*Indian J. Fish.*, *59(3)* : *69-76, 2012*

# Stock assessment and management options for whelks along south-eastern Arabian Sea

ANJANA MOHAN, V. KRIPA AND K. S. MOHAMED
*Central Marine Fisheries Research Institute, Kochi - 682 018, Kerala, India*
*e -mail: ram.anjana@gmail.com*

## ABSTRACT

Two species of whelks *viz., Babylonia spirata* and *Babylonia zeylanica* belonging to the family Buccinidae are commercially fished from Kollam, south-west coast of India, since early 1990's and are exported from India under the trade name 'Baigai'. The species is present all through the year in the fishing grounds, caught as by-catch in shrimp trawlers and is a targeted fishery from April to June, when more than 50% of the annual whelk catch is taken. *B. zeylanica* dominates the whelk catch (61% of the annual catch). The average catch rate in the modified trawlers for whelk was 400 kg unit$^{-1}$ day$^{-1}$. Following the von Bertalanffy growth function, asymptotic length and growth rate were estimated as 68.7 mm and 1.08 respectively for *B. spirata* and as 76 mm and 1.15 respectively for *B. zeylanica.* The $L_{50}$ estimated for *B. spirata* and *B. zeylanica* were 35.2 and 41.7 mm respectively. The optimum length of capture and mean generation time were 40 mm and 0.55 years for *B. spirata* and 44 mm and 0.48 years for *B. zeylanica* respectively. The annual mean length of *B. spirata* showed an increase from 37.4 mm in 2001 to 40.1 mm in 2002 and multiple cohorts have been observed. The relative yield-per-recruit analysis shows that, present rate of exploitation of *B. spirata* has reached the optimum and that of *B. zeylanica* has nearly attained the optimum. The faster growth rate, early maturity and continuous breeding behaviour explain the sustained fishery of *B. spirata* and *B. zeylanica* under a high fishing pressure along Kollam coast.

Keywords: *Babylonia spirata, Babylonia zeylanica*, Buccinidae, Population dynamics, Whelk fishery

## Introduction

Globally, gastropods have a documented commercial fishery and major species harvested are *Strombus* spp., *Haliotis* spp., *Busycon* spp., *Cymbium* spp., *Turbo cornutus* and *Buccinum undatum* (FAO, 2003). In India, gastropods have been mainly used for ornamental purposes and the major resources are the *Xancus pyrum* or the sacred chank, the top shell *Trochus niloticus* and the turbo shell *Turbo marmoratus* (Appukuttan and Philip, 1994). Their sedentary nature has made them vulnerable to overfishing and in many parts of the world the stocks are either depleted or on the verge of collapse (Leiva and Castilla, 2002). Recent developments in gastropod fishery indicate the need to have a strong database on the population parameters of targeted gastropods for effective management plans in order to avoid overexploitation and stock depletion.

In India, during the last decade, two species of whelks *viz.*, *Babylonia spirata* and *Babylonia zeylanica* of the family Buccinidae began to be fished and exported under the trade name 'Baigai' to China, Singapore, Thailand and Europe (MPEDA, 2005). The genus *Babylonia* includes scavenging gastropods found on sandy or muddy substrates of Indo-Pacific coasts (Altena and Gittenberger, 1981). *B. spirata,* or 'spiral babylon' has a wider distribution along east and west coasts of India and Andaman and Nicobar Islands (Ayyakkannu, 1994; Appukuttan and Philip, 1994; Sasikumar *et al*., 2006), whereas, *B. zeylanica,* or the Indian babylon is reported only from Kollam coast of Kerala. Though the fishery of *B. spirata* and *B. zeylanica* started as a trawl bycatch (Appukuttan and Philip, 1994), it gradually developed as a resource worth fishing exclusively with suitable modifications made in the trawl gear (Sabu *et al*., 2005). The sedentary lifestyle makes them vulnerable to overfishing and may require a novel management approach in future. The main objective of the study was to understand the population parameters like mortality rates, exploitation rate and relative yield per recruitment of the whelks, *B. spirata* and *B. zeylanica* along Kollam coast, in order to formulate appropriate management strategies.

## Materials and methods

### *Data collection for estimating catches*

Catch and effort data were collected from the Neendakara-Sakthikulangara fishing harbours in Kollam District of Kerala (08° 56' N, 76° 32' E) during January 2001-December 2003 using the stratified multistage random sampling design (Srinath *et al*., 2005). This data was used for estimating the monthly catch, catch per unit effort (CPUE) and percentage contribution of gastropods as well as whelks to the total marine fish catch of the area.

Length frequency distribution of *B. spirata* was studied by analysing random samples collected fortnightly during January 2001 to December 2002 and *B. zeylanica* for the period of one year from January to December 2002. The standard shell height (SH) of 1864 specimens *B. spirata* and 583 specimens of *B. zeylanica* were measured (Blundon and Vermeij, 1983) using digital calipers (Mikimoto™) to the nearest 0.1 mm and grouped into 2 mm class interval.

