International Scholars Journals

African Journal of Fisheries Science ISSN 2375-0715 Vol. 7 (1), pp. 001-009, January, 2019. Available online at www.internationalscholarsjournals.org © International Scholars Journals

Full Length Research Paper

Recruitment patterns and standing stocks of the beaked clam *Eumarcia paupercula* (Holten, 1802) in Maputo Bay, Mozambique

[13]E. D. Mugabe, [12]C. A. Amoda, [3]C.L. Griffiths

[1]Centre of Coastal Studies and School of Marine and Coastal Sciences, Eduardo Mondlane University, Chuabo Dembe, P.O. Box 128, Quelimane, Mozambique.
[2]National Institute of Fisheries Research, Av. Mao Tsé Tung 4603, Maputo, Mozambique.
[3]Marine Biology Research Institute and Department of Biological Sciences, University of Cape Town, Rondebosch 7701, South Africa.

Accepted 24 October, 2018

The beaked clam *Eumarcia paupercula* is abundant in Maputo Bay, where it forms the basis of a substantial artisanal fishery. This study aimed to understand the recruitment pattern of the *E. paupercula* population of Costa do Sol beach and to monitor seasonal changes in its standing stocks and how these are impacted by the fishery. Results from November 2012 – April 2014 sampling programme showed that recruitment took place throughout the year, with the highest recruitment rates occurring during early winter, with over 250 recruits.m^{-2} and lowest in late winter and early summer, with less than 20 recruits.m^{-2}. The abundance of the adult stock seemed to have little influence on recruitment rates. The total standing stock of *E. paupercula* across the approximately 144 000 m^{2} study site at Costa do Sol beach varied from a minimum of 7 238 kg in May to a maximum of 54 164 kg in November with a mean of approximately 25 300 kg. Seasonal changes in standing stock were controlled mainly by patterns of recruitment and of removal of adult clams by the artisanal fishery.

Keywords: Stock-recruit relationship, length frequency, Veneridae, bivalve fishery, tidal flat.

INTRODUCTION

The beaked clam *Eumarcia paupercula* is abundant in Maputo Bay, Mozambique, where it forms the basis of a substantial artisanal clam fishery which in turn provides a large proportion of the clams sold and consumed in Maputo City (Vicente and Bandeira, 2014; Mugabe, 2016). There is concern that this substantial commercial harvest may lead to overexploitation of the resource, yet little is known about the size or structure of the exploited *E. paupercula population or its* capacity to sustain the harvest. Earlier studies on *E. paupercula* include descriptions of its across-shore distribution patterns in Morrumbene Estuary, Mozambique (Day, 1974) and in Swartkops Estuary, South Africa (McLachlan and Grindley, 1974). Other more recent studies identified drivers for density distribution at the Mfolozi-Msunduzi and Knysna Estuaries in South Africa (Allanson et al., 2000; Ngqulana, 2012), and described the annual reproductive cycle of the population in Maputo Bay (Mugabe et al., 2017). This clam is found on muddy to sandy intertidal flats in Maputo Bay, with highest densities recorded in the sandy areas (Scarlet, 2005). Low densities (5 ind.m^{-2}) of *E. paupercula* were recorded in association with seagrasses in Costa do Sol (Vicente and Bandeira, 2014).

Various factors can affect recruitment in clams, but the most important of these is the size of the parent stock and their reproductive output (Gosling, 2003). The success of recruitment in clams depends on the biomass

Corresponding author E-mail: eulalia.mugabe@gmail.com

of the parental stock present in the ground, as well as their age structure (Caddy and Defeo, 2003). Kraeuter et al. (2005), for example, found that recruitment rates in *Mercenaria mercenaria* were strictly dependent on the parental stock density, particularly in high adult density conditions.

The standing stocks of clams can be expressed in terms of number of individuals, as biomass in terms of fresh total weight ($kg.ha^{-1}$) (Moses, 1990) or flesh dry weight (Bidegain et al., 2013), or by yield (Laxmilatha, 2013). Drivers of standing stocks, include exploitation or fishing mortality, as well as biological variables, such as natural mortality and fertility rate, and are the main influences for changes in *Mercenaria mercenaria* stock (Mann et al., 2005) and of recruitment for *Meretrix casta* (Laxmilatha, 2013). Abiotic factors such as sediment type (Mann et al., 2005), sediment load and low oxygen concentration may also negatively affect the stock of bivalves in tidal flats (Higano, 2004).

Peaks of reproductive activity are not always followed by peaks of recruitment, as larval dispersal by tidal currents and water flow can result in recruitment in different grounds from those occupied by the parent stock (Gosling, 2003). Also, the post-settlement period is crucial for recruitment, as recruits are subject to high mortality rates (Hunt et al., 2003). Study of recruitment is essential for fisheries management. According to Peterson (2002), when recruitment overfishing rates are high enough to affect the population maintenance, this can cause a total collapse of the commercial fishery in a particular area. Often, recruitment overfishing can be expected when adult stock biomass is reduced due to an intense harvesting.

