EXPERIMENTAL SPAT COLLECTING OF THE EDIBLE OYSTER, *SACCOSTREA CUCULLATA* BORN (BIVALVIA) IN THE KUNDUCHI CREEK, DAR ES SALAAM

YD Mgaya
Department of Zoology and Marine Biology
University of Dar es Salaam P.O. Box 35064,
Dar es Salaam, Tanzania

ABSTRACT

A one year study was carried out at Kunduchi Creek, Dar es Salaam, to determine spat settlement using the three different substrates (cultches): coconut shells, asbestos and cockle shells, set at three different depths, 0.5 m, 1 m, and 1.5 m. The experiment was set up at three different sites within the creek. There were no significant differences among treatments (sites, depths, cultches). However, spat settlement exhibited seasonal differences, with peak spatfall recorded during the long rains (April to May). There were significant differences in the number of spat between the upper and lower surfaces of the substrates, with more spat preferring the underside. It was concluded that the Kunduchi Creek is a potential site for oyster farming. However, since the area is heavily used by artisanal fisherfolk, any future plans to establish mariculture operations would have to take into consideration potential conflicts with other user groups.

INTRODUCTION

Saccostrea cucullata (Born 1778) is an edible oyster found in brackishwater environments where it cements onto mangroves, rocks, and other hard substrates including man-made structures (e.g. jetties, ship hulls, beacons). According to Lewis (1964) and Hartnoll (1976), these oysters are abundant in the upper eulittoral zone where they grow to a maximum shell length of 65 mm (van Someren and Whitehead 1961) but experience stunting in crowded conditions.

Oysters are found throughout the tropics and subtropics and are commonly harvested from wild populations. The most widely distributed species is *Saccostrea cucullata*, which is found throughout the Indian Ocean and tropical western Pacific (Rabesandratana 1971, Ray 1977, Richmond 1997). In spite of its adaptability to cultivation, *Saccostrea cucullata* farming has developed in only a few tropical countries. It has been commercially cultured in French Polynesia (Aquacop 1982), the Philippines (Angell 1986), Sulawesi, Indonesia (Latama 1997), and Mauritius (Joseph 1998). Among the mass-cultured oyster species in the tropics are *Crassostrea virginica* and *Crassostrea* spp. in Mexico, *Ostrea chilensis* in Chile, *C. gigas* in Mexico, *C. rhizophorae* in Cuba and Jamaica, *C. belcheri* in Malaysia and *Crassostrea* spp. in Senegal (Joseph 1998). In addition to these, a number of other countries grow local species of oysters on a small scale, for example, *C. brasiliana* in Brazil, *C. madrasensis* in India and *C. rhizophorae* in Venezuela and Panama (Joseph 1998).

An important pre-requisite for the success of oyster farming is the availability of spat (seed) in the required quantity at the right time. In temperate countries the bulk of oyster seed comes from hatcheries, however, in the tropics oyster spat are still collected from the wild and grown in protected areas to market size. Therefore, spat collection is an extremely important activity in oyster farming.

Spat settlement is a result of a number of interactions and processes that may be both physico-chemical and biological in nature. These include spawning, fertilization, planktonic larval development, settling and metamorphosis, the hydrodynamics and chemistry of ambient waters, as well as wave energy in a given area or time (Connell 1973, Nzali *et al.* 1998). The relative significance and interaction of these factors will ultimately produce an oyster population in an area.

Tropical oyster farmers are confronted with the difficulty of predicting spatfall (setting) from populations of oysters that may be spawning continuously. Sometimes they must avoid excessive setting. An understanding of the breeding season of oysters and knowledge of setting behaviour is necessary so that cultch may be placed in the most advantageous location. In this paper, the term *cultch* is used to mean substrate provided for attachment of larvae.

Regular sampling of planktonic oyster larvae has proven useful to oyster growers in the northern hemisphere to indicate the timing for setting up the cultch for spat collection. Cultching is timed with the appearance of pediveligers of oysters in the plankton. In large commercial farms, test panels made of glass are immersed on a routine sampling schedule and spatfall intensity monitored (Joseph 1998). Once the test panels indicate a good set in a given locality, previously prepared spat collectors are then deployed in the spat collection areas.

Timing is critical since cultch placed out too long before setting-size larvae appear will become fouled with resultant loss in spat (Quayle 1980). If cultch is set up late, the major period of spatfall may be missed. Detailed studies of this type over a sufficiently long period of time have not yet been done in Tanzania despite the potential of this oyster for farming (Mgaya *et al.* 1999). Thus, the present study was designed in order to: (1) assess parameters favourable to spat settlement (e.g. depth, cultch type), (2) determine whether seasonal variation in spat settlement exists, and (3) make observations on fouling, which if not controlled, may hinder culture operations.