*Growth*

Parameters of the von Bertalanffy growth function (VBGF), growth rate (*K*) and asymptotic length ($L_\infty$) were estimated from monthly length frequency data using ELEFAN routine of the FAO-ICLARM Stock Assessment Tools (FiSAT) program (Gayanilo *et al.,* 1988).

*Mortality coefficients*

The total mortality coefficient (Z) was estimated with an empirical formula used for estimating production/ biomass ratio of benthic invertebrate populations (Brey, 1999).

$Z = 10.154 - (0.271 * \log(M)) - (2824.247 * 1/(T+273)) - (0.063 * \log(D+1)) + (0.130 * DLife\text{-}ME) + (0.076 * DDiet\text{-}C) - (0.311 * DTaxon\text{-}M)$ where, M - mean individual body mass (3.22 and 3.5 kJ respectively for *B. spirata* and *B. zeylanica*); T- bottom water temperature (29 °C and 27 °C for *B. spirata* and *B. zeylanica* respectively); D - water depth (25 and 35 m for *B. spirata* and *B. zeylanica* respectively); ME - motile epifauna; Diet C- Carnivorous; Taxon- M - Mollusca.

The natural mortality coefficient (M) was estimated using Brey's (1999) equation for natural mortality rate (M) in benthic invertebrate populations.

$M = 1.672 + (0.993 * \log(1/A_{max})) - (0.035 * \log(M_{max})) - (300.447 * 1/(T+273))$ where, $A_{max}$ - maximum age (2.8 and 2.6 year for *B. spirata* and *B. zeylanica* respectively); $M_{max}$ - maximum individual body mass (6 and 15 g dry wt for *B. spirata* and *B. zeylanica* respectively); T - Bottom water temperature (29 °C and 27 °C for *B. spirata* and *B. zeylanica* respectively). The fishing mortality coefficient (F) was calculated from the formula F= Z – M. Here, the Z and M values estimated using Brey's equations were used for the estimation.

*Probability of capture*

Probability of capture by length of the whelks was estimated using FiSAT program. The mortality coefficients estimated earlier were used here for the analyses. The length class with the highest biomass ($L_{opt}$) and the average age at which an individual is capable of producing young ones ($t_g$) were estimated following Froese and Binohlan (2000).

*Relative yield-per-recruit (Y'/R)*

The Y'/R and relative biomass-per-recruit (B'/R) were obtained from the estimated growth parameters and probabilities of capture by length (Pauly and Soriano, 1986) using the routine available in FiSAT.

*Length cohort analysis*

Length based cohort analysis (Jones, 1981) was performed to estimate the dynamics of abundance and fishing mortality and number of survivors for each of the length class. The input parameters used were, $L_\infty$, *K* and F/Z.

## Results

*Fishery*

The mean annual whelk catch for 2001-2003 was estimated as 487 tonnes (t) contributing to 62.5% of the total gastropod catch from the area. The annual catch was lowest with 419.4 t in 2001 and highest with 586.5 t in 2002 indicating an increase of 28.5% within a year. This was followed by a decline of 22.4%, when the estimated catch dropped to 455 t in 2003. The estimated monthly mean catch of gastropods, whelk and the percentage contribution of whelk to the total gastropods caught off Kollam during 2001-2003 are given in Fig. 1. Both *B. spirata* and *B. zeylanica* were caught in all the months except during July when there is a regulatory ban on trawling (Fig. 2). The *B. zeylanica* dominated whelk catch contributing to 61% of the annual average catch. The estimated monthly catch of *B. zeylanica* ranged from 63 kg in January 2001 to 157.5 t in May 2001 with its percentage contribution to the total whelk catch varying between 1.3% in August 2003 and 92.7% in May 2001. Monthly catch of *B. spirata* ranged from 1.4 to 16.5 t in

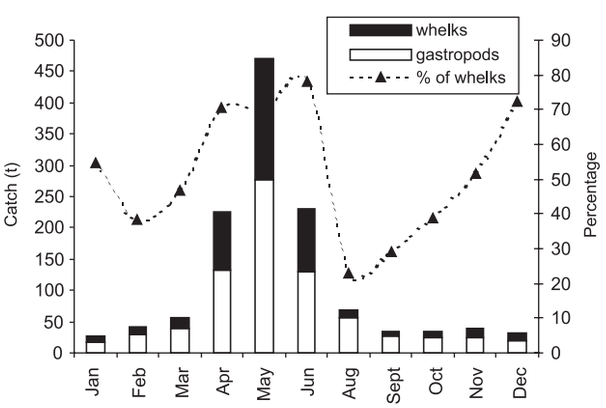


Fig. 1. Estimated average monthly catch (2001-2003) of gastropods as well as whelks and the percentage contribution of whelks to total gastropods catch from south-eastern Arabian Sea

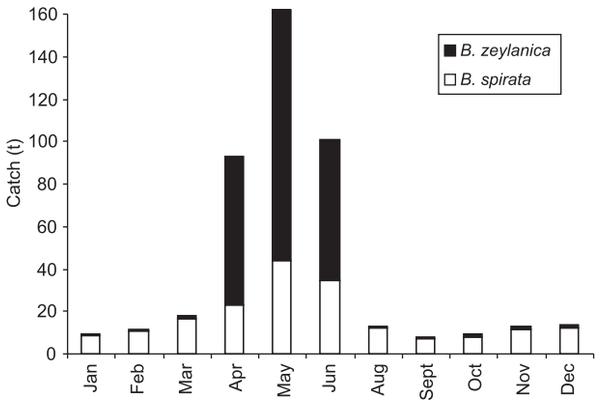


Fig. 2. Estimated average monthly catch (2001-2003) of *B. spirata* and *B. zeylanica* from south-eastern Arabian Sea

2001, which in the following year, was higher ranging from 5.8 to 95.1 t, but decreased and ranged between 2.4 and 42 t in 2003.

