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Population Densities and Annual Activities of *Mictyris brevidactylus* (Stimpson, 1858) in the Tanshui Mangrove Swamp of Northern Taiwan

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Jin-Taur Shih (1995) Population densities and annual activities of *Mictyris brevidactylus* (Stimpson, 1858) in the Tanshui mangrove swamp of northern Taiwan. *Zoological Studies* **34**(2): 96-105. This study reports on population densities, variations of population densities during the reproductive cycle, recruitment and growth of juveniles, and the egg-carrying period of *Mictyris brevidactylus* in the Tanshui mangrove swamp of northern Taiwan during 1988-1991. Peak population densities of crabs with carapace width (CW) > 4.0 mm occurred during the reproductive (egg-carrying, January to April) and prereproductive (October to December) seasons and reached 110-226 crabs/m^2. Low crab densities of 62-85 crabs/m^2 were found during nonreproductive season (May to September), with a value about one-third of the other two seasons. Annual crab densities (110-133 crabs/m^2) remained stable during the entire study period ($p = 0.6043$). After release of their broods, some of the one- and two-year-old crabs were found dead in their nests. The surviving crabs molted from May to July and continued growing increasing their CW 30% by November. Crabs were first observed carrying eggs in late January and were still being observed in late April. However, no egg-carrying crabs were found in May. The newly settled juveniles (1.2 mm CW) were first observed in April, attained 3.6 $\pm$ 0.4 mm CW, and comprised 70% of the total crab population density in June. At this time, the sexes of juveniles were identified. In December, most of juveniles reached > 5.5 mm CW and were almost sexually mature. The study of annual activities has helped understand the life history of *M. brevidactylus*.

Key words: Variations of population densities, Juvenile crabs, Recruitment, Egg-carrying period, Reproductive cycle.

The soldier crab, *Mictyris brevidactylus* is one of four species in the family *Mictyridae* (Crustacea, Decapoda). *Mictyris brevidactylus* occurs in most of the main estuaries on the west coast of Taiwan (Lin 1949, Takeda 1978, Fukui et al. 1989, Huang et al. 1992). Recently, the ecology and the reproductive biology of *M. brevidactylus* of Taiwan have been studied (Huang 1991, Shih et al. 1991, Shih and Chang 1991, Shih 1993). Research on other aspects of *M. brevidactylus* has been rare.

Nakasone and Akamine (1981) studied the population composition of *M. brevidactylus* in Okinawa and reported that it was mostly composed of two age classes, namely zero- and one-year-old crabs. The population densities of some mangrove-associated crabs, but not *M. brevidactylus*, were reviewed by Jones (1984). Similar studies on other speices of crab indicate that habitat, food, temperature, salinity, seasons, and interannual influences have caused variations of population abundance, or densities (Frith and Brunenmeister 1980, Hines et al. 1987 1990, Orth and Montfrans 1987, Shih 1990 1992, Shih et al. 1991, Hsueh 1991 1992, Hsueh et al. 1992 1993, McClintock et al. 1993). Therefore, it is necessary to study crab populations for long periods of time at various parts of its habitats for better understanding of their dynamics.

The Tanshui River has become polluted in recent years (Shih et al. 1991). It is urgent whether and how water pollution has affected the fauna of the Tanshui mangrove swamp. Before such evaluation can be made, a study on the faunal base data must be made. This work describes the variations of population densities during the reproductive cycle, recruitment and the growth of juveniles, and the egg-carrying period of *M. brevidactylus* in the Tanshui mangrove swamp during 1988-1991. Furthermore, this study provides basic information concerning the estuarine ecosystem of the Tanshui mangrove swamp itself. Such a population density study of *M. brevidactylus* may serve as a biological indicator by which to gauge the impacts of water pollution in the Tanshui River on this swamp.

MATERIALS AND METHODS

Study stations

The Tanshui mangrove swamp is located on the north bank of the Tanshui River mouth, Taiwan (25°08′N, 121°27′E; Fig. 1). This crescent-shaped swamp covers about 65 hectares and is bordered on the west by a loamy sand flat about two kilometers long. The habitat of *M. brevidactylus* is characterized by their hummocks which are located in the intertidal zone along the riverside during ebbtide. For this population study, six arbitrary study stations separated by 150-200 meter intervals were designated as M-1 to M-6 (Fig. 1). Since no *M. brevidactylus* were found on the north or east sides of this swamp, no stations were established in these areas.

