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Growth of the Sakhalin Surf Clam, *Spisula sachalinensis* (SCHRENCK), in Sendai Bay

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Summary

The growth pattern and the relationship between growth and maturation of the Sakhalin surf clam, *Spisula sachalinensis* (SCHRENCK), in Sendai Bay were studied by analyzing internal growth lines on the cutting plane of the shell. The internal growth line is formed annually as a result of the high water temperature of summer. No sexual dimorphism is recognized either in external morphology or in growth. Von Bertalanffy's growth equation gives a good approximation for the growth pattern of this species. Clams in Sendai Bay grow more quickly than those of northerly populations and their ecological longevity is 8–9 years. The shell length at first maturity is 6 cm but not all the clams under 7.5 cm spawn. Judging from the maturing pattern, a quasi-adult stage seems to exist between the immature and adult.

The Sakhalin surf clam, *Spisula sachalinensis* (SCHRENCK), is a large bivalve inhabiting open sandy coasts of cold water regions and the southernmost area of its range on the Pacific side of Japan is Kashimanada off Ibaraki Pref. Dredge nets with iron forks for catching the surf clam, which is an important fisheries resource, have been used on the sandy littoral bottoms off southern Miyagi Pref. to Fukushima Pref.

Yamamoto (1) and Kato and Hamai (2) reported the relation between age and growth. The present paper attempts to estimate growth rate through the relationship between age and size by analyzing internal growth lines on the cutting plane of the shell. This was done in order to examine the relationship between growth and maturation of the surf calm in Sendai Bay located near the southern limit of its range.

Materials and Methods

Regular samples were obtained from commercial catches by clam dredge nets in Isobe Ground (Fig. 1). Isobe Ground lies north and south for about 6 km along

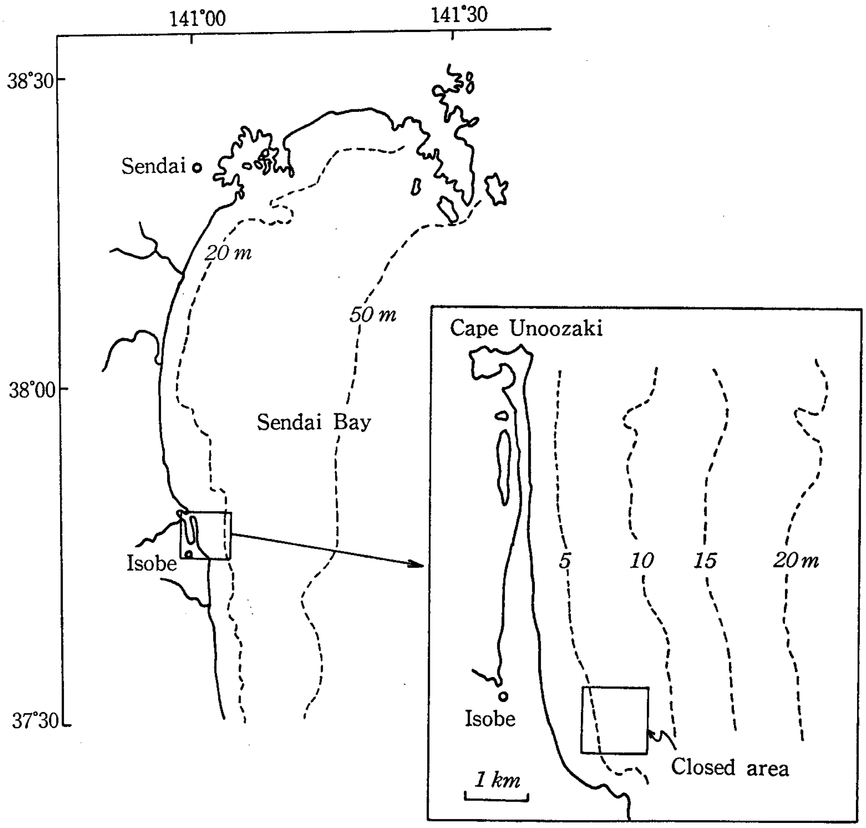

Fig. 1. Area surveyed

the coast. The surf clams are mainly exploited in areas shallower than 15 m. At the southwest corner of the Ground a small area has been closed for conservation of the breed.

Ecological surveys were carried out at intervals of a month or so during August 1978 – June 1980. Some samples were obtained tentatively from the closed area between March and June of 1979 and 1980. Year-old clams were collected in March 1981 to study their maturing conditions.

The shell length and height and the volume that the left shell can hold (left shell capacity) were measured. Then, the left shell, the soft part and the gonad were weighed. Then the clams were sexed by examining their gonads. The shell height is defined as the longest distance between the base of the umbo, from which the growth line commences, and the ventral margin. This was done to standardize the measurements of various sized clams.