The mean CPUE for whelk was 8, 6.8 and 9.1 kg during 2001, 2002 and 2003 respectively in shrimp trawlers. On an average, 8788, 9158 and 5272 boat trips were operated from Sakthikulangara-Neendakara harbours in 2001, 2002 and 2003 respectively. In all the years, maximum recorded CPUE was during June. During the peak whelk fishing season (April-June), modified trawl nets (20 to 40 boats) with additional weight in the foot rope and 40 mm cod-end mesh size are used for fishing yielding on an average 400 kg unit$^{-1}$day$^{-1}$. The fishing, starts in the early morning for *B. spirata*, while *B. zeylanica* is fished during night hours. Hauling is done 5 to 6 times a day depending on the catch. Each haul takes about 15 to 30 min.

*Size distribution*

The SH of *B. spirata* in the fishery ranged from 20 to 54 mm in the year 2001, while in the subsequent year it was 26 to 60 mm. *B. spirata* of SH less than 30 mm occurred in the fishery in all the months except during June in 2001 (Fig. 3a), while in 2002 small sized whelks (<30 mm) were observed only during January, April, September, November and December (Fig. 3b). About 88 % of the fishery was composed of 30–46 mm length group during 2001 and in the subsequent year this size group formed 92.5% of fishery. The annual percentages of smaller animals of SH less than 30 mm were 10.2 and 0.9% in 2001 and 2002 respectively. The presence of bigger snails (>46 mm) was negligible. The monthly mean SH of *B. spirata* was greater in 2002 than in 2001 (Fig. 4). The highest mean SH was observed in June and smallest in August during both the years. The lowest mean SH was 32.5 mm. Multiple cohorts were clearly visible in the fishery.

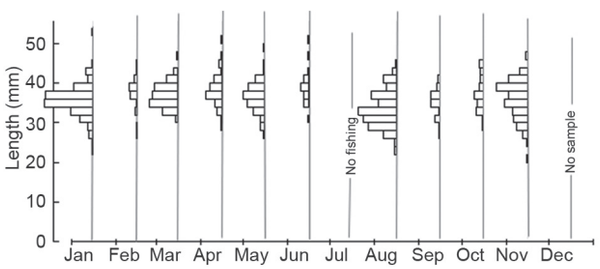


Fig. 3a. Length frequency of *B. spirata* landed from south-eastern Arabian Sea during 2001

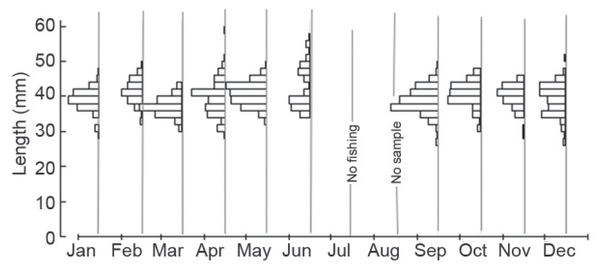


Fig. 3b. Length frequency of *B. spirata* landed from south-eastern Arabian Sea during 2002

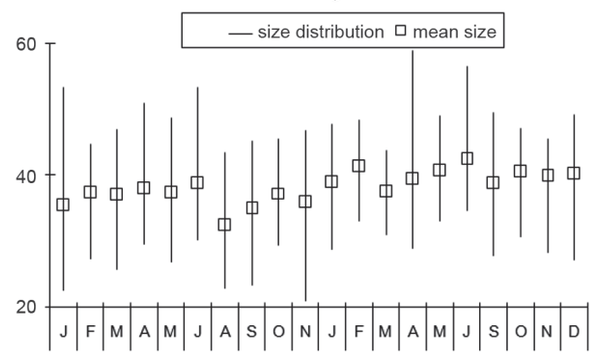


Fig. 4. Monthly mean shell height and range of shell height of *B. spirata* during 2001 and 2002 from south-eastern Arabian Sea

*B. zeylanica* of 40 to 60 mm (87.5%) supported the fishery throughout the year 2002 (Fig. 5). The smallest animal observed in the fishery was 24.2 mm and the largest 68 mm. Snails below 40 mm formed 4.7% of annual catch and above 60 mm formed 7.7%. During the peak fishing season (April – June), *B. zeylanica* of 46 to 64 mm length dominated the fishery (87.2%) and snails above and below this range formed 8.2 and 4.6% respectively. Smaller snails less than 40 mm were maximum during December (14.3%) followed by August (11.2%), October (10.3%) and negligible in other months. Larger snails (>60 mm) formed 25.5% during June. The annual mean shell height of *B. zeylanica* in 2002 was 49.9 mm. The highest mean length was observed in June and the least (42.6 mm) in October (Fig. 6). The mean length analysis shows that young ones form only a meagre part of the fishery for both species.