Collection of crabs

Field work was carried out at neap tide at least once every month during 1988-1991. At each study station, one sampling site was selected and a substratum sample of 1m × 1m × 0.2m was excavated. After breaking up the substratum, *M. brevidactylus* of visible size (> 4.0 mm carapace width, CW) were collected. The density of crabs collected from the substratum unit was expressed as the number of crabs per square meter. Due to inclement weather (rain, low temperature), disturbed habitat, or shortage of manpower, the number of samplings varied from month to month throughout the study period. For instance, M-1 and M-4 were chosen for a crab density study in 1988 and 1991. From 1989 to 1990, four to six samplings were taken at random from the six study stations according to month. Monthly mean (± 1 SE) crab densities represent the averaged densities of crabs from more than two samplings during that particular month (except July to November of 1991). Crabs were taken to the laboratory, rinsed, and wrapped in tissue paper to absorb excess water; then the sexes were identified and the carapace width of each individual was recorded. For this study, zero-year-old crabs were defined as juveniles which settled in April and became almost sexually mature by December of the same year. When the zero-year-old crabs reached January of the second year they were defined as one-year-old crabs. Crabs which entered the third year were defined as two-year-old crabs (Nakasone and Akamine 1981).

Data analysis

Because the stations at which samples were taken and the number of samplings varied from month to month, variations of *M. brevidactylus* density among stations for a single month were analyzed by one-way ANOVA. According to Shih (1993), the annual reproductive cycle of *M. brevidactylus* of Taiwan has three periods: reproductive

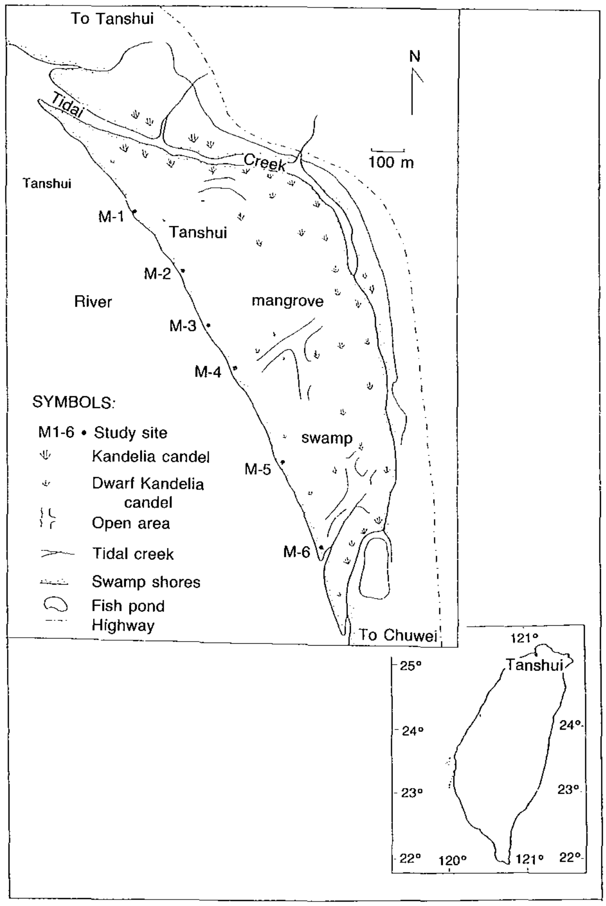


Fig. 1. Location of the Tanshui mangrove swamp of northern Taiwan and the study stations. Inset locates Tanshui on a map of Taiwan.

(egg-carrying, January to April), nonreproductive (May to September), and prereproductive (October to December) seasons. For purposes of analysis, the seasonal mean (± 1 SE) crab densities were calculated. The seasonal mean (± 1 SE) crab density variations within the same year and among years were also analyzed by one-way ANOVA. The size frequency distributions of male and female crabs were analyzed using a Sigmaplot 5.0 Program.

RESULTS

Population densities

As shown in Table 1, a total of fourteen samples were taken for crab density study in the month of January during the study period (1988-1991). No significant variations in crab density were found among the six stations ($F=0.630$, 5 and 8 *df*, $p=0.68$). The crab density at station M-6 in December 1991 was very high and caused a slight variation ($F=5.428$, 5 and 5 *df*, $p=0.04$). No significant variations were found among stations for the other eleven months.

The annual pattern of monthly mean (± 1 SE) densities of *M. brevidactylus* (>4.0 mm CW) in 1988 is shown in Fig. 2a. The first population density peak (146-226 crabs/m^2) occurred from

Table 1. The density variations of *Mictyris brevidactylus* among samplings taken at random from six study stations for each month in the Tanshui mangrove swamp during 1988-1991[a]

Month	*F*	*df*	*p*
January	0.630	5, 8	0.6828
February	2.705	5, 9	0.0923
March	1.068	5, 8	0.4434
April	0.902	5, 8	0.5236
May	2.356	5, 8	0.1347
June	0.529	5, 6	0.7490
July	0.969	4, 7	0.4803
August	1.295	4, 7	0.3580
September	0.520	5, 3	0.7559
October	2.064	5, 6	0.2017
November	1.131	5, 6	0.4345
December	5.428	5, 5	0.0435[b]

[a]Crab densities from samples taken at random from the six study stations in the same month during 1988-1991 were pooled and analyzed by one-way ANOVA.
[b]In December 1990, the crab density at M-6 station was very high (272 crabs/m^2) and caused variations (p = 0.0435).

