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***Research Article** (Open Access)*

STUDIES ON SOME ASPECTS OF BIOLOGY OF BLOOD CLAM *ANADARA GRANOSA* (L.) FROM KAKINADA BAY, EAST COAST OF INDIA

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ABSTRACT
Scale of four stages of maturity (maturing, matured, spent and recovery) in *Anadara granosa* was described in the present study. The size at first maturity in females was reported at 3.7cmand in males was reported at 3.9cm length in *A. granosa*. They spawn throughout the year with peak spawning season during August to December in during study period. Sex Ratio indicated that the males and females were not equally distributed during the study period. The sex ratio for male to female was 1:1.6 in first year; 1:2 in second the year. Analysis of covariance showed a significant difference between two sexes ($P<0.05$). A single length weight relationship $W= 0.00000189512L^{3.03536}$ was given. Isometric growth was noticed in *A. granosa*. The age and growth studies showed that *A. granosa* attain a length of 2.7cm in first year, 4.1cm in second year. Growth rate in the initial months was high and then decreased in the subsequent months when the blood clam reached adult size.

Keywords: *Anadara granosa, Growth Rate, Sex Ratio, Spawning Season*

INTRODUCTION
Studies on biology of fisheries stocks are very essential to know the life cycles, length-weight relationship and age and growth. Studies on reproductive biology of fisheries stocks are essential for determination of spawning season, fecundity and for estimation of reproductive potential of a population. Such studies coupled with data on survival rates of early stages in life history are necessary for estimation of population size and fluctuations in the abundance of different year–classes. The relative success or failure of the spawning in any year in a population affects the fishery. Studies on maturation, spawning and fecundity are essential in fishery management. Studies pertaining to the fecundity reveal useful information about the reproductive potential of any organism. Fecundity is a basic means of regulating the rate of reproduction to changing conditions (Suwanjarat *et al.*, 2009). The analysis of length weight data constitutes an essential part of investigation on any fisheries stock.
Some of the earlier authors studied biology on marine bivalves from varies parts of the world, Uyan and Aral (2000), Gosling (2003), Kulkarni (2001; 2002; 2005), Stern-Pirlot and Wolff (2006), Jaiswar and Ansari *et al.*, (2007), Mohite *et al.*, (2009), Suwanjarat *et al.*, (2009).
Relatively very few studies on the biology have been carried out on *A. granosa* from Kakinada Bay. Due to the paucity of information on biology of marine bivalves, the present study aimed to observe variations by obtain detailed information on maturation, spawning season, size at first maturity, sex ratio, length–weight relationships, age and growth studies of *Anadara granosa* from Kakinada Bay. The biological data may also be utilized for mass scale farming of marine bivalves to solve the malnutrition problems.

MATERIALS AND METHODS
Study area
The samples were collected from Kakinada Bay, near Chollangi village in the stretches of Coringa estuary, East coast of India during June 2013-May 2015. Geographically, Coringa estuary extends from Kakinada in

the north to the Gautami Godavari in the south. It is located between 16°-30' to 17°-00'N latitudes and 82°-14' to 82°-23'E longitudes. It is the second largest stretch of Mangrove forests in India with 35 species belonging to twenty four families and more than 120 bird species. It is home to the critically endangered white backed vulture and the long billed vulture**.**

Biology of bivalves

Bivalves were collected randomly on every month from study area by hand picking at low tide time (Approximately 1 m depth) by using motor boat during June, 2013 to May 2015 **(Figure 1).** Bivalves were packed in wet gunny bag and transferred to the wet laboratory of Department of Marine Living Resources of Andhra University and kept in the seawater with suitable salinity and allow them for depuration. Bivalves were cleaned off all epifauna and epiflora with a brush and washed. These bivalves were identified based on standard taxonomic Keys (Carter *et al.,* 2011).

Figure 1: *Anadara granosa* collection from Kakinada bay

The marine bivalve *A. granosa* (385 males ranging from 2 cm to 6 cm TL and weight 5g to 108g; 622 females ranging from 1.9 cm to 5.9 cm TL and weight 4g to 102g) was selected for this study because this was available in plenty throughout the year.

