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SPECIES COMPOSITION AND SPATIAL DISTRIBUTION OF INFAUNAL BIVALVES IN THE INTERTIDAL FLATS OF PENGHU[1]

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Kun-Hsiung Chang, Chang-Po Chen, Hwey-Lian Hsieh, Wei-Cheng Su, Sing-Haw Hu and See-Cheng Lee (1982) Species Composition and spatial distribution of infaunal bivalves in the intertidal flats of Penghu *Bull. Inst. Zool., Academia Sinica* **21**(1): 1-8. From May, 1979 to May, 1980, a total of 1124 infaunal bivalves, belonging to 4 families, 10 genera were collected at a three-month interval from the sandy tidal flats of Penghu, where the samplings were carried out in three tidal levels. Among them, *Tapes variegata* Sowerby, *Gafrarium tumidum* (Roding), and *Marcia hiantina* (Lamarck) comprised respectively 1.3%, 90% and 0.6% of the total, and were distributed with a gradient from high tide level to low tide level. The characteristics of the spatial and temporal distribution of *G. tumidum* were discussed in detail.

With a view to improving mariculture in Penghu, an ecological survey of the shore was carried out from the intertidal region down to a depth of 10 meters. In Penghu, the intertidal area is huge, about equal to the land mass, and practical methods of putting it to use are under discussion. The knowledge of the fauna and its distribution in this area is necessary in order to plan for mariculture. A report on the occurrence of juvenile penaeid shrimps in the intertidal area of Chitou Bay has been issued[1]. In this paper the species composition and spatial distribution of the infaunal bivalves on the intertidal flat of Penghu are considered.

During the course of this study, ten species of infaunal bivalves were found on three intertidal flats, which were chosen for quantitative sampling. Among them, *Gafrarium tumidum* was the most abundant, and a report on its growth and production is published elsewhere[7]. *Tapes variegata* is commercially the most important, but the population density is very low. Because of these factors, reproductive periodicity and habitat preference of *T. variegata* were investigated[2].

MATERIALS AND METHODS

The bivalves were sampled quantitatively from three intertidal flats, viz. Chiang-Mei, Hsiao-Chih-Kan and Chi-Tou at intervals of three months from May, 1979 to May, 1980 (Fig. 1). The flat was divided into three zones: high, middle and low tide levels, and three

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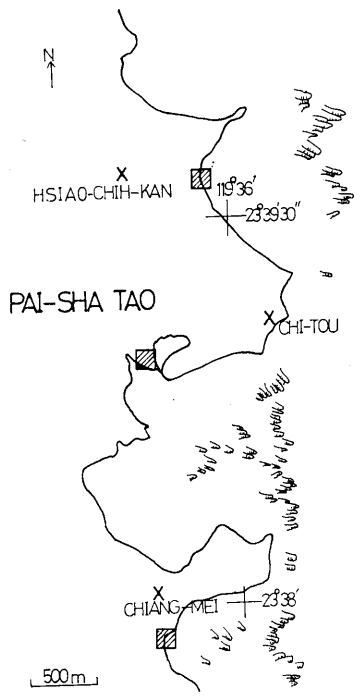

Fig. 1. Map of the study area.

plots were set 10 m apart in each zone along the coastal line. Each plot measured 1×5 m and was dug carefully to a depth of 5 cm by an iron spade to collect bivalves, which were recorded in each 1 m² unit area.

In order to avoid the influence of collecting activity of local people, the sampling plots were chosen at places which had not been dug recently (disturbed areas could be recognized because they were uneven and the gravel was turned over).

The bivalves were identified according to color illustrations in shell books[4,5,6], and *T. variegata* was identified with Lan's key[8].

The ratio of mean square to mean ($s^2 : \bar{X}$) of *G. tumidum* density in each plot was used to reveal the distribution patterns of the bivalve within plots[3]. For comparing the spatial and temporal changes of *G. tumidum* density in different sampling flats, mean density was calculated as the arithmatic mean of the three plots in each tide level on each sampling date.

