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Population Dynamics and Mantle Autotomy of the Figsnail *Ficus ficus* (Gastropoda: Mesogastropoda: Ficidae)

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Li-Lian Liu and Sheau-Ping Wang (1999) Population dynamics and mantle autotomy of the figsnail *Ficus ficus* (Gastropoda: Mesogastropoda: Ficidae). *Zoological Studies* **38**(1): 1-6. *Ficus ficus*, a member of the Mesogastropoda, exhibits a special behavior of mantle autotomy as a defensive mechanism. This study was conducted to characterize the population dynamics of *F. ficus* and the occurrence of autotomic behavior in the field. Monthly collections of *F. ficus* were made between May 1992 and June 1993. A total of 2186 individuals were sampled with shell lengths ranging from 28 to 95 mm. Small individuals with shell lengths < 35 mm were found only between July and September 1992. Seasonal variation in the abundance of figsnails was observed: while few figsnails (less than 75 individuals) were collected from May to July, abundant snails were obtained from November to February. Sexual dimorphism in shell length (male < female) was also found. Sex ratios varied from 0.3 to 2.3 in favor of females between March and September. The male-biased sex ratios observed between October and February indicate that egg-laying migration might exist. The autotomic tissue weighed from 0.03 to 8.86 g and comprised 0% to 34% of the total body weight. A negative correlation between the percentage of autotomic tissue and shell length was observed ($y = 30.88 - 0.27x$; $R^2 = 0.35$; $p < 0.01$). Figsnails with newly regenerated tissue (indication of recent occurrence of defensive autotomy) comprised < 1% of the total samples, with 0 to 3 individuals appearing in each monthly collection. The results indicate that autotomized figsnails might be more vulnerable to predation than are intact snails, or that the occurrence of defensive autotomy in natural environments might be low.

Key words: *Ficus ficus*, Figsnail, Population dynamics, Autotomy.

Figsnails (Mesogastropoda: Ficidae) are commonly found in the warm seas of the world (Feinberg 1979), yet little is known about the biology of this relatively small family. Based on previous studies, it is known that figsnails are medium to large in size, lack an operculum, and have a radula of the taenioglossan type. As far as we are aware, there are 12 species in this family: *Ficus ventricosa* (Sowerby), *F. gracilis* (Sowerby), *F. subintermedia* (Orbigny), *F. variegata* Roding, *F. carolae* Clench, *F. communis* Roding, *F. filosa* (Sowerby), *F. eospila* (Peron-Lesueur), *F. howelli* Clench and Farfante, *F. atlanticus* Clench and Aguayo, *F. investigatoris* E.A. Smith (Abbott and Dance 1983), and *F. ficus* Linnaeus (Lai 1987). Four species, i.e., *F. ficus*, *F. gracilis*, *F. subintermedia*, and *F. filosa*, have been recorded (Lai 1987) from Taiwan with *F. ficus* the most common species.

Among the 12 species of *Ficus*, *F. subintermedia* and *F. ficus* are the best known. In *F. subintermedia*, Arakawa and Hayashi (1972) reported sexual dimorphism of the shell (female > male) and propodium (edges of propodium blunt in female and hook-shaped in male). In *F. ficus*, Wang (1993a) observed that copulation and egg-laying often occurred at night to early morning in the laboratory during the period of November to February, and undigested polychaetes (*Onuphis* sp. and *Diopatra* sp.) were found in the stomach. Liu and Wang (1996) reported that *F. ficus* under stress sheds a certain part of its mantle on the side

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of the inner lip as a special defensive mechanism. Regeneration of the autotomic tissue occurred in the following week and reached a normal size within 2 mo. The newly regenerated tissue is thin, membrane-like, and shows color changes from transparent white to white. Moreover, defensive autotomy can not be induced in figsnails with newly regenerated thin membrane-like tissues. Thus, based on the appearance and the size of the autotomic tissue, recently autotomized snails can be easily recognized in the field.