Following determination of size and sex, the left shell was cut in halves along the dorso-ventral axis by the use of a diamond saw to make visible the internal growth lines on the cutting plane. The longest distances between the umbo base and the growth line on the external surface of the shell were connected, thus constructing a curve called the growth axis, which runs along the shell surface bending toward the posterior side. In practice, the intersection of the internal growth line on the shell is shifted along the external growth line until the distance from the umbo base becomes longest.

Results

1. *Age Determination*

Fig. 2 shows diagrammatically the internal structure of a shell cut longitudinally. Internal growth lines are observed as translucent bands, 0.5 mm or less wide, running in parallel with the growth plane.

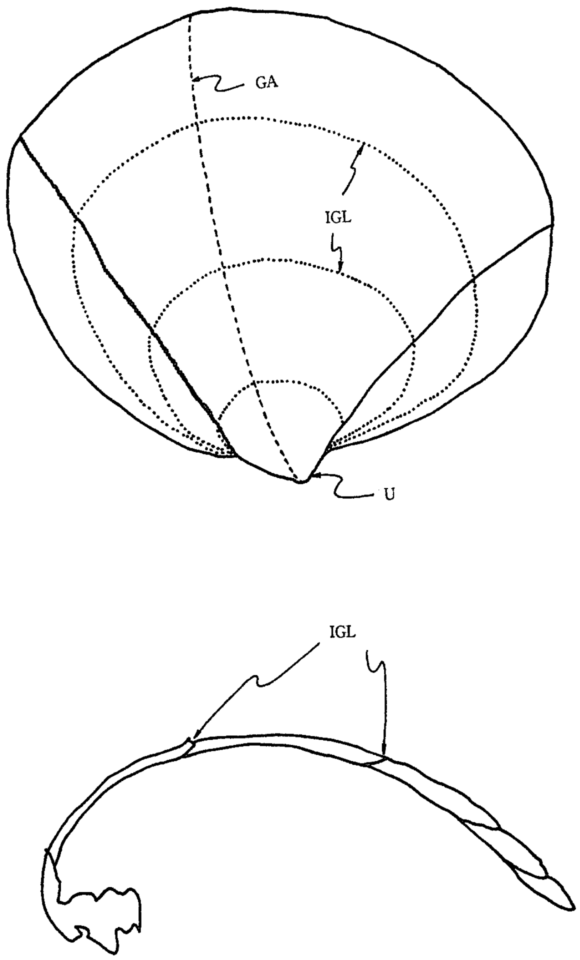

FIG. 2. Diagrammatic representation of a left shell of a surf clam, showing internal growth lines (IGL), a growth axis (GA), and an umbo (U). top: overseen view bottom: lateral view in profile.

It was first determined whether the internal growth line was formed once a year. Fig. 3 shows the seasonal changes in the proportions of shells having internal growth line at the periphery. The values remained over 50% for about four months from early August to mid-November, in particular 100% in September and October, and dropped to zero in January through June, revealing that an internal gro wth line was formed every summer.

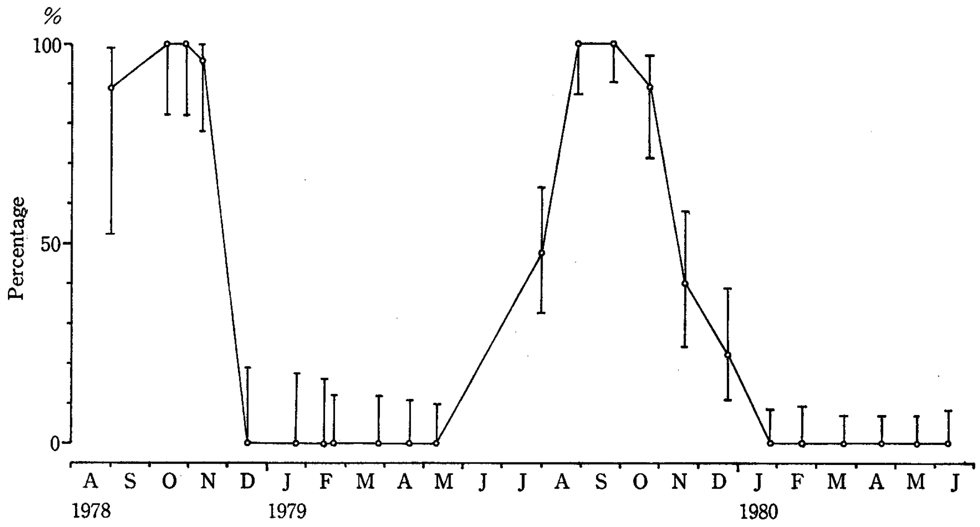

FIG. 3. Seasonal change in proportion of shells with internal growth line at their periphery. Vertical bar is 95% confidence interval about mean.

Shells were grouped into the corresponding ages. Age-n group contains the clams with the n-th internal growth line at the periphery of their shells and those having (n–1)–th line with subsequent growth outside it. The first growth line is formed about 4 months after birth in mid-April to early May.

2. *Growth*

Table 1 shows the means and standard deviations of shell height in a successive internal growth line formation (h_n) for 1972–1977 year classes with their weighted mean in the exploited and closed areas.

