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GROWTH OF *CHICOREUS CAPUCINUS* (GASTROPODA: MURICIDAE) AT ANG SILA, THAILAND

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ABSTRACT. **–** To test the hypothesis that seasonal patterns of growth occur in tropical marine invertebrates, 954 specimens of *Chicoreus capucinus* (Lamarck, 1822) were measured and tagged at Ang Sila, Thailand, in November 1999 and remeasured in May and November 2000. Data were analyzed with a von Bertalanffy growth equation. Growth was strongly seasonal, averaging 3.4 ± 0.4 mm in November 1999 to May 2000 and 0.5 ± 0.3 mm in May to November 2000. Mean annual growth during the year was 3.8 ± 0.5 mm. Growth was rapid in the initial year of life to an estimated length of 20.9 mm. Growth slowed considerably in succeeding years, with individuals reaching 45.2 mm in four years and 50.3 mm in six years. A resurvey of the site three years after tagging recovered only three tagged animals from a total of 309 examined, indicating that *C. capucinus* has a relatively short lifespan. Possible reasons for the seasonal growth pattern, particularly monsoon patterns, are discussed.

KEYWORDS. **–** Seasonality, growth rate, life span, size frequency.

INTRODUCTION

The general paradigm for tropical marine organisms, including marine molluscs, has been that climatic conditions in tropical localities are relatively stable. Because of this, organisms in the tropics were thought to breed and grow throughout the year. However, it is now recognized that tropical systems have considerable seasonal variations, such as the monsoons, which occur in vast areas of the Indian and western Pacific Oceans. These seasonal variations would be expected to result in seasonal patterns in the biology of species living there. There have been few studies of growth in tropical marine mollusc species. Most (e.g. Frank, 1965; Ward, 1967; Vohra, 1970; Balaparameswara Rao, 1976; Yamaguchi, 1977) have not reported seasonal growth patterns. In contrast, seasonal growth is well known in subtropical and temperate molluscs (Phillips & Campbell, 1968; Phillips, 1969; Spight, 1969; Underwood, 1974; Wells & Threlfall, 1982; Kent, 1983; Moran et al., 1984; Wells, 1984; Tong, 1986; Wells & Keesing, 1987; Gosselin & Bourget, 1989). In contrast to these studies, a recent paper by Tan (1999c) reported strong seasonal growth patterns in two species of *Thais* in Peninsular Malaysia.

Molluscs are an important component of the fauna of mangrove communities in the tropical and subtropical Indo-West Pacific. They are diverse (Macnae, 1967; Saenger et al., 1977) and many species have a high density and/or biomass (Brown, 1971; Wells, 1983, 1984, 1986). Species living in mangroves can be divided into those that are found on adjacent rocky, sandy, or muddy shores and that simply use mangroves as an incidental habitat, and species that are restricted to mangroves. Cantera et al. (1983) concluded that gastropods in mangroves are primarily a widespread soft-bottom fauna, with only 20% of the species restricted to the tree zones. The few species of molluscs that occur only in mangroves are often numerically dominant and ecologically important. Species characteristic of mangroves have developed mechanisms such as resorbing of calcium carbonate from internal shell structures that allow them to survive in this difficult habitat (Vermeij, 1974, 1978). Although numerous species of molluscs live in mangroves, their lifespans and population dynamics are very poorly known.

The muricid *Chicoreus capucinus* (Lamarck, 1822) is widespread in the western Pacific Ocean from Fiji to the

Table 1. Comparison of population parameters of *Chicoreus capucinus* at Ang Sila, Thailand, in Nov.1999 and Nov.2002.

