Seasonal and Long-term Fluctuations in a Population of *Patelloida heroldi* (Mollusca: Gastropoda) on a Boulder Shore in Japan

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**Abstract:** Population density and size composition of the limpet *Patelloida heroldi* were investigated over a 6-year period on a boulder shore at Amakusa, western Kyushu. The vertical distribution range extended from the low to the mid intertidal zone. The density on the shore showed an increasing trend over the 6-year period, with a clear seasonal fluctuation: high in spring-summer and low in fall-winter. The size frequency histogram of each sampling occasion had 1–3 peaks. The maximum shell length was 17.80 mm. By following the temporal changes of the size frequency histograms, the recruitment and growth of cohorts were estimated. Recruitment of new cohorts (3–5 mm in shell length) occurred mainly in winter. They grew up to 10 mm within 8 months. Longevity of cohorts was variable, but always less than one and half years. Previous ecological studies on this genus are reviewed in relation to recent taxonomic work.

**Keywords:** vertical distribution, size histograms, density, growth, recruitment

**Introduction**

Limpets are ecologically important components of communities on rocky and boulder shores (Branch, 1981). Many studies on the life history of limpets have been done in many areas of the world as a basis for understanding community dynamics and ecosystem functions. In Japan, most ecological studies on limpets have been carried out on rocky shores detailing variously on activity behavior (Hirano, 1981; Iwasaki, 1994), life history (Niu et al., 1992; Iwasaki, 1998), energy budget (Niu et al., 1998), and interspecific interactions with other species (Iwasaki, 1993). Ecological studies on limpets on boulder shores have been relatively few (Takada, 1997; Kurihara, 2002), although limpets are abundant there and several species co-exist sympatrically (Takada & Kikuchi, 1991; Tokeshi et al., 2000). As a part of comparative population studies on herbivorous gastropods, including limpets, on a boulder shore (Takada, 1996, 1997), this study has focused on long-term fluctuations in a population of *Patelloida heroldi* (Dunker).

Recently, Nakano & Ozawa (2005) revised the taxonomic status of the *P. pygmaea* group, and recognized three species in central Japan, *P. pygmaea* (Dunker), *P. conulus* (Dunker) and *P. heroldi*, and reported habitat segregation of these species: *P. pygmaea* on shells of *Crassostrea gigas*, *P. conulus* on shells of *Batillaria multiformis* and *B. cumingii*, and *P. heroldi* on rocks. It should be noted that in some earlier ecological studies on “*P. pygmaea*” in Japan that were carried out on shores without *C. gigas*, the species examined was probably *P. heroldi* instead of *P. pygmaea*. In Hong Kong, Morton (1980) recognized the morphological differences and habitat segregation between two of these species, *P. conulus* (as *P. lampanicola*) and “*P. pygmaea*”. Liu (1994a, b) investigated seasonal changes in population and reproduction of “*P. pygmaea*” over a

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one-year period in Hong Kong. However, Nakano & Ozawa (2005) subsequently did not find *P. pygmaea* in Hong Kong, and assigned samples from there to *P. ryukyuensis* Nakano & Ozawa, which occurs on shells of *Saccostrea cucullata* and *Crassostrea angulata*. Thus, the taxonomic status of material examined in previous ecological studies of *Patelloida* spp. in Japan and adjacent areas requires reevaluation.

The purpose of this study is to examine the seasonal and long-term patterns of population fluctuations of *P. heroldi* on a boulder shore and especially to examine any long-term trends in density fluctuation over the 6-year study period and any related changes in vertical distribution, size composition, recruitment, and growth.

**Materials and Methods**

The study was carried out on a moderately sheltered shore on the eastern side of Magarizaki spit (32°31′ N, 130°02′ E) on Amakusa Shimoshima Island, western Kyushu, Japan. The shore slopes gently and the whole intertidal zone is covered by cobbles and small boulders (long axis < 50 cm, hereafter referred to as boulders). These boulders are ovular, and composed of weathered chert and rhyolite. The boulders are stable except during severe spring gales or summer typhoons. The tide is semi-diurnal and the mean tidal range is 3.3 m during the spring tides. On the upper surface of boulders in the high and mid intertidal zones, macroscopic sessile organisms are almost absent, while in the low intertidal zone there are brown algae (e.g., *Ishige* spp. and *Sargassum* spp.) and other sessile organisms. Shells of *Crassostrea gigas* and *Batillaria* spp., which form the host habitat for *Patelloida pygmaea* (Dunker) and *P. conulus* (Dunker) (Nakano & Ozawa 2005), respectively, were not observed on the shore. The characteristics of the benthic community on this boulder shore have been described in detail elsewhere (Takada & Kikuchi 1991). However, it should be noted that *P. heroldi* was previously incorrectly referred to as “*Collisella* heroldi” in Takada & Kikuchi (1991).