The sexual dimorphism in growth was statistically tested for the 1975–year class, which was large in size and convenient for test, resulting in insignificant sexual difference and unsexed use of the data (Table 2).

Table 3 shows the means and standard deviations of the shell lengths at successive internal growth line formations (l_n), calculated from the weigthed means in Table 1, based on the close linear regression of shell height on shell length as depicted in Fig. 6.

The Walford plots depicted from Table 3 produced straight lines (Fig. 4), showing the von Bertalanffy's growth pattern. Growth curves are depicted assuming spawning occurred on May 1 and the internal growth line was formed on October 1 (Fig. 5). The claculated values fairly coincided with the measurements and no significant difference was found between the growth curve of the exploited population and that of the closed one.

The growth curves verify that most growth occurred during the first 2–3 years and the clams substantially stopped growing in their seventh year after a gradual decrease in growth rate.

TABLE 1. *Mean (upper) and Standard Deviation (lower) of Shell Heights at Successive Internal Growth Line Formation (h_n) by Year Class.*

Exploited area

Year class	Sample size	Shell height (cm)							
		h_1	h_2	h_3	h_4	h_5	h_6	h_7	h_8
1972	4	1.16 0.18	4.57 0.35	6.12 0.50	7.11 0.27	7.44 0.38	7.77 0.44	8.02 0.52	8.15 0.48
1973	10	1.01 0.15	4.06 0.74	5.96 0.73	6.78 0.61	7.29 0.44	7.59 0.45	7.67 0.40	
1974	18	1.00 0.15	4.50 0.38	6.43 0.35	7.26 0.36	7.72 0.46	7.77 0.37		
1975	208	0.90 0.12	4.18 0.41	6.43 0.45	7.20 0.51	7.38 0.47			
1976	52	0.91 0.13	4.23 0.51	6.45 0.36	7.22 0.31				
1977	136	0.85 0.15	4.14 0.39	6.06 0.35					
Weighted mean		0.90 0.14	4.19 0.43	6.33 0.45	7.18 0.49	7.42 0.47	7.70 0.40	7.78 0.45	8.15 0.48

Closed area

Year class	Sample size	Shell height (cm)							
		h_1	h_2	h_3	h_4	h_5	h_6	h_7	h_8
1972	4	1.09 0.22	4.52 0.56	6.26 0.74	7.08 0.41	7.37 0.33	7.59 0.27	7.76 0.23	7.75 0.26
1973	16	1.00 0.21	4.20 0.55	6.30 0.73	6.87 0.49	7.23 0.39	7.47 0.36	7.48 0.28	
1974	5	0.95 0.22	4.47 0.46	6.40 0.46	6.90 0.30	7.23 0.34	7.39 0.24		
1975	116	0.89 0.11	4.43 0.36	6.34 0.36	7.01 0.35	7.26 0.31			
1976	9	0.83 0.14	4.37 0.42	6.08 0.30	6.63 0.14				
1977	106	0.71 0.13	3.95 0.38	5.78 0.36					
Weighted mean		0.83 0.17	4.07 0.88	6.14 0.48	6.98 0.37	7.26 0.32	7.48 0.32	7.56 0.29	7.75 0.26

While Igarashi *et al.* (3) reported a 14-year-old clam from the same area, the oldest one in the present study was twelve years old (12.8 cm in shell length).

3. *Relative Growth of Shell*

The regression of shell hieght on shell length and that of left shell capacity on shell length are shown in Figs. 6 and 7, respectively. The relation in the former

TABLE 2. *Significance Test between Sexes for Mean Shell Height at Successive Internal Growth Line Formation (h_n) for 1975–Years Class.*

Sample Size: Male (M) 92 Female (F) 105

	Sex	Mean (cm)	Var.	F-test	
				Mean	Var.
h_1	M F	0.90 0.89	1.16×10^{-2} 1.15×10^{-2}	$F_0<F_{(0.01)}$	$F_0<F_{(0.01)}$
h_2	M F	4.30 4.26	1.76×10^{-1} 1.81×10^{-1}	$F_0<F_{(0.01)}$	$F_0<F_{(0.01)}$
h_3	M F	6.33 6.38	1.66×10^{-1} 1.63×10^{-1}	$F_0<F_{(0.01)}$	$F_0<F_{(0.01)}$
h_4	M F	7.04 7.09	1.87×10^{-1} 2.10×10^{-1}	$F_0<F_{(0.01)}$	$F_0<F_{(0.01)}$
h_5	M F	7.22 7.25	1.40×10^{-1} 1.27×10^{-1}	$F_0<F_{(0.01)}$	$F_0<F_{(0.01)}$