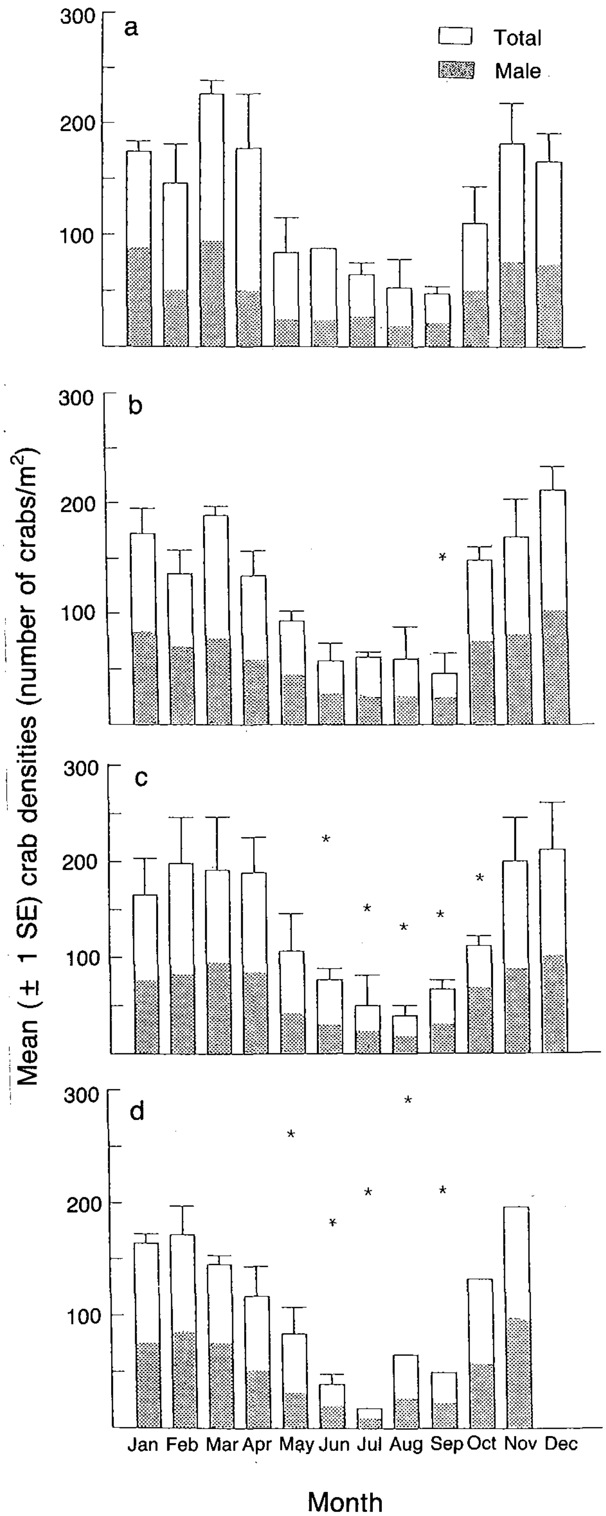


Fig. 2. Monthly mean (± 1 SE) densities of *Mictyris brevidactylus* (>4.0 mm CW) in the Tanshui mangrove swamp of northern Taiwan during 1988-1991. Numbers of samplings are different for each year, (a) for 1988, $n=2$; (b) for 1989, $n=4$-6; (c) for 1990, $n=4$-6; (d) for 1991, $n=1$-2. Asterisks represent the total population density of zero-, one- and possibly two-year-old crabs.

January to April (reproductive season). The second peak (110-182 crabs/m^2) occurred from October to December (prereproductive season). Low crab densities occurred during the nonreproductive season (May to September) and reached 67 crabs/m^2, which was about one-third to one half of densities during the reproductive or prereproductive seasons. Similar annual patterns of monthly mean (± 1 SE) crab densities from 1989 to 1991 are shown in Figs. 2b, 2c, and 2d. The mean (± 1 SE) densities of the 1988 reproductive season show significant variations ($p<0.03$) when compared to the mean densities during the 1989, 1990, and 1991 reproductive seasons. Variations ($p<0.02$) were also found among prereproductive seasons of different years, but no variations ($p=0.93$) were found between nonreproductive seasons. However, annual mean (110-133 crabs/m^2) crab densities showed no significant variations during the entire study ($p<0.60$).