The aims of this study were to determine seasonal patterns in recruitment and standing stock of the *E. paupercula* population in Maputo Bay in order to support management of this valuable commercial and subsistence resource*.* This burrowing venerid bivalve is distributed along the south and east coasts of South Africa as well as in southern Mozambique (Branch *et al*., 2010), and according to previous findings, has a short life span of about two years (Mugabe, 2016).

MATERIAL AND METHODS

Study Area

Maputo Bay is located in southern Mozambique, between 25º55' and 26º10'S, and 32º40' and 32º55' E and has a total area of 1280 km^2, of which approximately 774 km^2 constitutes the sub-littoral zone, with the remainder equally divided between intertidal areas and sand dunes (Lencart e Silva et al., 2010). Sampling for *E. paupercula* took place at Costa do Sol beach, an intertidal sandflat that is the major fishing area in Maputo Bay and a major source of harvested *E. paupercula*.

Recruitment data collection

Patterns of recruitment were determined by analysing seasonal fluctuations in the size structure of the *E. paupercula* population by recording the length-frequency distribution of individuals sampled from Costa do Sol beach between November 2012 and April 2014. The intertidal zone, where sampling took place, is approximately 300 m wide during low spring tides. Six transects, perpendicular to the coastline, were used. Clams were only found between 15-250 m from the high water mark, the uppermost 15 m being a steeper section of shore too elevated to support clams. Thus, transects lines were 240 m long and sampling stations were located at 10 m intervals along each line, making 24 quadrats (0.25 m^2) per line. The transects were separated from each other by 100 m.

All *E. paupercula* individuals within each quadrat were counted to determine the density, and up to a maximum of 30 individuals from each sample were measured to the nearest 0.01 using Vernier callipers for shell length (maximum distance along the anterior-posterior axis). If the sample contained more than 30 individuals, 30 were randomly selected for measurement. Each Individual total weight (g) was taken for determination of stock.

Recruits are defined here as individuals in the size range 2-10 mm, following the definition of Kandeel (2013) and Adkins et al. (2014) for other venerids. Long time series data for stock-recruitment relationship for *E. paupercula* are not available for Maputo Bay and the present study presents the widest data range of 18 months. However, even these data are not adequate for stock-recruitment relationships (SRRs) using standard models, such as those of Ricker (1954) and Beverton and Holt (1957). Thus, stock-recruitment relationship presented was determined by plotting density of recruits against the density of adults, to find a logarithmic relationship using the Pearson correlation analysis.

Standing stock of *Eumarcia paupercula*

The *Eumarcia paupercula* standing stock in Costa do Sol was estimated in terms of wet biomass (total live weight). The biomass in each month was calculated by multiplying the mean individual fresh weight of each clam size class by the number of individuals in that size class per m^2 ($ind.m^{-2}$). The monthly biomass per m^2 was then calculated as the sum of the biomass of each size class present in that month. This was also extrapolated for the total study area of approximately 144 000 m^2 of clam bed. A similar approach was used to estimate the biomass of the hard clam *Mercenaria mercenaria* (Mann et al., 2005), and Manila clam *Ruditapes philippinarum* (Juanes et al., 2012). Special attention was given to the stock biomass of the fishable clams (≥ 22mm), in order to discuss the impact of fishing on the standing stock.

Data analysis

Analysis of variance was performed to compare the seasonal variation in the density and the mean length of *Eumarcia paupercula*, considering Mozambique's summer to between October and March and winter between April and September (Canhanga and Dias, 2005). Levene's test was conducted to test the homogeneity of variances between seasons. Data for stock-recruitment relationship analysis were log transformed, due to the inequality of variance in the number of recruits across the sampling period. Then, correlation analysis was performed for four length-classes, through One-way ANOVA. All statistical analyses were performed in SPSS 22.0 at a significance level of 0.05.

RESULTS

Seasonal length-frequency distribution

A total of 9 982 individuals of *Eumarcia paupercula* were used for length-frequency analysis. All four size-classes (2-10, 11-20, 21-30, 31-40 mm), defined according to the population size-distribution, were present throughout all the sampling months (Figure 1).

The least abundant size class was consistently the largest clams (31 – 40 mm), which reached their lowest proportion (0.33%) and highest proportions (4.90%) of the population in May and February 2013, respectively. The most intensively harvested size class of clams (21 – 30 mm) reached their maximum frequency of 53.01% during October 2013 and minimum of only 1.17% in May 2013. During October 2013, the fishable stock comprised over 50% (53.79%) of total biomass, as was the case in September 2013 (50.85%). In the remaining months the fishable sizes formed less than 50% of the total population and the lowest frequency was found in May 2013, when the fishable clams comprised only 1.51% of the total stock.

Recruitment patterns

Monthly changes in the density of recruits over the study period are shown in Figure 2. Strong peaks in recruitments around March 2013 and 2014 were clearly noticeable. High densities of recruits (2 – 10 mm) were detected in the following months and were clear and easy to follow with the unimodal pattern as they grow. The density of these cohorts reached over 250 ind.m^{-2}. On the other hand, new cohorts noticed during the summer (December 2012 and November 2013) were of lower intensity as those from the winter, were not easy to follow with a multimodal distribution. The densities of the winter cohorts were below 20 ind.m^{-2}.