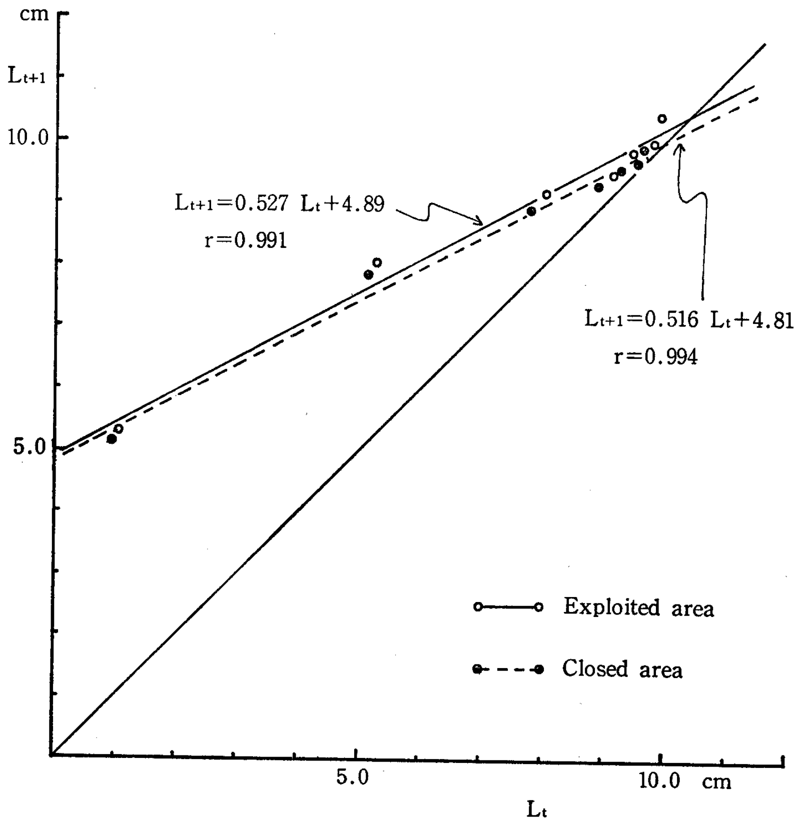

FIG. 4. Walford plots for the shell lengths of surf clam for 1972–1977 year classes.

TABLE 3. *Mean and Standard Deviations of Shell Lengths at Successive Internal Growth Line Formation (l_n) Calculated for 1972–1977 Year Classes.*

		Shell length (cm)							
		l_1	l_2	l_3	l_4	l_5	l_6	l_7	l_8
Exploited area	Mean	1.06	5.29	8.04	9.14	9.44	9.80	9.91	10.38
	S.D.	0.18	0.55	0.58	0.63	0.61	0.52	0.58	0.62
Closed area	Mean	0.97	5.14	7.80	8.88	9.24	9.52	9.63	9.86
	S.D.	0.21	1.13	0.61	0.47	0.42	0.41	0.37	0.34

