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Analysis of the Morphometric Characters of the Kuruma Shrimp (*Penaeus japonicus*) in the East China Sea and the Taiwan Strait

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ABSTRACT

Morphometric variation was used to examine the stock structure of the kuruma shrimp in the East China Sea and the Taiwan Strait. Nine samples were collected, one from the north of the East China Sea, two from the south of the East China Sea, three from the inshore areas of Taiwan, and three from the middle of the Taiwan Strait. The 11 measurements made for each individual were size-standardized by Burnaby's method, and resulting measurements were used in the canonical variate analysis and cluster analysis by sexes. The results showed that all sampling areas were clustered into three distinct groups for each sex, the first group included the north of the East China Sea, the second group included inshore areas of Taiwan, the third group included the other areas. Shrimps often migrate from inshore to offshore as they grow to specific size, so the second group (the smaller individuals) was considered as the unrecruiting offspring of the third group (the larger ones). The morphometric variation between the second and the third groups could be attributed to different life stage. We, therefore, suggest that the kuruma shrimp in the East China Sea and the Taiwan Strait can be discriminated into two stocks. One is in the north of the East China Sea, and the other is in the south of the East China Sea and the Taiwan Strait. The present study demonstrates that the utility of morphometric characters for defining stocks of kuruma shrimp is available, but further verification of the stock structure (e.g., genetic evidence) is essential.

Key words: *Morphometric variation, Stock structure, Canonical variate analysis, Cluster analysis.*

INTRODUCTION

Knowledge of stock structure is essential for rational exploitation and management of exploited species. Morphological variability among different geographical populations could be attributed to different genetic structure of populations and to different environmental conditions prevailing in each geographic area (Mamuris *et al.*, 1998). The animals, therefore, with the same morphometric measurements are often assumed to constitute a stock (Waldmen *et al.* 1988), and that has been used widely in fishery stock differentiation studies (Avsar, 1994).

Multivariate analysis of a set of morphometric characters is regarded as a more appropriate method than the use of a single character to identify different stocks (Thorpe, 1987). Morphometric variation is often confounded by size factor, so morphometric data analyzed should be free from the effects of size variation. Several methods can be used to obtain size-free morphometric data, such as regression technique (Reist, 1985), shearing principal components analysis (Humphries *et al.*, 1981) and Burnaby's method (Bookstein *et al.*, 1985).

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Kuruma shrimp (*Penaeus japonicus*) is one of the highly valued demersal species in Taiwan trawler fisheries operated in the East China Sea and/or the Taiwan Strait. Many studies on the biology of kuruma shrimp had been conducted in Taiwan (Liao and Chen, 1972; Tsai *et al.*, 1992; Tzeng and Yeh, 1998), but the stock structure of kuruma shrimp is still absent. In this present paper, we examine the extent of morphometric variability in different kuruma shrimp populations in the East China Sea and the Taiwan Strait using multivariate method to reveal the existence of different stocks.

MATERIALS AND METHODS

Nine samples were collected in different geographic waters (Fig. 1), one from the north of the East China Sea (N30), two from the south of the East China Sea (N27 and TAS), three from the inshore areas of Taiwan (PUT, TAI and TON), three from the middle of the Taiwan Strait (N22, N23 and N24). Sex was identified and separated. A total of 11 measurements was made on each specimen (Fig. 2). They were antennal spine width (ASW), hepatic spine width (HSW), carapace length (CL), diagonal carapace length (DCL), first abdominal segment length (FSL), first abdominal segment width (FSW), first abdominal segment height (FSH), second abdominal segment length (SSL), sixth abdominal segment high (SISH), sixth abdominal segment width (SISW), body length (BL).