Recruitment and growth of juvenile crabs

Newly settled juvenile crabs (zero-year-old, 1.2-2.5 mm CW) were first found in mid-April. Therefore, the population of *M. brevidactylus* was comprised of at least two age classes, namely zero-, one- and possibly two-year-old crabs in April. In May, zero-year-old crabs reached a mean size of 2.8 ± 0.5 mm CW. Due to the small size, only one population density study of zero-year-old crabs was conducted in May of 1991 (Fig. 2d) when their density reached 178 crabs/m^2 and they comprised 67.9% of the population. The author was unable to determine the sexes of young crabs in May. During June to September of 1990 and 1991, the population density of zero-year-old crabs was studied at station M-3 (Figs. 2c and d). As shown in Fig. 2c, the densities of zero-year-old crabs were 85-145 crabs/m^2 which represented 57.1-68.5% of the total population.

Zero-year-old crabs grew rapidly during the summer months. Fig. 3 and Fig. 4 show the size frequency distributions of the zero- and one-year-old crabs in 1990 (results for 1989 and 1991 not shown). Zero-year-old crabs reached a mean size of 3.6 ± 0.4 mm by June. At this time, the juveniles formed the dominant age group in the size frequency distribution analysis. The sexes of young crabs were determined at this time. The mean carapace width of male zero-year-old crabs reached 4.4 ± 0.3 mm, 5.1 ± 0.4 mm, and 5.2 ± 0.3 mm CW in July, August and September, respectively. The females attained 5.1 ± 0.2 mm CW in September. Most zero-year-old crabs reached > 5.5 mm CW by October and mixed with the one-year-old crabs (9.8 ± 0.5 mm CW).

After releasing broods, the one- and two-year-old crabs molted between May and July. During this period, dead crabs (> 7.0 mm CW) were found in their nests. The surviving crabs continued growing and their mean CW increased from 7.6 ± 0.6 mm to 9.8 ± 0.5 mm by November. The sex ratio varied from month to month and was biased toward more females as shown in Fig. 2. The annual male to female ratios were 0.60, 0.93, 0.74 and 0.81 for the years 1988 to 1991, respectively.

Egg-carrying period

Egg-carrying crabs were first recorded in late January in the Tanshui mangrove swamp. The crabs which were used to determine the percentage of egg carriers were from the samplings used for the density study. As shown in Fig. 5, stations M-1 and M-2 were chosen to record frequency of egg-carrying crabs from January to April in 1988 and there were 3-4%, 48.8-53.0%, 78.2-79.7%, and 13.9-20.8% egg-carrying crabs in each month respectively. No difference was found between these two stations. However, there were differences among stations during 1989-1991. For instance, in February 1990, 17.0% of females were egg-carriers at station M-2 compared to 72.0% at station M-5. In March, egg-carriers at M-2 reached 91.1% while at M-5 they had already dropped to 57.5%. Two results were recorded during the entire study period: 1) the peak phase of egg-carrying crabs was in March; and 2) no egg-carrying crabs were found in May.

DISCUSSION

M. brevidactylus occurs in great abundance in the Tanshui mangrove swamp of northern Taiwan. Crab densities peak in the reproductive season in the first part of the year, and the population is comprised of at least two age classes, namely one- and two-year-old crabs. The second peak phase is found in the prereproductive season. Similarly, Huang (1991) found 58-258 crabs/m^2 in mid-Taiwan from March to April in 1990. But the crab density for *M. longicarpus* in Okinawa reported by Yamaguchi (1976) was 33-66 crabs/m^2, and it was relatively low compared with values found in this study. In the nonreproductive season, crab densities are relatively low compared with

