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SOME ASPECTS OF REPRODUCTIVE BIOLOGY AND ALLOMETRIC GROWTH OF TWO SPECIES OF *NERITA* (GASTROPODA: MOLLUSCA) FROM NORTHERN ARABIAN SEA

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ABSTRACT

Egg masses of two species of *Nerita*; viz., *N. albicilla* and *N. textilis*, are reported for the first time from the coast of Karachi, northern Arabian sea. The egg capsules of *N. textilis* are similar to those of *N. albicilla* but larger in size. The dimensions of the egg capsules and larvae of these species are also presented. Allometric studies of *N. albicilla* and *N. textilis* showed that shell height increased faster than width in all the populations. Relative growth of the shell width decreased with increasing shell height in all populations of *N. albicilla*. Coefficient of variation for shell height and shell width of *N. albicilla* varied with seasonal changes.

Key words: Egg capsules, larvae, allometric studies, relative growth, coefficient of variation.

INTRODUCTION

Although gastropod molluscs form the major component of invertebrate population on the rocky beaches of the Karachi coast (Ahmed, 1977 and 1997; Ahmed *et al.*, 1982; Barkati and Burney, 1995), very few studies have been undertaken dealing with spawning season and growth patterns. In a series of papers Barkati and Ahmed (1980; 1983; 1984a, b, c, 1985) contributed information on the reproductive biology of *Planaxis sulcatus*, *Thais*, *Cerithium*, *Cypraea*, *Nodilittorina* and *Conus* species, respectively from Karachi coast. Few reports showed the larval development and egg capsules of members of the family Neritidae. Lebour (1945) documented the spawn and larvae of three species of *Nerita* from Bermuda. The egg capsules and development of *N. senegalensis* from tropical West Africa was studied by Knudsen (1950). Natarajan (1957) studied the egg mass and larval development of some prosobranchs including *N. albicilla* from the Gulf of Mannar and the Palk Bay, India. The reproduction and early life histories of *Melanerita melanotragus* along the New South Wales coast, Australia was documented by Anderson (1962). The preliminary observations on eggs and larvae of *N. orgzarum* and *N. albicilla* from Bombay was conducted by Desai (1962). Underwood (1974) described the reproductive cycle of *N. atramentosa* at Cape Banks, New South Wales, Australia. The reproductive system and breeding condition of mangrove dwelling *N. birmanica* from Malaya was observed by Berry *et al.* (1973). Spawning and development of *N. oryzarum* was studied by Kasinathan *et al.* (1975).

In gastropod mollusc, the growth pattern is mostly estimated through size frequency distribution (Laxton, 1970; Branch, 1974; Houbrick, 1974; Borkowski, 1974; Yamaguchi, 1977; Creese and Underwood, 1976; Villiers, 1981; Underwood, 1984; Sreenvisan and Natarajan, 1986; Ahmad and Hill, 1994; Ompi, 1994; Rondo, 1995). Equal importance is given to study growth through allometric analyses. Following are few examples: *Urosalpinx cinerea* from North America (Franz, 1971), *Haliotus discus discus* from Japan (Kojima *et al.*, 1977), *Notoacmea schrenckii* from Ogasawara Island (Asakura and Nishihama, 1987), *Telescopium telescopium* from Indonesia (Soekendarsi and Palinggi, 1995). Similar approach for members of the family Neritidae is restricted to just two papers (Hughes, 1971; Kulkarni and Jaiswar, 2000).

Study of growth in molluscs in Pakistan is largely confined to bivalve molluscs (Asif, 1979; Barkati and Khan, 1987; Barkati and Choudhry, 1988; Ahmed, 1988; Siddiqui and Ahmed, 2001). A couple of publications are available on the allometric pattern of two species of gastropods viz. *Telescopium telescopium* (Barkati and Tirmizi, 1988) and *Cellana radiata* (Fatima and Timuri, 1991).