Parameter	Nov 1999	Nov 2002
Mean ± 1 S.E.	42.7 ± 0.4 mm	40.9 ± 0.3 mm
Range	18–71 mm	19–54 mm
< 35 mm	13.6%	12.3%
35–54 mm	82.9%	87.7%
> 54 mm	3.5%	0.0%
N	954	309

Philippines, Thailand and Singapore (Houart, 1992; Gribsholt, 1997) and in Australia from North West Cape, Western Australia, to Queensland (Wells & Bryce, 2000). Feeding and reproduction of *C. capucinus* have been reported by several authors, the most recent of which are Aungtonya & Vongpanich (1997), Tan (1999a), Tan & Oh (2002) and Wells et al. (2001). Tan (1999b) reported the occurrence of tributyltin-induced imposex in *C. capucinus* in Singapore. *Chicoreus capucinus* has been reported as living in several habitats, including the prop roots of *Rhizophora* (Wells & Slack-Smith, 1981) and muddy sand (Houart, 1992) and is frequently common in mangroves. Wells et al. (2001) reported that the species lives in a number of habitats in a mangrove system at Ang Sila, Thailand, including *Avicennia* trees, a sandy shore, on bamboo poles, and on a disused concrete structure. The present paper examines whether there is a seasonal pattern of growth of this common mangrove species and provides basic information on the lifespan of the animals.

MATERIALS AND METHODS

A survey of the habitat at Ang Sila, Thailand (13°19'03"N 155°47'05"E) was undertaken during the first two weeks of Nov.1999, and the results described by Wells et al. (2001). All *Chicoreus capucinus* encountered were measured to the nearest 1 mm with dial calipers. Each shell was cleaned with a toothbrush and an individually numbered plastic tag was attached to the outer shell just above the final varix with cyanoacetate glue ("Super Glue"). Tagging was done in the field during the first day, but because of concern over loss of tags adhering in the rain, tagging was done in the laboratory on subsequent days. All specimens were returned to the field on the morning after they were removed, and were placed aperture down on the damp mud surface. Resurveys were made in May and Nov.2000, and all tagged individuals encountered were again measured. A final resurvey was made in Nov.2002, during which the first 500 *C. capucinus* encountered were measured. Voucher material is held by the Zoology Museum, Institute of Marine Sciences, Burapha University.

A Gulland-Holt Plot of mean length (mm) and growth rate (mm per month) was used to estimate the growth parameters for the von Bertalanffy growth model (King, 1995). L_∞ (asymptotic size) and K (growth coefficient) are parameters of the von Bertalanffy model, which in its general form, $L_t = L_\infty [1 - \exp(-Kt)]$, can be used to generate an age-size relationship, where L_t is the size at time t. Use of the model here assumes that size at t = 0 is zero. Statistical analyses were conducted with a Student's t-test.

RESULTS

A total of 954 *Chicoreus capucinus* were measured in Nov.1999 (Fig. 1). These animals ranged in size from 18 to 71 mm, with a mean of 42.7 ± 0.3 (SE) mm. However, small animals formed only a small proportion of the population; only 130 (13.6%) were smaller than 35 mm. The great majority (751 or 82.9%) of the animals were in the middle-size range of 35–54 mm. Only 33 animals (3.5%) were larger than 54 mm (Table 1). The population three years later was

