2
10	92	6.6	98	6.6	94	8.0
11	98	5.1	108	6.6	101	7.4
12	107	5.3	115	6.3	108	7.4
13	112	7.3	122	6.1	114	6.9
14	114	4.0	127	6.6	121	6.5
15	120	6.2	133	6.1	123	7.5
Total Number of Clams	553		298		652	

[1] from Table 5.

Mortality

The equation describing the relationship of shell length to shell width of Bering Sea *S. polynyma* is: Width = -0.09457 + 0.70105 (length). The first age class with a width (the smallest shell measurement of *S. polynyma*) exceeding 75 mm would be the 12-year-old clams. This would be the first age group in which 100% of the individuals would be retained by the 75 mm rings of the sampling dredge. Therefore, mortality estimations are restricted to age groups 12 through 16 (Table 7, Fig. 9). The mortality calculations, columns 3 and 5 of Table 7, indicate that mortality changes markedly with age. Individuals 12 years of age undergo 9% mortality; this rate increases to 27%, 40% and 67% for the year classes 13 through 15 respectively. The latter data are the means of two mortality calculations (Table 7). No other calculations of mortality for this species are available for comparison.

Recruitment

A complete analysis of recruitment success is not possible, because only clams 12 years of age and older are quantitatively represented in the dredge samples. However, if mortality is considered and the estimated original number of individuals at age 12 for year classes 13 through 16 (Table 7) are examined, then recruitment to the age groups 12 through 16 appears to be relatively stable. The close fit of the data points to the mortality curve (Fig. 9) also suggests recruitment was fairly constant in these year classes (Gruffydd, 1974).

The recruitment success of clams younger than 12 is unknown and cannot be estimated from the data with the techniques utilized. Further study of recruitment success should be encouraged since total year class failures

Table 7. The distribution of *Spisula polynyma* at each age and the relationship between age and percent natural mortality. Data includes clams actually aged and clams assigned an age on the basis of shell length.

Age	Number at Age from Original Data	Natural Mortality % from Original Data	Number at Age from Curve Figure 5[1]	Natural Mortality % from Curve Figure 5[1]	Estimated Original Number at Age 12[2]
9	64	-	-	-	-
10	141	-	-	-	-
11	367	-	-	-	-
12	668	10.5	665	7.5	-
13	598	27.2	615	27.2	658[3]
14	435	43.4	448	36.6	614[4]
15	246	60.2	284	73.5	492
16	98	100.0	75	100.0	427
17	0	-	0	-	0
Total	2617[5]				

1 Technique of Gruffydd (1974).
2 Based on the mean of both mortality (%) estimations.
3 668 x 9% = 60; 60 + 598 = 658
4 658 x 27.2% = 179; 179 + 435 = 614
5 Total based on aged clams and clams with length data converted to age (see Methods p. 4).