On the shore, I set up five tide levels at 10 m intervals (Fig. 1) on the slope in order to cover the entire vertical distribution range of *P. heroldi*. The highest tide level (TL 1) was located 2.1 m above MLWS (mean low water of spring tides) and the lowest (TL 5) at 0.1 m above MLWS. The sampling area extended 40 m along the shoreline. Quantitative sampling was carried out 59 times using a 0.25 m$^2$ quadrat (50 cm × 50 cm) during the spring low tides from June 1987 to January 1993. Intervals between the sampling dates were generally of one month, but sometimes extended up to four months. Four replicates of the quadrat were set randomly at each tide level, except on three occasions (three quadrats at TL 3 and five quadrats at TL 4 in August 1987, and three quadrats at TL 2 in August 1990). All individuals of *P. heroldi* in each quadrat area were collected. From June 1990, sampling at TL 5 was not carried out. Sampling points were recorded on a map of the shore to avoid repeated sampling from the same points for at least a two-year period. In the laboratory, the collected *P. heroldi* were fixed in 10% seawater buffered formalin and their shell length was measured within an accuracy of ±0.05 mm with vernier calipers.

Long-term trends in the temporal fluctuation in density at TL 2, TL 3 and TL 4 were examined by estimating linear regressions against the Julian day of the sampling date (based on January 1st in 1987). The number of individuals at each quadrat was transformed into the square-root value (\( \sqrt{x} \)) before analysis.

Size-frequency histograms of *P. heroldi* were constructed for every sampling occasion by pooling the data of shell length at all the tide levels. Average shell length of a cohort was estimated by a method of Aizawa & Takiguchi (1999), which allow the fitting of a set of normal curves to a size-frequency histogram using the SOLVER routine in MS-EXCEL (Microsoft Co.). Maximum likelihood estimate was employed to determine the means and standard deviations of the fittest normal curves. The number of normal curves fitted to a histogram was decided to
minimize any abrupt changes of the number itself between the previous and the next sampling occasions. Then, the recruitment events and subsequent growth of the cohort were estimated over the 6-year study period.

Results

*Patelloida heroldi* occurred in all five tide levels (Fig. 2), but very few individuals could be obtained from the TL 1 and TL 5, the highest and the lowest levels on the shore, respectively. Overall maximum density was 19.50 individuals per 0.25 m² at TL 4 on May 28, 1991. Mean density of *P. heroldi* varied spatially and temporally (Fig. 2), but the center of the vertical distribution appeared below the mid tidal level (MTL). In a total of 59 observations, the maximum density was observed 43 times at TL 4, 13 times at TL 3 and three times at TL 2.

A long-term increasing trend in density was statistically significant at TL 2, TL 3 and TL 4 (Table 1). At TL 2 and TL 3, the densities were lower and showed less fluctuation during the first half of the study period (1987–1989) than during the second half (1990–1993) (Fig. 2). At TL 3 and TL 4, the density tended to be higher in summer and lower in winter. At TL 3, this seasonal trend became quite obvious during the second half of the study period (1990–1993). At TL 2, however, the temporal fluctuation in density did not form a clear seasonal trend.

During the whole study, the largest individual was 17.80 mm in shell length sampled at TL 3 on May 1st, 1992, and the smallest individual was 1.25 mm at TL 4 on February 8th, 1990. Figures 3 and 4 show the temporal changes in the size frequency histograms of *P. heroldi* over the 6-year period. Small sized individuals (≤ 3.00 mm in shell length) were observed from August to April, mainly in winter, suggesting winter recruitment to the benthic population.