Maturity of gonads determined by external appearance like colour, size, area occupied by them in the body cavity and microscopic observations of ova (Narasimham, 1980). Determination of spawning season was based on percentage occurrence of mature bivalves. Percentage occurrence of mature bivalves in a month gave an idea of the spawning season (West, 1990). For this, the occurrence of various maturity stages of males and females in different months was calculated by grouping the specimens according to maturity stages in each month and calculated their percentage. The period, during which the percentage of occurrence of mature bivalve was high, it was considered as the spawning season. The size at first maturity was determined for males and females at that average size at which 50% of the population attains first maturity (Narasimham, 1980). For this study, matured males and females were examined and their percentage frequencies falling in different length groups were studied.

RESULTS AND DISCUSSION

A. *Reproductive biology*

a. Maturation of gonads

Ovaries

Stage 1 (Maturing): Ovaries were small, light pink color, oval or flask shaped.

Stage 2 (Matured): Ovary attains maximum size and round in shape and pink in color. Oocytes were nucleated; size ranges from 30 to 40µm diameter.

Stage 3 (Spent): Follicular walls collapse and shrink further. Phagocytes appeared. The vesicular connective tissue increased.
Stage 4 (Recovery): Majority of the follicles with reabsorbed ovaries of irregular shape and size **(Table 2).**

Testes

Stage 1 (Maturing): Gonad was small, inconspicuous and colorless. Secondary spermatocytes appeared in large numbers along with the primary spermatocytes in four bivalves.
Stage 2 (Matured): Gonad attains maximum size, cream colored; entire lumen was filled with bunches of spermatozoa.
Stage 3 (Spent): Follicular walls collapse and shrink further; unreleased sperms undergo degeneration. The vesicular connective tissue increased.
Stage 4 (Recovery): Gonad was small and translucent, with much connective tissue. No traces of gametes were seen **(Table 3).**

***b*. Size at first maturity**

The percentage frequency of matured males 3.9 cm, whereas in female 3.7 cm. The minimum size in *A. granosa* having ripe stage was 2.9 cm for males and 2.8 cm for females respectively during study period **(Figure 2 and 3).**

c. Spawning season

Monthly percentage occurrence of males and females in different stages of maturity during the study period was recorded. The highest percentages of matured gonads were observed in October, November and December. Seasonally the highest percentage of matured gonads was observed during post-monsoon, probably peak spawning season.

d. Sex ratio

The trends in the ratio of males and females in different months showed that the females were dominated the catches entire study period except September and February in first year and April in second year. The sex ratio for male to female in first year was 1:1.63 and 1:2.04 in second year **(Figure 4 and 5, Table 4).**

B. Length–Weight relationship

Estimation of the constant 'a' and exponent 'b' in the linear form were made in the logarithmic form, **(Table 5).**

Males: Log W = -0.79574 + 3.16215 Log L (r = 0.97)
or
$W = 0.0000142518L^{3.16215}$ (r = 0.97)
Females: Log W = -0.49201 + 2.94413 Log L (r = 0.95)
or
$W = 0.00000469408L^{2.94413}$ (r = 0.95)

Results of covariance are given in **Figure 6 and 7.** Since F value was significant at 5% level, it can be suggested that difference between slopes of males and females was significant. The length–weight data of females and males can be pooled to obtain a common regression equation for both the sexes.
Pooled: Log W = -0.61904 + 3.03536 Log L (r = 0.96)
Or
$W = 0.00000189512L^{3.03536}$ (r = 0.96)

The scattered diagram of observed weight against length of the *A. granosa* revealed a curvi-linear relation between the two variables for both the sexes. Logarithmic data showed straight line relationship between the males and females.

C. Age and growth studies

The $L\infty$ obtained for *A. granosa* was 7.79 cm and K = 0.3 yr^{-1} with highest Rn value 0.237. The calculated growth performance index (Ø') was 5.3374.
t_0 for *A. granosa* (-0.45) was calculated by substituting $L\infty$ and K in Pauly's equation.
The values of $L\infty$, K and t_0 were substituted in the Von Bertalanffy growth equation and the length of the *A. granosa* at specific time was expressed as:

$L_t = 7.79\ (1\text{-}e^{-0.3(t-0.237)})$

On the basis of these formula, growth curves of *A. granosa* was drawn **(Figure 8)** according to Von Bertalanffy growth equation. The length attained in mm at ages of 3, 6, 9 and 12 months for *A. granosa* was given below **(Table 1).**

Table 1: Age vs. length.

Age in months	Length in cm
3	1.5
6	1.9
9	2.4
12	2.7

Based on the ELEFAN I method *A. granosa* attained a total length of 2.7 cm during first year, 4.1 cm during second year, 5.0 cm during third year and 5.7 cm during fourth year. The ELEFAN method confirmed the longevity of *A. granosa* to be 48 months **(Figure 9).**

The monthly growth rate for *A. granosa* showed that the percentage of growth rate in the initial months was high and then decreased in the subsequent months indicating that the *A. granosa* after reaching adult stage showed low growth rates.