Figsnails can be caught in sandy or muddy subtidal habitats by bottom trawling (Lai 1987). In Taiwan, they are a common edible shellfish with low economic value due to the toughness of the autotomic tissue. In general, people eat figsnails after removing the autotomic tissue. The figsnail is a bycatch of the shrimp fishery off the west coast of Taiwan and in the Taiwan Strait. Since they can be caught in large numbers and the newly regenerated tissue can be identified by size and appearance, we thought it feasible to study them, especially since mantle autotomy in meso-gastropods is uncommon. Therefore, studies on the population dynamics and mantle autotomy of *F. ficus* were initiated.

MATERIALS AND METHODS

Monthly collections of *F. ficus* were made between May 1992 and June 1993 on the 5th, 6th, or 7th day of the month by bottom trawling off the coast of Kaohsiung (120°17′E, 22°38′N). Trawling was made by fishing boat at depths of 30 to 40 m for 40 min through a distance of about 30 km. During trawling, the autotomic behavior of *F. ficus* might have been induced. Such autotomized snails could be recognized as those lacking autotomic tissue and by a wound mark on the mantle. Based on the condition of autotomy, the collected figsnails were sorted into autotomized (without autotomic tissue, i.e., portion of mantle had been cast off during trawling) and intact (with autotomic tissue) groups. After the status of autotomy was recorded, figsnails were separated according to their sex: males are those with a vas deferens and penis, and females are those with a female opening and albumen gland. Then, shell length, total body weight (after removal of shell), and autotomic tissue weight (if present) were recorded. The percentage of autotomic tissue relative to total body weight was determined as (autotomic tissue weight/total body weight) x 100%.

χ^2-tests were used to determine the sex ratio and the difference of shell length between the 2 sexes (SAS 1985). The relationship between shell length and percentage of autotomic tissue was evaluated by linear regression analysis, and covariance analysis was used to test for a difference between slopes of males and females.

RESULTS

A total of 2186 individuals was collected from May 1992 to June 1993. Autotomized figsnails, apparently induced by trawling, numbered 1574 comprising 72% of the total samples, with the rest being 612 intact individuals. A positive relationship between shell length and body weight was found in *F. ficus* when autotomic tissue was excluded ($y = 1.900 - 0.106x + 0.001x^2 + 6.386E\text{-}5x^3$; $R^2 = 0.90$; $p < 0.01$, $N = 2186$).

The analyses of monthly size frequency histograms from May 1992 to June 1993 showed that shell length of *F. ficus* ranged from 28 to 95 mm (Fig. 1). Small individuals with shell lengths of < 35 mm were found only from July to September. Seasonal variation in abundance was also observed: more than 200 figsnails were collected from November to February, and fewer than 75 individuals were collected from May to July. Sexual dimorphism in shell length, with females being significantly larger than males, was also observed (Fig. 1; Table 1).

Sex ratios deviating from 1:1 were common (Table 1), with female to male ratios ranging from 0.3 to 2.3. In general, more females than males were found from March to September, with female to male ratios ranging from 0.9 to 2.3. However, from October to February, ratios changed to 0.3 to 0.8 in favor of males.

In the intact group ($N = 612$), the weight of autotomic tissue ranged from 0.03 to 8.86 g, and it comprised 0% to 34% of total body weight (Fig. 2). A distributional gap of between 2% to 5% was observed. Figsnails with autotomic tissue at < 1% of the total weight were recognized as having recently autotomized in the field. The autotomic tissue was semitransparent white and small. A total of 19 figsnails occurred in monthly numbers of 0 to 3.