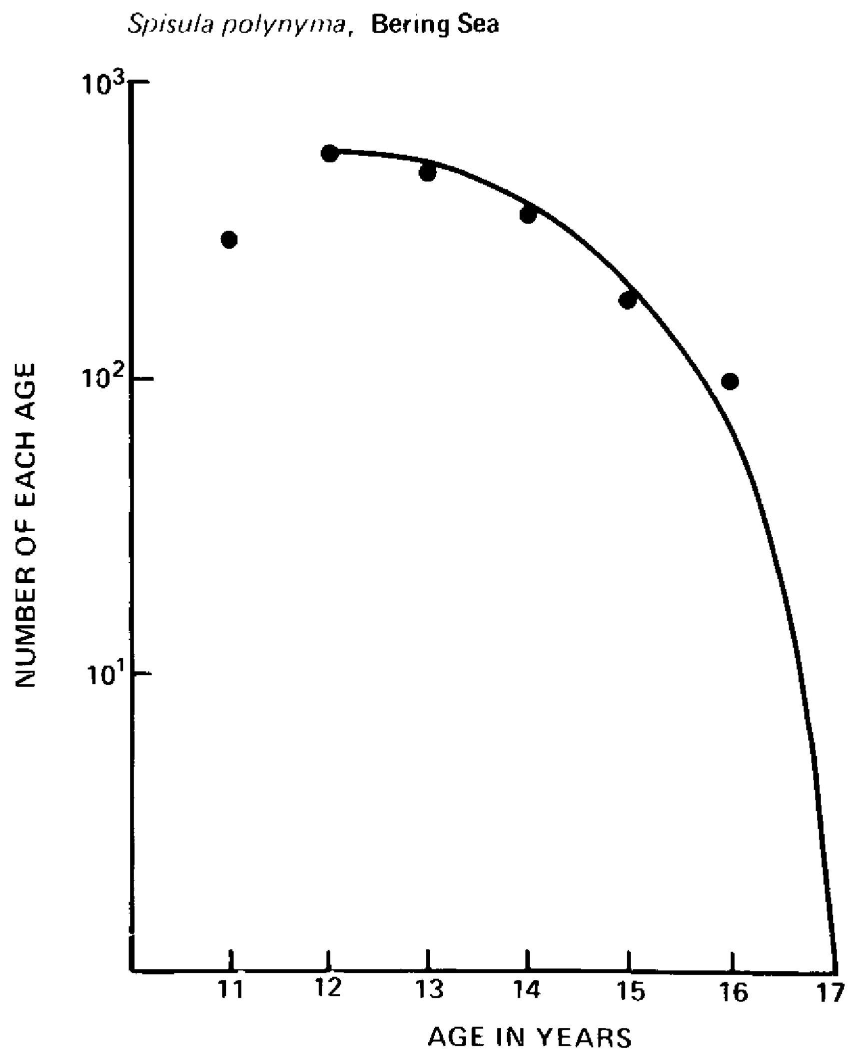

Figure 9. Graph of abundance vs. age for all clams collected.

have been observed in other Alaskan clams: *Protothaca staminea* (Paul and Feder, 1973; Paul *et al.*, 1976), *Saxidomus gigantea* (Quayle and Bourne, 1972), *Nucula tenuis, Glycymeris subobsoleta, Macoma calcarea* and *Tellina nuculoides* (Feder *et al.*, in press).

Size and Age at Maturity

Clams used in this investigation were considered mature if they met the following criteria: males - alveoli filled with developing and mature spermatozoa or in a partially spawned condition; females - alveoli filled with large, similar-sized ova or in a partially spawned condition (see Bayne, 1976; Ropes, 1968; Ropes and Stickney, 1965 for discussions of bivalve reproduction biology).

Sex could not be determined in clams less than 5 years of age, mean shell length of 48 mm. In most of the 5-year-old clams gonadal tissue was present, but obvious gametes were absent in 89% of the specimens examined (Table 8). In the sexually mature 6-year-old clams the amount of gonadal tissue producing gametes was relatively small in comparison to the size of entire gonad. Thus, 6-year-old clams probably do not release significant amounts of gametes during spawning. Eighty-two percent of the 7-year-old clams, 69 mm shell length, were sexually mature, and appeared to be in a partially spawned or spent condition. All of the older clams examined, except a single 10-year-old, were sexually mature. The sex of the 10-year-old clam could not be determined.

Histological preparations for this study were made on a small sample from a single collection period. Therefore, results summarized here should be considered preliminary, and further study, inclusive of seasonal sampling, should be encouraged.

Table 8. Age, size, number and percent maturity of Bering Sea *Spisula polynyma* examined histologically.

Age	Mean Shell Length (mm)	Number of Clams	Percent Mature	Comments
2	12	1	0	No gonadal tissue present
3	28	3	0	No gonadal tissue present
4	35	6	0	Only one clam had gonadal tissue
5	48	18	11	Two mature clams partially spawned
6	57	15	40	Four mature clams partially spawned; 1 clam spent
7	69	11	82	Seven mature clams partially spawned; 2 clams spent
8	78	5	100	Four mature clams partially spawned; 1 clam spent
9	85	5	100	Four mature clams partially spawned; 1 clam spent
10	94	1	0	Sex undetermined
11	101	3	100	Three mature clams partially spawned
12	-	0	-	
13	114	2	100	Two clams spent

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