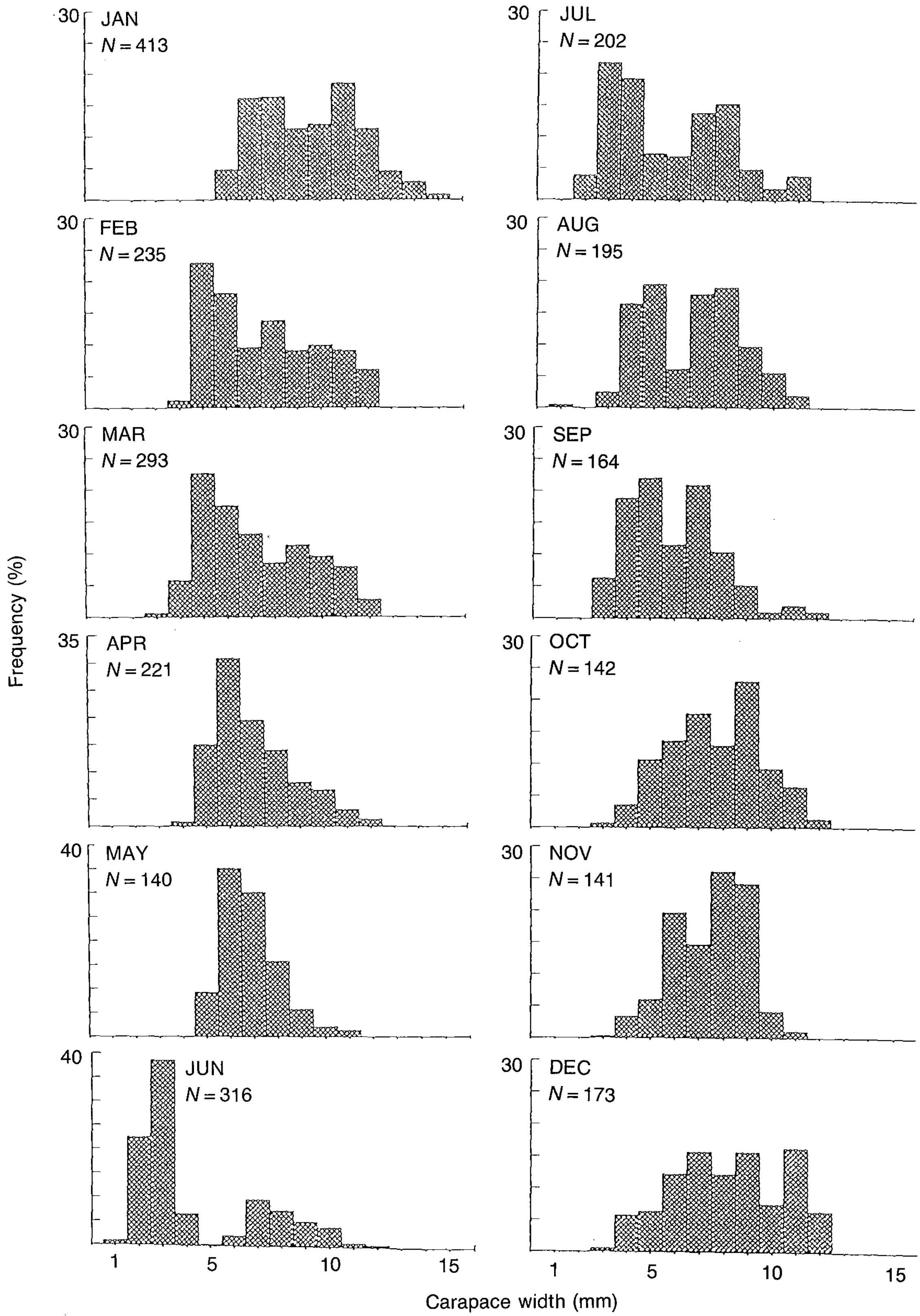


Fig. 3. Size frequency distributions of male *Mictyris brevidactylus* collected in 1990. Sample sizes (*n*) are given for each graph.