We examined the distribution of carapace length of each sample, and found the male sample from Taichung harbor (TAI) composed two different age groups. Two sub-samples, therefore, were constructed to reduce the effect of ontogenetic allometry. The carapace length of specimens was larger than 42 mm was categorized as TAIL, and the others as TAIS. The number of group analyzed, therefore, was nine for female, but ten for male. The

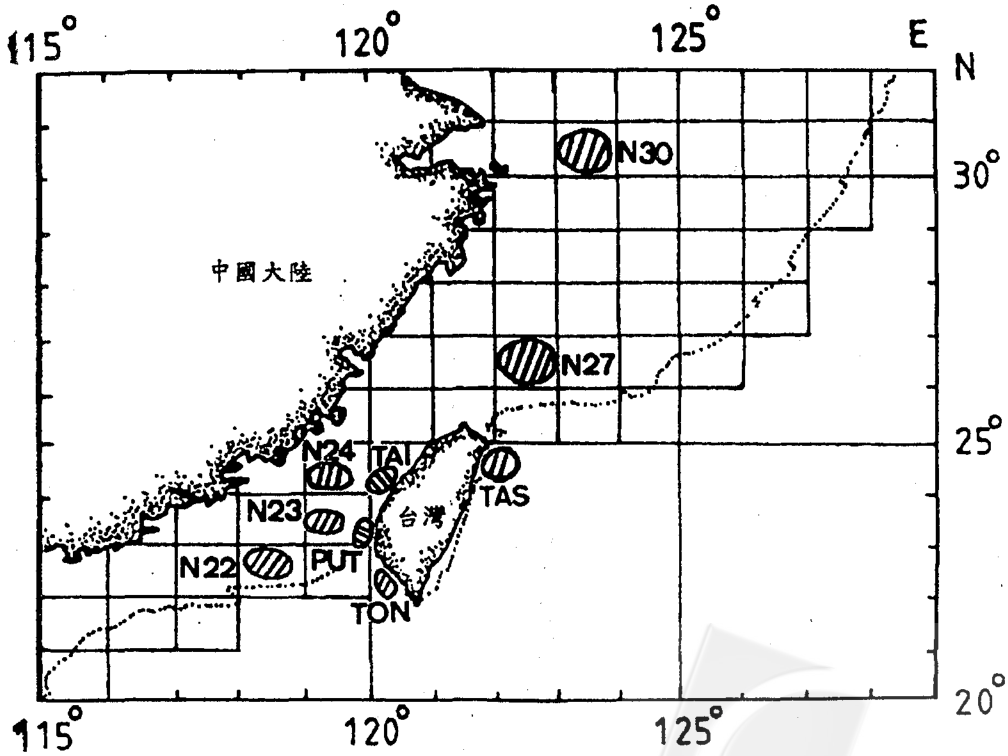

Fig. 1. Shadowed area showing the sampling area from the East China Sea and the Taiwan Strait.