During a great part of summer (November - February), the density of recruits had little variation throughout the sampling period, but lower recruitment rates were recorded in the summer of 2012 (Figure 2). Figure 2 also illustrates that highest densities of recruits were found during EW (March - May 2013 and March - April 2014). This result was also revealed by the significantly greater densities ($P < 0.05$) of recruits during winter, comparing to summer. This pattern suggests a seasonal pattern in the recruitment of *E. paupercula* in Maputo Bay.

The seasonal mean density of harvestable sizes in relation to the overall population is plotted in Figure 3. The high peak of fished population was observed in January 2013. This fished size was defined according to the smallest clam recorded (22 mm) in the samples of collectors (Mugabe et al., *in prep*.). The density of fished population showed a dissimilar pattern of that of the whole population in April-May 2013, but in the remaining months, the pattern of density variations was similar to that of the entire population where the density of the fished population decreased, while that of the overall population was increasing. Figure 3 shows that densities of harvestable sizes fall to only 5% and 1.3% of the total population in April and May 2013, respectively, when the population is mostly composed by non-target sizes.

The negative correlation ($a = -1.26$) between stock and recruits density produced determination coefficient of 0.48 between the density of spawning stock and recruits. Consequently, this coefficient indicated a negative stock-recruitment relationship with the high recruitment rates correlated with low densities of adults (Figure 4).

Eumarcia paupercula standing stocks

The estimated mean biomass of *Eumarcia paupercula* at Costa do Sol ranged from a minimum of 48.25 g.m^{-2} in May 2013 to a maximum of 273.55 g.m^{-2} in November 2013. Thus, total standing stock in the study area varied by over an order of magnitude from only 7 238 kg in May to 54 164 kg in November with a mean of approximately 25 300 kg. The biomass of the fishable stock was highest during November 2013 at 30 800 kg and lowest during May 2013 at 1 150 kg. The fluctuations in the fishable stock biomass followed the same pattern as that of the total stock (Figure 5), since adults have a dis-proportionate effect on overall biomass.

DISCUSSION

Seasonal density

Relative high densities of *Eumarcia paupercula*, of up to 500 ind.m^{-2}, were recorded in the present study, compared to densities of only 15 ind.m^{-2} found by Scarlet (2005) in other beaches of Maputo Bay. High densities of clams, such as found in this study, are not unusual on Southern African beaches, for example, densities of *Donax serra* of 141 ind.m^{-2} and 1 911 ind.m^{-2} (recruits < 8mm) have been reported in a Namibian (Laudien et al.,

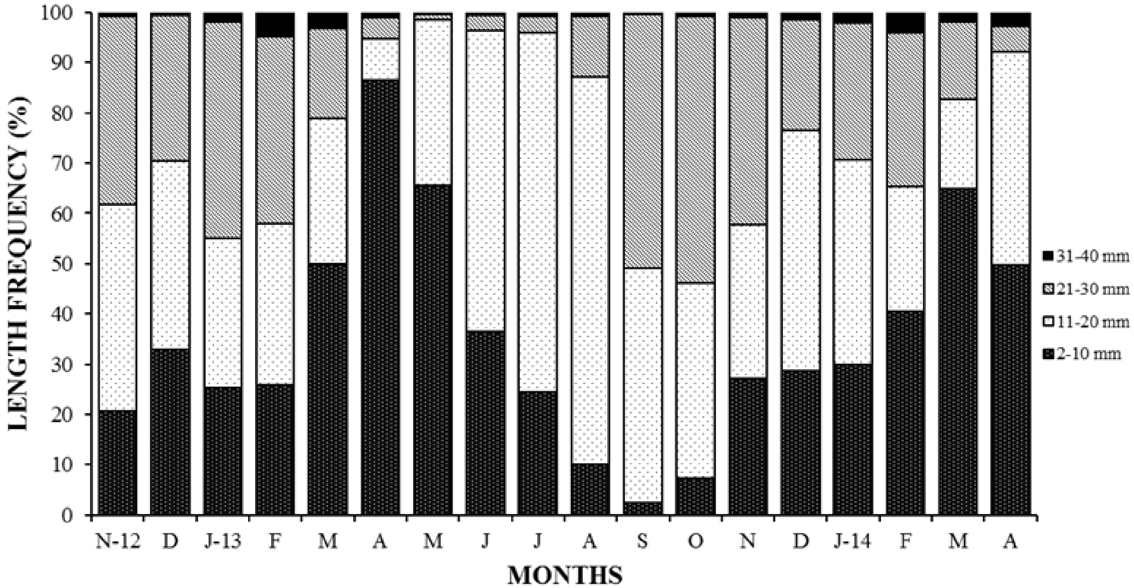

Figure 1. Length-frequency classes (%) of E. *paupercula* population at Costa do Sol beach November 2012 - April 2014.