Size composition also appeared variable among tide levels. At each of the 59 sampling occasions, differences in median shell length of sampled *P. heroldi* between upper tide levels (TL 1, TL 2 and TL 3 were pooled) and lower tide levels (TL 4 and TL 5 were pooled) were tested (Mann-Whitney U test) and statistically significant differences were detected in 38 sampling occasions. The median shell length tended to be larger at the upper tide levels than in the lower tide levels in these occasions, except for January 10th, 1990. Excluding the sampling occasions in 1987 and 1988 due to the low number of individuals captured, non-significant differences in median shell length were observed only within sample occasions around the winter season (October to March). These results suggest that a tendency toward recruitment at the upper tide levels during October to January resulted in the reduction in the median shell length.

Seasonal and tide level influences on the recruitment were clarified by an inspection of new
Fig. 2. Temporal fluctuation of the mean density (± SE, n = 4) of *Patelloida heroldi* at the five tide levels. Open circles showed that no individual was obtained. *, n = 3; **, n = 5.
recruits of *P. heroldi* (Fig. 5). Individuals of \( \leq 6 \) mm shell length were regarded as new recruits to the population. Abundance of new recruits was high in winter and low in summer, with annual variations in range of abundance. During the October–January period, the new recruits tended to occur more at the upper tide levels than in the following February–April period, as suggested above. But in the 1991–1992 winter period, new recruits occurred more evenly in the upper and in the lower tide levels.

The size-frequency histogram of each sampling occasion had 1–3 peaks that were considered to represent the modal sizes of cohorts (Fig. 3, Fig. 4). Providing the cohort showed a normal distribution with its average size close to the peak size of the histogram, the cohorts were estimated by fitting a set of normal distributions to the histogram. Arrows above the histograms (Fig. 3, Fig. 4) show estimated cohort sizes (average shell length of a cohort). Identical cohorts could be detected through the series of the size-frequency histograms and they were labeled by alphabet letters beside the arrows on the figures. Following the temporal changes in estimated shell length of identical cohorts, growth curves of cohorts were obtained (Fig. 6). New cohorts appeared in winter, corresponding with the winter recruitment of small sized individuals. Four recruits of cohorts were recognized in the 1988–1989 winter period, with three recruits in the 1989–1990 and the 1990–1991 winters. Some of the new cohorts could only be followed for one or two months. It was not possible to estimate the number of recruitment events in the 1992–1993 winter period due to an insufficient number of samples.

Longevity of cohorts was variable, but always less than one and half years. No clear seasonal patterns in the disappearance of cohorts were observed. Most of the cohorts appeared in the size range of 3–5 mm (except cohorts d, e, l, and o). They grew to 10 mm within 8 months. Rapid growth was recognized in two cohorts (g and m) that reached 10 mm within 6 months. Growth rates of seven cohorts (g, h, j, k, m, n, and p) up to the month in which the average shell length of cohorts first exceeded 10 mm ranged from 0.57–1.20 mm in shell length per month. The growth curves of some cohorts (d, k, m, n, and p) reached a plateau around 10–12 mm in shell length. But the growth curves of some other cohorts (b, g, h, and j) increased steadily to over 12 mm.

**Discussion**

As discussed in the taxonomic study of Nakano & Ozawa (2005), the species status of *Patelloidea heroldi*, *P. pygmaea*, *P. conulus* and *P. ryukyuensis* has been confused for years. Although some of the older literature on the ecology of these *Patelloidea* spp. referred to “*P. pygmaea*”, their appropriate status can be inferred from the co-occurring host animals, such as *Batillaria* spp., *Crassostrea* spp. and *Saccostrea* spp., described in the literature. Table 2 shows some of the ecological studies on *Patelloidea* spp. based on the geographic areas and the host animals. Detailed ecological studies have been done in Hong Kong, but the population examined by Liu (1994a, b) occurred with *Saccostrea cucullata*, which is the preferred host substrate of *P. ryukyuensis* (Nakano & Ozawa, 2005). Studies on the boulder shore in Amakusa were done on *P.*

**Table 1.** Long-term trend of *Patelloidea heroldi* density (y) at the three tide levels (TL 2, TL 3, and TL 4) examined by linear regression (y = a + bx) against the Julian day (x) of the sampling date (based on the January 1st in 1987). The density data were yielded by square-root transformation of the number of individuals in each quadrat.