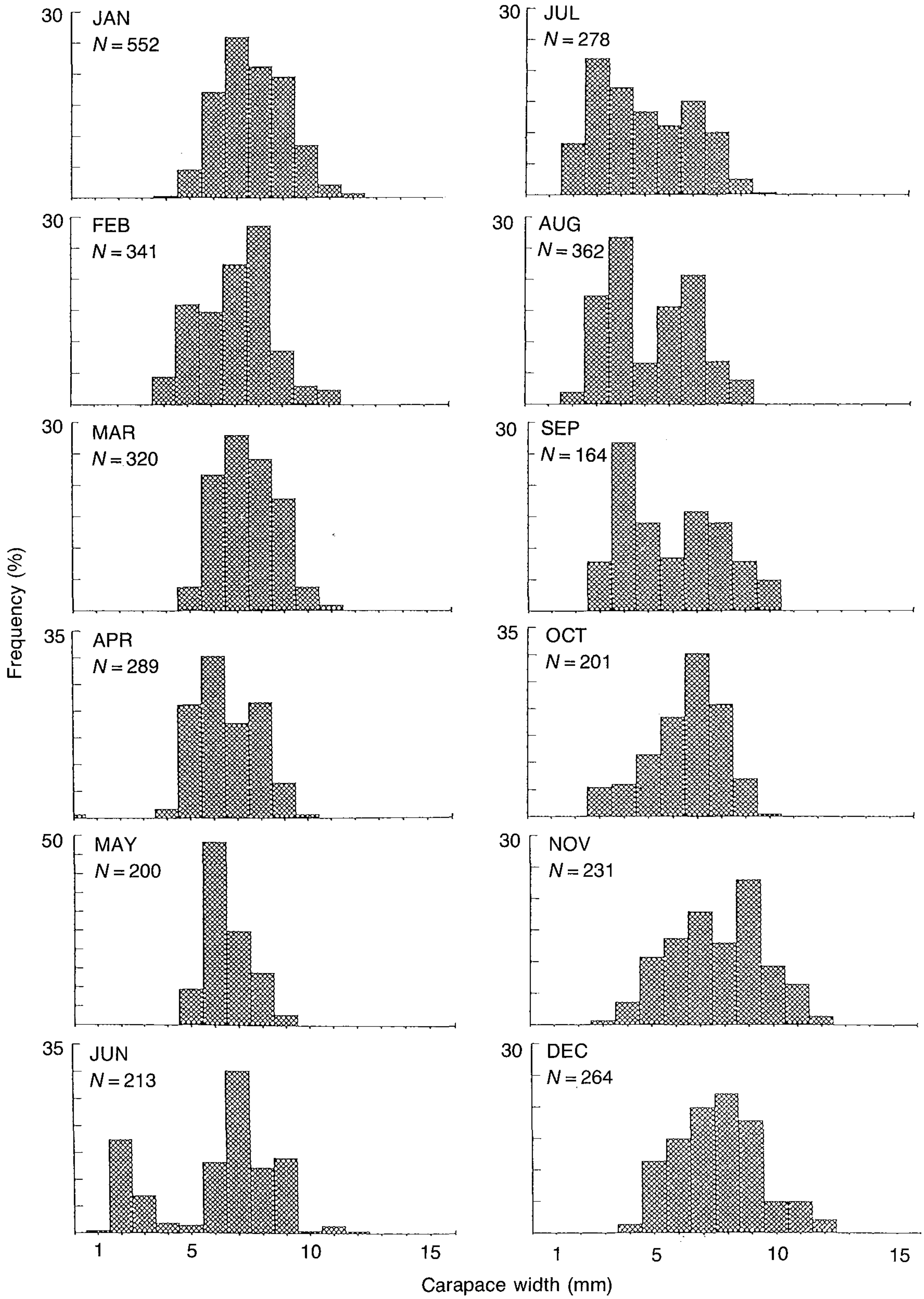


Fig. 4. Size frequency distributions of female *Mictyris brevidactylus* collected in 1990. Sample sizes (*n*) are given for each graph.

the other two seasons. The author has two observations which may explain low densities in the nonreproductive season: 1) crabs (> 7.0 mm CW), which had died supposedly of natural causes, were found in their nests in late April; and 2) Ocypodes began eating *M. brevidactylus* in May. However, the zero-year-old crabs comprised about 70% of the crab population from June to September. After the recruitment of the newly settled juveniles, the population densities recovered from a low phase in the nonreproductive season to the peak phase in the prereproductive season. In addition, annual mean densities of *M. brevidactylus* showed no significant variations from 1988 to 1991, therefore the present study demonstrated that the cycling annual population densities remained relatively stable during the course of the entire study.

Crab habitats, food, temperature, salinity, seasons and interannual influences have been reported to affect the crab population abundance, or densities (Frith and Brunenmeister 1980, Hines et al. 1987 1990, Orth and Montfrans 1987, Shih 1990 1992, Hsueh 1991 1992, Hsueh et al. 1992 1993, McClintock et al. 1993). It is also true that the habitat of *M. brevidactylus* in the Tanshui mangrove swamp is affected by tides and floods. Even the organic content and the soil texture varied between study stations (Shih et al. 1991). However, these differences in habitat seemed to little affect the local densities of *M. brevidactylus*. First, no significant variations in population densities were found among samples taken from the six stations in any single month. Second, this species occurred along a two kilometer strip of intertidal zone habitat. Crabs were found to move around seeking more suitable substratum. In fact, the newly settled juveniles were found in thin substratum (1-2 cm). When juveniles were older, they moved to relatively thicker substratum (> 10 cm). Besides the reproductive cycle, lateral redistribution and the recruitment of juveniles, the author is unaware of any other factors which might have affected the population densities of this crab.

Annual activities of *M. brevidactylus*, observed in this study and from the author's previous report, are summarized in Fig. 6. Crabs were first observed to carry eggs in late January and to reach the peak phase in March. No egg-carrying females were observed in May. Even in March, percentage of the egg-carrying females varied from station to station. Presumably crabs started to breed asynchronously at the six stations along the riverside. Huang (1991) also observed that female *M. brevidactylus* in the mid-Taiwan had the same egg-carrying