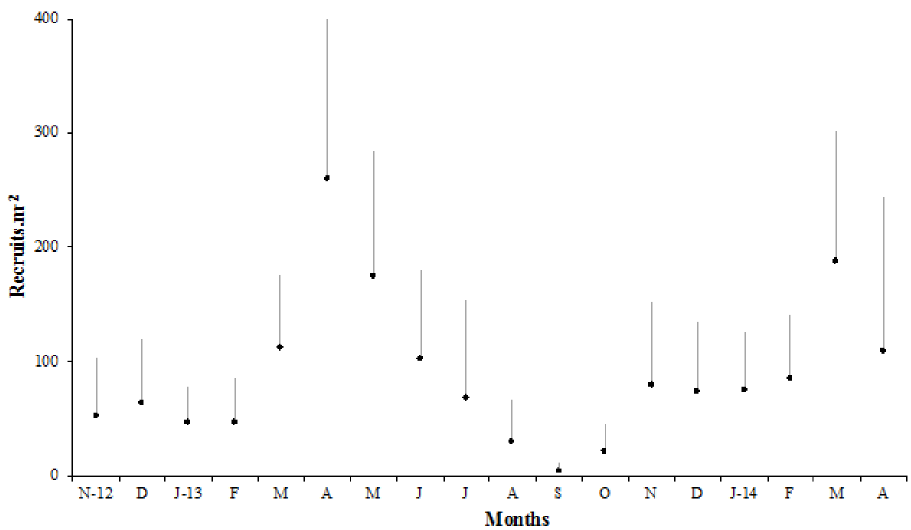

Figure 2. Monthly mean density (+SD) of recruits (2 – 10 mm) of E. paupercula per m2 at Costa do Sol beach during November 2012-April 2014.

2003) and South African (Lastra and McLachlan, 1996) sandy beaches, respectively. Contrary to the present study, densities of *Mercenaria mercenaria* were low (<20 ind.m^{-2}) in Chesapeake Bay (Mann et al., 2005); however, another venerid, *Austrovenus stutchburyi* was recorded at densities varying from <100 - 2000 ind.m^{-2} in Canterbury, New Zealand (Adkins et al., 2014).

Distribution of animals in dissipative beaches, such as the Costa do Sol, is thought to be mostly influenced by physical factors (McLachlan, 1990) and clam species have variable degrees of connectivity between local populations through larval dispersal (Defeo and McLachlan, 2005). Study of effects of currents movements on larval dispersal would assist in understanding whether the clams from that nearby population contribute in increasing the size of the studied

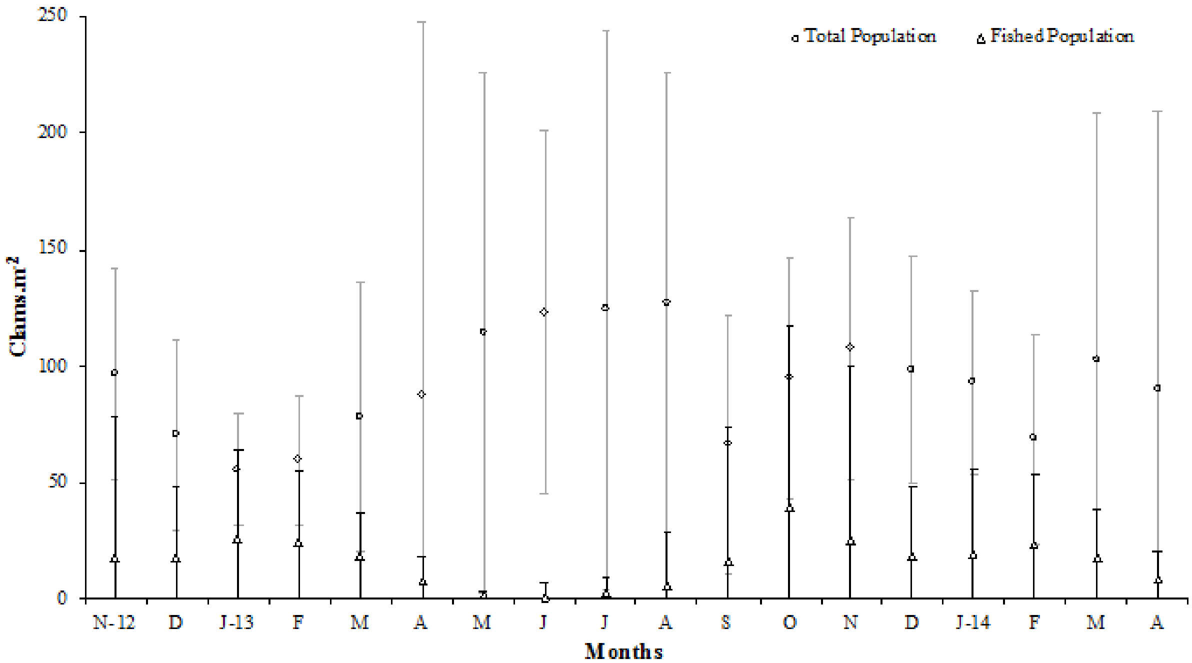

Figure 3. Seasonal variation in the mean density (per m2 ±SD) of E. paupercula at Costa do Sol beach from November 2012-April 2014. Densities of clams suitable for collection (triangles) and the entire population (circles) are shown separately.

population.

Recruitment patterns

Recruitment, reflected by the presence of *Eumarcia paupercula* <10 mm, occurred all year round, but with highest rates during March - April. It takes four to five months for the majority of these new settles to reach the sizes of > 10 mm in August-September, when the peak sizes are 21-30 mm; however, although in lower rates than the earlier, recruitments takes place later in November and December.