<table>
<thead>
<tr>
<th>Tide level</th>
<th>N</th>
<th>Adjusted R²</th>
<th>a</th>
<th>b</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>TL 2</td>
<td>235</td>
<td>0.322</td>
<td>0.125</td>
<td>0.00118</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>TL 3</td>
<td>235</td>
<td>0.367</td>
<td>0.818</td>
<td>0.00129</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>TL 4</td>
<td>237</td>
<td>0.200</td>
<td>1.482</td>
<td>0.00101</td>
<td>&lt; 0.0001</td>
</tr>
</tbody>
</table>
Fig. 3. Temporal changes in the size-frequency histograms of *Patelloida heroldi* from June 1987 to May 1990. Samples from five tide levels (TL 1–5) were pooled. Arrows with small alphabet letter above the histograms show mean shell length of the cohort estimated by fitting a normal curve (see text for details).
Fig. 4. Temporal changes in the size-frequency histograms of *Patelloida heroldi* from June 1990 to January 1993. Samples from four tide levels (TL 1-4) were pooled. Scales of the vertical axes were different from those in Fig. 3. Arrows with small alphabet letter above the histograms show mean shell length of the cohort estimated by fitting a normal curve (see text for details).
Fig. 5. Temporal changes in abundance of new recruits (shell length ≤ 6 mm). Note that the abundance at the five tide levels (TL 1–5) were pooled from June 1987 to May 1990, but only four tide levels (TL 1–4) from June 1990 to January 1993. Asterisk (*) shows that no new recruit was obtained at the sampling occasion.

Fig. 6. Growth curves obtained by the temporal changes of the shell length of the cohorts. Estimated average (± SD) of the normal curves fitted to the size-frequency histograms (Fig. 3 and Fig. 4) are shown. Small alphabet letter beside each growth curve corresponds identical cohorts in Fig. 3 and Fig. 4. Dashed lines indicate that the identity of the cohort is questionable.

_heroldi_ (Takada & Kikuchi, 1991; Ota et al., 1996; Takada, 1999; Tokeshi et al., 2000; Takada, 2001), because of the absence of _Batillaria_ spp. and _Crassostrea_ spp. Studies on _P. pygmaea_ have been very few. _P. conulus_ was referred to as “_P. lampanicola_” in some studies (Morton, 1980; Oshima & Furota, 1980). Studies on _P. conulus_ may be crucial because its most preferred host, _B. multiformis_, has become an endangered species in recent years (Furota et al., 2002).
Table 2. Summary of ecological studies on “Patelloida pygmaea” (including P. pygmaea, P. conulus, P. heroldi, and P. ryukyuensis) in Japan and adjacent areas (not an exhaustive list).

<table>
<thead>
<tr>
<th>Area</th>
<th>Habits</th>
<th>Presence of host animals*</th>
<th>Subjects</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ishikawa, Honshu, Japan</td>
<td>rock</td>
<td>absent</td>
<td>community, distribution</td>
<td>Yajima (1978)</td>
</tr>
<tr>
<td>Tokyo Bay, Honshu, Japan</td>
<td>sand flat</td>
<td>Batillaria</td>
<td>community, distribution</td>
<td>Oshima &amp; Furota (1980)</td>
</tr>
<tr>
<td>Shirahama, Honshu, Japan</td>
<td>rock, boulder</td>
<td>Batillaria, Crassostrea</td>
<td>community, long-term change</td>
<td>Ohgaki et al., (1997)</td>
</tr>
<tr>
<td>Naruto, Shikoku, Japan</td>
<td>artificial</td>
<td>Batillaria</td>
<td>community, growth</td>
<td>Sato et al., (1997)</td>
</tr>
<tr>
<td>Mukaishima, Seto Inland Sea, Japan</td>
<td>rock, boulder</td>
<td>?</td>
<td>distribution, activity</td>
<td>Hirano (1981)</td>
</tr>
<tr>
<td>Sakurajima, Kyushu, Japan</td>
<td>boulder</td>
<td>absent</td>
<td>community, habitat</td>
<td>Inadome &amp; Yamamoto (2005)</td>
</tr>
<tr>
<td>Cheju Islands, Korea</td>
<td>rock, sand</td>
<td>Batillaria</td>
<td>community</td>
<td>Lee &amp; Hyun (1992)</td>
</tr>
<tr>
<td>Yantai, Bohai Sea, China</td>
<td>rock</td>
<td>Batillaria</td>
<td>community</td>
<td>Zhuang (1997)</td>
</tr>
<tr>
<td>Hong Kong, China</td>
<td>sand flat, cobble</td>
<td>Batillaria, Saccostrea</td>
<td>distribution, habitat, morphological divergence,</td>
<td>Morton (1980)</td>
</tr>
<tr>
<td>Hong Kong, China</td>
<td>?</td>
<td>Saccostrea</td>
<td>distribution, density, growth, reproduction, pollution</td>
<td>Liu (1994a, b), Liu &amp; Morton (1998)</td>
</tr>
<tr>
<td>Hong Kong, China</td>
<td>rock</td>
<td>Saccostrea</td>
<td>pollution, heavy metal</td>
<td>Blackmore (2001)</td>
</tr>
</tbody>
</table>