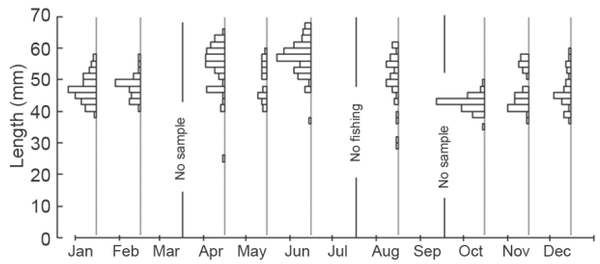


Fig. 5. Length frequency of *B. zeylanica* landed from south-eastern Arabian Sea during 2002

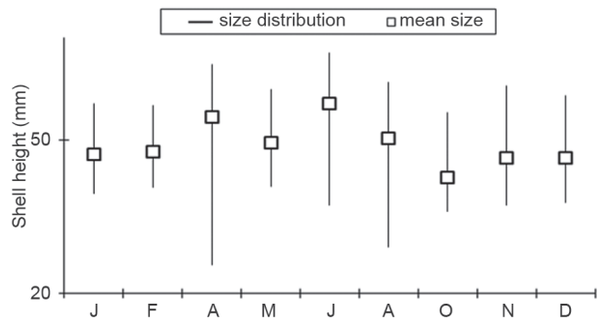


Fig. 6. Monthly mean and range of shell height of *B. zeylanica* landed from south-eastern Arabian Sea during 2002

*Growth*

The observed $L_{max}$ of *B. spirata* and *B. zeylanica* were 58.9 and 68 mm respectively. Using ELEFAN I routine the best fitting (with high goodness of fit) growth curves were selected and $L_\infty$ and *K* were estimated as 68.7 mm and 1.08 respectively for *B. spirata*. The parameters were estimated as 76 mm and 1.15 respectively for *B. zeylanica* (Table 1). Both the species appear to grow at fast rate and attains maximum size within 3 years. The life span of *B. spirata* was calculated as 2.8 years and of *B. zeylanica* as 2.6 years.

Table 1. Population parameters estimated for *B. spirata* and *B. zeylanica*

| Parameters | *B. spirata* | *B. zeylanica* |
|---|---|---|
| $L_\infty$ (mm) | 68.7 | 76 |
| K ($y^{-1}$) | 1.08 | 1.15 |
| Z ($y^{-1}$) | 6.05 | 5.02 |
| M ($y^{-1}$) | 1.61 | 1.65 |
| F ($y^{-1}$) | 4.4 | 3.6 |
| E | 0.73 | 0.71 |
| $E_{max}$ | 0.73 | 0.77 |
| $E_{0.1}$ | 0.66 | 0.72 |
| Spawning stock biomass (t) | 92.9 | 267.7 |
| Standing stock biomass (t) | 216.2 | 404.1 |
| Recruitment numbers | 84,565 | 92,782 |

*Mortality coefficients*

The estimated value of Z was 6.05 and 5.02 for *B. spirata* and *B. zeylanica* respectively. The natural mortality coefficient (M) was estimated as 1.61 and 1.65 for *B. spirata* and *B. zeylanica* respectively. The fishing mortality coefficient was estimated as 4.44 and 3.37 for *B. spirata* and *B. zeylanica* respectively.

*Probability of capture*

Probability of capture, $L_{25}$, $L_{50}$ and $L_{75}$ in the trawl net estimated were 33.06, 35.2 and 37.09 mm respectively for *B. spirata* (Fig. 7). The corresponding values for *B. zeylanica* were 39.74, 41.7 and 43.52 mm respectively. The $L_{opt}$ estimated for *B. spirata* was 40 mm and the estimated mean generation time was 0.55 years and for *B. zeylanica* the $L_{opt}$ was 44 mm and it attains $t_g$ at 0.48 year.

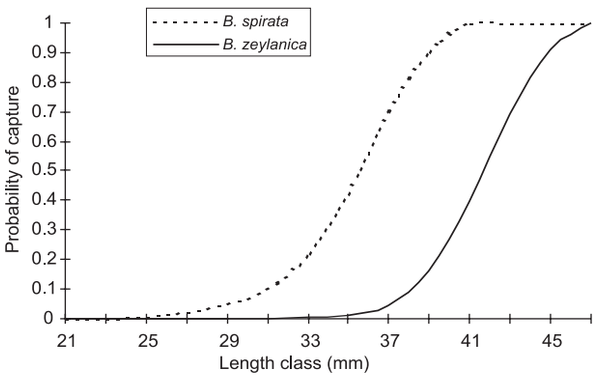


Fig. 7. Probabilities of length at capture estimated for *B. spirata* and *B. zeylanica* from south-eastern Arabian Sea

*Relative yield-per-recruit (Y'/R)*

The relative yield-per-recruit (Y'/R) and relative biomass-per-recruit (B'/R) were determined as a function of $L_c/L_\infty$ and M/K respectively. The $L_c/L_\infty$ and M/K at $E_{max}$ for *B. spirata* were 0.512 and 1.49 respectively. Fig. 8 shows the maximum allowable limit of Y'/R for *B. spirata*. The present exploitation ratio (0.73) has reached the optimum exploitation ratio $E_{max}$ (0.73).