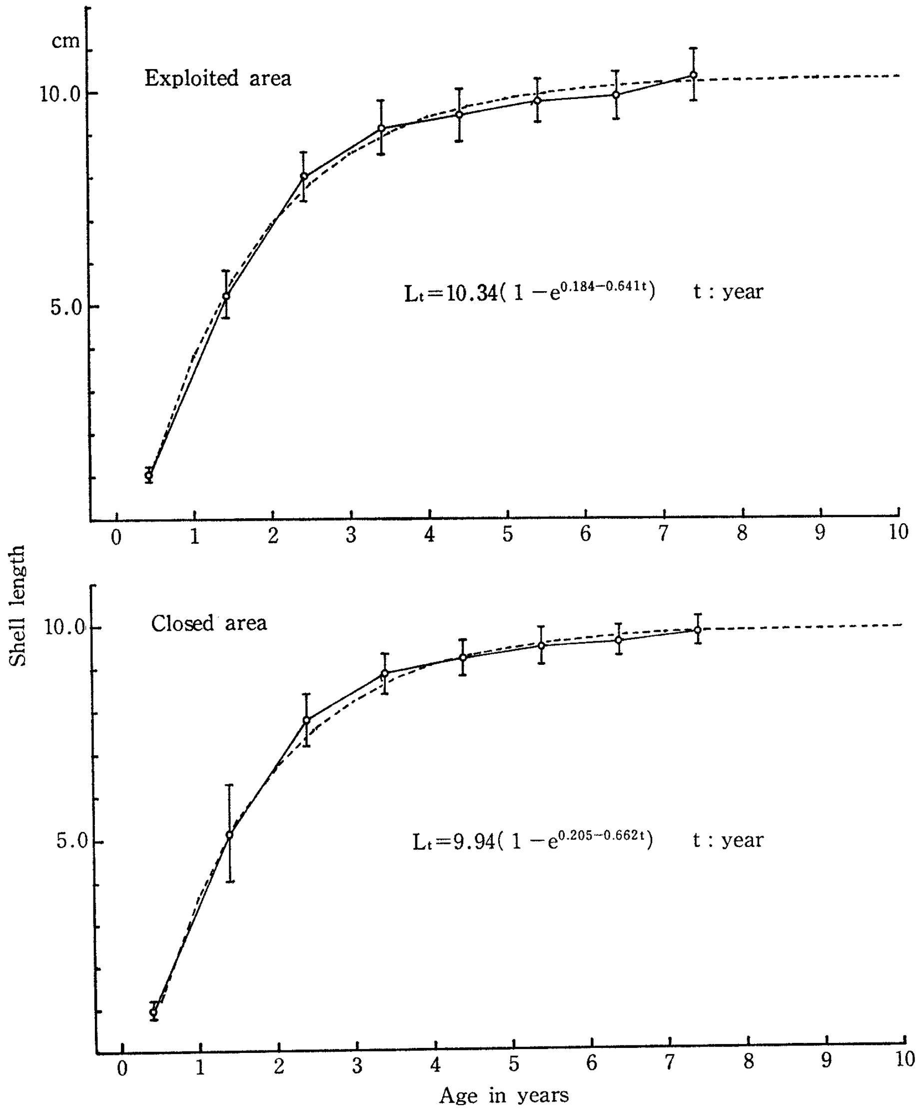

FIG. 5. Observed (solid line) and calculated (broken line) growth curves of shell length. Vertical bar denotes a standard deviation on each side.

case is isauxetic, and the relative growth coefficient in the latter is about three, showing a consistent feature over shell length range beyond 3 cm.

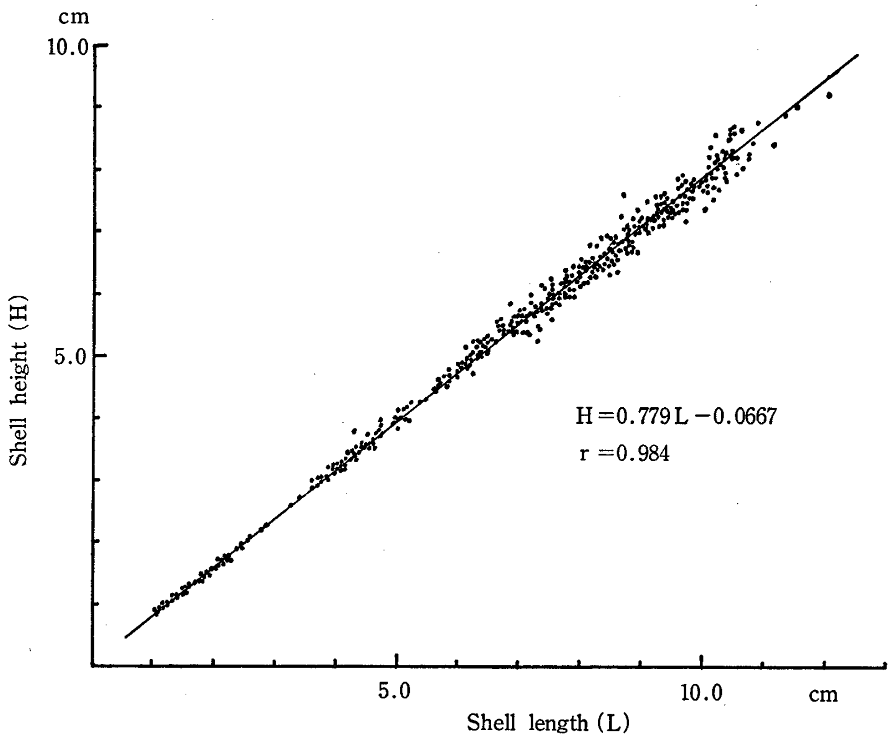

FIG. 6. Regression of shell height (H) on shell length (L).

Three different regressive relationships were found between shell length and weight, depending on the length range; (i) under 6 cm, (ii) between 6.5 and 7.5 cm, and (iii) over 8 cm (Fig. 8). The relative growth coefficients for (i) and (iii) are almost equal to each other, while the initial growth constants differ. The growth coefficient for (ii) is larger than those of the others, forming a transitional characteristic between them. The intersectional length between (i) and (ii), and that between (ii) and (iii) are 6.37 and 7.55 cm, respectively.

4. *Relationship between Growth and Maturation*

Fig. 9 shows the relationship between gonosomatic index (GSI=$10^2\times$gonad weight/soft part weight) and shell length just prior to spawning in 1979. The GSI values became quite large abruptly beyond 7.5 cm in shell length for both sexes, and all of these clams were mature with ripe eggs or active spermatozoa.

On the other hand, clams under 7.5 cm had the following two characteristics. First, mature and immature clams, for which sexing by use of a light microscope is difficult, were found mixed without any maturing ones present. Secondly, the egg diameter of the mature clams was similar to that of clams over 7.5 cm in shell length, although their GSI's did not exceed half.