MATERIALS AND METHODS

Field trips were made on various sites along the Karachi coast at low tides on monthly basis for a period of one year from August 1994 to July 1995. The individuals and egg capsules of *N. albicilla* (Linnaeus) were abundantly present on Manora, Kemari, Buleji, Nathiagali and Cape Monze whereas those of *N. textilis* (Gmelin) were found only on Nathiagali and Cape Monze. The individuals of both species were placed in separate glass bowls for spawning in the laboratory. The water of bowls were changed daily. The dimensions of the egg capsules were taken.

The larvae that hatched from the egg capsules were observed under a stereoscope. The shell dimensions of the developing larvae were measured and figures drawn. They were fixed in 5 % formalin at different stages and then preserved in 70 % ethanol.

For studying the growth pattern, the height (apex to the tip of the siphonal canal) and width (maximum thickness of the last whorl) of the shells of gastropod species were measured with the help of a dial vernier caliper to the nearest 0.01 mm.

Zar (1974) was followed for the statistical treatment of data. The allometric growth is expressed by an equation

$$y = a.x^b$$

where x is used as independent and y as dependent variable, respectively, whereas a and b are constants. The constant b, which is equilibrium constant or a coefficient of allometry, indicates the ratio of the growth rates of two variables used.

The regression line or the least-square line can be calculated by the equation

$$\log y = \log a + b \log x$$

where y = dependent variable
x = independent variable
a = y intercept
b = slope of the line

Coefficient of variation was calculated from the standard deviation expressed as percentage of the mean.

RESULTS

Breeding Season

Nerita albicilla is one of the abundant gastropod species occurring on the mid and high zones of the rocky shores along the Karachi coast. *Nerita textilis* is strictly limited in distribution, found only near the low water mark at Nathiagali and Cape Monze. A large number of egg capsules of *N. albicilla* were found attached to rocks, stones and shells (empty as well as alive) of *Turbo* and *Nerita*. Both species seems to breed all the year round as their egg capsules were observed throughout the year. However, relatively more capsules are available in the month of June and July. Individuals of *N. albicilla* deposited egg capsules in the laboratory in February, June, July, October and November during the year 1994-95. Altogether, 8 individuals collected from Manora and Buleji spawned in the laboratory. Some individuals deposited spermatophores in the laboratory in February and September. The egg capsules of *N. textilis* were collected in the month of December, January, March and June from Cape Monze rocky shore. The larvae hatched in the laboratory four days after collection.

Table 1. Dimensions of egg mass and larval shells of *Nerita albicilla* and *N. textilis*. The values in the table are means ± standard deviation.

	Nerita albicilla	*Nerita textilis*
Egg mass diameter (mm)	2.4	2.98
No. of eggs per mass	426 ± 68.51	-
Incubation period (days)	20 - 27	-
Larval shell height at hatching (um)	129.82 ± 10.81	165.78 ± 0.05
Larval shell width at hatching (um)	105.26 ± 3.63	125.43 ± 0.06

Characteristics of Egg capsules, Eggs and Larvae

The egg capsules of *N. albicilla*, like those of other species of *Nerita* are calcareous and pretty hard. They are almost round in shape (Fig. **1A**). The surface is uneven, but the walls of eggs are clearly demarcated. Each capsule has a membranous base and calcareous convex top. The top has numerous circular shaped structures placed close to each other containing eggs. The case also contains some thick blackish fluid for nourishment. The colour of the capsule is white, which changed to dirty white or yellowish during the course of development. Kasinathan *et al.* (1975) also noted a change of colour from milky white to brown in *N. oryzarum*. The dimensions of the egg capsules

and larvae of this species are given in Table 1. The number of eggs ranged from 324-530 per capsule (av. 426). The larvae come out of the capsules as free-swimming veligers. The hatching time of the larvae varied from 20 – 27 days (av. 24). The larvae probably escape by making a hole in the centre of the capsule. Larvae started beating velum and moving after one minute of coming out of capsule. The number of egg capsules deposited in the laboratory ranged from 2-6 capsules per specimen. Empty egg capsules remained attached to the stones in the bowls and shed off when touched. Larval shell height measured 129.82 µm and shell width was 105.26 µm just after hatching (Fig. **1B**).