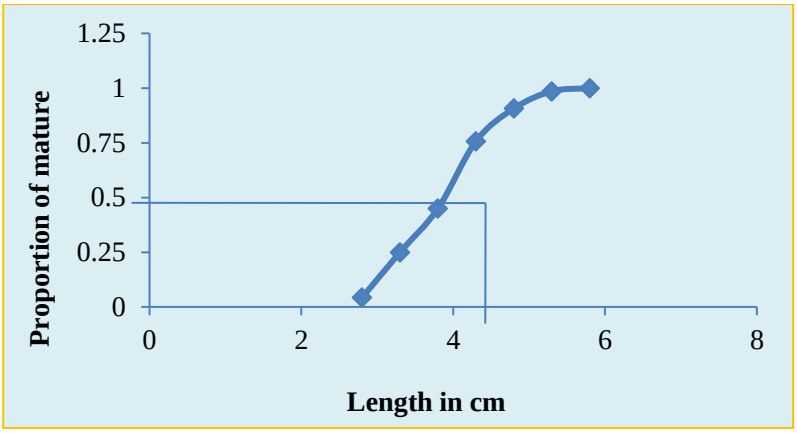

Figure 2: Size at first maturity in males of *A. granosa* during June 2013-May 2015.

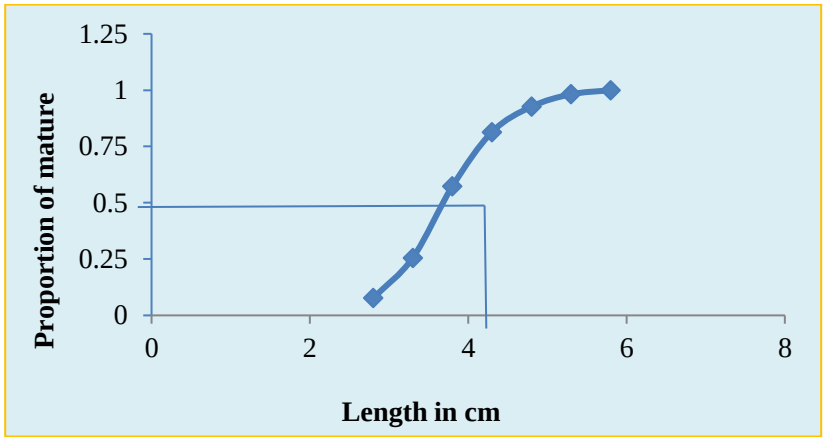

Figure 3: Size at first maturity in females of *A. granosa* during June 2013-May 2015.

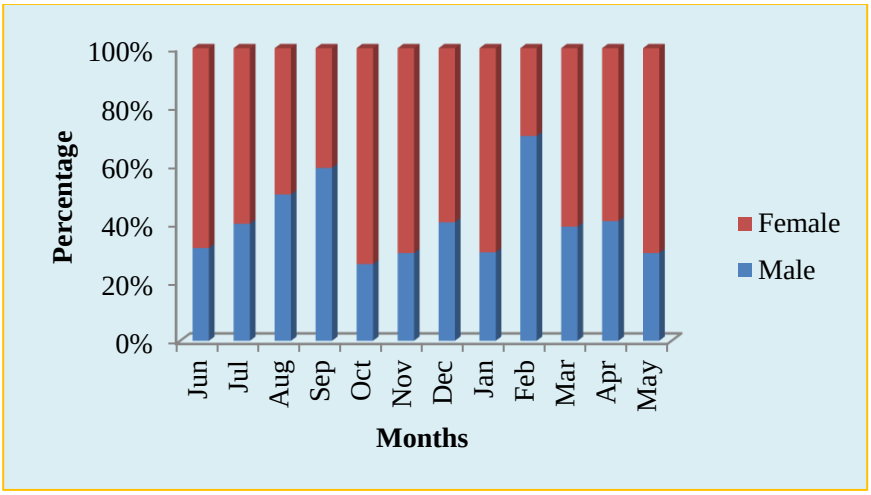

Figure 4: Monthly variations in sex ratio of *A. granosa* during June 2013-May 2014.