*Host animals of Patelloida spp. (Nakano & Ozawa, 2005) are based on the habitat descriptions of the references in the fifth column, but only shown to genus (see text for details).

Vertical distribution and density fluctuation

The range of vertical distribution of P. heroldi on the boulder shore in Amakusa extended from the mid (TL 2) to the low (TL 4) intertidal zone. This agrees with previous observations in Amakusa (Takada & Kikuchi, 1991; Ota et al., 1996; Takada, 2001). Over the six-year period, the vertical range of distribution appeared stable. The considerable density increase at TL 2 during the second half of the study period (1990–1993) may suggest an upward extension of the distribution range, but not as far as TL 1. It was not possible to detect any long-term change in the lower limit of the range, because the series of samplings was terminated after the first three years.

Within the vertical range, the density at TL 4 was generally the highest. The density at TL 3 was apparently lower than that at TL 4 during the 1987–1989 period, but during the 1990–1993 period the density at TL 3 and TL 4 fluctuated around a similar level (5–20 individuals / 0.25m²). This corresponds to the larger parameter of the long-term trend of the density increase (Table 1) at TL 3 (b = 0.00129) than at TL 4 (b = 0.00101).

The density of P. heroldi fluctuated seasonally, being high in summer and low in winter. This seasonal pattern of density fluctuation was obvious at TL 4 during the whole six-year
period. At TL 3, this pattern became apparent during the 1990–1993 period, when the density became higher. The winter increase in density corresponds with the winter recruitment of the small individuals on the shore. The summer decrease in density was mostly due to mortality, but patterns of survival were not investigated. The unclear seasonal pattern at TL 2 was partly due to the lack of a clear seasonal pulse in recruitment there.

**Size composition and recruitment**

Size composition of *P. heroldi* was not homogeneous along the range of the vertical distribution, as observed in some other intertidal gastropods (Vermeij, 1972; Takada, 1996). Generally, the individuals at the upper tide levels (TL 1–3) were larger than those at the lower tide levels (TL 4–5). Various life-history characters have been shown to affect the spatial heterogeneity of size composition in populations of intertidal gastropods (Takada, 1996), including spatial variations in recruitment, growth, mortality, migration, and interactions of these characters. In the case of *P. heroldi*, a simple hypothesis that recruitment of small individuals to the lower tide levels would cause this size heterogeneity pattern is to be rejected, because small individuals tended to occur at the upper tide levels from October to January, and at lower tide levels from February to April. Temporal variation in the vertical position of recruitment has also been recognized in *Monodonta labio* on the same boulder shore in Amakusa (Takada, 1996). Although some environmental factors may similarly affect both *M. labio* and *P. heroldi*, this study does not have sufficient data to discuss further the recruitment of *P. heroldi*.

Ota *et al.* (1996) showed that a dense coverage of the barnacle *Chthamalus challengeri* (ca. 60% of the boulder surface) in the barnacle patch decreased the density and mean size of *P. heroldi* (as “*P. pygmaea*”), but no barnacle patches were observed within the present study area over the whole study period. In Sakurajima, the density of “*P. pygmaea*” showed a positive correlation with the number and size of boulders (Inadome & Yamamoto, 2005), but on an adjacent area of the boulder shore in Amakusa, Takada (1999) demonstrated that the number of boulder layers did not affect the density of *P. heroldi* (as “*P. pygmaea*”). So barnacle patches and boulder layers are considered not to have affected the spatial and temporal fluctuations observed in this study.