The egg capsules of *N. textilis* are rounded in shape found attached firmly to the rocks. Characteristics of egg capsules of *N. textilis* are not been described earlier. The egg capsules are similar to those of *N. albicilla* but larger in size. The dimensions of the egg capsule are given in Table 1. The larvae hatched out in the laboratory after four days of collection from the field in January, so, it is not possible to give the hatching time. The empty capsules are of yellowish green colour. The larval shell height was 165.78 µm and shell width was 125.43 µm just after hatching (Fig. **1C**).

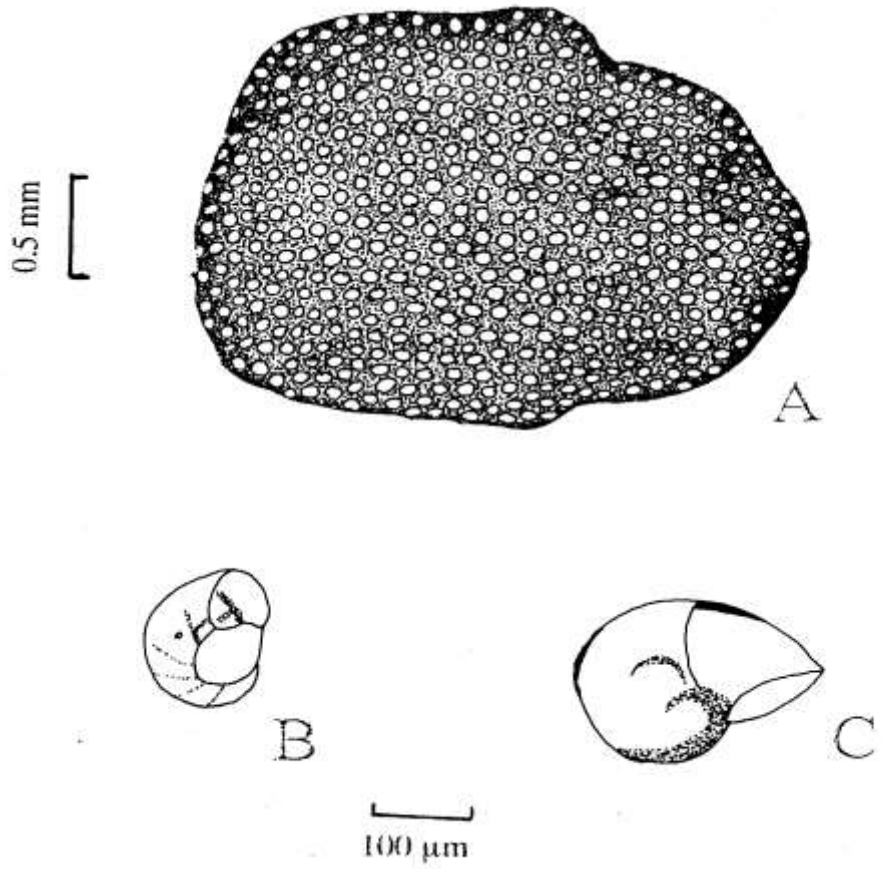

Fig. 1. *Nerita albicilla*: A. dorsal view of an egg mass; B. ventral view of larval shell just after hatching. C. *N. textilis*: ventral view of larval shell just after hatching.

Allometric Growth
Shell Height – Shell Width Relationship for *Nerita albicilla*

A t-test analysis showed that all values of b are significantly different from theoretical slope at $p < 0.001$. Shell height increased faster than shell width in all the samples i.e. negative allometry (Table 2).

Relative Growth

The snails, *N. albicilla* collected were grouped into 5 mm classes to study the changes in shell width with increasing shell height. The results show that the relative growth (per cent increment) of the shell width decreased with increasing shell size (Table 3). The percent increment was highest in snails of smaller size.