METHODS

Study area

The study was carried out in the Kunduchi Creek (6^o40'32"S/39^o13'35"E), Dar es Salaam between December, 1996 and November, 1997. The study area was close to the Kunduchi fishing village, approximately 18 km north of Dar es Salaam City. At this locality the coastline is protected from the Indian Ocean swell by inshore reefs and islands and thus affords suitable habitat for the growth of mangrove communities (Fig. 1).

Kunduchi Creek has been mentioned as being suitable for oyster culture (Matthes 1974). It is influenced by two monsoon seasons dictated by the behaviour of the Intertropical Convergence Zone. The northeast monsoon (November – March) is characterized by higher air temperatures, lower wind speeds, calmer seas and a reduced velocity (1 – 2 knots) of the East African Coastal Current (EACC). The southeast monsoon (April – October) is typified by cooler air temperatures, higher winds, rougher seas with the velocity of the EACC increasing to a speed of 4 knots (McClanahan 1988, Horrill *et al.* 2000). Like in other places along the Tanzanian coastline, the tides are of the mixed semi-diurnal type, but the inequality of successive high and low waters, although more marked during neap tides, does not obscure the rise and fall of the tides twice in every 24 hours (Horrill *et al.* 2000). The mean spring tidal range is 3.3 m, while the mean neap tidal range is 1.13 m.

Preparations for the experiment

Three sites, A, B, C within the Kunduchi Creek (Fig. 1) were chosen on the basis of their proximity to each other, suitability in terms of depth, and location away from the artisanal fishing ground. These sites are considered homogeneous since there is no definite habitat or environmental differences among them, thus they are treated as replicates. Three rafts were constructed for the three sites in the Creek to collect spat over the rainy and dry seasons. Rafts were 1 m x 0.76 m and were constructed using locally available bamboo poles. Bamboo material offers good flotation and supports the cultch at the appropriate depths. The rafts were anchored to concrete blocks with 6 m steel chains (Fig. 2).

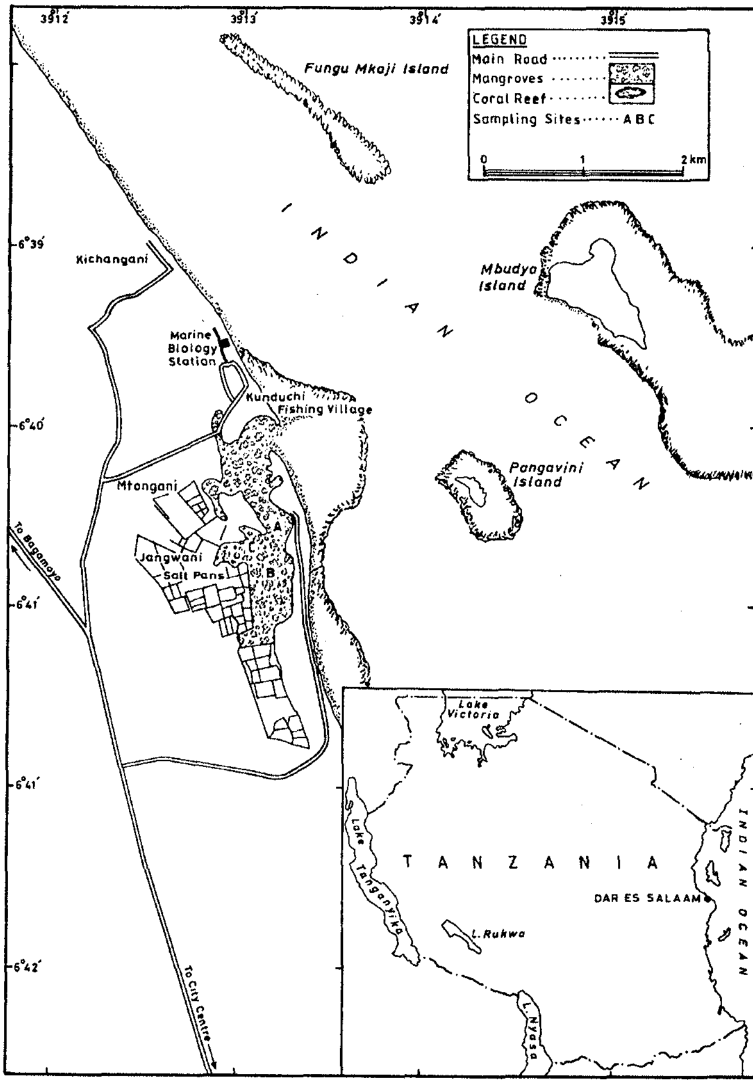

Fig. 1: Map of Kunduchi Creek Dar es Salaam, Tanzania, and surroundings, showing location (A-C) of the three sampling sites (replicates)

The substrates were selected on the basis of their relative cheapness and availability. These were cockle *(Anadara antiquata)* shells, coconut shells and asbestos (in a plate form). Both coconut shells and asbestos plates were broken up into pieces of about 5 cm x 3 cm. The spat collectors were strung with twine (24 ply) of about 4 m length. The collectors were strung in such a way that about 1 m remained free. This was used to tie the cultch onto the raft. The collectors were separated by means of a knot tied under each collector. Each cultch consisted of about 8 spat collectors and a distance of 3 cm was left between each one of them (Fig. 2).