Time between spawning and settlement varies among venerids, but mostly ranges between 15-30 days (Stead et al., 1997). However, the settlement process is influenced by the high mortality rates during the post-settlement process and is difficult to measure because of the individuals' small sizes. Approximately 40 days after spawning (Mugabe et al., 2017) a new cohort was established in the *E. paupercula* population. This is a strong indication that recruitment rates follow peaks of spawning. For *Ruditapes decussatus*, the first settlement was observed after 27 days (Aranda-Burgos et al., 2014) and for *Venus antiqua*, the first recruits appeared 30 days after the main spawning event (Stead et al., 1997). The finding of Mouëza et al. (1999) is closer to that of this study as, after three weeks of fertilization, *Anomalocardia brasiliana* reached 1 mm, compared to the minimum size in the present sampling of 2 mm.

Highest recruitment rates observed in winter (April) are normal for clams in the subtropical and tropical zones. Similarly, Turra et al. (2014) also found the best recruitment of *Tivela mactroides* during winter in Brazil (23°40'). Peak recruitment was observed in April of 2013, but a month earlier in April of 2014, probably due to minor changes between years in climatic conditions that cue spawning. In flat dissipative sandy beaches, such as Costa do Sol beach, the recruitment process is highly controlled by the biological density-related mechanisms (mostly predation and competition), rather than by the water movement and wave break, which is not harsh in these beaches (Defeo and McLachlan, 2005). These parameters should be addressed in future studies to better understand the differences in recruitment periodicity across-shore.

There was a negative correlation between density of adult stock and recruitment rates for the beaked clam in Maputo Bay. This suggests that the presence of recruits depend on other factors, most probably abiotic factors such as sediment composition (Lastra and McLachlan, 1996; Hunt et al., 2003; Kandeel, 2013) and water flow speed (Hunt et al., 2003). In the case of *E. paupercula* in Maputo Bay, long time-series data are not available and also the clam stock was never closed to exploitation. Nevertheless, the collectors move from one stock to another, redirecting their effort onto new clam ground (after natural recovery) once the first area is depleted.

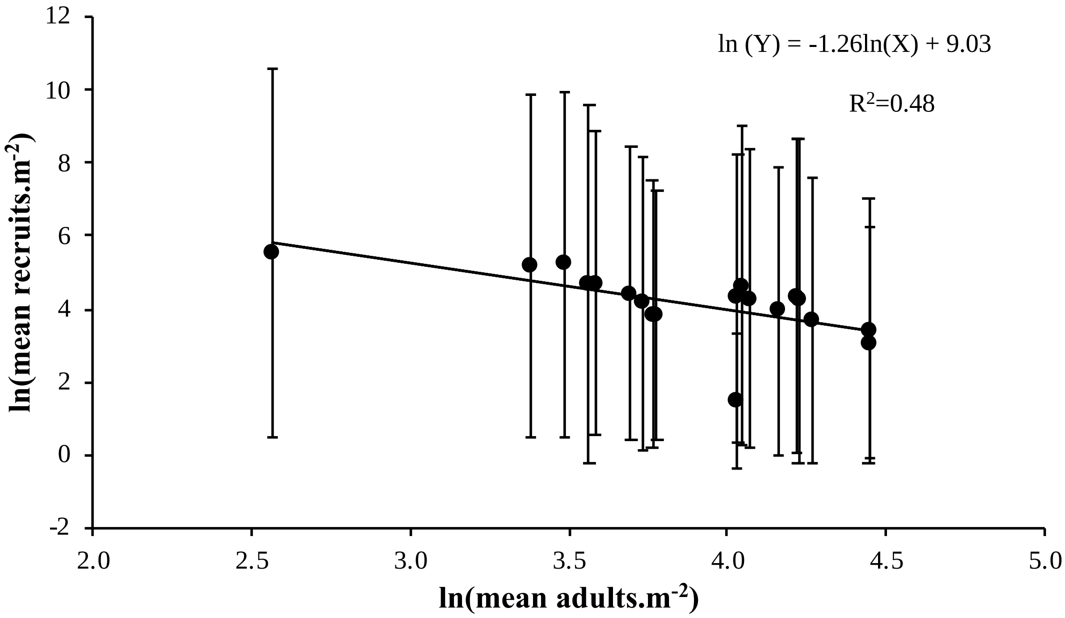

Figure 4. Correlation between the mean abundance (±SD) of adults and recruits for monthly samples of *E. paupercula* from November 2012-April 2014.