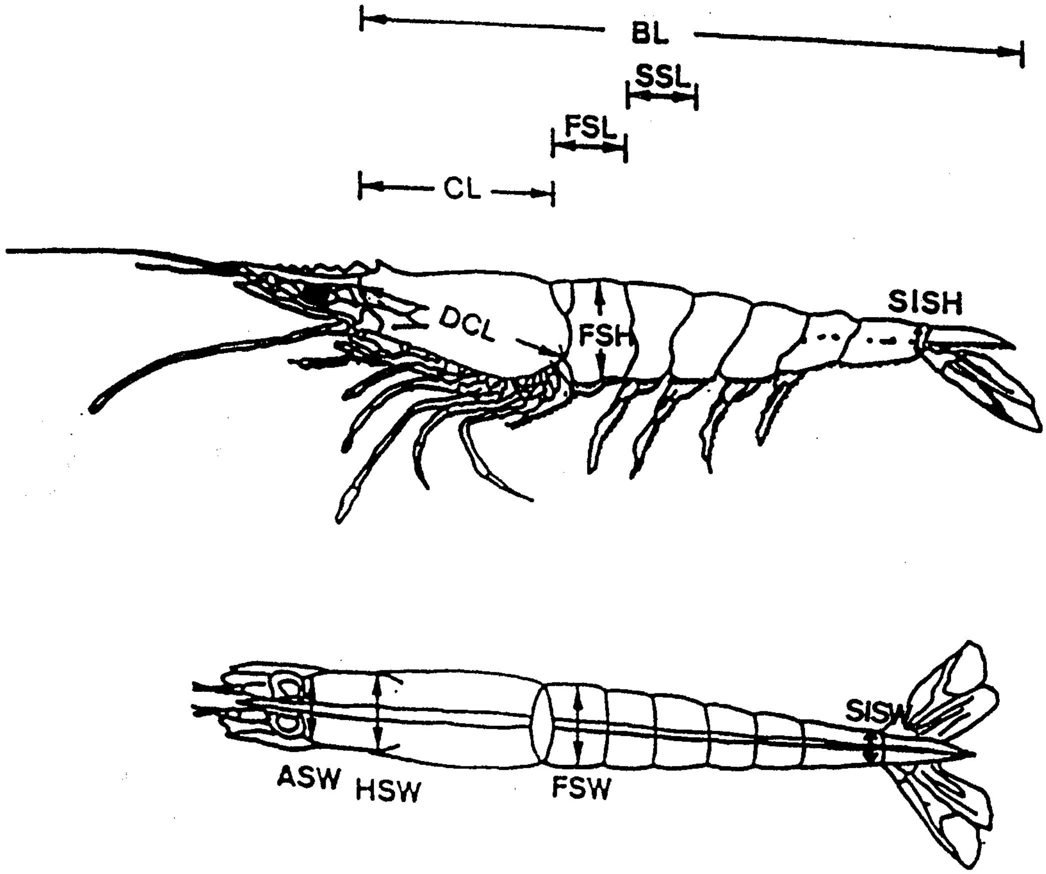

Fig. 2. Diagram of *Penaeus japoncus* showing the body parts measured.

sample size, sampling area code, range of carapace length and relative information are in Table 1. The individuals obtained from the inshore waters around Taichung harbor, Putai and Tonkong are relative smaller than the ones from the other waters.

Morphological variation by sexual dimorphism with respect to growth in kuruma shrimp (Tzeng and Yeh, 1998) could be greater than by geographic distribution, therefore, the analyses of morphometric characters should be separated by sex. Burnaby's method was used to remove the effect of size variation. The resulting measurements were subjected to canonical variates analysis (CVA) and cluster analysis.

After CVA was conducted, the first two canonical vectors were plotted. Confidence levels for observed groups were shown by the use of 95% confidence ellipse (Owen and Chmielewske, 1985) around the mean of each group.

The dendrogram was constructed by unweighted pair-group method with arithmetic averages (UPGMA) by using Mahalanobis distances between population centroids (Sneath and Sokal, 1973). Sampling areas were regarded as operation taxonomic units. DuPraw's (1964) procedure also was used to increase the resolving power of the cluster analysis by eliminating the extreme group from the initial analysis, and also constructed the dendrogram on the remaining samples.

RESULTS

The cumulative percentages of total variances explained by the first two eigenvalues for male and female were shown in

Table 1. Code of sampling area, sex, sample size, sampling date and mean and range of carapace length of kuruma shrimp for morphological analysis

Area code	Sex	Sampling date	Sampling area	Sample size	Mean and range of carapace length	
N30	F	DEC. 1995	30°-31°N	73	64.99	55.02-73.31
	M		123°-124°E	108	48.19	43.93-54.42
N27	F	DEC. 1995	26°N-27°N	132	57.11	51.15-62.84
	M		122°-123°E	122	48.19	43.93-54.42
N24	F	DEC. 1995	24°10'-24°15'N	61	60.84	55.61-68.38
	M		119°36'-120°E	79	45.73	42.00-55.58
N23	F	DEC. 1995	22°50'-23°N	61	58.14	53.09-64.82
	M		119°-120°E	51	48.95	44.52-54.90
N22	F	DEC. 1995	21°30-22°N	96	67.13	59.20-73.11
	M		118°30'-119°E	23	54.33	51.11-58.02
TAS	F	DEC. 1995-	Water around	38	59.76	55.47-65.03
	M	MAR. 1996	Tashi harbor	44	48.03	43.34-55.77
TAIL	F	DEC. 1995-	Water around	32	50.81	40.35-60.67
	M	MAR. 1996	Taichung harbor	41	44.96	42.06-50.93
PUT	F	DEC. 1995-	Water around	86	33.18	23.53-41.20
	M		Putai harbor	105	31.98	21.33-40.04
TON	F	MAR. 1997	Water around	246	30.88	23.14-41.94
	M		Taichung harbor	236	29.57	21.53-41.07
TAIS		DEC. 1995-	Water around			
	M	MAR. 1996	Taichung harbor	47	31.69	22.51-41.05

