J. mar. biol. Ass. India, **46** (2) : 154 - 161, July - Dec., 2004

Reproductive biology of the tropical abalone *Haliotis varia* from Gulf of Mannar

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Abstract

The annual reproductive cycle of two populations of the abalone, *Haliotis varia* Linnaeus, separated by 90 km, in the Gulf of Mannar, was studied. Six maturity stages were distinguished. The sex ratio of abalone (>25mm shell length) at Tuticorin and Mandapam did not differ significantly from 1:1 ratio. Sexual maturity was first attained at a size of 18-20 mm and 22-24 mm for males and females respectively at Tuticorin, and 20-22 mm and 22-24 mm at Mandapam. The gonado-somatic index (GSI) and the relative abundance of different maturity stages were used in determining the annual reproductive cycle. The breeding season of the population extended from December to February in Tuticorin and November to January in Mandapam. The spawning season coincided with the end of northeast monsoon period in both populations. The gonad maturation was linked to the variation in water temperature and salinity. Seasonal low values in both these parameters coincided with the breeding season of *H. varia*. The results indicated the scope for production of mature specimens throughout the year by induced maturation through regulation of salinity and temperature.

Key words: Tropical abalone, *Haliotis varia*, reproductive cycle, environmental variables, gonadosomatic index.

Introduction

Abalones are one of the most economically important edible gastropods, which support significant commercial fishery in many parts of the world. They live on rocky coralligenous substrates from shallow coastal waters to depths of about 60 m. Eventhough commercial fishing of temperate abalones was in vogue from time immemorial, their exploitation in tropical waters is relatively a recent enterprise owing to its small size. However, the culture of the tropical abalones is now intensified due to the increasing demand for live small abalones in the international market (Chen, 1989). The only identified species of abalone in India is *Haliotis varia*, which grows to a maximum length of 8 cm (Fig. 1). It is distributed in the Gulf of Mannar and Andaman and Nicobar Islands. There is no commercial exploitation of this species in India. Some efforts have been made to study the seed production and reproduction in this species (Najmudeen, 2000; Najmudeen *et al.*, 2000; Najmudeen and Victor, 2004). Sufficient literature is available in the last two decades on the spawning and gametogenic cycle of different abalone species in the temperate waters (Bang and Hahn,

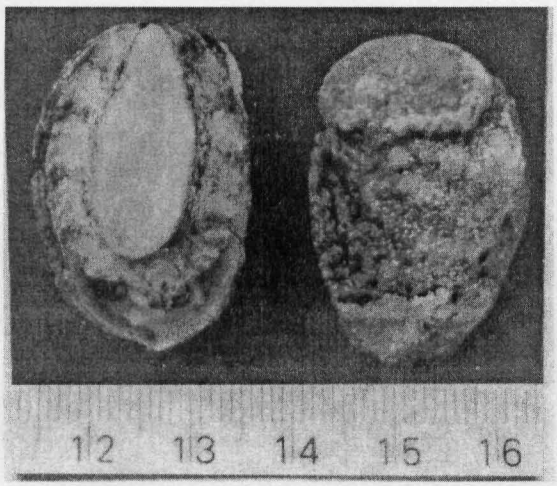

Fig.1. *Haliotis varia*

1993; McShane and Neylor, 1996; Wood and Buxton, 1996). Relatively few studies have been reported from the tropical abalones (Jarayaband *et al.*, 1994; Apisawetakan *et al.*, 1997; Capinpin *et al.*, 1998; Jabreen *et al.*, 2000). Some aspects of the reproductive biology of *H. varia* at Andaman Sea Coast of Thailand have been studied by Bussarawit *et al.*, (1990). The present study was carried out to determine the gonad maturation process and reproductive cycle of the two populations of *H. varia* in the Gulf of Mannar, to document the probable environmental stimuli that control the gametogenic activity.

The authors are thankful to the Director, Central Marine Fisheries Research Institute, Cochin for the constant encouragement and providing necessary facilities. The study was financed by Indian Council of Agricultural Research, New Delhi.