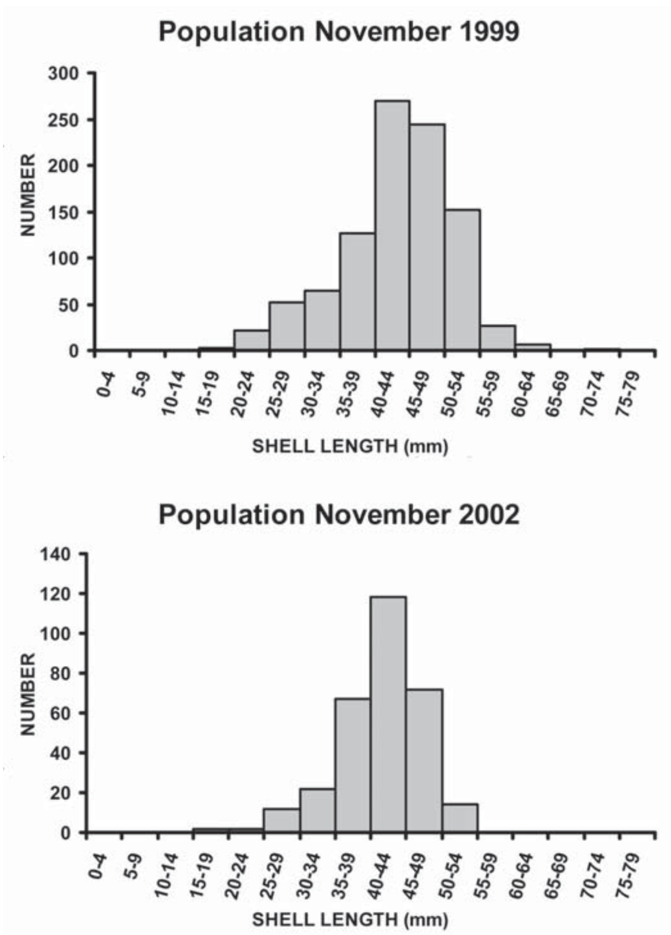

Fig. 1. Size-frequency histograms of *Chicoreus capucinus* at Ang Sila, Thailand, in Nov.1999 and Nov.2002.

Table 2. Growth of *Chicoreus capucinus* at Ang Sila, Thailand, between Nov.1999 and May 2000.

Initial size (mm)	N	Number that did not grow	Number that grew	Growth increment for those that grew (mm)
20–24	3	0	3	11.7 ± 3.0
25–29	6	0	6	8.5 ± 0.9
30–34	14	0	14	8.4 ± 0.5
35–39	35	4	31	5.4 ± 0.5
40–44	56	31	25	2.0 ± 0.4
45–49	38	32	6	0.7 ± 0.3
50–54	32	25	7	0.6 ± 0.3
55–59	1	0	1	2
60–64	1	0	1	5
Total	186	92	94	6.8 ± 0.8

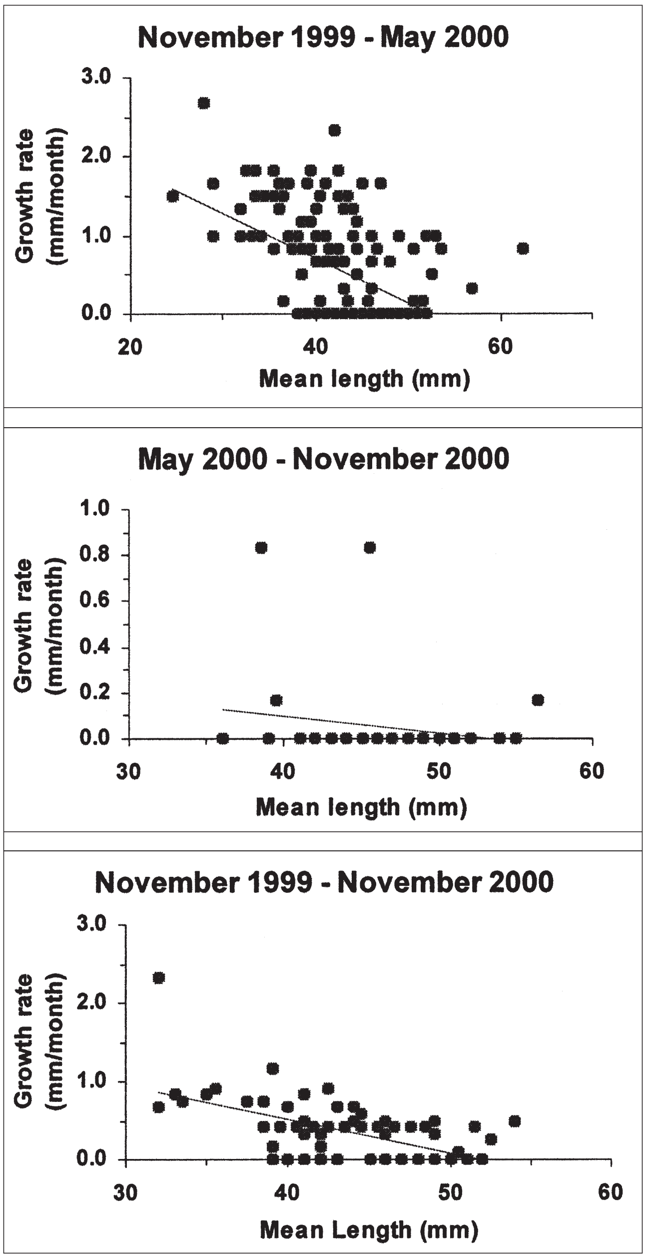

Fig. 2. Incremental growth of *Chicoreus capucinus* at Ang Sila, Thailand, in three periods between Nov.1999 and Nov.2000.

very similar, with a mean size of 40.9 ± 0.3 mm. The primary difference was that no animals recorded greater than 55 mm in shell length were recorded in 2002. Only three of the 309 animals measured in Nov.2002 had tags.