Table 2. The male's values is 92%, but the female is 86%. The first two canonical variates were plotted in Fig. 3 and Fig. 4 for male and female, respectively. Nine sampling areas including ten data sets for male were clustered into three distinct groups, one group included N30; another included PUT, TON and TAIS; the other included N27, TAS, N24, TAIL, N23 and N22. The result for female was very similar to that for male. Nine sampling areas were also clustered into three distinct groups, one group included N30; another included PUT and TON; the other included N27, TAS, N24, TAIL, N23 and N22.

The UPGMA dendrograms were constructed for male (Fig. 5) and female (Fig. 6). Three major groups were observed for male, one containing N30; another containing PUT, TON and TAIS; the other containing N27, TAS, N24, TAIL, N23 and N22. Three distinct groups were also observed for female, one group containing N30; another containing PUT and TON, the

Table 2. The first, second eigenvalues and their corresponding cumulative percentage of total variance explained for male and female data sets adjusted by Burnaby method

Sex	First eigen.	Cum. %	Second eigen.	Cum. %
Male	5.49674	(0.73)	1.43838	(0.92)
Female	3.48741	(0.68)	0.94864	(0.86)

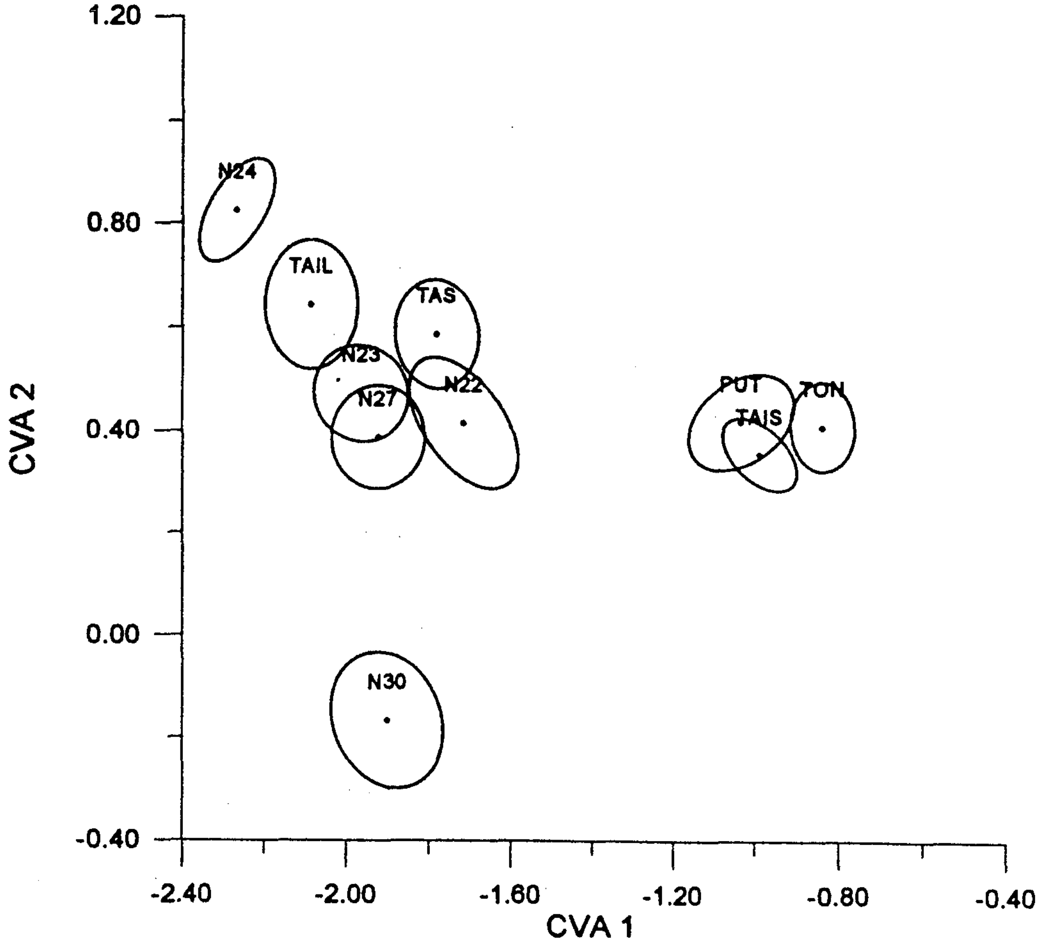

Fig. 3. Plot of 95% confidence ellipses around group spreads and group means of the first two canonical scores estimated from the ten data sets of male adjusted by Burnaby's method.

other containing N27, TAS, N24, TAIL, N23 and N22.

The TON, PUT and TAIS sampling areas were excluded to increase the resolving power of the cluster analysis in this study. The dendrograms were shown in Fig. 7 and Fig. 8 for male and female, respectively. Both results were very similar. Two major groups were observed, one containing N30 and another containing the other areas.

DISCUSSION

Nine sampling areas were clustered into three distinct groups for each sex, the first group included the north of the East China Sea, the second group included inshore areas of Taiwan, the third group included the south of the East China Sea and the middle of the Taiwan Strait. Another cluster analysis excluding the effect of smaller individuals (collected from PUT, TAI and TON) indicated that seven sampling areas were clustered into two distinct groups for each sex, the first group included the north of the East China Sea, the second group included the south of the East China Sea and the middle of the Taiwan Strait. These demonstrated that there was a considerable morphological divergence between N30 and the other sampling areas. Penaeid shrimps often migrate from inshore to offshore as they