Material and methods

Monthly, live samples of *H. varia* (shell length >25 mm) were collected from the intertidal rocks at Tuticorin (Lat.08° 45′ N, Long.78° 12′ E) and Mandapam (Lat. 09° 16′ N, Long. 79° 12′ E) in the Gulf of Mannar from a depth of 1-3 meters, during December 1997 to February 1999. The abalones transported to the laboratory were stocked in a 1.5 tonne capacity FRP tank containing filtered seawater and kept overnight to allow the clearance of waste materials accumulated in their body.

Monthly, on an average nearly 45 specimens from each station were taken for studying the annual gonad cycle and gametogenesis. The total body weight of each animal was taken to the nearest milligram (mg). The shell length, shell width and shell height of each abalone were measured, using Vernier Callipers, to the nearest millimetre. The specimens were then shucked and dissected to examine the gonad and sex ratio. The soft body weight, digestive gland weight and gonad weight were taken on a wet weight basis. Various morphological characters of the gonad, such as, colour, percentage of gonad in the conical appendage, gonad volume and digestive gland volume were also recorded. The classification system for testes and ovary was based on the different stages followed by Wood and Buxton (1996). The ovary sections were classified according to the changes in relative abundance of the different cell types, as determined through assessment of diameter of 50 oocytes per individual

using a compound microscope fitted with a calibrated micrometer.

Sex ratio of *H. varia* was determined monthly. Chi-square goodness-of-fit tests were used to find significant variation if any from 1:1 ratio. To determine the size at first sexual maturity, a series of young abalones ranging from 6 mm onwards were collected during the peak spawning season and their gonad condition was documented. They were grouped into 2 mm length intervals and the percentage of individuals with mature gonads was calculated against each of the class intervals to estimate the minimum size at which 50% of the size class was sexually mature (Shepherd and Laws, 1974). The gonadosomatic index (GSI) for each abalone was calculated using the formula, GSI = wet weight of gonad in gram/soft body weight of abalone in gram x 100 (Webber and Giese, 1969). Similarly, the hepatosomatic index (HSI) was calculated using the formula, HSI = wet weight of whole digestive gland in gram/soft body weight of abalone in gram x 100. To see if there was a significant relationship between GSI and environmental parameters, the data were tested with Pearson rank correlation. Differences in GSI for males, females and pooled sexes over time and between populations were compared using one factor analysis of variance (ANOVA). In addition to variation in gonad indices, the relative abundance of different maturity stages were recorded throughout the period to study the reproductive cycle.

During each sampling, the temperature, *p*H, dissolved oxygen and salinity of the surface water of the collection site were recorded. *p*H was measured using a digital *p*H meter. Dissolved oxygen was determined by Winkler method and salinity by following Strickland and Parsons (1968).

Results

The process of vitellogenesis in *H.varia* starts when the primary oocytes reach 50 mm in diameter. Ripe ovary is exclusively filled with vitellogenic oocytes. Based on the size, shape, colour and texture of the gonad and microscopic structure through histological examination, testes and ovary at different stages of maturity were placed into six categories: I) early maturing/ recovering, II) late maturing, III) ripe, IV) partially spawned, V) spent and VI) immature stages.

Sex ratio

Studies on 574 abalones (Shell length >25 mm) (males 274 and females 300) from Tuticorin and 444 specimens (223 males and 221 females) from Mandapam indicated no significant variation in sex ratio between months in both the populations.

Size at first sexual maturity

Males and females developed their first gametes at different sizes (Table 1). At Tuticorin, 50% maturity was attained at a shell length of 18-22 mm for males and 22-24 mm for females compared to 20-22mm and 22-24 mm respectively at Mandapam. The smallest female abalone

Table 1. *Size at first sexual maturity of* H. varia *in Tuticorin and Mandapam*

Shell length (mm)	Percentage (mature)			
	Tuticorin		Mandapam	
	Male	Female	Male	Female
12 - 14	0.0	0.0	0.0	0.0
14 - 16	0.0	0.0	0.0	0.0
16 - 18	0.0	0.0	0.0	0.0
18 - 20	75.0	25.0	20.0	0.0
20 - 22	80.0	33.3	50.0	0.0
22 - 24	92.1	54.5	80.0	50.0
24 - 26	94.3	66.7	83.3	62.5
26 - 28	100.0	78.6	95.5	87.5
28 - 30	100.0	100.0	100.0	100.0

with apparent mature (vitellogenic) eggs showed a shell length of 19.2 mm at Tuticorin and 23.4 mm at Mandapam.