In this study, analysis of cohorts by fitting several normal curves to the size-frequency histograms yielded estimates of recruitment, growth, and disappearance of the cohorts over the 6-year period. Although the sampling at TL 5 was not carried out after June 1990, low density at TL 5 did not affect the interpretation of the results.

Recruitment of cohorts composed of small individuals occurred in winter. Several recruitment events were recognized in a year. The results of this study show that four cohorts were recruited during the 1988–1989 winter while only one cohort was recruited during the 1987–1988 winter. This increase in the number of recruitment events corresponded with the subsequent increase in density. So, the annual variations in size composition may be partly due to the long-term increasing trend in density, and to the annual variations in recruitment.

On the other hand, mortality of *P. heroldi* was not estimated in this study. Some of the new cohorts disappeared within the first few months, while other cohorts could be traced for about one year. These results suggest that *P. heroldi* on the boulder shore in Amakusa is an annual population with recruitment in winter. In Hong Kong, the longevity of “*P. pygmaea*” was concluded to be one year and a few months, but the recruitment extends for 8-months from February to October (Liu, 1994a). This difference may be partly due to a geographic difference, but it is also probable that “*P. pygmaea*” described by Liu (1994a) is *P. ryukyuensis*, instead of *P. heroldi*. 
**Growth and longevity of estimated cohorts**

Estimation of the growth curve and longevity by using multiple size cohorts is known to have some potential biases in comparison to estimation by following marked individuals (e.g. Takada, 1995). But, the method using size cohorts produces useful estimates for detecting annual variations and comparing with the results from other regions or species. This study showed that cohorts of 3–5 mm (shell length) in average size grow up to 10 mm within 8 months. Growth rates were variable among the cohorts (0.57–1.20 mm per month), so no annual variations or long-term trends could be detected. On the same boulder shore the lottid limpet *Nipponacmea* spp. grows up to 16–20 mm within a year (Takada, 1997). The lifespan of these *Nipponacmea* spp. is also almost annual but their growth rates are larger than the growth rate observed for *P. heroldi* in this study. At Naruto in northeastern Shikoku, an experimental study using artificial boulders (Sato et al., 1997) showed that the average shell length of “*P. pygmaea*” increased from 6 mm (April) to 11 mm (October): the growth rate was similar to the present study.

In Hong Kong, “*P. pygmaea*” of 7.7 mm average shell length grows to 13.8 mm after one year (Liu, 1994a): 0.51 mm per month. This growth rate is smaller than the present study. But the mean shell length of the population was variable among shores in Hong Kong, probably due to pollution (Liu & Morton, 1998). The “*P. pygmaea*” population had a low density with a large mean shell length in a heavily polluted area. Liu & Morton (1998) indicated a negative density effect on size of the limpets. In the present study, temporal variations in the density of *P. heroldi* were demonstrated, but factors controlling these variations were not specified. Some environmental factors and interspecific interactions may affect the variations.

In conclusion, the present study examined the population of *P. heroldi* on a boulder shore over a six-year period. The density fluctuated seasonally and increased over the six years. Analysis of size-frequency histograms allowed assessment of recruitment, growth and longevity of the cohorts. Effects of environmental and interspecific factors on the population characters of *P. heroldi* should be studied in future.

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**References**


Iwasaki, K. 1993. Synergistic effects of mixed grazing by intertidal limpets on sessile organisms:


Yajima, T. 1978. Studies on the intertidal communities of the Japan Sea I. General features of the
転石海岸におけるヒメコザラ個体群の長期変動

高田宣武

要 約

九州天草の転石海岸において、ヒメコザラ個体群の密度とサイズ組成を、6年間にわたって観察した。ヒメコザラの密度は時間的空間的にバラツキがあるものの、中潮帯から低潮帯にかけて分布した。また、夏季に低密度、冬期に高密度となる季節変動を示したが、6年間の調査期間中は全体として増加傾向にあった。サイズ頻度分布は1 ～ 3 のピークをもつ単峰型もしくは多峰型を示した。サイズ頻度分布のコホート分離を行い、経時変化を見ることによって、コホートの加入と成長を推定した。新規コホート（殻長3 ～ 5 mm）の加入は冬期におこり、8ヶ月で殻長10 mmまで成長した。各コホートの寿命はバラツキが大きいが一年半以内であった。