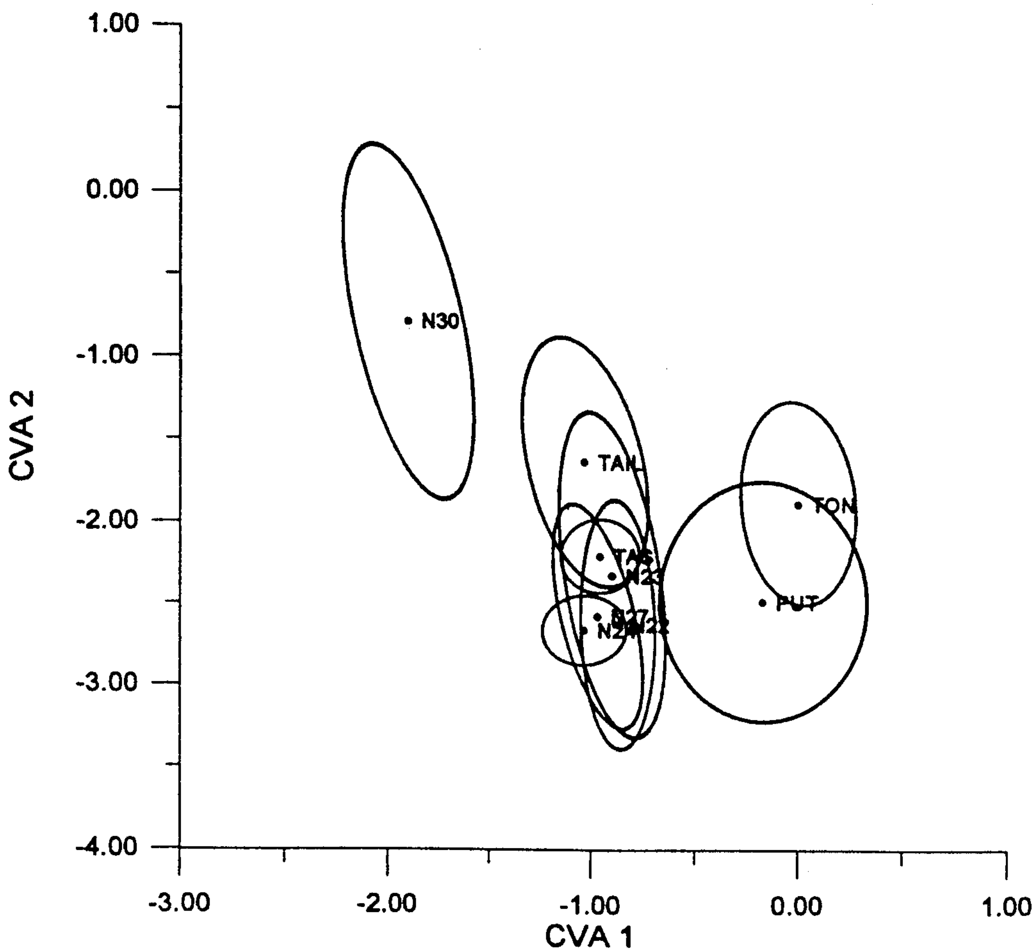

Fig. 4. Plot of 95% confidence ellipses around group spreads and group means of the first two canonical scores estimated from the nine data sets of female adjusted by Burnaby's method.

grow to specific size or life stage (Garcia and Le Reste, 1981), so the inshore group (the smaller individuals) was considered as the unrecruiting offspring of the third group. The morphometric variation between the inshore group and the third group could be attributed to different life stage. If a stock is considered as an intra-specific group of individuals that exhibit unique phenotypic attributes, then based on these results, the kuruma shrimp in these waters should have two separate stocks. One stock is in the north of the East China Sea and the other is in the south of the East China Sea as well as the Taiwan Strait.