Relative Variability

Seasonal variations in coefficient of variation for shell height and shell width of the *N. albicilla* are described below:

Table 2. Regression analysis for height to width relationships of *Nerita albicilla* (gastropod) from Buleji and *N. textilis* from Nathiagali, Karachi.

Month	Sample Size	Log a (y intercept)	b (Coefficient of allometry)	r2 (Coefficient of determination)	Calculated t-statistic	Probability P
			Nerita albicilla			
Aug.	108	-0.037	0.697	0.201	-6.71	0.001
Sept.	128	0.051	0.479	0.708	-36.03	0.001
Oct.	122	0.014	0.581	0.591	-22.11	0.001
Nov.	298	0.064	0.472	0.584	-42.74	0.001
Dec' 94	92	0.030	0.565	0.590	-19.57	0.001
Jan.	208	0.031	0.573	0.664	-34.64	0.001
Feb.	81	-0.038	0.746	0.705	-17.68	0.001
Mar.	142	-0.047	0.754	0.946	-64.76	0.001
Apr.	127	0.003	0.591	0.514	-18.86	0.001
May	129	0.012	0.581	0.764	-34.29	0.001
June	104	-0.012	0.642	0.585	-18.06	0.001
July'95	124	0.031	0.591	0.557	-20.37	0.001
			Nerita textilis			
Jan. 1995	94	0.002	0.788	0.357	-8.311	0.001
Dec' 94	37	0.078	0.702	0.799	-5.000	0.001
Mar.	42	-0.034	0.856	0.778	-25.653	0.001
June'95	32	0.165	0.573	0.558	-4.59	0.001

Table 3. Relative growth (Per cent) in shell width of *Nerita albicilla* from Buleji rocky shore.

Months	Size Class (cm)					
	0.51 - 1.00	1.01 - 1.50	1.51 - 2.00	2.01 - 2.50	2.51 - 3.00	3.01 - 3.50
Aug.	-	-	-	18.644	12.857	-
Sept.	-	-	16.393	11.268	8.861	-
Oct.	-	-	17.647	15.000	13.043	-
Nov.	-	20.313	14.286	11.364	9.184	-
Dec' 94	-	-	18.919	13.636	10.000	-
Jan.	-	-	17.949	13.043	11.538	8.621
Feb.	-	-	23.529	19.048	-	-
Mar.	74.074	34.043	25.397	17.722	15.054	-
Apr.	-	-	33.333	25.000	-	-
May	-	25.000	13.333	17.647	10.000	-
June	-	25.000	20.000	16.667	14.286	-
July'95	-	-	17.949	15.217	11.321	8.475