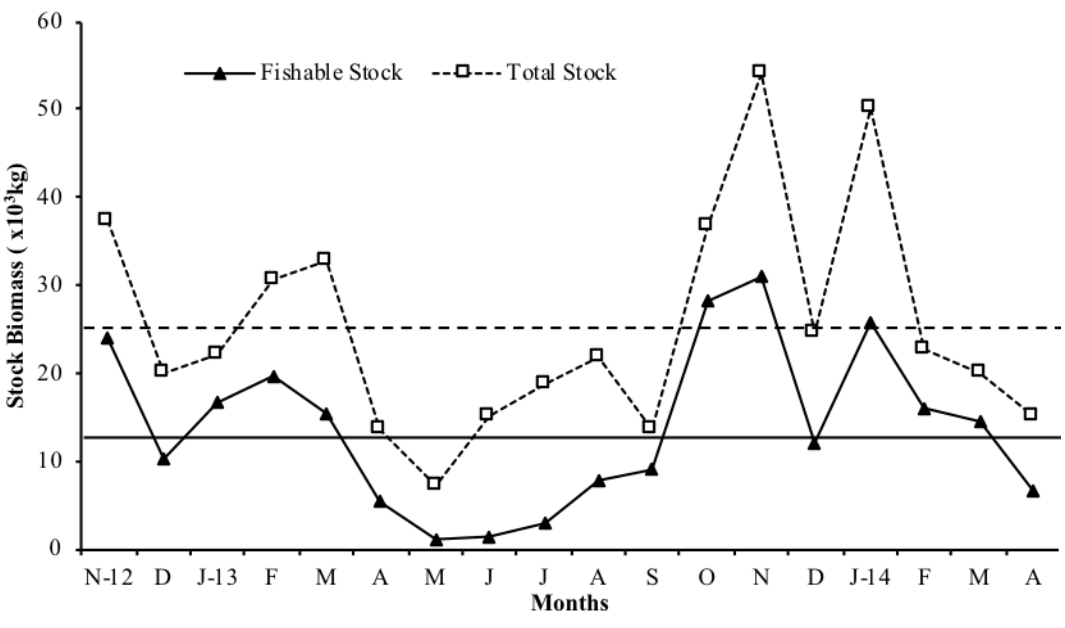

Figure 5. Seasonal variations of E. paupercula monthly total and fishable stock biomass (≥ 22 mm) in the entire sample area during November 2012-April 2014. Horizontal lines indicate average biomass of total (dashed) and fishable (continuous) stocks.

Biotic factors, such as predation, may cause decline in clams density by increasing mortality rates, particularly of smaller individuals, and hence reducing recruitment rates (Hunt et al., 2003). For example, during a growth experiment, set in the sampling area, 17 marked clams were found dead with a tiny hole drilled through one of the valves (Mugabe et al., *in prep*). This is indicative of predation by snails (Morton, 2005). Among other snails inhabiting the study site, the predatory muricid *Murex brevispina* and *Thais carinifera* were reported as common by Vicente and Bandeira (2014).

The study area is also known to shelter large populations of blue crab *Portunus pelagicus,* which is commonly found in shrimp by-catch (Machava et al., 2014), and also targeted in artisanal fisheries (Inacio et al., 2014). This crab species belongs to the family Portunidae, which is known to include clam predators (Byers et al., 2010). Predation rates and prey preferences by these crabs have not been reported for the study area, but they are common in the tidal channels of the Bay (de Boer et al., 2002).

The fishery is a driver, among others, such as recruitment (Laxmilatha, 2013) and natural selective predation (Ma et al., 2006) for the density and size distribution of clams. Some examples of the probable consequences of human exploitation include lower total density of the exploited species, and hence lower total biomass and decrease in the predator-prey ratio (de Boer et al., 2002). In their study of the impact of human exploitation on the benthic community of Maputo Bay, de Boer and Prins (2002) did not find any of these predicted effects. In this study, fishing may have contributed to the mortality rates of recruits because of the hand-gathering technique applied, by disturbing the sediment, which restricts e.g. the movement of *Mesodesma mactroides* (Brazeiro and Defeo, 1999).

***Eumarcia paupercula* standing stocks**

Standing stocks

The standing stock of *Eumarcia paupercula* was influenced both by the recruitment pattern and seasonal removal of adult clams over the study period. The highest mean density of recruits of 250.m^{-2} (April 2013) compared to the highest density of 94.m^{-2} adults (October 2013), suggests that approximately 38% of recruits reach fishable size. The arrival of recruits, which was accompanied by the changes in the length frequency histograms over the sampling periods, is clearly critical to sustaining the harvestable stock. Although it was clear that once the clams grow to a certain size, they are quickly removed, the major spat falls were regular during the study (April 2013 and March 2014), which contributed to the pronounced monthly variability in the size distributions of the stock. The fast growth rates of *E. paupercula* (Mugabe et al., *in prep*) is critical in maintaining the harvestable stock, as the age at entry into the fishery (22 mm length) is estimated to be only 0.5 year.

CONCLUSION

Recruitment of new individuals takes place year round. The principal recruitment event takes place in March-April, with lowest recruitment rates in August to October. The abundance of adult stock seems to have little influence in recruitment rates of *E. paupercula* in Maputo Bay. Nevertheless, recruitment events follow spawning peaks previously recorded by Mugabe et al., (2017).

The present study was carried out in the biggest fishing centre of Maputo Bay, where the highest number of invertebrate collectors was documented. The standing stock of *Eumarcia paupercula* was influenced by the recruitment and removal of adult clams by fishery over the study period. The arrival of recruits, which was accompanied by the changes in the length distribution over the sampling periods, is clearly critical to sustaining the harvestable stock.