Growth was strongly seasonal. In the period Nov.1999 to May.2000, 92 of the 186 recaptured animals grew an average of 6.8 ± 0.8 mm. The growth rate for the entire sample, including those that did not grow, was 3.4 ± 0.4 mm. The growth increment clearly decreased with increasing shell length (Table 2, Fig. 2). There was no statistical difference (t-test, $p > 0.05$) between the initial sizes of individuals that grew and those that did not. The greatest individual growth increments were from 20 to 36 mm and from 35 to 49 mm. In contrast, only four of the 42 animals recaptured in both May and Nov.2000 grew during that period. These four animals grew an average of 5.0 ± 1.6 mm; overall the population had a mean growth increment of 0.5 ± 0.3 mm. For the full year between Nov.1999 and Nov.2000, 49 of 85 recaptured animals grew an average of 6.2 ± 0.6 mm. Overall, the population had a mean growth increment of 3.8 ± 0.5 mm. One individual shell grew 28 mm, from 18 to 46 mm; the next three fastest-growing individuals each increased by 11 mm.

Table 3 shows the von Bertalanffy growth parameters of *Chicoreus capucinus* at Ang Sila in three periods between Nov.1999 and Nov.2000. The von Bertalanffy growth equations are plotted in Fig. 3. The results are similar for the periods of Nov.1999–May.2000 and Nov.1999–Nov.2000, but the growth rate was substantially reduced in the May–Nov.2000 period. Table 4 shows predicted shell lengths at various ages in the three periods. Growth was rapid in the initial year of life, with the two rapid growth periods estimating a mean size of 26.0 and 20.9 mm after the first year. Growth slowed rapidly in succeeding years, and after seven years, the estimated sizes for the Nov.1999–May.2000 (52.0 mm), and Nov.1999–Nov.2000 (50.3 mm) periods were very similar, but animals growing at the rate indicated by the period of May–Nov.2000 would have only reached 24.1 mm.

Table 3. Von Bertalanffy growth parameters of *Chicoreus capucinus* at Ang Sila, Thailand, in three periods between Nov.1999 and Nov.2000.

Character	Nov.1999–May 2000	May 2000–Nov.2000	Nov.1999–Nov.2000
K (mm/month)	0.0571	0.0073	0.0433
L_∞	52.41	52.66	51.65
N	187	42	85

DISCUSSION

Chicoreus capucinus at Ang Sila exhibited clearly seasonal growth over a one-year period, with the mean growth increment for the Nov.1999-May.2000 period being 3.4 ± 0.4 mm, and that of the May.2000-Nov.2000 period being 0.5 ± 0.3 mm. For the entire year, the mean growth increment was 3.8 ± 0.5 mm. The von Bertalanffy growth equation for the full year of the study estimated that the animals would reach a mean size of about 20.9 mm at the end of the first year of life. Growth slowed considerably in succeeding years, with the animals reaching 45.2 mm in four years and 50.3 mm in six years. A resurvey of the site three years after tagging recovered only three tagged animals from a total of 309 examined. Although some tags could have been lost over time, this suggests that the individuals in the population had nearly completely changed over the three years.