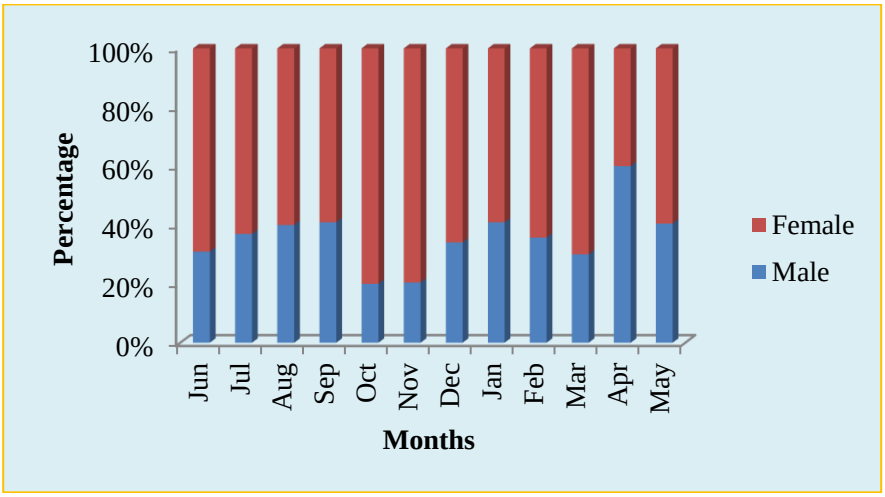

Figure 5: Monthly variations in sex ratio of *A. granosa* during June 2014-May 2015.

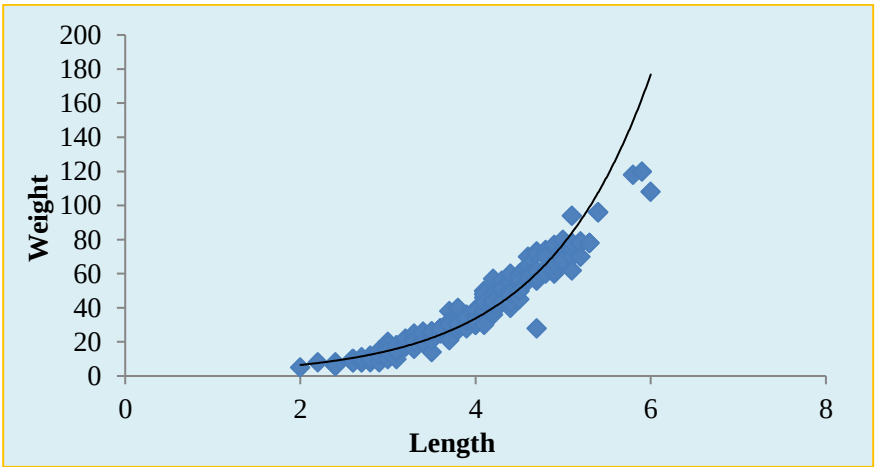

Figure 6: Scattered diagram showing relationship between length and weight for males of *A. granosa* during June 2013-May 2015.

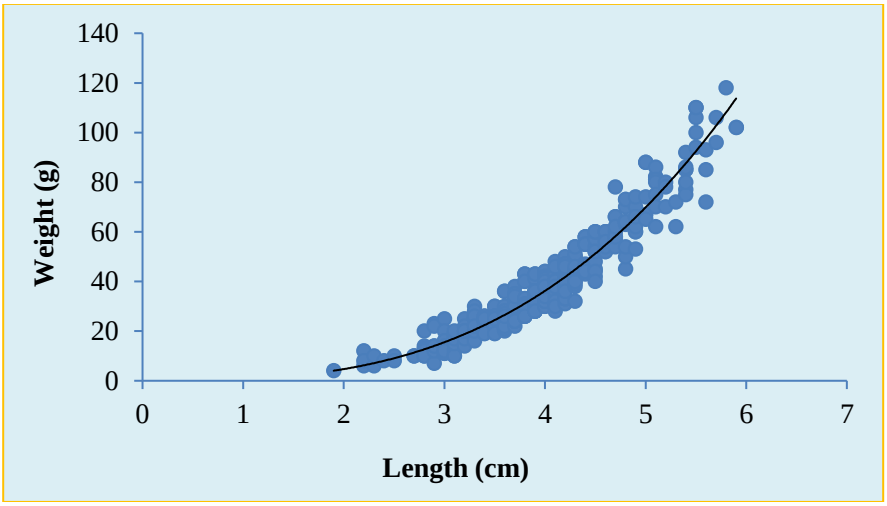

Figure 7: Scattered diagram showing relationship between length and weight for females of *A. granosa* during June 2013-May 2015.