ACKNOWLEDGEMENTS

This study was supported by the International Foundation for Science (IFS A5497-1). We wish to thank Sara Tembe and Flora Manjate for the field and laboratory support.

REFERENCES

Adkins SC, Marsden ID and Pirker JG. 2014. Variation in population structure and density of *Austrovenus stutchburyi* (Veneridae) from Canterbury, New Zealand. *Journal of Shellfish Research*. 33(2):343–354.

Allanson BR, Nettleton J and De Villiers CJ. 2000. Benthic macrofauna richness and diversity in the Knysna Estuary: a 50 year comparison. *Transactions of the Royal Society of South Africa*. 55(2):177–185.

Aranda-Burgos JA, Da Costa F, Nóvoa S, Ojea J and Martínez-Patiño D. 2014. Embryonic and larval development of *Ruditapes decussatus* (Bivalvia: Veneridae): a study of the shell differentiation process. *Journal of Molluscan Studies*. 80:8–16.

Beverton RJH and Holt SJ. 1957. On the dynamics of exploited fish populations. *UK Ministry of Agriculture, Fish and Fisheries Investigations*. Series 2:19.

Bidegain G, Sestelo M, Roca-Pardiñas J and Juanes JA. 2013. Estimating a new suitable catch size for two clam species: implications for shellfishery management. *Ocean and Coastal Management*. 71:52–63.

de Boer W. F and Prins HHT. 2002. Human exploitation and benthic community structure on a tropical intertidal flat. *Journal of Sea Research*. 48:225–240.

de Boer WF, Blijdenstein A and Longamane F. 2002. Prey choice and habitat use of people exploiting intertidal resources. *Environmental Conservation*. 29(2):238–252.

Branch GM, Griffiths CL, Branch ML and Beckley LE. 2010. *Two Oceans. A guide to the Marine Life of Southern Africa*. Cape Town: Struik Nature.

Brazeiro A and Defeo O. 1999. Effects of harvesting and density dependence on the demography of sandy beach populations: the yellow clam *Mesodesma mactroides* of Uruguay. *Marine Ecology Progress Series*. 182:127–135.

Byers JE, Wright JT and Gribben PE. 2010. Variable direct and indirect effects of a habitat - modifying invasive species on mortality of native fauna. *Ecology*.