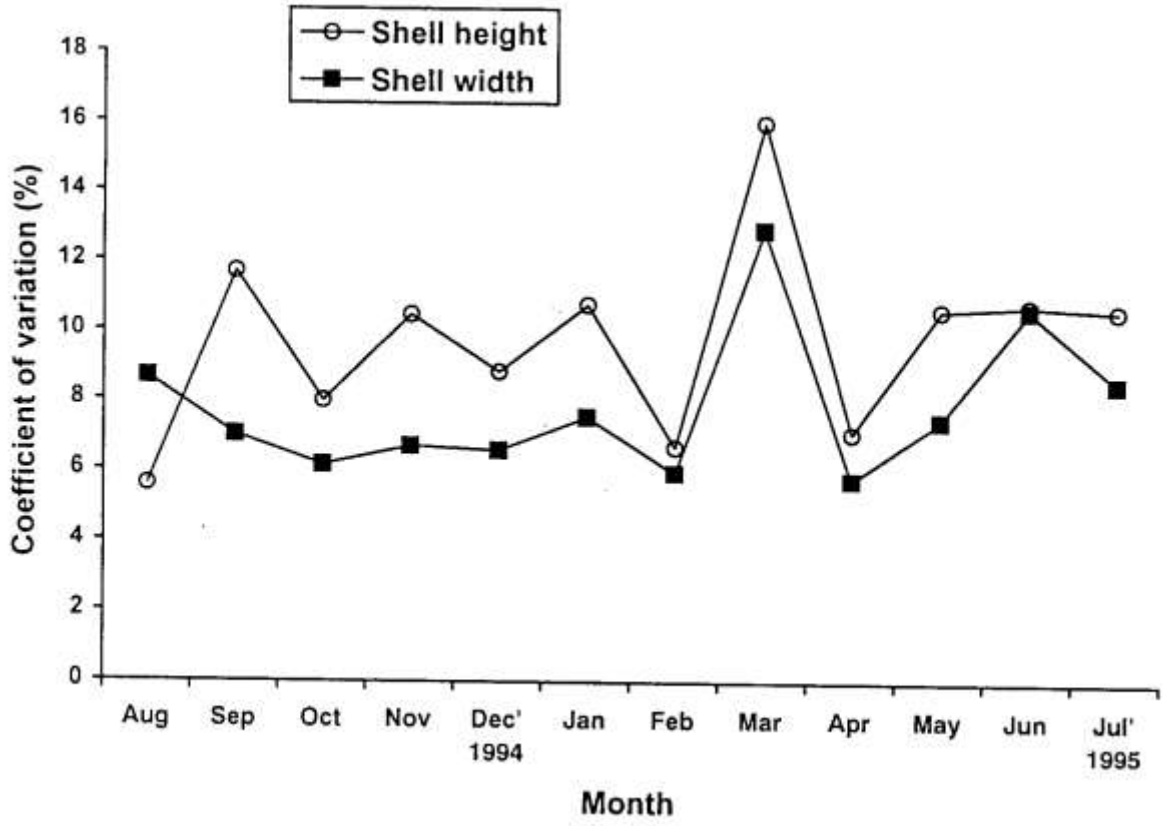

Fig. 2. Seasonal variation in coefficient of variation (%) for shell height and shell width of *Nerita albicilla*.

Shell height: The values of variability in shell height follow an alternate increase and decrease from the lowest in August to its highest in March. The variability value suddenly dropped in April followed by a gradual increase in rest of the months (Fig. **2**).

Shell width: Values of variability in shell width gradually decreased from August up to February. The values suddenly increased to its highest in March and dropped to its lowest in April (Fig. **2**).

Shell Height – Shell Width Relationship for *Nerita textilis*

The shell height of the gastropod increased faster than shell width in all the samples showing negative allometry. The values of the slope are significantly lower than the theoretical slope (1.0) at P>0.001 (Table 2).

DISCUSSION

Few studies were undertaken on the breeding habits of Neritida molluscs. Species of family Neritidae varied greatly with respect to the time of spawning. Lebour (1945) studied the eggs and larvae of three species of *Nerita* from Bermuda. He observed that *N. peloranta* spawned from June to August whereas *N. versicolor* laid eggs in an aquarium only on June. However, *N. tesselata* breeds from July to November and began again in February but no spawning observed in December and January. The spawning of *Melanerita melanotragus* began in the late winter and continued until the late summer at New South Wales (Anderson, 1962). Underwood (1974) found that the spawning season of *N. atramentosa* at Cape banks, Australia was in summer with a peak in January and was finished by February. Kasinathan *et al*. (1975) observed that *N. oryzarum* spawned during September to December both in the laboratory and in the field from Bombay waters. Kolipinski (1965) found that *N. tessellate* spawned regularly throughout the year, whereas *N. fulgurans* and *N. versicolor* showed short breeding seasons in early and late summer, respectively in Florida. Berry *et al.* (1973) working on the mangrove dwelling *Nerita birmanica* from Malaya observed that breeding appears to be continuous but with slight variation. Natarajan (1957) collected the egg

masses of *N. albicilla* in the month of February, April, May, July, August and September from the Gulf of Mannar and the Palk Bay, India. In the present study, *N. albicilla* seems to breed all the year round as its egg capsules may be collected in all seasons from the Karachi coast. Hence, according to Ahmed's (1980) scheme, *N. albicilla* can be categorized as year-round spawner in the subtropical environment. The egg capsules of *N. textilis* was observed in December, January, March, June and September on the low tidal zone of Nathiagali and Cape Monze rocky shores; the capsules collected in March were found empty.