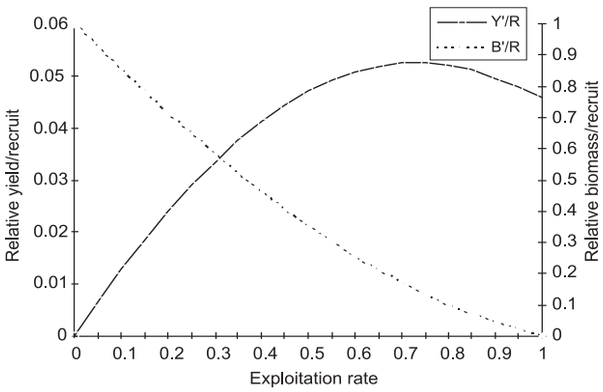


Fig. 8. Relative yield-per-recruit and biomass-per-recruit of *B. spirata* from south-eastern Arabian Sea

The $L_c/L_\infty$ and M/K at $E_{max}$ were 0.548 and 1.435 respectively for *B. zeylanica*. Fig. 9 shows the estimated values of Y'/R and B'/R for the study period. The present exploitation ratio E (0.71) has almost attained $E_{max}$ (0.77), whereas the $E_{0.1}$ was 0.717 and $E_{0.5}$, 0.3769. The $E_{0.1}$ and $E_{0.5}$ values (Table 1) obtained for both species in the analysis shows that even 10% increase in the fishing effort will affect detrimentally the whelk population in south-eastern Arabian Sea.

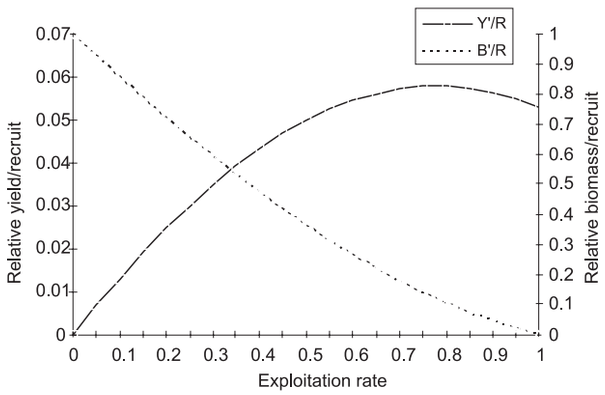


Fig. 9. Relative yield-per-recruit and biomass-per-recruit of *B. zeylanica* from south-eastern Arabian Sea

*Length cohort analysis (LCA)*

The results of length cohort analysis of *B. spirata* showed that the time interval (Δt) increased from 0.04 in 20-22 mm size class to 0.21 in 58-60 mm size class. Fishing mortality (F) increased to a maximum of 5.98 in the length class 40-42 mm and the maximum exploitation (79.8 t) was in the size class 38-40 mm. The catch comprised mainly of 38-40 mm size class. The biomass increased from 11.9 t in the size class 20-22 mm to the maximum (22.3 t) in the size class 32-34 mm and gradually reduced to 0.3 t in 56-58 mm. The total yield of *B. spirata* estimated was 423.3 t and the spawning stock biomass formed 43% of the standing stock. Standing stock, spawning stock biomass and the number recruited obtained in the LCA are given in Table 1.

The result of length cohort analysis of *B. zeylanica* showed that the Δt increased as size increases. Fishing mortality was negligible for smaller length groups (up to 45 mm). Highest fishing mortality has observed for the largest length group 66–68 mm. Exploitation was highest in the size group 56–58 mm. The biomass increased from 13.8 t in the size class 24-26 mm to the maximum (28.5 t) in the size class 42–44 mm and gradually reduced to 1.3 t in 64–66 mm. The total yield was estimated as 356.4 t for the year 2002 and the spawning stock was 66% of the standing stock. The standing stock biomass, the spawning stock biomass and recruitment number obtained in the LCA are given in Table 1.

## Discussion

The annual catch of *Babylonia* spp. in Kollam Harbour increased from 188.9 t in 1993 (Appukuttan and Philip, 1994) to 586.5 t in 2002, which can be attributed to targeted trawling using modified gear. There is a substantial difference in the CPUE for *Babylonia* spp. between the regular shrimp trawler and the trawler with modified trawl targeting exclusively whelks (Appukuttan and Philip, 1994; Sabu *et al*., 2005). Along the Indian east coast, *Babylonia* spp. is caught by modified ring net at Pondicherry (Chidambaram, 1997) and by trawlers along Tuticorin coast (Selvarani, 2001).