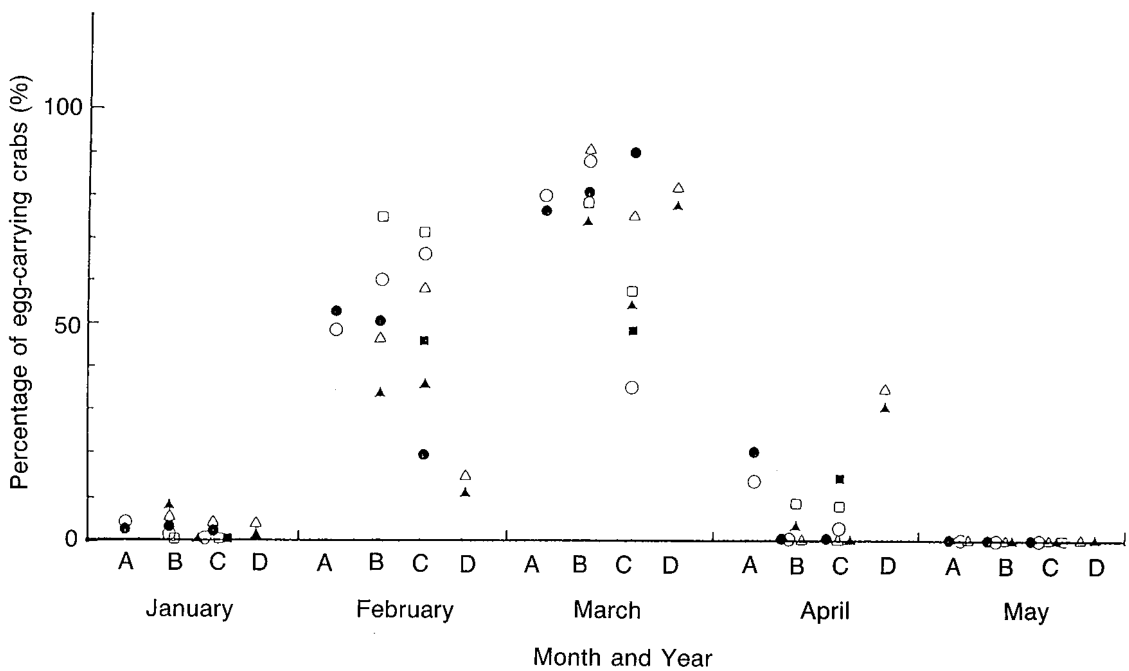


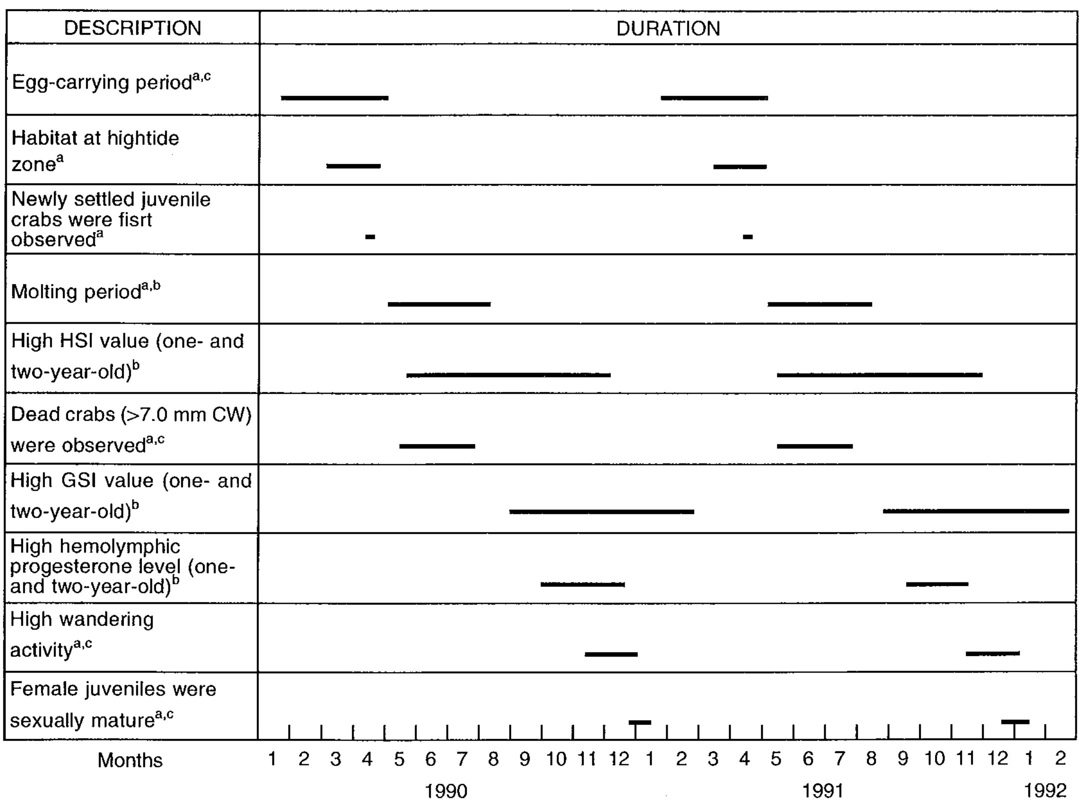
Fig. 5. The percentage of egg-carrying female *Mictyris brevidactylus* from January to May during 1988-1991. Letters A, B, C, and D represent the years of 1988, 1989, 1990, and 1991, respectively. The symbols ○, ●, △, ▲, □, ■ represent the six study stations (M-1 to M-6 in Fig. 1). The number of female crabs used for analyses varied between 215 and 456 per month during the entire study period.

period as reported in this study. However, Yamaguchi (1976), and Nakasone and Akamine (1981) reported that for *M. longicarpus* in Okinawa and *M. brevidactylus* in Japan the egg-carrying periods were from December to March. It is clear that the breeding season occurs in the cold of winter in both Japan and Taiwan.