A moderately high degree of reproductive isolation is necessary for the formation and maintenance of discrete stocks (Horrall, 1981). Reproduction isolation can be developed through different spawning locations, spawning frequency and spawning dates. Two spawning areas were found in the Taiwan Strait and the East China Sea. One is located in the middle of the Taiwan Strait (Liao and Chen, 1972), but the other is located in the north of the East China Sea (Yamada *et al.*, 1986). In the north of the East China Sea, the spawning season lasts from April until October, with the peak usually occurring between June and August (Yamada *et al.*, 1986). In the Taiwan Strait, two peaks of spawning season were observed; one is between March and May, and the other is between

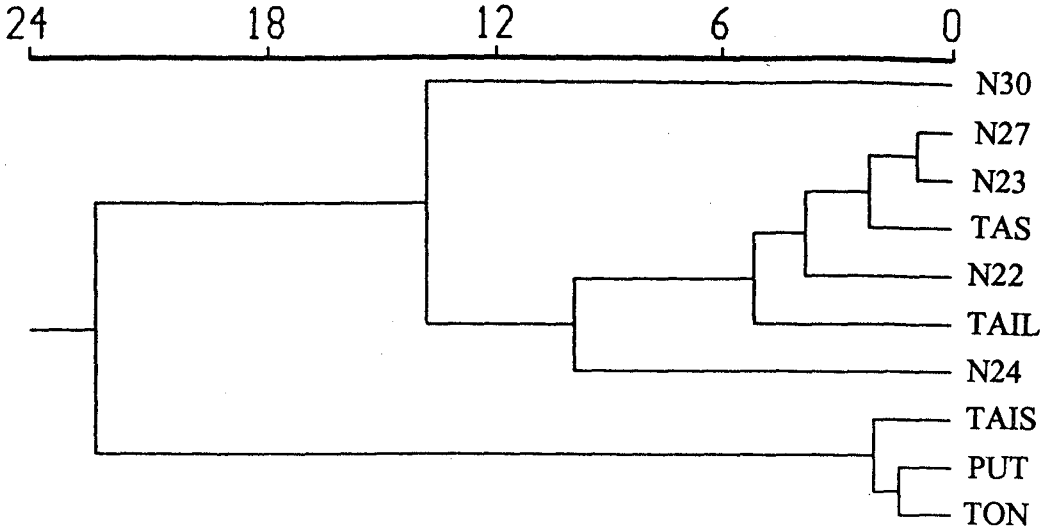

Fig. 5. Dendrograms of ten data sets from nine sampling areas for male.