According to Anderson (1962), the egg capsules of family Neritidae are very characteristic in their shape and appearance. Deposition of discontinuous egg capsules is a characteristic of all the nerites so far studied including the species of present study. The egg capsules of *N. albicilla* and *N. textilis* are calcareous and dome shaped on the top and membraneous at the base. Similar capsules are produced by *Nerita reticulata, N. versicolor, N. peloronta, N. tesselata* and *Melanerita melanotragus* (Risbec, 1932; Andrews, 1935; Lebour, 1945; Anderson, 1962). The diameter of the egg capsules of different *Nerita* species ranged from a minimum of 1.0 mm for *N. oryzarum* (Kasinathan *et al*., 1975) to a maximum of 4 mm for *N. peloranta* (Lebour, 1945). The average diameter of the egg capsules of *N. textilis* is 3.0 mm from Cape Monze rocky shore. The egg capsules of *N. albicilla* from the Karachi coast has about the same size as described earlier for *N. albicilla* from the Gulf of Mannar and the Palk Bay, India.

The egg capsules of *N. albicilla* from Pakistan contained an average of 426 eggs. Anderson (1962) recorded between 20 to 40 eggs per capsule for *M. melanotragus* from New South Wales. The number of eggs varied from 149 to 175 for *N. senegalensis* (Knudsen, 1950). According to Natarajan (1957), the number of eggs per capsule varied from 121 to 85 for *Nerita albicilla* from the Gulf of Mannar and the Palk Bay, India. Desai (1962) recorded 20-50 eggs for *N. orgzarum* from Bombay. The number of eggs per capsule in the present study (324-530) is the highest of all the *Nerita* species studied so far.

Anderson (1962) observed that hatching occurs at about two weeks after the capsules of *M. melanotragus* were laid. The veligers of *N. oryzarum* hatched out from the egg capsule in about five weeks from Bombay waters (Kasinathan *et al*., 1975). Natarajan (1957) could not give the time of development of *N. albicilla* from the egg to the hatching stage. However, Risbec (1932) found that after 52 days the veligers of *N. albicilla* from the New Caledonia were still unhatched but moving freely inside the capsule. In the present investigation, the hatching time of the larvae for *N. albicilla* varied from 20 – 27 days. The hatching time of *N. textilis* could not be determined as the larvae hatched from the capsule in the laboratory after four days of collection. Above observations showed that the hatching time of *N. albicilla* is more than *M. melanotragus* and less than *N. oryzarum*.

Nerita albicilla and *N. textilis* hatched as pelagic veligers in the same manner as *N. tesselata* (Lebour, 1945), *N. senegalensis* (Knudsen, 1950), *M. melanotragus* (Anderson, 1962) and *N. oryzarum* (Kasinathan *et al*., 1975). However, some marine neritids complete their development within the capsule and hatch at a full-metamorphosed crawling stage. Among them are, *Nerita reticulate* and *Theodoxus meleagris* (Risbec, 1932; cited in Anderson, 1962). Higher fecundity rate per capsule was noticed in the present study for *N. albicilla* as compared to *N. oryzarum* (Kasinathan *et al*., 1975). In the present study, an average of 343 larvae were hatched. Kasinathan *et al*. (1975) observed that the number of embryos in a capsule of *N. oryzarum* ranged from 28 to 42 from Bombay waters.

The veliger shell of *N. tesselata* measured 0.16 mm across (Lebour, 1945). The veliger shell of *N. oryzarum* measured 95-110 um in diameter from Bombay waters (Kasinathan *et al*., 1975). The newly hatched veligers of *N. albicilla* have a shell of one whorl and measured 0.150-0.167 mm across the shell (Natarajan, 1957). Veligers of *N. senegalensis* on hatching have ¾ whorl and a shell length of 150 u (Knudsen, 1950). In the present study, the larval shell height of *N. albicilla* was 129.82 µm and shell width was 105.26 µm just after hatching. And the larval shell height of *N. textilis* was 165.78 µm and shell width was 125.43 µm just after hatching. The veliger shells of *N. albicilla* and *N. textilis* are about the same size as in *N. tesselata* (Lebour, 1945), *N. oryzarum* (Kasinathan *et al*., 1975), *N. senegalensis* (Knudsen, 1950) and *N. albicilla* (Natarajan, 1957).