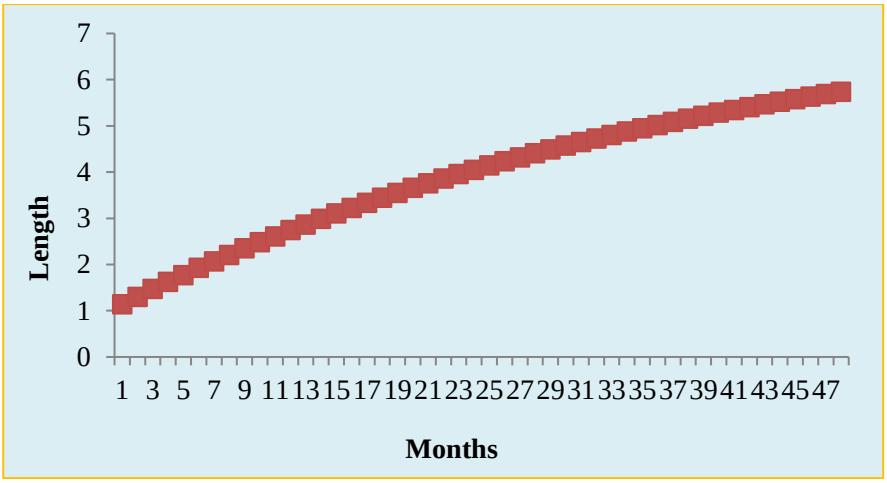

Figure 8: Month wise growth curve of *A. granosa* drawn on the basis of Von Bertalanffy growth equation.

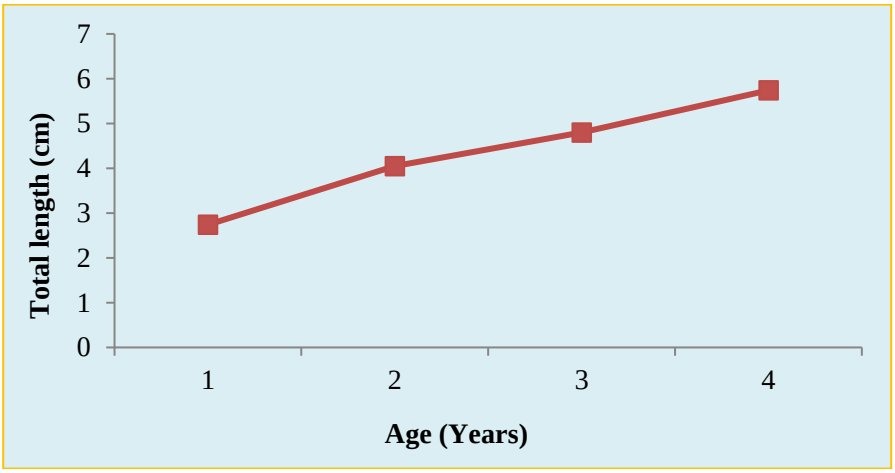

Figure 9: Year wise growth curve of *A. granosa* drawn on the basis of Von Bertalanffy growth equation.

Table 2: Season wise percentage frequency of maturity stages in females of *A. granosa* during June 2013-May 2015.

Season	**Maturing %**	**Matured %**	**Spent %**	**Recovery %**
Monsoon 2013	49	35	8	8
Post monsoon 2013-14	43	46	11	-
Pre monsoon 2014	26	29	21	24
Monsoon 2014	46	26	12	16
Post monsoon 2014-15	9	69	22	-
Pre monsoon 2015	18	-	57	25

Table 3: Season wise percentage frequency of maturity stages in males of *A. granosa* during June 2013-May 2015.

Season	**Maturing%**	**Matured%**	**Spent%**	**Recovery%**
Monsoon 2013	68	26	-	6
Post monsoon 2013-14	16	64	20	-
Pre monsoon 2014	6	23	47	24
Monsoon 2014	38	33	29	-
Post monsoon 2014-15	13	50	31	6
Pre monsoon 2015	38	12	29	21

Table 4: Sex ratio for *A. granosa* during study period.