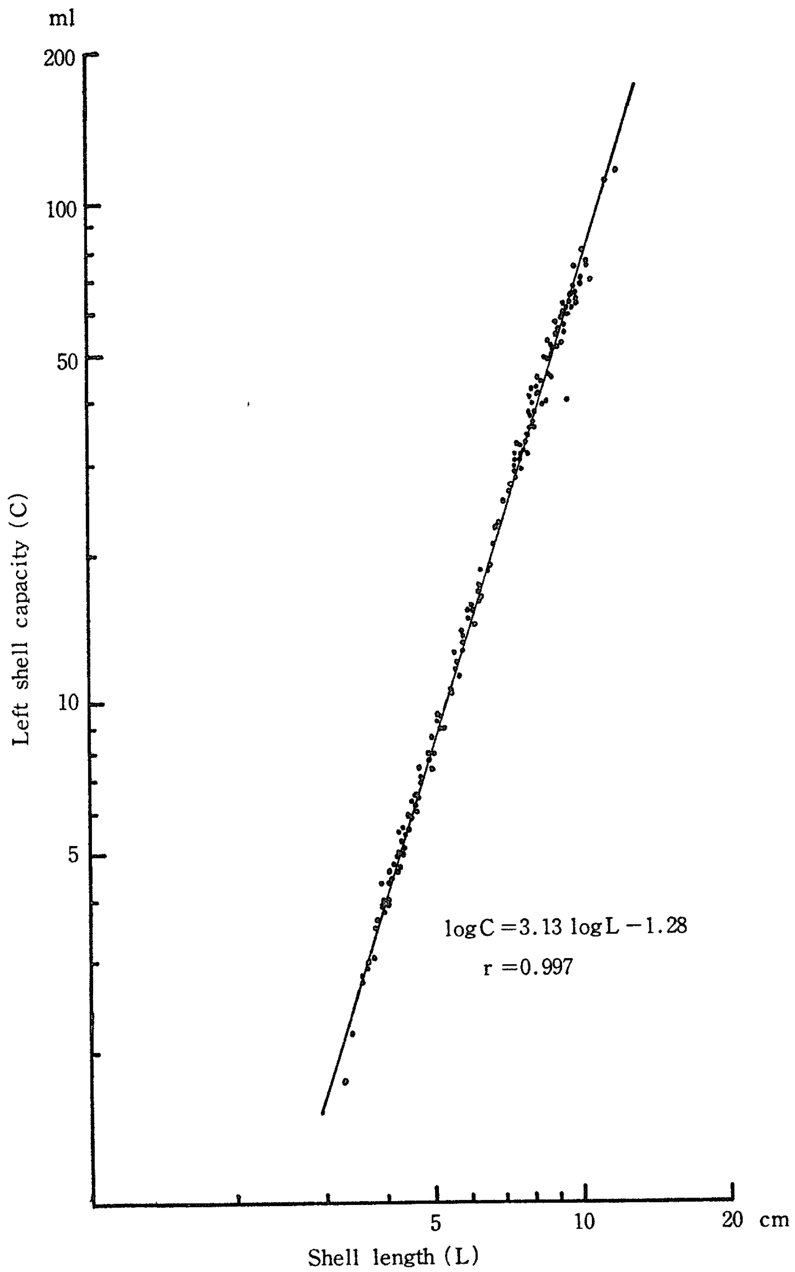

FIG. 7. Regression of left shell capacity (C) on shell length (L).

Clams under and those over 7.5 cm in shell length turned out to be two years and three years and over old, respectively, by ageing. Year-old clams (3.28–5.49 cm with mean of 4.32 cm) collected in July 1978 did not seem to have spawned since they did not hold ripe eggs unlaid, while those in March 1981 (2.08–3.41 cm with mean of 2.85 cm) were in the immature stage.

Fig. 10 shows the incidence of maturing samples from February to April 1979. Almost all the clams larger than 7.4 cm were maturing, while most samples between 5.8 and 6.2 cm remained unmatured, and 20–25% of the clams of the intermediate size were in the immature stage.