DESCRIPTION OF SAMPLING FLATS

Three intertidal flats were chosen along the east coast of Pai-Sha Tao which is the third largest island of Penghu. Chiang-Mei is located at the end of an inner bay and the slope of the flat is very gentle. The substratum was mainly composed of pebbles (4 mm in diameter), medium sand (0.25–0.125 mm in diameter) and fine sand (0.125 mm in diameter) (Fig. 2). Fine sand was dominant and was a special feature of the substratum at Chiang-Mei, whereas, sand was less abundant at the other two flats. Chi-Tou flat was composed of sand and coral debris deposited or relocated after the invasion of typhoons in the summer or the north-east monsoon in winter and its substratum was very unstable. Shiao-Chih-Kan, located at the north-east, was a typical eroded coast composed of large pebbles and boulders (15 mm in diameter) mixed with pebbles deposited on the surface of medium sand.

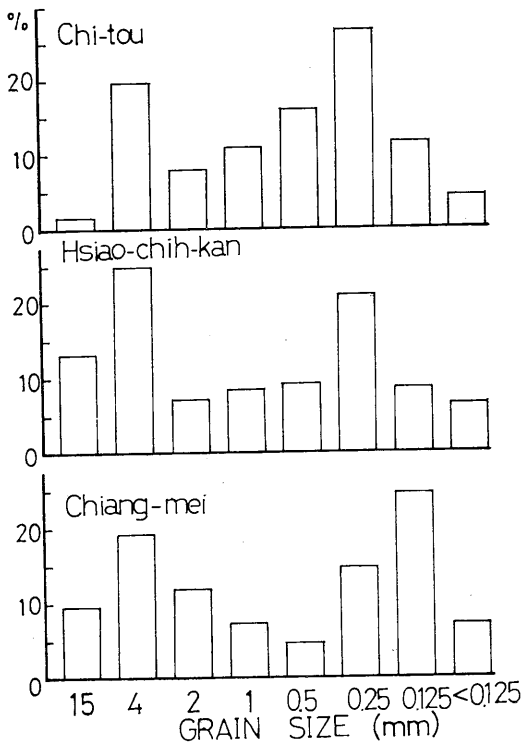

Fig. 2. Percentage composition (by weight) of substrate samples.

TABLE 1

The species composition and abundance of infaunal bivalves in intertidal zones of Penghu

Species \ Stations / Sampling date	Chiang-Mei					Hsiao-Chih-Kan					Chi-Tou					Total (%)
	1979			1980		1979			1980		1979			1980		
	May	Aug.	Nov.	Feb.	May	May	Aug.	Nov.	Feb.	May	May	Aug.	Nov.	Feb.	May	
Mytilidae																
Modiolus metcalfei (Hanley)	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	2(0.18)
Lucinidae																
Epicodakia divergens (Philippi)	2	0	0	0	0	1	6	5	3	2	0	1	0	0	0	20(1.78)
Cardiidae																
Fragum fragum (Linnaeus)	3	0	0	4	5	2	0	0	0	1	3	0	0	0	0	18(1.60)
Veneridae																
Gafrarium tumidum (Roding)	55	92	124	125	85	42	87	37	51	144	22	28	43	60	25	1020(90.75)
Pitar sulfureum Pilsbry	0	2	1	2	0	0	0	0	0	0	0	0	0	0	0	5(0.44)
Dosinorbis japonicus (Reeve)	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1(0.09)
Tapes variegata Sowerby	0	0	0	1	0	2	2	1	3	5	0	0	0	0	1	15(1.33)
Marcia hiantina (Lamarck)	0	0	0	2	0	0	0	5	0	0	0	0	0	0	0	7(0.62)
Anomalocardia squamosa (Linnaeus)	4	3	6	12	8	0	0	0	1	1	0	0	0	0	0	35(3.11)
Irus mitis (Deshayes)	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1(0.09)
Total					537					402					185	1124

RESULTS

1. Species composition of infaunal bivalves

The 1124 individuals of bivalves collected in this study were assigned to 10 species, belonging to 4 families and 10 genera (Table 1). Among them, *Gafrarium tumidum* (Roding) was dominant, comprising 90% of the total. Of commercial bivalves, three kinds were found, viz. *G. tumidum*, *T. variegata* and *Marcia hiantina* (Lamarck). The latter two were chiefly collected from Hsiao-Chih-Kan flat.

On the sampling flats, the greatest quantity, 8 species and 537 individuals were collected from Chiang-Mei, while Hsiao-Chih-Kan with 7 species and 420 individuals and Chi-Tou with 5 and 185, respectively.