Because the newly regenerated autotomic tissue was small, the tissue contributed very little (almost 0%) to total body weight. However, this may have influenced the data analysis of the relationships between shell length and body

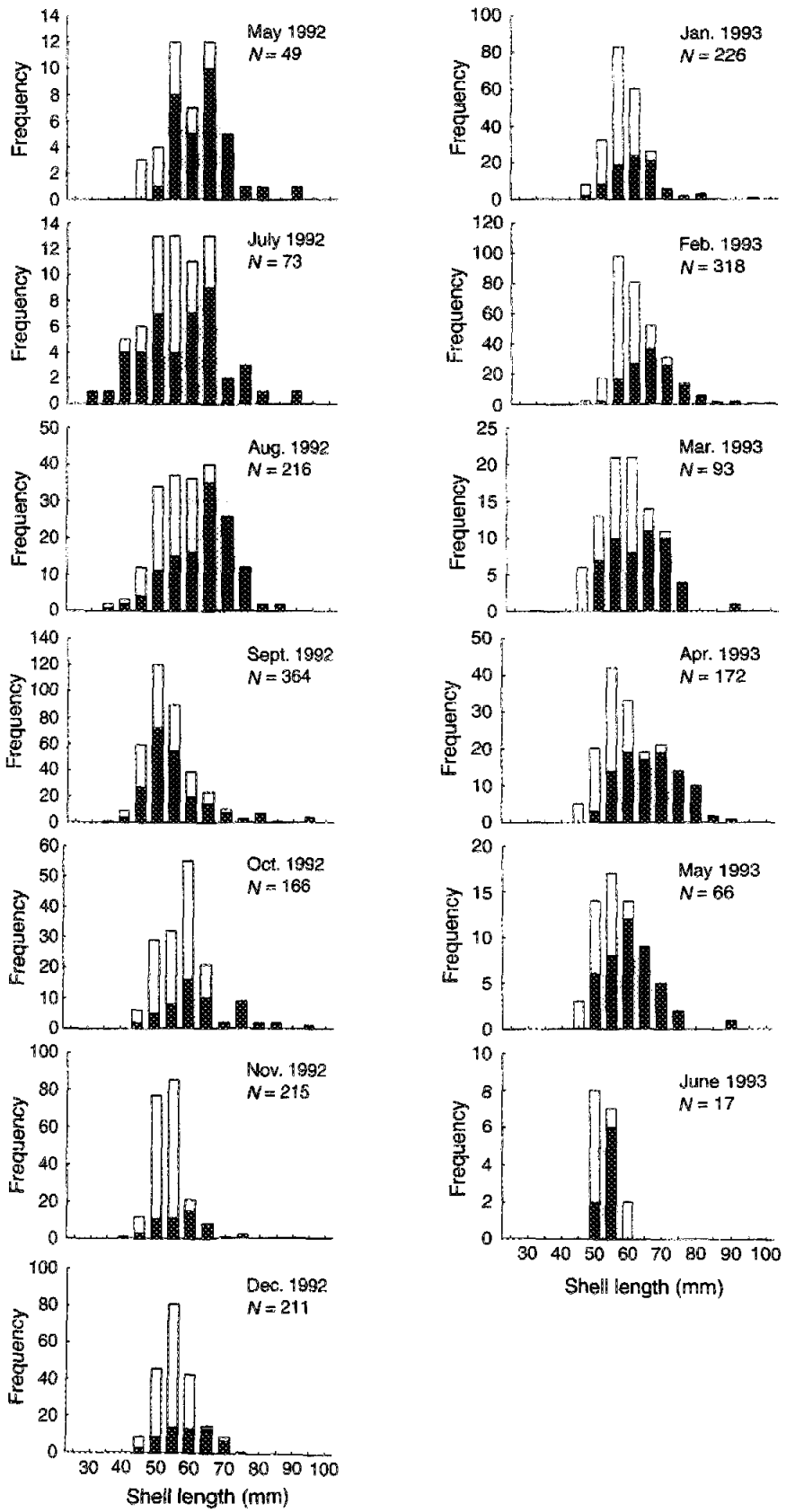

Fig. 1. Size-frequency histograms of *Ficus ficus*. Filled histograms: female; open histograms: male.