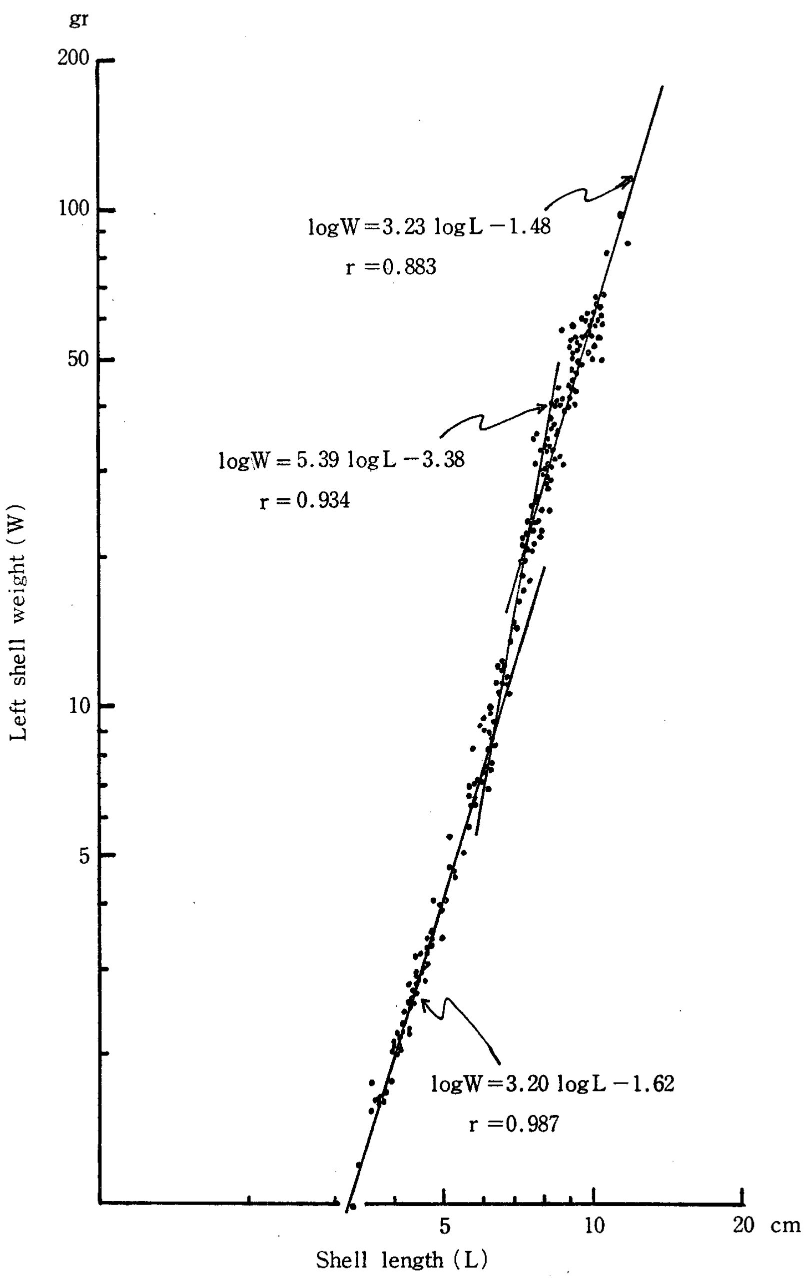

Fig. 8. **Regressions of left shell weight (W) on shell length (L).**

Discussion

In studies on other bivalves, the growth line formation has been discussed in relation to either the hibernal low water temperature (4–6) or the stress of spawning (7–9).

In regards to the period of growth line formation of the surf clam, Yamamoto (1) related that the growth line is formed in the period from November to April with cessation of growth as the water temperature falls below 5°C in Sakhalin. Kato and Hamai (2) reported that this period is from May to June immediately after spawning in Hakodate Bay.