Month	**Total**	**Male**	**Female**	**% of Male**	**% of Female**	**M:F ratio**
June	42	13	29	30	70	1:2.3
July	46	17	29	38	62	1:1.6
Aug	40	16	24	40	60	1:1.5
Sep	44	18	26	42	58	1:1.4
Oct	40	8	32	20	80	1:4
Nov	44	9	35	20	80	1:4
Dec	44	15	29	33	67	1:2
Jan	44	18	26	42	58	1:1.4
Feb	42	15	27	36	64	1:1.8
March	40	12	28	30	70	1:2.3
April	40	24	16	60	40	1:0.7
May	42	17	25	40	60	1:1.5
Total	508	182	326	35.82	64.18	1:2.04

Table 5: Comparison of regression lines of length weight relationship in males and females of *A. granosa* during June 2013-May 2015.

Source	**Mean-X**	**Mean-Y**	**A**	**b**	**r**	**Growth index**
Males	1.357	3.494	-0.79574	3.16215	0.975768	**Isometric**
Females	1.362	3.519	-0.4920	2.94413	0.959959	**Isometric**
Pooled	1.360	3.510	-0.61904	3.03536	0.966405	**Isometric**

A scale of for maturation stages (Maturing, Matured, Spent and Recovery) was described in the present study on *Andara granosa*. It was adopted to evaluate variations in frequency of maturity stages more precisely and to determine the spawning period specifically. The present work was in agreement with earlier studies in *Anadara granosa*. Khalil *et al.*, (2017) studied on reproductive biology of *A. granosa* from northern region

of the strait of Malaca. Suwanjarat *et al.,* (2009) identified five stages of gonad maturity in *A. granosa* from Pattani Bay.

The size at first maturity in females was reported at 3.7cm but minimum size at which ripe gonads were noticed as 2.8cm. Almost similar finding were noticed in bivalves by Narasimham, 1980, 1987; Siddal, 1980, Jayabal and Kalyani, 1986, Vakily, 1989, Sawant and Mohite, 2013. The minor variations may be attributed to environmental, geographical and species variations.

The present study observed bivalve spawn throughout the year, based on the availability of matured and spent stages during October to December in *A. granosa* were considered as peak spawning season. Mane (1976) reported peak spawning season during October in *Katelysia opima*.

The sex ratio for male to female during the study period was 1: 1.83 in *A. granosa*. Females were dominated the catches at Kakinada Bay. It has evident that both the sexes were not equally distributed and hence can be inferred that there was a significant deviation in the sex ratio from the expected 1:1 ratio in the catches during the study period at Kakinada Bay. Female dominance was also noticed in earlier works (Narasimham, 1987). On the contrary, male dominance was also noticed in bivalves (Rajapandian and Rajan 1983; Hamli *et al.,* 2015; Efriyeldi *et al.,* 2022).

The growth coefficient 'b' may range from 2 to 4 (Koutrakis and Tsikliras, 2003). The growth coefficient 'b' generally lies between 2.5 and 3.5 and the relation is said to be isometric when it was equal to 3 (Carlander, 1977). In the present study the growth coefficient 3.0 in *A. granosa*. The values of 'b' in the current study demonstrated that *A. granosa* showed isometric growth, as mentioned by Koutrakis and Tsikliras, (2003), Khalil *et al.,* (2021). Narasimham (1969) mentioned 'b' values as 3.20, 3.20 and 3.64, showed positive allometric growth from different length groups in *A. granosa* from Kakinada bay.

The von Bertalanffy Growth Function (VBGF), a reliable explanation for growth rate of cockles (Caddy, 1989; Vakily, 1992), was examined in the present study for *A. granosa* and had a perfect fit for the length frequency data. Yin *et al.,* (2003) found that the growth curve in bivalves was sigmoid in shape and the von Bertalanffy growth model was able to provide an ideal fit in relation to length frequency. Furthermore, the sigmoid growth curves were observed in bivalves by Tsoularis and Wallace (2002) and Lei and Zhang (2004).

Kamal and Khan (1988) observed that animal attains a length of 88.43mm, 114.69mm and 121.91mm at the age of 1, 2 and 3 years respectively from Bangladesh. In the present study we have recorded *A. granosa* length in the first year was 2.7cm. Nurul Amin *et al.,* (2008) reported high growth rate (6.7 cm) in first year in *C. madrasensis* from Bangladesh. In the current study the growth parameters showed almost similarities with the results of Narasimham (1980 and 1988a), Bahitar *et al.,* (2023).

Conclusion

Study on biology of *A. granosa* is essential to know the maturity, spawning season, growth and availability of spat (seed) for mass scale farming. The present study indicated that the *A. granosa* spawns throughout the year, so that the seed is available throughout the year and it is quite suitable for coastal aquaculture of bivalves.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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