91(6):1787–1798.
Caddy JF and Defeo O. 2003. *Enhancing or restoring the productivity of natural populations of shellfish and other marine invertebrate resources*. Fisheries Technical Paper No. 448 Rome: FAO.
Canhanga S and Dias JM. 2005. Tidal characteristics of Maputo Bay, Mozambique. *Journal of Marine Systems*. 58:83–97.
Day JH. 1974. The ecology of Morrumbene Estuary, Moçambique. *Transactions of the Royal Society of South Africa*. 41(1):43–97.
Defeo O and McLachlan A. 2005. Patterns, processes and regulatory mechanisms in sandy beach macrofauna: a multi-scale analysis. *Marine Ecology Progress Series*. 295:1–20.
Gosling E. 2003. *Bivalve Molluscs. Biology, Ecology and Culture*. Oxford: Fishing New Books.
Higano J. 2004. Influence of environmental changes in tidal flats on the filtration and respiration of bivalve mollusks. *Bulletin Fisheries Research Agency*. 1:33–40.
Hunt HL, McLean DA and Mullineaux LS. 2003. Post-settlement alteration of spatial patterns of soft shell clam (*Mya arenaria*) recruits. *Estuaries*. 26(1):72–81.
Inacio A, Leong E, Samucidine K, Masquine Z and Paula J. 2014. Artisanal fisheries in Maputo Bay. In *The Maputo Bay Ecosystem*. S. Bandeira & J. Paula, Eds. Zanzibar: WIOMSA. 303–319.
Ishii R, Sekiguchi H, Nakahara Y and Jinnai Y. 2001. Larval recruitment of the Manila clam *Ruditapes philippinarum* in Ariake Sound, southern Japan. *Fisheries Science*. 67:579–591.
Juanes JA, Bidegain G, Echavarri-Erasun B, Puente A, García A, García A, Bárcena JF, Álvarez C, et al. 2012. Differential distribution pattern of native *Ruditapes decussatus* and introduced *Ruditapes philippinarum* clam populations in the Bay of Santander (Gulf of Biscay): considerations for fisheries management. *Ocean and Coastal Management*. 69:316–326.
Kandeel E. 2013. Recruitment pattern of commercially harvested clam, *Venerupis aurea* (Bivalvia: Veneridae) at the southern region of lake Timsah, Suez Cana, Egypt. *Thalassia Salentina*. 35:11–28.
Kraeuter JN, Buckner SC and Powell EN. 2005. A note on a spawner-recruit relationship for a heavily exploited bivalve: the case of Northern quahogs (hard clams), *Mercenaria mercenaria* in Great South Bay New York. *Journal of Shellfish Research*. 24(4):1043–1052.
Lastra M and McLachlan A. 1996. Spatial and temporal variations in recruitment of *Donax serra* Roding (Bivalvia: Donacidae) on an exposed sandy beach of South Africa. *Revista Chilena de Historia Natural*. 69:631–639.
Laudien J, Brey T and Arntz WE. 2003. Population structure, growth and production of the surf clam *Donax serra* (Bivalvia, Donacidae) on two Namibian sandy beaches. *Estuarine, Coastal and Shelf Science*. 58:105–115.
Laxmilatha P. 2013. Population dynamics of the edible clam *Meretrix casta* (Chemnitz) (International Union for Conservation of Nature status: Vulnerable) from two estuaries of North Kerala, south west coast of India. *International Journal of Fisheries and Aquaculture*. 5(10):253–261.
Lencart e Silva JD, Simpson JH, Hoguane a M and Harcourt-Baldwin J-L. 2010. Buoyancy-stirring interactions in a subtropical embayment: a synthesis of measurements and model simulations in Maputo Bay, Mozambique. *African Journal of Marine Science*. 32(1):95–107.
Ma H, Grassle JP and Rosario JM. 2006. Initial recruitment and growth of surfclams (*Spisula solidissima* Dillwyn) on inner continental shelf of New Jersey. *Journal of Shellfish Research*. 25(2):481–489.
Machava V, Macia A and de Abreu D. 2014. By-catch in the artisanal and semi-industrial shrimp trawl fisheries in Maputo Bay. In *The Maputo Bay Ecosystem*. S. Bandeira & J. Paula, Eds. Zanzibar: WIOMSA. 291–295.
Mann R, Harding JM, Southworth MJ and Wesson JA. 2005. Northern quahog (hard clam) *Mercenaria mercenaria* abundance and habitat use in Chesapeake Bay. *Journal of Shellfish Research*. 24(2):509–516.
McLachlan A. 1990. Dissipative beaches and macrofauna communities on exposed intertidal sands. *Journal of Coastal Research*. 6(1):57–71.
McLachlan A and Grindley JR. 1974. Distribution of macrobenthic fauna of soft substrata in Swartkops Estuary, with observations on the effects of floods. *Zoologica Africana*. 9(2):211–233.
Morton B. 2005. Predator-prey interactions between *Lepsiella* (*Bedeva*) *paivae* (Gastropoda: Muricidae) and *Katelysia scalarina* (Bivalvia: Veneridae) in Princess Royal harbour, Western Australia. *Journal of Molluscan Studies*. 71(4):371–378.
Moses BS. 1990. Growth, biomass, mortality, production and potential yield of the West African clam, *Egeria radiat*a (Lamarck) (Lamellibranchia, Donacidae) in the Cross River system, Nigeria. *Hydrobiologia*. 196(1):1–15.
Mouëza M, Gros O and Frenkiel L. 1999. Embryonic, larval and post larval development of the tropical clam, *Anomalocardia brasiliana* (Bivalvia, Veneridae). *Journal of Molluscan Studies*. 65:73–88.
Mugabe ED. 2016. Aspects of the Biology, Ecology and Fishery of the Beaked Clam *Eumarcia paupercula* (Holten, 1802), in Maputo Bay. PhD Thesis. Department of Biological Sciences: University of Cape Town. South Africa.
Mugabe ED, Amoda CA and Griffiths CL. 2017. Reproductive biology of the beaked clam *Eumarcia paupercula* (Bivalvia: Veneridae) from Maputo Bay, Mozambique. *Western Indian Ocean Journal of Marine Science*. 2(2):69–77.

Ngqulana SG. 2012. Spatial and temporal distribution of the benthos in the Mfolozi-Msunduzi Estuary, Kwazulu-Natal. MSc Thesis. University of Zululand.

Peterson CH. 2002. Recruitment overfishing in a bivalve mollusc fishery: hard clams (*Mercenaria mercenaria*) in North Carolina. *Canadian Journal of Fisheries and Aquatic Sciences*. 59:96–104.

Ricker WE. 1954. Stock and recruitment. *Journal of the Fisheries Research Board of Canada*. 11:559 – 623.

Scarlet MP. 2005. Clams as a resource in Maputo Bay - Mozambique. MSc Thesis. Department of Marine Ecology: Goteborg University. Sweden.

Stead RA, Clasing E, Navarro JM and Asencio G. 1997. Reproductive cycle and cohort formation of *Venus antiqua* (Bivalvia: Veneridae) in the intertidal zone of southern Chile. *Revista Chilena de Historia Natural*. 70:181–190.

Turra A, Petracco M, Amaral ACZ and Denadai M. 2014. Temporal variation in life-history traits of the clam *Tivela mactroides* (Bivalvia: Veneridae): density-dependent processes in sandy beaches. *Estuarine, Coastal and Shelf Science*. 150:157–164.

Vasconcelos P, Moura P, Pereira F, Pereira AM and Gaspar MB. 2018. Morphometric relationships and relative growth of 20 uncommon bivalve species from the Algarve coast (southern Portugal). *Journal of the Marine Biological Association of the United Kingdom*. 98(03):463–474.

Vicente E and Bandeira S. 2014. Socio-economics of gastropods and bivalves from seagrasses - comparison between urban (disturbed) and rural (undisturbed) areas. In *The Maputo Bay Ecosystem*. S. Bandeira & J. Paula, Eds. Zanzibar: WIOMSA. 329–335.