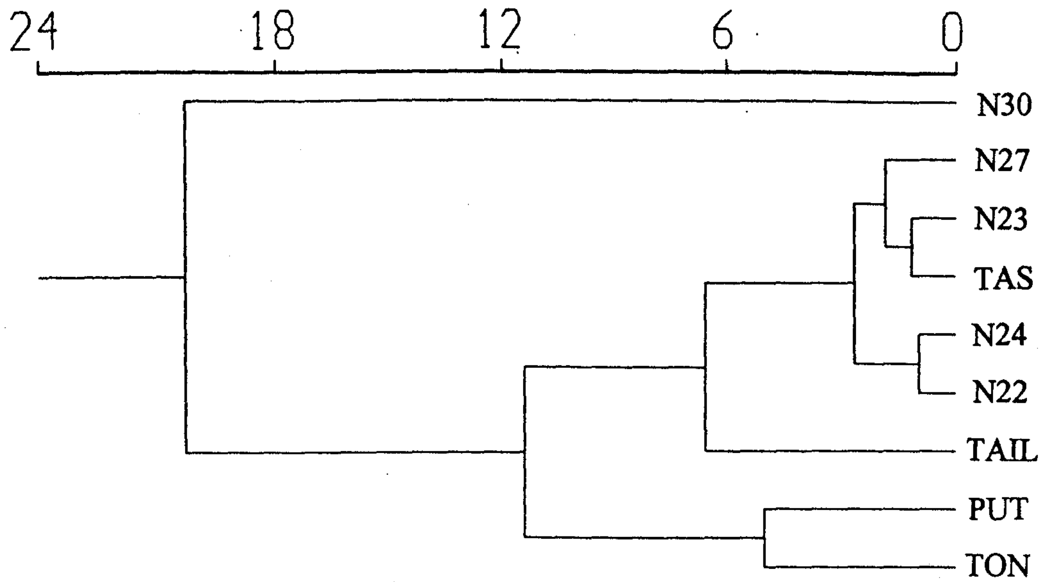

Fig. 6. Dendrograms of nine data sets from nine sampling areas for female.

September and October. The spawning frequency is one for the stock in the north of the East China Sea, but is two in the Taiwan Strait (Liao and Chen, 1972; Yamada *et al.*, 1986). These biological evidences support indirectly the result of two stocks existing in the Taiwan Strait and the East China Sea. Similar stock structure for some demersal fish was also found in these waters, such as Lizard fish (Liu and Tung, 1956,1959; Yeh and Liu, 1973).

The morphometric characters were effected by genetic and environmental factors. Thus, phenetic differences between examined populations may reflect either genetic differences between the stocks or environmental differences between localities. The study on genetic

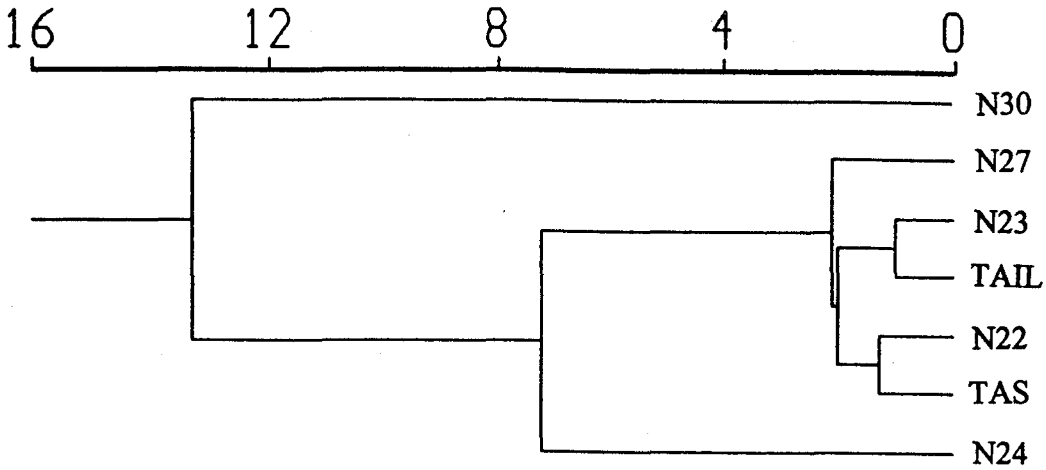

Fig. 7. Dendrograms of male data sets excluding TON, PUT and TAIS.