2. Spatial distribution zones of three commercially important bivalves

The densities of these three bivalves at different tide levels of Hsiao-Chih-Kan are listed in Table 2. Generally, *G. tumidum* and *T. variegata* occurred in all tidal areas, whereas *M. hiantina* was found in the middle and low tide zones and was absent from the high tidal area. Furthermore, there was a slight difference in the presence of the three bivalves at different tidal levels: *G. tumidum* was mainly distributed at high and middle tide levels, *T. variegata* at high tide level, and *M. hiantina* in the low tide level.

3. The distribution pattern of *G. tumidum*

The relative frequency distribution of *G. tumidum* collected in each 1 m^2 is shown in Figs. 3-5 for each sampling flat. At Hsiao-Chih-Kan, the histogram has a long right tail in August 1979 and May 1980, indicating that a large number of individuals was collected at some 1 m^2 units. As for Chiang-Mei, the histograms of 5 samplings are very similar, and their modes shift gradually from 0 in August 1979 to 1 in November 1979 and then 2 in February 1980.

Fig. 6 shows the relationship between the mean and the mean square of *G. tumidum* densities, estimated in each plot of the three flats investigated. At Chiang-Mei flat, *G. tumidum* was found at most sites to distribute randomly, i.e., $s^2 \fallingdotseq \bar{X}$. Only in 8 plots s^2 were found larger than $\bar{X}$, which means that the distribution pattern inclined toward patchness. However, those plots with patchness only comprised 12% of the total, 42 plots. In Hsiao-Chih-Kan flat, *G. tumidum* had 11% of plots patchy, whereas, in Chi-Tou only 4.4% of plots were patchy. Therefore, the distribution pattern of *G. tumidum* in each plots was generally random. The density of *G. tumidum* at each tide level was calculated as the arithmatic mean of the three plots on the same tide level. The temporal changes of *G. tumidum* in three tidal zones are shown in Table 3 and Fig. 3. At Hsiao-Chih-

TABLE 2

Spatial distribution patterns of infaunal bivalves in intertidal zones of Hsiao-Chih-Kan, Penghu

Species	Intertidal zones		
	High	Middle	Low
	Density (ind./m^2)		
Gafrarium tumidum	1.86±1.02*# (0.82—3.28)	2.29±2.14 (0.73—6.07)	0.49±0.60 (0.07—1.53)
Tapes variegata	0.13±0.11 (0 —0.27)	0.02±0.05 (0 —0.12)	0.01±0.03 (0 —0.07)
Marcia hiantina	0	0.03±0.06 (0 —0.13)	0.04±0.08 (0 —0.19)

* averaged from the population density of May, August, November 1979, and February, May 1980; mean±standard error.

\# range of estimated population density on these months.

Kan, the fluctuations of *G. tumidum* densities in August 1979 and May 1980 coincided with the occurrence of some sampling plots with patchy distribution (Fig. 3). It suggests that these fluctuations were caused by only a few plots with high density of *G. tumidum* and did not involve the whole flat. In contrast, at Chiang-Mei, the change of *G. tumidum* density was related to the whole flat, for the 5 histograms of numbers of *G. tumidum* collected in each 1 m² are very similar.

DISCUSSION

Zonation pattern of marine animals living on intertidal rock shore is well known[9]. However, the zonation pattern on sandy beaches is often less apparent, although it generally occurs[10]. In Penghu, the spatial distribution of *T. variegata*, *G. tumidum* and *M. hiantina* with a gradient from high tide level to low tide

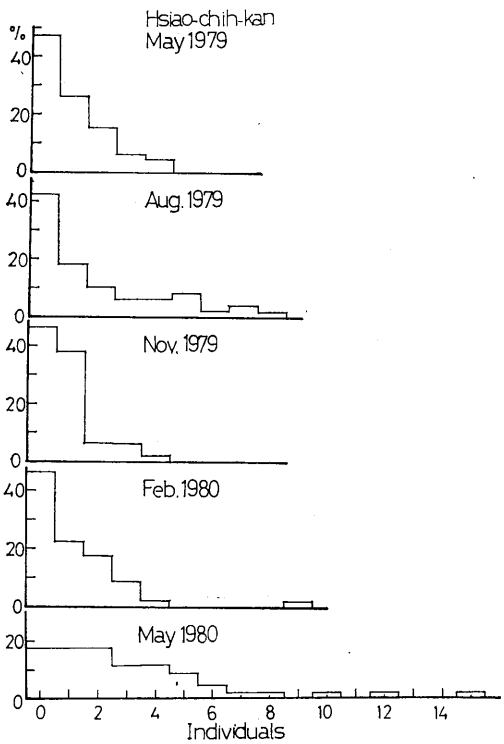

Fig. 3. Relative frequency distribution of individuals of *G. tumidum* collected in each plot at Hsiao-Chih-Kan.