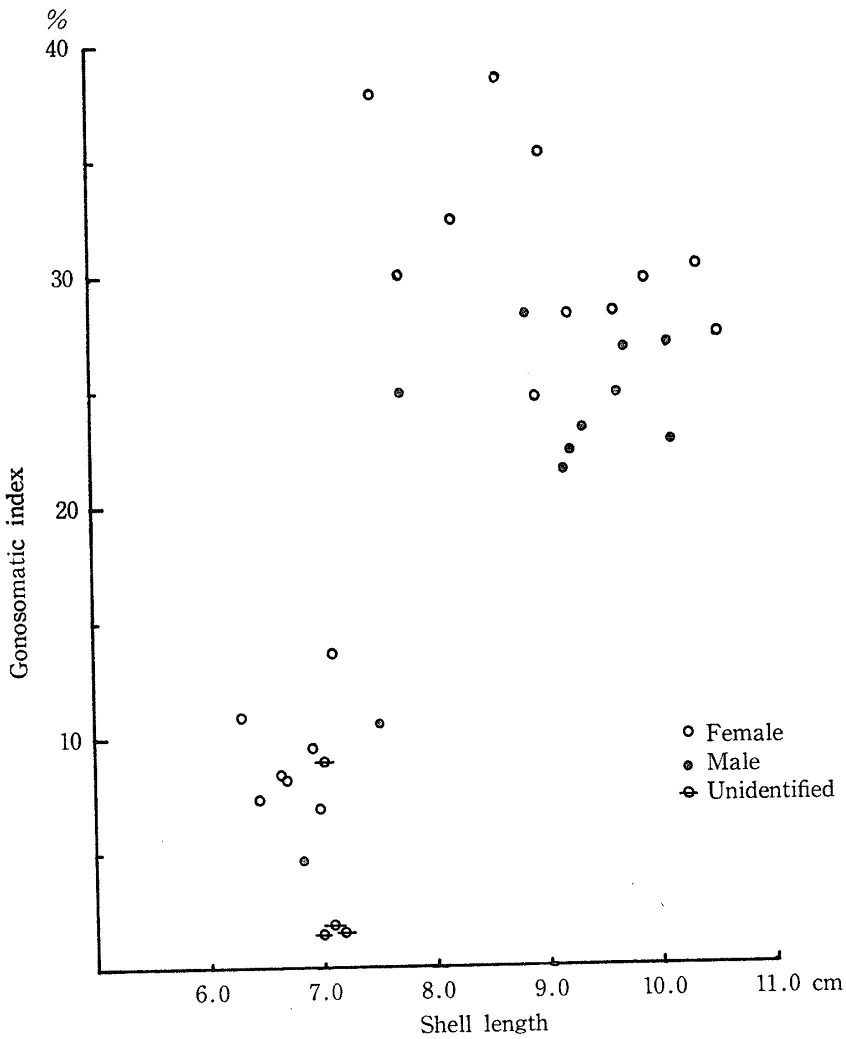

FIG. 9. Relation between gonosomatic index and shell length on April 20, 1979.

As previously stated, however, the growth line is formed from August to November in Sendai Bay and it is apparent that neither low temperature nor stress of spawning are responsbile for this phenomenon. The water temperature isopleth in central Sendai Bay in recent years (10) shows that the surface temperature becomes lowest in March and highest in August. Since the general trend of water temperature in the littoral region is considered to be the same as offshore, growth line formation seems to occur in the warmer season.

It is assumed that the growth line is formed by the estival interruption of growth, with the decline of physiological activity under high water temperature. Such a phenomenon is considered to be related to the fact that this species is of cold water origin and Sendai Bay is located near the southernmost limit of its range.

The physiological longevity of the clam in this area seems to be 12–14 years. However, since the growth substantially ceases beyond 6 years and clams of 10 years and more are scarcely caught, the ecological longevity is inferred to be 8 to 9 years.

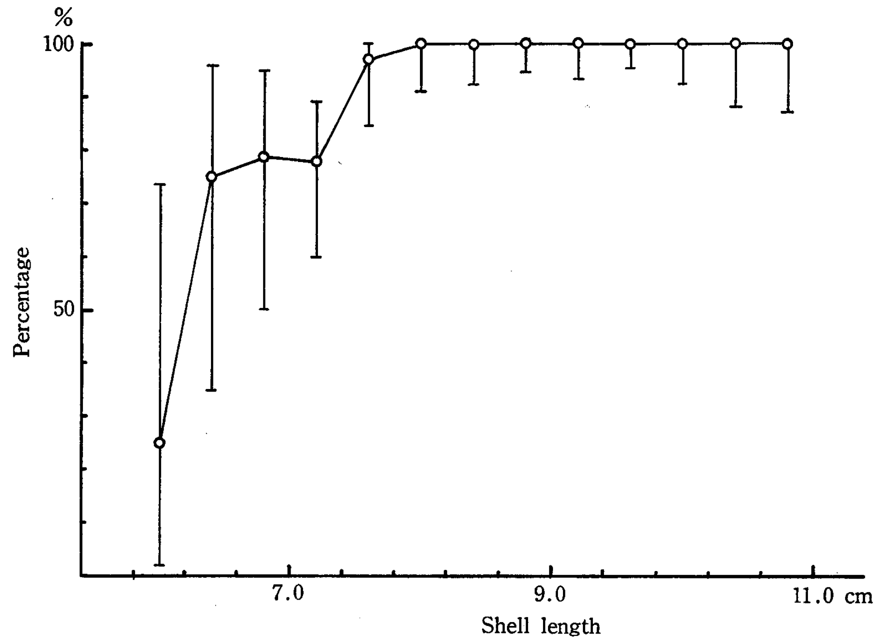

FIG. 10. Proportion of maturing clams by size in the pre-spawning season (Feb.-Apr. 1979). Vertical bar is 95% confidence interval about mean.

Sexual dimorphism is not found either in the external appearance or in the growth pattern.

Comparison of the growth curves in Sendai Bay with those in Sakhalin (1) and in Hakodate Bay (2) revealed the increasing tendency of growth rates in the southern region, similar to the razor clam, *Siliqua patula*, studied by Weymouth *et al.* (4) and the hard clam, *Mercenaria mercenaria*, by Ansell (11), in which growth rates increased with temperature.

Morphological changes as a basis to identify developmental stages did not occur in terms of relative growth between the external parts of the shells over 3 cm in length.

While the clams became reproductive two years after their birth when shell length reached 6 cm, their ability to reproduce was considerably low until they grew to 7.5 cm, showing that the energy allocation to brood production still remained low during this period (Fig. 9). It is interesting that the change in the relationship shell length and shell weight (Fig. 8) and the change in GSI (Fig. 9) concurred.

In conclusion, the developmental stages of the surf clam can be defined as below.

Immature: 3–6 cm long.

Quasi-adult: 6–7.5 cm long. Less energy is allocated to reproduction than adult although they mature and spawn.

Adult: over 7.5 cm long.

Twenty or twenty-five percent of clams 6–7.5 cm long remained immature, while no quasi-adult clam larger than 7.5 cm was found, probably suggesting that some clams transferred from immature to adult without experiencing the quasi-adult stage.

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