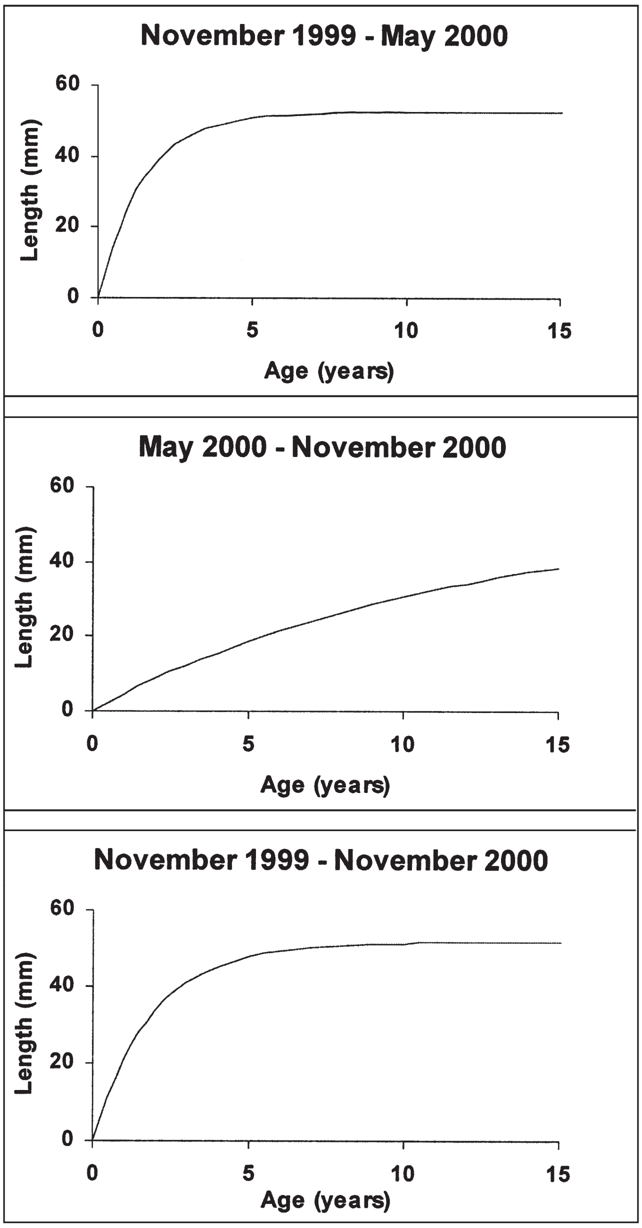

Fig. 3. Von Bertalanffy growth curves of *Chicoreus capucinus* at Ang Sila, Thailand, in three periods between Nov.1999 and Nov.2000.

The seasonality of *Chicoreus capucinus* is contrary to the pattern previously found in most studies of tropical marine molluscs (e.g. Ward, 1967; Vohra, 1970; Balaparameswara Rao, 1976; Yamaguchi, 1977), but is very similar to that found by Tan (1999c) for *Thais clavigera* (Küster, 1858) and *T. jubilaea* Tan & Sigurdsson, 1990, in Peninsular Malaysia from Jan.1991 to Apr.1992. Both *Thais* species showed the same pattern of maximal shell growth during northeastern monsoons (November–March). Mean positive growth rates for each were generally above 0.5 mm/month during the months of December to February, although there were some interannual and interspecific differences. The maximal mean monthly growth rates were 1.7 mm/month for *T. clavigera* and 1.6 mm/month for *T. jubilaea* in Dec.1991. In contrast, there was little or no growth during the remainder of the year. The maximum sizes were 38 mm for *T. clavigera* and 37 mm for *T. jubilaea*.

The mean annual growth of 3.8 ± 0.5 mm in *Chicoreus capucinus* is similar to that reported for other muricids. Tong (1986) found growth rates in *Thais clavigera* in Hong Kong of 2.0–5.5 mm/yr, with growth rates varying between sheltered and exposed shores. Tan (1999c) found 3–5 mm/yr for *T. clavigera* and *T. jubilaea* in peninsular Malaysia.

Various authors have suggested a number of possible causes for seasonality in growth. The most commonly suggested for temperate environments is temperature (Phillips & Campbell, 1968; Phillips, 1969; Spight, 1969; Underwood, 1974; Kent, 1983; Moran et al., 1984; Tong, 1986; Gosselin & Bourget, 1989). Availability of food (Chow, 1987) and changes in salinity and photoperiod (Houston, 1971) have also been suggested. It is also likely that growth rates decline during the reproductive period when the available energy resources are used for development of sperm, eggs, and other reproductive requirements. It is interesting that at Ang Sila, *Chicoreus capucinus* deposits egg cases in November (Wells et al., 2001; K. Chalermwat, pers. obs.), part of the

Table 4. Predicted shell lengths at various ages of *Chicoreus capucinus* at Ang Sila, Thailand, in three periods between Nov.1999 and Nov.2000.