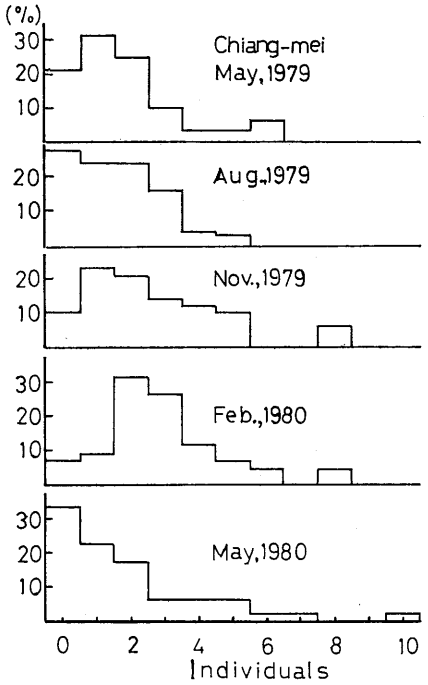

Fig. 4. Relative frequency distribution of individuals of *G. tumidum* collected in each plot at Chiang-Mei.

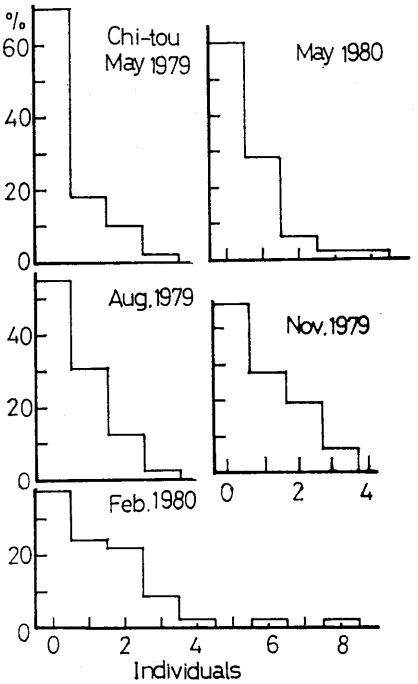

Fig. 5. Relative frequency distribution of individuals of *G. tumidum* collected in each plot at Chi-Tou.

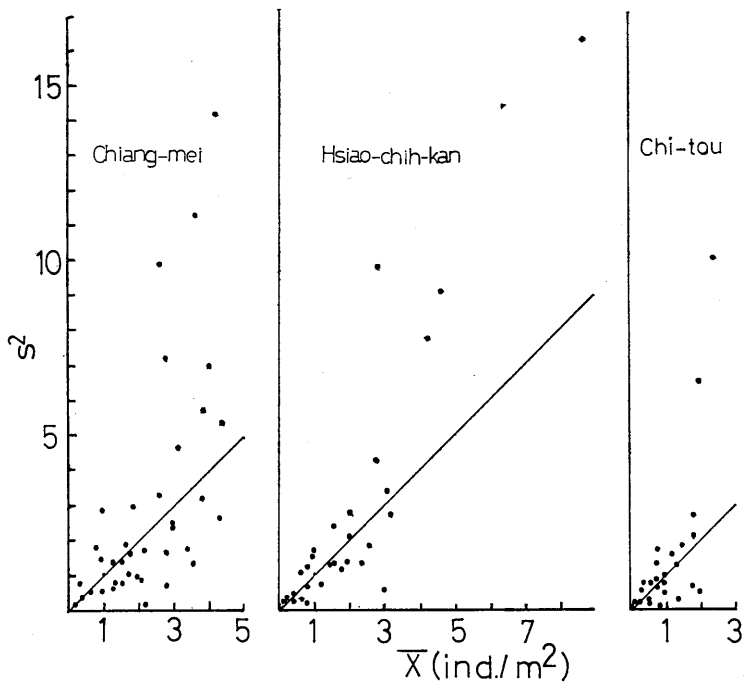

Fig. 6. The relationship between the mean and mean square of *G. tumidum* density estimated in each plot.