weight, and between shell length and percentage of autotomic tissue. Therefore, these 19 individuals were excluded in the following calculations, leaving 593 individuals (286 females and 307 males) for further consideration. A positive relationship between shell length and body weight was found, i.e., $y = 1.037x - 0.018x^2 + 1.722E\text{-}4x^3 - 19.329$; $R^2 = 0.90$; $p < 0.01$. The percentage of autotomic tissue in males and females varied monthly, but no trend could be determined (Fig. 3). Negative correlations between the percentage of autotomic tissue and shell length were found in both males and females. By covariance analysis, slopes of males and females showed no differences ($p > 0.05$). Therefore, males and females were pooled to calculate the regression equation. A negative correlation between the percentage of autotomic tissue and shell length was obtained, i.e., $y = 30.88 - 0.27x$; $R^2 = 0.35$; $p < 0.01$ (Fig. 4).

DISCUSSION

An unbalanced sex ratio in favor of females, following the seasonal cycle of copulation and spawning, has been reported for many gastropods, such as *Buccinum undatum*, *Urosalpinx cinerea*, and *Eupleura caudata* (Cole 1942, MacKenzie 1961, Martel et al. 1986). A general migration towards the rocky substrata in shallower water for egg-laying and a return to the deeper soft substrata for food such as bivalves have been observed in *B. undatum* (Martel et al. 1986). It is assumed that such migration serves to locate sites for either favorable larval development or minimizing predation. Thus, the varied sex ratios for *F. ficus* in our monthly samples (Table 1) would indicate that egg-laying migration may exist. According to Wang (1993a), the peaks of copulation and egg-laying in *F. ficus* are from November to January

Table 1. Mean shell length and sex ratio of *Ficus ficus*

Month	*N*	Sex	Shell length (mm) (mean ± std)	χ^2-test significance	Sex ratio (F/M)	χ^2-test significance
May 92	34	F	54.9 ± 5.3	$p < 0.01$	2.3	$p < 0.05$
	15	M	47.2 ± 3.5			
July 92	46	F	58.7 ± 11.0	$p < 0.01$	1.7	$p > 0.05$
	27	M	51.8 ± 6.5			
Aug. 92	133	F	61.9 ± 8.3	$p < 0.01$	1.6	$p < 0.01$
	83	M	51.6 ± 5.9			
Sept. 92	213	F	60.0 ± 11.9	$p < 0.01$	1.4	$p < 0.01$
	151	M	52.6 ± 6.2			
Oct. 92	59	F	60.9 ± 10.2	$p < 0.01$	0.6	$p < 0.01$
	107	M	54.0 ± 5.3			
Nov. 92	52	F	54.5 ± 6.3	$p < 0.01$	0.3	$p < 0.01$
	163	M	50.1 ± 3.8			
Dec. 92	62	F	56.5 ± 7.4	$p < 0.01$	0.4	$p < 0.01$
	149	M	52.3 ± 4.2			
Jan. 93	88	F	58.5 ± 8.1	$p < 0.01$	0.6	$p < 0.01$
	138	M	52.9 ± 4.3			
Feb. 93	138	F	63.6 ± 8.7	$p < 0.01$	0.8	$p < 0.05$
	180	M	54.9 ± 4.5			
Mar. 93	52	F	59.8 ± 8.1	$p < 0.01$	1.3	$p > 0.05$
	41	M	52.7 ± 6.3			
Apr. 93	102	F	64.2 ± 8.9	$p < 0.01$	1.5	$p < 0.05$
	70	M	52.1 ± 5.1			
May 93	45	F	63.4 ± 8.2	$p < 0.01$	2.1	$p < 0.01$
	21	M	53.0 ± 4.7			
June 93	8	F	50.5 ± 2.3	$p > 0.05$	0.9	$p > 0.05$
	9	M	50.0 ± 4.1			

F: female; M: male.

and January to February, respectively. Laid egg capsules are translucent-white and rectangular, about 0.5 to 1 cm long without a stalk (Fig. 5). Thus, our collection of fewer females during the reproductive season (October to February) would signify that a copulated female *F. ficus* might migrate to sites with hard substrata to deposit its egg capsules for firm attachment. Although few *F. ficus* individuals were observed between May and July (Fig. 1; Table 1), no explanation for this phenomenon is available.