Gonado-somatic index

At Tuticorin, the highest GSI values were observed in January to March. The values decreased thereafter indicating completion of the spawning by end of the period (Fig. 2). The lowest values were in August and October. The values suggested that the breeding season of *H. varia* at Tuticorin coincided with the post monsoon period (December-March) compared to November-February at Mandapam. In both the stations, the standard deviation for the monthly values of GSI was high which indicated the asynchronous spawning behaviour between individuals.

The hepatosomatic index (HSI) also significantly varied between months in both the populations ($P<0.05$). There was a negative correlation between HSI and GSI in both populations (Figs.2 & 3).

Relative abundance of different maturity stages

Almost all the maturity stages were present throughout the year. At Tuticorin, the partially spawned stage (33%) occurred in September compared to July in Mandapam (Figs. 4 & 5). The increase in the number of partially spawned and spent stages in December and November at Tuticorin and Mandapam respectively indicated the real onset of spawning. The

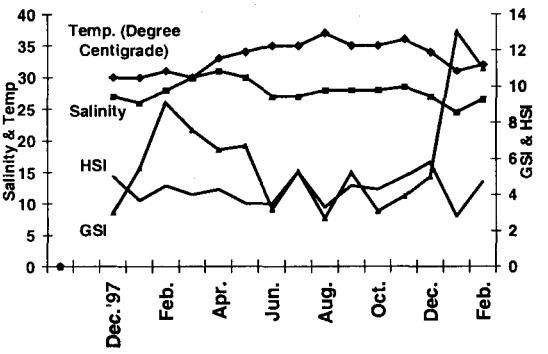

Fig. 2. *Monthly GSI and HSI values in* H.varia, *salinity (ppt) and surface water temperature (°C) at Tuticorin*

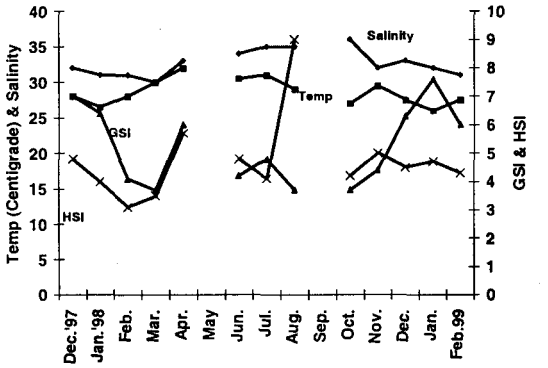

Fig.3.*Monthly GSI and HSI values in* H.varia, *salinity (ppt) and surface water temperature (°C) at Mandapam*

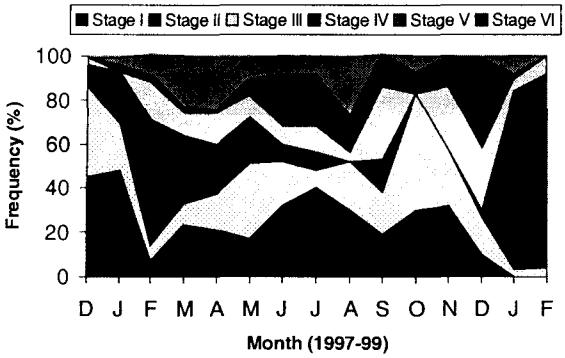

Fig. 4. *Relative abundance of different maturity stages in* H. varia *at Tuticorin*

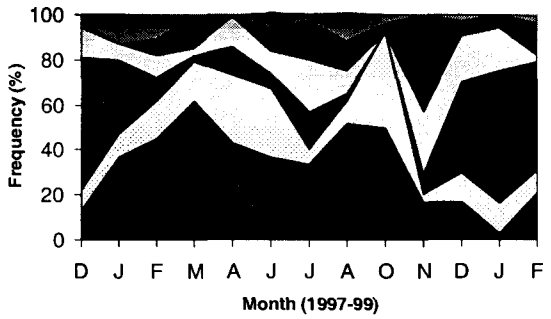

Fig. 5. *Relative abundance of different maturity stages in* H. varia *at Mandapam (Symbols as in* Fig.4*)*

higher percentage occurrence of ripe specimens in January and February at both centres indicated the active breeding season of *H. varia.* In March, 62% were in early maturing stage showing active recovery immediately after spawning.