Even after a decade of fishing, the seasonal variations in whelk fishery remain the same as that reported by Appukuttan and Philip (1994). As most of the fishing units concentrate on high value resources like shrimps and cephalopods, exclusive whelk fishing is seldom undertaken and this is the main cause for seasonal variation of whelk catch. Another reason for the fluctuations is its demand in the export market. When there is an export order for this resource, commercial fishing is intense and the fishing boats harvest nearly 250 t within a month.

Maximum shell height of *B. spirata* observed presently is similar to that observed in Porto Novo (Shanmugaraj *et al*., 1994; Shanmugaraj and Ayyakkannu, 1997) and smaller than that in Pelabuhan Ratu Bay, Indonesia (Yulianda and Dhanakusumah, 2000). Size distribution of *B. spirata* and *B. zeylanica* was wide and the percentage of exploited young ones was less. Compared to *B. spirata*, larger snails of *B. zeylanica* supported the fishery. Since the same trawls were used for *B. spirata* and *B. zeylanica*, the influence of gear on selecting the large sized whelk can be eliminated and the non-occurrence of small-sized whelk in the fishery is due to their absence in the natural bed. Moreover, the condition of the gonads of both male and female whelks was either in the ripe or spent stage (Anjana, 2007). Percentage of immature or indeterminate stages were <10, which indicates that this is a spawning stock. Martin *et al*. (1995) suggest spawning congregations and ontogenic migration of *Bolinus brandaris* towards deeper waters. Narvarte (2006) has supported the view that local movements and migration of whelks may occur due to predating or reproductive behaviour and may contribute to large variations in densities in the same location. Philip and Appukuttan (1997) reported that, along the Kollam coast during the fishing season of whelks, in one particular fishing boat an unusual catch of 1t of *B. zeylanica* was obtained in a day. This indicates that *B. zeylanica* congregates for spawning along the Kollam coast within 20-50 m depth zone.

The Z and F values were higher for *B. spirata* than that of *B. zeylanica*. The present rate of exploitation of

*B. spirata* was the same as the optimum exploitation rate whereas for *B. zeylanica* the present exploitation rate was a little less than the optimum. In a study on the whelk *Cittarium pica* fishery along the Caribbean coast of Costa Rica, the length frequency histogram showed a strong shift towards smaller sizes at exploited sites than at unexploited site and the Z values were also higher (Z = 4.47) at exploited site compared to the unexploited site (Schmidt *et al*., 2002). They concluded that exploitation rates more than 0.6 at both the sites indicated overexploitation and recruitment overfishing and they recommended regulating the fishery through minimum catch size and closure of fishery during its reproductive period.

The exploitation rates of *B. spirata* and *B. zeylanica* have reached the optimum level and the population is under fishing pressure. However, the fishery is able to sustain because both the whelks are having a higher growth rate compared to other gastropod species such as the sacred chank (*Xancus pyrum*) (Devaraj and Ravichandran, 1988; Lipton and Selvakku, 2001), *Trochus niloticus, Turbo marmoratus, C. pica* (Schmidt *et al*., 2002), *Strombus gigas* (Berg and Olsen, 1989), *Buccinum isaotakii* (Ilano *et al*., 2004) and *B. undatum* (Kenchington and Glass, 1998; Valentinsson *et al.,* 1999). The $L_{opt}$ of *B. spirata* was 40 mm and the average age at which an individual produces young ones is 0.55 years. This means that the species produces its offspring at an early age of 6 or 7 months. Hua *et al*. (2001) stated that *Babylonia areolata* began to spawn after 7 months in captivity. The monthly mean shell heights indicate that the main recruitment to the fishery is in August and from the multiple cohorts observed in the population it can be inferred that *B. spirata* is a continuous breeder. The annual mean length of *B. spirata* showed an increase from the previous year, which indicates that there is no recruitment overfishing of the population in the area. Along with these, the proportion of spawning stock to the standing stock in south-east Arabian Sea point to the resilience of the population under a heavy exploitation rate.

The annual mean length of *B. zeylanica* (49.9 mm) was above the $L_{opt}$ of 44 mm and its $t_g$ was estimated as 0.48 year. Higher K value, and low $t_g$ indicates resilience of the population to the heavy exploitation rates observed. Length cohort analysis shows that average biomass of survivors is 113% of the yield during 2002 and 66% of the standing stock biomass is spawning stock biomass. Bruce (2006) has compared the fishery of the knobbed whelk in the Bay of Delaware and in the Atlantic Ocean and related the larger mean length of whelk in the ocean to the lower level of fishing effort and exploitation rate. The Delaware catch data also implicated that the fishery is at a peak as catch and effort have been consistently high. Similarly, the Chilean muricid fishery has declined due to stock overexploitation (Castilla, 1995, 1997, Castilla *et al*., 1998). Hobday and Tegner (2000) summarised the management history for the California abalone fishery, where several regulatory extraction tools were implemented between 1901 and 1997 such as minimum size limit, commercial permit fee, minimum commercial catch, recreational limit and recreational and commercial gear regulation to improve the fishery. In spite of these management tools, the abalone populations in California continued to decline, until total closure was decreed in 1997.