Age (yr)	**Length (mm)**		
	Nov.1999–May 2000	**May 2000–Nov.2000**	**Nov.1999–Nov.2000**
1	26.0	4.4	20.9
2	39.1	8.5	33.4
3	45.7	12.2	40.8
4	49.0	15.6	45.2
5	50.7	18.7	47.8
6	51.6	21.5	49.4
7	52.0	24.1	50.3

period during which growth occurs. However, as growth was examined only over six-month intervals, it is possible that *C. capucinus* was reproducing and growing during different parts of this period.

Tan (1999c) speculated that the reason for seasonal growth in *Thais clavigera* and *T. jubilaea* was that growth occurred during the monsoonal period when a combination of high rainfall, increased mean sea level because of onshore winds, and lower air temperatures reduced desiccation, allowing snails to forage more. Long-term mean monthly temperatures at nearby Bangkok average 27.5°C in the November–April period and 28.5°C in May-October (World Climate, 2007), with very little difference. The greatest range in mean monthly temperatures is from 25.5°C in December to 30.1°C in April. In contrast, there are substantial differences in rainfall, with an average of 208 mm falling November–April, whereas rainfall increases six-fold to 1,234 mm in June–October. It seems likely that young, rapidly growing individuals are present in the population after the November reproductive season, and their presence dominates the growth rate early in the calendar year. The major growth period is thus during the dry season, and growth is substantially lower in the wet season, when the young individuals are larger. This pattern is exactly the opposite of that found by Tan (1999c) for the two species of *Thais* in Malaysia.

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THAI ABSTRACT

รายงานวิจัยเรื่องนี้เป็นการทดสอบสมมติฐานเกี่ยวกับการเจริญเติบโตของสัตว์ไม่มีกระดูกสันหลังในเขตร้อนโดยการวัดและติดเลขหมายให้กับหอยมะระดำ *Chicoreus capucinus* (Lamarck, 1822) จำนวนทั้งสิ้น 954 ตัว บริเวณอ่าวอ่างศิลา ในเดือน พฤศจิกายน พุทธศักราช 2542 และทำการจับหอยที่ติดเลขหมายไว้มาวัดขนาดใหม่ในเดือนพฤษภาคม และพฤศจิกายน 2543 ข้อมูลการเจริญเติบโตถูกนำมาเข้าสมการ von Bertalanffy และพบว่าอัตราการเจริญเติบโตมีความสัมพันธ์กับฤดูกาลในระดับสูง โดยหอยมีอัตราการเพิ่มขึ้นของความยาวเปลือกเฉลี่ย 3.4±0.4 มม. ระหว่างเดือน พฤศจิกายน 2542 ถึง พฤษภาคม 2543 และเพิ่มความยาวเปลือกเพิ่มขึ้นเพียง 0.5±0.3 มม. ในช่วงเดือน พฤษภาคม ถึง พฤศจิกายน 2543 โดยอัตราการเจริญเติบโตเฉลี่ยของช่วงเวลาทั้งปีมีค่าเทากับ 3.8±0.5 มม. พบว่าหอยเพิ่มความยาวเปลือกได้สูงในช่วงอายุ 1 ปีแรก จนมีขนาดเฉลี่ย 20.9 มม. ในปีต่อๆมา อัตราการเพิ่มของความยาวเปลือกจะลดลงอย่างมากโดยหอยมะระดำจะมีขนาดความยาวเปลือกเฉลี่ย 50.3 มม. ภายในระยะเวลา 6 ปี การสำรวจพื้นที่ศึกษาหลังจากเวลาผ่านไป 3 ปี พบหอยที่มีเลขหมายเพียง 3 ตัว จากหอยที่จับมาทั้งหมด 309 ตัว ซึ่งบ่งบอกว่าหอยชนิดนี้มีช่วงชีวิตสั้น ผู้วิจัยอภิปรายถึงสาเหตุที่หอยมีการเจริญเติบโตแตกต่างกันในช่วงฤดูกาลที่แตกต่างกันโดยเฉพาะช่วงฤดูมรสุม

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