Furthermore, figsnails smaller than 28 mm were not collected in our sampling site. Similarly, bottom trawlings near our sampling site at depths of 10 to 30 m did not reveal small individuals either (H.Y. Chen pers. comm., L.S. Feng pers. comm.). Certainly the habitat of juvenile figsnails must differ from that of adults. However, it is unknown whether the juvenile stays remains at the spawning ground.

We found a low incidence of figsnails (19 individuals; see Fig. 2) with newly regenerated tissue (indication of recent defensive autotomy in the field) in our samples. According to the study by Liu and Wang (1996), the mantle tissue of *F. ficus* increases in size and acts as a protective cover when the animal is under stress. If the stress is relaxed, the mantle tissue is restored to its original condition. Otherwise, shedding of the autotomic tissue occurs. In other words, if predatory pressure is not long-lasting and/or severe enough, defensive autotomy may not be induced. Therefore, the low number of figsnails with newly regenerated tissues may indicate that predatory stress did not reach the level which evokes defensive autotomy during our study period. If stress had induced defensive autotomy, then many of the autotomized figsnails would have died since they are more vulnerable to predation than intact snails. Another possibility is that predation pressure of *F. ficus* might be low in

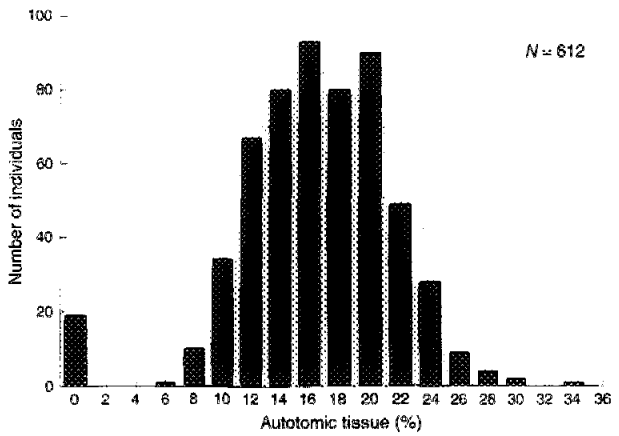

Fig. 2. Frequency histograms of the percentage of autotomic tissue weight relative to total body weight in *Ficus ficus*.

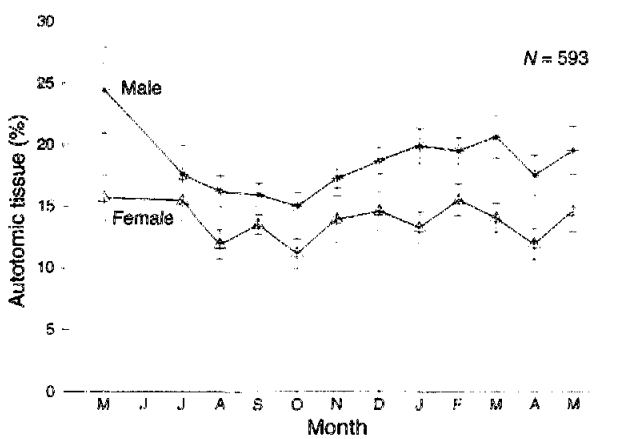

Fig. 3. Seasonal variations in percent of autotomic tissue weight relative to total body weight in *Ficus ficus*. Error bars: 95% confidence interval of the mean.