At Tuticorin, the mean annual range of variation in water temperature was by 4.2ºC. The period of gamete maturation and spawning coincided with a decrease in water temperature and salinity at both the places. There was a negative correlation (*r*-value >-0.4) between GSI and salinity values (Figs.2, 3). The low value of salinity also coincided with high GSI but the correlation was not significant. The dissolved oxygen and *p*H of the surface water did not show any regular pattern and correlation with GSI (r values <0.4).

Discussion

H. varia exhibited a broadcast spawning behaviour; i.e., at spawning, the gametes are released into the environment and fertilisation is external. The mature gonad of broadcast spawners constituted (15%) a large part of the body weight. In *H. cracherodii,* it is 20% (Webber and Giese, 1969) and 25% in pismo clam (Giese *et al.*, 1967). Histological studies revealed that the gonad of *H. varia* is similar to the description given by Newman (1967) for *H. midae* and Young and DeMartini (1970) for *H. rufescens.*

As in the present case most studies in abalone including those in the tropical populations have reported 1:1 sex ratio (Newman, 1967; Webber and Giese, 1969; Young and DeMartini, 1970; Poore, 1973; Bussarawit *et al.*, 1990; Capinpin *et al.*, 1998).

In several marine invertebrates, the stage of sexual maturity has been shown to be a function of size (Wenner *et al.*, 1974). In both populations of *H.varia,* from the two centres, the males matured at an early shell length. Along the Andaman Sea Coast of Thailand, the minimum size of individual *H. varia* having mature eggs reported was 17.3 mm (Bussarawit *et al.*, 1990

Temperate species of abalones generally have distinct annual spawning

seasons whereas tropical species appear capable of spawning round the year (Jarayabhand *et al.*, 1994). In the present study, *H. varia* appeared capable of spawning in most months of the year. Bussarawit *et al.* (1990) suggested that there was a greater gametogenic activity in tropical than the temperate species based on their observations of a rapid post spawning recovery in *H. varia* at Phuket. Webber and Giese (1969) reported that *H. cracherodii* spawned only during a 6-week period in a year. However, some temperate abalones are also capable of spawning throughout the year, e.g., *H. roei* (Shepherd and Laws, 1974). The differences in the breeding season in two populations in nearby areas have been reported by many authors. Newman (1967) found sufficient difference in the timing and intensity of spawning in *H. midae* at three sites. Muller (1984) observed a shift in breeding season in *H. sporadica* from two stations, only 12 km apart. There was a slight difference in the breeding period between the two populations of *H. varia*. There was a negative correlation observed between the hepatosomatic index (HSI) and GSI. Similarly, Boolootian *et al.* (1962) noticed that the HSI was negatively correlated with gonad index both in *H. cracherodii* and in *H. rufescens*.

Shepherd and Laws (1974) highlighted the impact of local environmental conditions in the regulation of reproductive activity. Spawning of ripe abalone in nature may be induced by a sudden change in temperature caused by tides (Capinpin *et al.*, 1998). Synchronised spawning in *H. varia* is restricted only to the three months. *H. asinina* spawns synchronously, every two weeks in a predictable manner (Jabreen *et al.*, 2000). In the present study, the surface water temperature and salinity were lowest during northeast and post monsoon period. It is reported that, on the Indian coast, intensities of breeding of crustaceans and molluscs differ in accordance with the southwest and northeast monsoon, thus showing distinctive peaks in the reproductive cycle (Varadarajan and Subramoniam, 1982). As the gonad development in *H. varia* is shown to be influenced by annual temperature and salinity fluctuations, it is possible to obtain mature specimens throughout the year by controlling these parameters in the laboratory. The availability of ripe specimens throughout the year will facilitate the establishment of abalone hatchery operations in the country.

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