The faster growth rate, fast population turn-over ratio, continuous breeding behaviour, short life span, three months targeted fishing and partial harvest for the rest of the year of the species explain the sustainable fishery of the whelks is under a higher exploitation rate. Moreover, the undersized whelks are not exploited, since the presence of younger ones was negligible in the commercial fishery. Hence, the present state of fishing is not leading to a stock depletion of whelk population in south-eastern Arabian Sea. Maintaining adequate spawning stock and preventing recruitment overfishing should be the chief goals of fisheries management to ensure the future productivity of the stock and therefore no further increase in effort is recommended.

## Acknowledgements

The work was supported by grants from AP Cess Fund (Project code: 3030600013) of Indian Council of Agricultural Research (ICAR), New Delhi, India. Authors are thankful to the Director, CMFRI for encouragement and grateful to Dr. K.K. Appukuttan, former Head of Molluscan Fisheries Division, CMFRI for the guidance in the preparation of the manuscript.

## References

Altena, C. O. V. R. and Gittenberger, E. 1981. The genus *Babylonia* (Prosobranchia, Buccinidae). *Zoologische Verhandelingen*, 188: 1-57.

Anjana Mohan 2007. *Ecobiology and fisheries of whelk, Babylonia spirata (*Linnaeus, 1758*) and Babylonia zeylanica (*Bruguiere, 1789*) along Kerala coast, India*. Ph. D. Thesis, Cochin University of Science and Technology, Kochi, India, 174 pp.

Appukuttan, K. K. and Philip, M. B. 1994. Gastropods - an emerging resource in the bycatch of shrimp trawlers at Sakthikulangara- Neendakara area. *Seafood Export J.*, 25 (21): 5–17.

Ayyakkannu, K. 1994. Fishery status of *Babylonia spirata* at Port Novo South-east coast of India. *Phuket Mar. Biol. Cent. Spl. Publ*., 13: 53–56.

Berg, C. J. and Olsen, D. A. 1989. Conservation and management of queen conch *S. gigas* fisheries in the Caribbean. In: Caddy, J. F. (Ed.), *Marine invertebrate fisheries: their assessment and management*. John Wiley and Sons Inc., USA, p. 421–442.

Beverton, R. J. H. and Holt, S. J. 1966. Manual of methods for fish stock assessment Part-2. Tables of yield functions for fishery assessment. *FAO Fish. Tech. Paper*, 38(1): 67 pp.

Blundon, J. A. and Vermeij, G. J. 1983. Effect of shell repair on shell strength in the gastropod *Littorina irrorata. Mar. Biol*., 76: 41-45.

Brey, T. 1999. Growth performance and mortality in aquatic macrobenthic invertebrates. *Adv. Mar. Biol*., 35: 153–223.

Bruce, D. G. 2006. The whelk dredge fishery of Delaware. *J. Shellfish. Res.,* 25(1): 1–13.

Castilla, J. C. 1995. The sustainability of natural renewable resources as viewed by an ecologist and exemplified by the fishery of the mollusk *Concholepas concholepas* in Chile. In: Munasinghe, M. and Shearer, W. (Eds.), *Defining and measuring sustainability.* The International Bank for Reconstruction and Development, The World Bank, Washington D.C., USA, p. 153–159.

Castilla, J. C. 1997. Chilean resources of benthic invertebrates, fishery, collapses, stock rebuilding and the role of coastal management areas and National parks. *Proc. Second World Fish. Congr*., CSIRO, Collingwood, Australia, p. 130–135.

Castilla, J. C., Manríquez, P., Alvarado, J., Rosson, A., Pino C., Espóz, C., Soto, R., Oliva, D. and Defeo, O. 1998. Artisanal "Caletas" as units of production and co-managers of benthic invertebrates in Chile. *Canadian Spl. Publ. Fish. Aquat. Sci*., 125: 407–413.

Chidambaram, L. 1997. A note on whelk (*Babylonia* spp.) fishery in Pondicherry. *Mar. Fish . Infor. Serv. T & E Ser.*, 147: 15.

Devaraj, M. and Ravichandran, V. 1988. Dynamics of Indian chank fisheries. *Bull. Cent. Mar. Fish. Res. Inst.*, 42(1): 100–105.

FAO, 2003. http,//www.fao.org/fi/statist/statist.asp

Froese, R. and Binohlan, C. 2000. Empirical relationships to estimate asymptotic length, length at first maturity and length at maximum yield per recruit in fishes, with a simple method to evaluate length frequency data. *J. Fish Biol.*, 56: 758-773.

Gayanilo Jr, F. C., Soriano, M. and. Pauly, D. 1988. A draft guide to the COMPLEAT ELEFAN. *ICLARM Software Project*, 2: 65 pp.

Hobday, A. J. and Tegner, M. J. 2000. Status review of white abalone *(Halotis sorenseni*) throughout its range in California and Mexico. *NOAA Tech. Memor.,* NMFS- SWR-035, 90 pp.