Between March and April, the habitat of *M. brevidactylus* was in the hightide zone. It is believed that female crabs began releasing their broods at this time (Jones 1984). Since the development of zoea and megalopa larvae was not studied, the time of larval settlement is unknown. However, newly settled juvenile crabs (1.2 mm CW) were first observed in April. The length of the brood incubation period is presumably 30-45 days as reported by Nakasone and Akamine (1981).

M. brevidactylus (> 5.5 mm CW) molted following the breeding season. Crabs associated with mangroves are reported to molt after breeding (Cheung 1969, Webb 1977, Nakasone and Akamine 1981, Chang et al. 1985, Shih et al. 1991). During the molting period, dead crabs were observed in their nests and beside the openings of the hummocks. Although mortality was not specifically studied, based on the population density study, it is possible to estimate that at least half of the one- and two-year-old crab population did not survive the nonreproductive season. Life span was not studied, but it is possible that a small number of crabs lived for three years as suggested by Nakasone and Akamine (1981). After molting, the surviving one- and two-year-old crabs experienced peak values of their hepatosomatic index during May-November. The gonadosomatic index (GSI) values and hemolymphic progesterone levels increased to peak levels by December. At this time, one-year-old females were ready for a second cycle of reproduction, and became two-year-old crabs (by definition) in the following January.

Newly settled juveniles comprised about 70% of the crab population in June. Similarly, Nakasone and Akamine (1981) found that zero-year-old *M. brevidactylus* in Okinawa comprised 75% of the population in April. The zero-year-old crabs grew rapidly during the summer months and attained



[a]Shih et al. (1991).
[b]Shih (1993).
[c]This study.

Fig. 6. The annual activities of *M. brevidactylus* in the Tanshui mangrove swamp of northern Taiwan during 1990-1992.

> 5.5 mm CW by October. These crabs had low GSI values and low hemolymphic progesterone levels until September. By December, after both GSI and progesterone values had increased two to threefold, the zero-year-old crabs were almost sexually mature.

Populaton densities of *M. brevidactylus* fluctuated with the reproductive cycle. The lowest density was found in the nonreproductive season. This drop in density was due largely to the natural death of the one- and two-year-old crabs. In the same period, recruitment of juvenile crabs caused the population density to recover from the yearly low to high density. During the course of the study, annual mean densities remained relatively stable. The present study demonstrates that a long period of study time is required for an assessment of the cycling population densities of mangrove-associated crabs. The composition and texture of crab habitat changes from time to time in the Tanshui mangrove swamp (Shih et al. 1991), but it did not appear to affect the density significantly. The crabs' food, plus other factors such as salinity, and temperature which may affect the population density should be studied to clarify their roles. A complete life history, including such information as fecundity, development of zoea and megalopa, and mortality which were not included in this study, would certainly help to better understand variations of population densities of *M. brevidactylus*.

The present study provides basic information on the estuarine ecosystem of the Tanshui mangrove swamp and can serve as a biological indicator for the impact of water pollution in the Tanshui River on this swamp. Currently efforts are being made to clean up the pollution in the Tanshui River. The population density of *M. brevidactylus* should be studied again after pollution in the Tanshui River has been reduced. This follow up data should then be compared with the present study in order to evaluate the effect of water pollution in the Tanshui River on the fauna of this swamp.

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淡水紅樹林短趾和尙蟹(*Mictyris brevidactylus*)之族群密度及年活動周期

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本研究報告1988－1991間淡水紅樹林沼澤區內短趾和尙蟹的族群密度、族群密度隨生殖季節的變化、幼蟹的補充和生長及成蟹的抱卵期。短趾和尙蟹(＞4.0mm CW)於一年內有兩個族群密度高峯期，第一高峯期在元月至四月(抱卵期)，另一個見於十月至十二月(生殖前期)，其族群密度爲110-226隻／m^2。低族群密度在五月至九月(非生殖期)，僅有62-85隻／m^2，約爲另二期的三分之一。不過四年研究期間，其族群年平均密度並無顯著的差異(p=0.6043)，頗爲穩定。成蟹於四月底釋放幼蟲後，於五至七月間脫皮，此期間有部分成蟹死亡。存留的成蟹繼續生長，至十二月可再度行生殖。於元月底首見抱卵之雌蟹，至四月底仍可見抱卵之蟹，但五月已不再見。幼蟹(1.2mm CW)於四月出現於棲地，六月時其背甲寬達3.6±0.4mm，約構成棲地短趾和尙蟹族群密度的70％，其性別也是於六月方可辨認。經過夏天之迅速生長，至十二月幼蟹背甲寬均超過5.5mm，並且已達性成熟。文中有短趾和尙蟹年活動周期的記錄，對瞭解其生活史有所助益。

關鍵詞：族群密度的變異, 幼蟹, 幼蟹的補充, 抱卵期, 生殖周期。

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