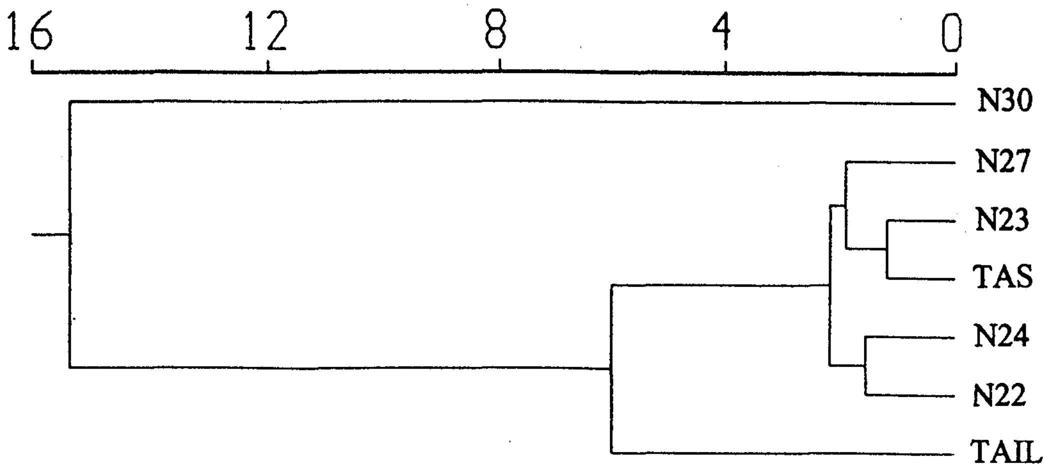

Fig. 8. Dendrograms of female data sets excluding TON and PUT.

structure of population is still absent for this species. These morphological differences may be attributed to two environmental factors prevailing in each area. Firstly, there is a large fresh water input in the north of the East China Sea, and this input also supply the major source of nutrients; in the Taiwan Strait and the south of the East China Sea, there is only small rivers with limited water flow and the major source of nutrients is from the Kuroshio water masses. Secondly, in the north of the East China Sea, the mean temperature of the sea is lower than in the Taiwan Strait and the south of the East China Sea.

The multivariate morphometric characters of the kuruma shrimp samples from N24 and TAIL are lightly different from the ones collected from different sampling areas in the south of the East China Sea and the Taiwan Strait (Fig. 3 and Fig. 4). This variation may be because the water masses in the winter time and the flow pattern in adjacent waters of Taichung harbor are clearly different from those sampling areas in the Taiwan Strait and the south of the East China Sea (Tzeng *et al.*, 1998). The present study demonstrated that the utility of morphometric characters for defining stocks of kuruma shrimp is available, but further verification of the stock structure reported here is required. Pepin and Carr (1992) recommended that attempts to define population based on differences in morphometric features must be verified by genetic evidence in order to confirm that the former differences reflect some degree of reproductive isolation rather than simply environmental distinctiveness.

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東海及台灣海峽產斑節蝦(*Penaeus japonicus*)之外部形態分析

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利用外部形態之變異檢視東海及台灣海峽產斑節蝦之系群結構。採集1個來自東海北部、2個來自東海南部、3個來自台灣西部沿岸及3個來自台灣海峽中部等共9個樣本加以分析。每一樣本量測所得之11個形質，經Burnaby法標準化後，依性別分別以直交變值分析法(Canonical variate analysis)及集群分析法加以分析。結果顯示，無論雌雄，全部之採樣區域皆可分爲3個集群：第一群爲東海北部群、第二群爲台灣沿岸群及其它採樣區組成之第三群。因蝦類成長至一定之大小或階段會從沿岸洄游至外海，故第二群(小個體)被視爲第三群(較大個體)之未加入之子代；兩群之形質變異，只是不同生活階段之故。因此，東海及台灣海峽產斑節蝦應可分爲二個系群：一爲東海北部群；另一群則分佈於台灣海峽與東海南部。本研究利用外部形態已成功之判別斑節蝦之系群結構，但更進一步之驗証如遺傳學証據是必須的。

關鍵詞：形質變異，系群結構，直交變值分析法，集群分析法。

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