Hua, P. N., Thu, N. T. X., Minh, M. D., Hung, P. D. and Yen, K. T. 2001. Spawning characteristics of *Babylonia areolata* (Neogastropoda: Buccinida). *Phuket Mar. Biol. Cen. Spl. Publ*., 25(1): 161-165.

Ilano, A.S., Ito, A., Fujinaga K. and Nakao, S. 2004. Age determination of *Buccinum isaotakii* (Gastropoda, Buccinidae) from the growth striae on operculum and growth under laboratory conditions. *Aquaculture,* 242: 181–195.

Jones, R. 1981. The use of length composition data in fish stock assessments (with notes on VPA and cohort analysis). *FAO Fish. Circ*., 734 : 60 pp.

Kenchington, E. and Glass, A. 1998. Local adaptation and sexual dimorphism in the waved whelk (*Buccinum undatum*) in Atlantic Nova Scotia with Applications to fisheries management. *Canadian Tech. Rep. Fish. Aquat. Sci*., 2237: 43 pp.

Leiva, E. G. and Castilla, J. C. 2002. A review of the world marine gastropod fishery, evolution of catches, management and the Chilean experience. *Rev. Fish Biol. Fish.,* 11: 283–300.

Lipton, A. P. and Selvakku, M. 2001. Tagging and recapture experiments in the Indian sacred chank, *Turbinella pyrum* along the Gulf of Mannar and Palk Bay, India. *Phuket Mar. Biol. Cent. Spl. Publ*., 25(1): 51-55.

Martin, P., Sánchez, P. and Ramón, M. 1995. Population structure and exploitation of *Bulinus brandaris* (Mollusca, Gastropoda) off the Catalan coast (north-western Mediterranean). *Fish. Res*., 23: 319–331.

MPEDA 2005. *Statistics of Marine Product Exports – 2005*. MPEDA, Ministry of Commerce and Industry, Govt. of India, 670 pp.

Narvarte, M. A. 2006. Biology and fishery of the whelk *Buccinanops globulosum* (Kiener, 1834) in northern coastal waters of the San Matias Gulf (Patagonia, Argentina). *Fish. Res*., 77: 131–137.

Pauly, D. and Soriano, M. L. 1986. Some practical extensions to Beverton and Holt's relative yield-per-recruit model. In: Maclean, J. L., Dizon L. B. and Hosillo L. V. (Eds.), *Proc. First Asian Fisheries Forum,* Asian Fisheries Society, Manila, Philippines, p. 491–496.

Philip, M. B. and Appukuttan, K. K. 1997. Heavy catches of whelks, *Babylonia* spp. in trawl catches off Quilon, south-west coast of India. *Mar. Fish. Infor. Serv. T&E Ser.*, 147: 12–14.

Sabu, S., Gibinkumar, T. R., Pravin P. and Boopendranath, M. R. 2005. Trawl for whelk (*Babylonia* spp.) fishing, off Quilon, Kerala, India. *Proceedings of the International symposium on "Improved sustainability of fish production systems and appropriate technologies for utilisation",* 6-18 March, 2005, Cochin, p. 496-501.

Sasikumar, G., Rohit, P., Ramachandran, N., Nagaraja, D. and Sampathkumar, G. 2006. Emerging small scale trap fishery for whelk (*Babylonia spirata*) in Malpe, southern Karnataka. *Mar. Fish. Infor. Serv T&E Ser*., 188: 14–17.

Schmidt, S., Wolff, M. and Vargas, J. A. 2002. Population ecology and fishery of *Cittarium pica* (Gastropoda, Trochidae) on the Caribbean coast of Costa Rica. *Rev. Biol. Trop*., 50(3/4): 1079–1090.

Selvarani, J. 2001. Whelk processing industry at Thirespuram-Tuticorin. *Mar. Fish. Infor. Serv. T&E Ser*., 167: 11–12.

Shanmugaraj, T. and Ayyakkannu, K. 1997. Culture of *Babylonia spirata* (L.) (Neogastropoda, Buccinidae). *Phuket Mar. Biol. Cen. Spl. Publ*., 17(1): 225–228.

Shanmugaraj, T., Murugan, A. and Ayyakkannu, K. 1994. Laboratory spawning and larval development of *Babylonia spirata* (L) (Neogastropoda, Buccinidae). *Phuket Mar. Biol. Cen. Spl. Publ*., 13: 95–97.

Srinath, M., Kuriakose, S. and Mini, K. G. 2005. Methodology for the estimation of marine fish catches in India. *CMFRI Spl. Publ*., 86: 57 pp.

Valentinsson, D., Sjodin, F., Jonsson, P. R., Nilsson, P. and Wheatley, C. 1999. Appraisal of the potential for a future fishery on whelks (*Buccinum undatum*) in Swedish waters, CPUE and biological aspects. *Fish. Res*., 42: 215–227.

Yulianda, F. and Dhanakusumah, E. 2000. Growth and gonad development of babylon snail *Babylonia spirata* (L.) in culture. *Phuket Mar. Biol. Cen. Spl. Publ*., 21(1): 243–245.

Date of Receipt : 29.07.2011
Date of Acceptance : 10.08.2012