Few publications with emphasis on allometric relationships of gastropods have been carried out. Some authors have studied the length and weight relationship of different species. For instance, *Nerita undata, N. plicata, N. polita, N. albicilla* and *N. textilis* (Hughes, 1971), *Haliotus discus* (Kojima *et al.*, 1977), *Burnupena spp., Fissurella mutabilis, Oxystele sinensis, O. variegata, Patella barbara, P. cochlear, P. granularis, P. longicosta, P. oculus, Siphonaria capensis, S. deflexa* and *Nucella dubia* (McQuaid *et al.*, 1985), *Chicoreus ramosus* (Benny and Ayyakkannu, 1992), *Telescopium telescopium* (Barkati and Tirmizi, 1986; Soekendars and Palinggi, 1995), *Nerita oryzarum, N. polita, N. albicilla* and *Neritina crepidularia* (Kulkarni and Jaiswar, 2000). Conversely, some authors have worked on the length and width relationship of different gastropod species. Among them are, *Heliosoma anceps* (Herrmann and Harman, 1975), *T. cornutus* (Chung, 1976), *Concholepas concholepas* (Ch. Guisada and Castilla, 1983), *Monodonta turbinata* (Schifano, 1983), *Patella caerulea* and *P. rustica* (Paredes and Acuna, 1991) and *Cymbium pepo* (Ayessou *et al*., 1998).

Results of allometric relationships for these gastropod species are linearly related. The results of the present

study also showed that relationships between shell height - shell width of *N. albicilla* is linearly correlated and are in general agreement to the above results. However, according to Fatima and Temuri (1991), the relationship between shell length and shell height of *Cellana radiata* was weakly correlated. The analysis of regression coefficient for shell height and shell width relationship of *N. albicilla* showed that growth rates of these variables varied seasonally. The same inference was drawn by Branch (1974) and Barkati and Tirmizi (1986).

Results of the present investigation indicate a faster increase in shell height than width in all the population of *N. albicilla.* The same inference was drawn by Branch (1974) for *Patella longicosta*, Ch. Guisada and Castilla (1983) for *Concholepas concholepas*, Barkati and Tirmizi (1986) for *T. telescopium*, Sultana (1991) for *Trochus stellatus* and *Euchelus asper* and Jabeen (1991) for *T. coronatus* and *T. intercostalis*. However, according to Chung (1976), the regression analysis of diameter of aperture on shell length between regions and spire length on shell length of *T. cornutus* were not significantly different at Cheju City and Songwipo. According to Schifano (1983), the relative thickness of *Monodonta turbinata* is positively and significantly correlated with temperature of seawater.

The results of the present study showed that the relative growth of the shell width decreased with increasing shell size. The percent increment was highest in snails of smaller size. Herrmann and Herman (1975) also noted that as the snails grow larger they increase in size at a slower rate. Slower growth of snails with fall in temperature was also noted by them. Similarly, Branch (1974) also observed that the shell growth is rapid in the first year and then decreases in different *Patella* sp. A negative linear relationship exists between initial length and increment per year. Shell thickness increases throughout life. Different species of *Patella* grows at different rates. These relative rates are probably related to the nutritive value of the different food sources. According to Underwood (1984), the rate of growth of *N. atramentosa* was positively correlated with the amount of chlorophyll in the substratum and was not apparently affected by the greater period of submersion and concomitant time available for feeding towards the lower levels on the shore at Cape Banks, New South Wales. According to Ch. Guisada and Castilla (1983) the differences observed in the growth rate is due to difference in feeding behaviour and temperature.

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