TABLE 3

The spatial and seasonal changes of population densities of *G. tumidum* in intertidal zones of Penghu

Location	Sampling date	Intertidal zones		
		High	Middle	Low
		Density (ind./m²)		
Chiang-Mei	May, 1979		0.98±0.45	3.08±0.22
	Aug.	1.97±0.97*	1.36±0.57	1.32±0.71
	Nov.	1.60±0.87	3.41±0.54	2.88±0.99
	Feb., 1980	2.40±0.35	3.40±0.80	2.53±0.94
	May	0.67±0.81	1.47±1.36	3.47±0.70
Hsiao-Chih-Kan	May, 1979	0.93±0.10	1.42±0.68	0.39±0.22
	Aug.	3.28±1.34	1.78±1.26	0.07±0.12
	Nov.	0.82±0.40	1.47±0.61	0.07±0.12
	Feb., 1980	2.27±1.70	0.73±0.64	0.40±0.20
	May	2.00±1.22	6.07±2.91	1.53±1.45
Chi-Tou	May, 1979	0.48±0.43	0.60±0.40	0.27±0.14
	Aug.	0.28±0.48	0.94±0.10	0.47±0.50
	Nov.	0.89±0.44	1.30±0.82	0.53±0.23
	Feb., 1980	1.53±0.61	1.07±0.81	1.40±0.87
	May	0.40±0.35	0.47±0.46	0.80±0.72

* mean±standard error.

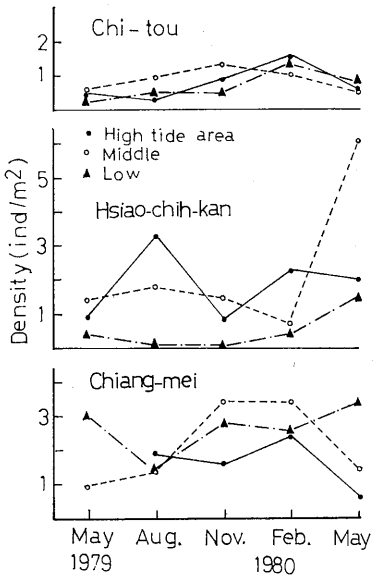

Fig. 7. Seasonal fluctuation of *G. tumidum* densities at three investigated areas.

area is a good example of the zonation patterns of bivalves living in intertidal sand shores.

In Penghu, local people collect *T. variegata* and *G. tumidum* with hand spades from intertidal flats, whereas they collect *M. hiantina* from sublittoral areas by probing with an iron rod into substratum to irritate the clam, causing it to close its valves and eject water from the siphon, which reveals the presence of the clam.

During this study period, many local people collecting the clam at either tidal or subtidal area were observed at Hsiao-Chih-Kan, but only a few people collecting at subtidal area in Chiang-Mei. However, at Chi-Tou, people collected pistol shrimps instead of clams. Therefore, human activity might be one of factors that caused the great fluctuation in the *G. tumidum* density estimated at Hsiao-Chih-Kan.

Moreover, many *G. tumidum* had been collected from the previously investigated areas. It seems that *G. tumidum* had moved in from other areas either actively or passively. When the subtratum is more or less heterogeneous, *G. tumidum*, may aggregate in more suitable substrata forming patchness in its spatial distribution. Hsiao-Chih-Kan is the largest intertidal flat among those investigated flats, and there is a greater chance of chosing a sampling plot with patchy distribution for *G. tumidum*, causing the larger fluctuations of *G. tumidum* densities.

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澎湖潮間帶潛棲性二枚貝之組成及其分佈

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自民國六十八年五月至六十九年五月，每三個月在澎湖講美、小赤嵌、岐頭三地區之潮間帶採集一次。每一採集地又分高潮位、中潮位及低潮位三區，在每一潮位內各取三個長 5～6 公尺，寬 1 公尺的方格，記錄二枚貝的種類及數量。共計採得 4 科，10 屬，1124 個個體。其中厚殼仔 *Gafrarium tumidum*，佔總個體數的 90%；海瓜子 *Tapes variegata*，佔 1.3%；淺蜊 *Marcia hiantina* 佔 0.6%。以上三種具有經濟價值。以三個採集地而言，講美種類、個體數都最多，有 8 種，537 個個體。厚殼仔是潮間帶潛棲性二枚貝類的顯着種。而海瓜子及淺蜊主要是在小赤嵌一地採得。

比較三種經濟性二枚貝在小赤嵌三個潮位的密度（個體數/m^2），發現海瓜子主要分布在高潮位，厚殼仔在中潮位，淺蜊則分布在低潮位。