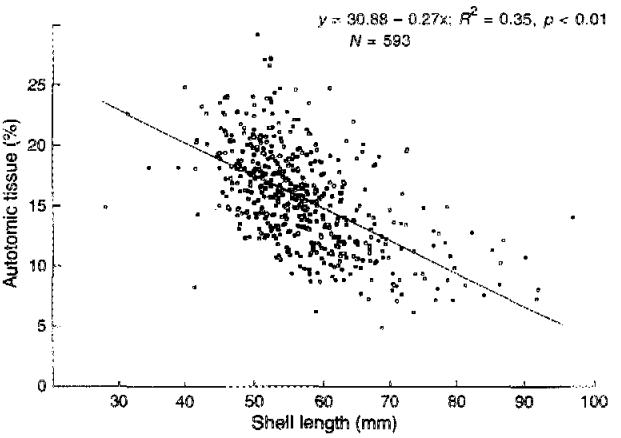

Fig. 4. Relationship between shell length and percentage of autotomic tissue relative to total body weight in *Ficus ficus*.

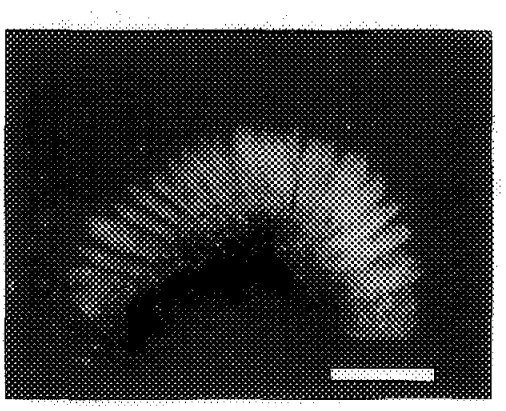

Fig. 5. Egg capsules of *Ficus ficus*. Scale bar = 1 cm.

natural environments. Although predation of *F. ficus* in the field is unknown, puffer fish and box crabs are known to attack live figsnails in the laboratory (pers. observation). As puffer fish and box crabs are rarely seen in the sampling area, it can be concluded that predation pressure may be low. Inasmuch as a complete regeneration of the autotomized tissue takes about 2 mo (Wang 1993b), a possibility of rapid regeneration in our samples is ruled out.

A negative correlation between the percentage of regenerated autotomic tissue and shell length in *F. ficus* (Fig. 4) indicates age-specific differences in the growth of autotomic tissue. Older figsnails may not expend as much energy for regenerating tissue as do younger snails. Older snails may allocate a larger portion of their energy for either reproduction or other somatic growth. However, further studies are needed to test this hypothesis.

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花球枇杷螺 (*Ficus ficus*) 之族群動態與自割研究

劉莉蓮[1] 王曉萍[1]

花球枇杷螺 (*Ficus ficus*) 是腹足綱中腹足目的一員，具有自割外套膜的防禦機制。本研究之目的在探討花球枇杷螺之族群動態及防禦性自割在野外之變化。自 1992年5月至 1993年6月，每個月收集離雄附近海域底拖之花球枇杷螺共採集 2186個樣品，殼長範圍介於 28~95 mm之間，其中殼長小於 35 mm之小型個體僅在7至9月間出現。枇杷螺豐度呈現季節性變化，其中11至2月數量較多，在5至7月間族群數量較其它月份低，個體數少於 75隻。雌性個體的平均殼長大於雄性個體，殼長有性雙型的現象。雌雄性比介於 0.3 - 2.3之間，其中3至9月間雌性個體較多，10至2月間雄性個體較多，顯示花球枇杷螺可能有產卵遷移行為。花球枇杷螺自割組織的重量介於 0.03~8.86 g之間，占個體總重的 0%~34%。殼長和自割組織占個體總重百分比有顯著的負相關 ($y = 30.88 - 0.27x$; $R^2 = 0.35$; $p < 0.01$)。只有少於 1%之樣品有新生的再生自割組織（顯示近期在野外曾有防禦性自割發生），在每個月樣品中只有 0~3隻個體。本結果顯示具新生自割組織之枇杷螺可能較易遭到捕食或在自然環境下防禦性自割可能很少發生。

關鍵詞：花球枇杷螺，枇杷螺，族群動態，自割。

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