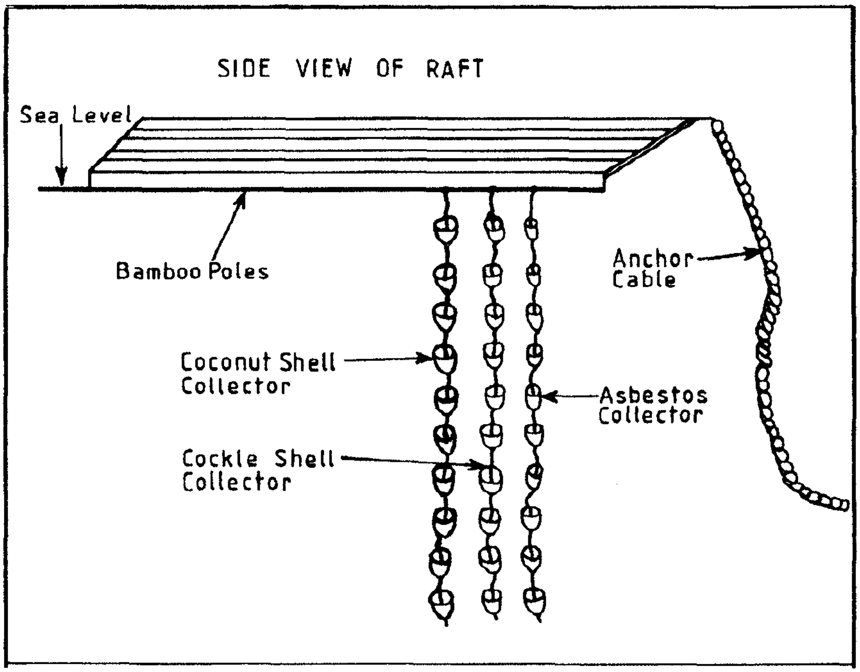

Fig. 2: Spat collector and side view of the raft

Field work

The cultches were suspended from the raft and left to hang at three depths (0.5 m, 1 m, 1.5 m). The raft was placed in an area where even at the lowest spring tides there was some water deep enough for the longest cultch to hang with a space of about 30 cm left from the bottom. This was deemed necessary to prevent the benthic predators from reaching the cultches.

The cultches were hung and left in water for 30 days after which they were sampled. This was done during the whole study period, when existing cultches were removed and new ones hung.

Temperature and salinity were measured once every month to the nearest 0.1 °C and 0.1 ‰ using a mercury thermometer and refractometer, respectively. A routine check was done once a fortnight to see if the raft was firmly attached to the chain connecting it to the anchors and that there were no loose connections.

Laboratory work

Examination of the cultches was conducted in the laboratory using a dissecting (stereoscopic) microscope (x 10 magnification). The spat that settled per cultch were counted and their location on the upper or under side of the substrate was recorded. Settlement of other marine organisms (fouling organisms) was also noted. The used cultches were thoroughly cleaned and deployed again for spat collection in subsequent months.

Statistical analyses

Statistical analyses were carried out using GraphPad InStat™ statistical package (GraphPad Software, San Diego, California). Spat settlement during rainy and dry seasons was compared using unpaired t-test, and settlement on the upper and undersides of substrates was compared using paired t-test. Pearson's correlation coefficient was used to examine the relationship between salinity/temperature and spat settlement. Differences between treatments (sites, depths, cultches) were assessed using one-way analysis of variance. Square root transformation was performed on spat counts data prior to ANOVA and t-test to guard against violation of the assumptions underlying ANOVA, which include homoscedasticity of variances and normally distributed residual variation (Zar 1984). Differences at $p<0.05$ were considered significant.

RESULTS

Variations of environmental factors and levels of spat settlement

Monthly surface water temperature and salinity ranged from 27.4 to 33.2 °C and 29.8 to 36 ‰ respectively (Fig. 3). Spat settlement was detected after about 4 weeks from the time the cultches were placed in the Creek. No significant correlation was detected between spat settlement and temperature ($r = 0.203$, $p = 0.527$). However, significant negative correlation was observed between salinity and spat settlement ($r = -0.698$, $p = 0.012$), and a significant positive correlation between rainfall and spat settlement ($r = 0.608$, $p = 0.036$). Notably, the pattern of spat settlement shows a peak during April to May—a period which coincides with the long rainy season (Fig. 4). A comparison of spat settlement between rainy and dry seasons showed a significant difference ($t = 5.151$, d.f. $= 22$, $p<0.0001$).

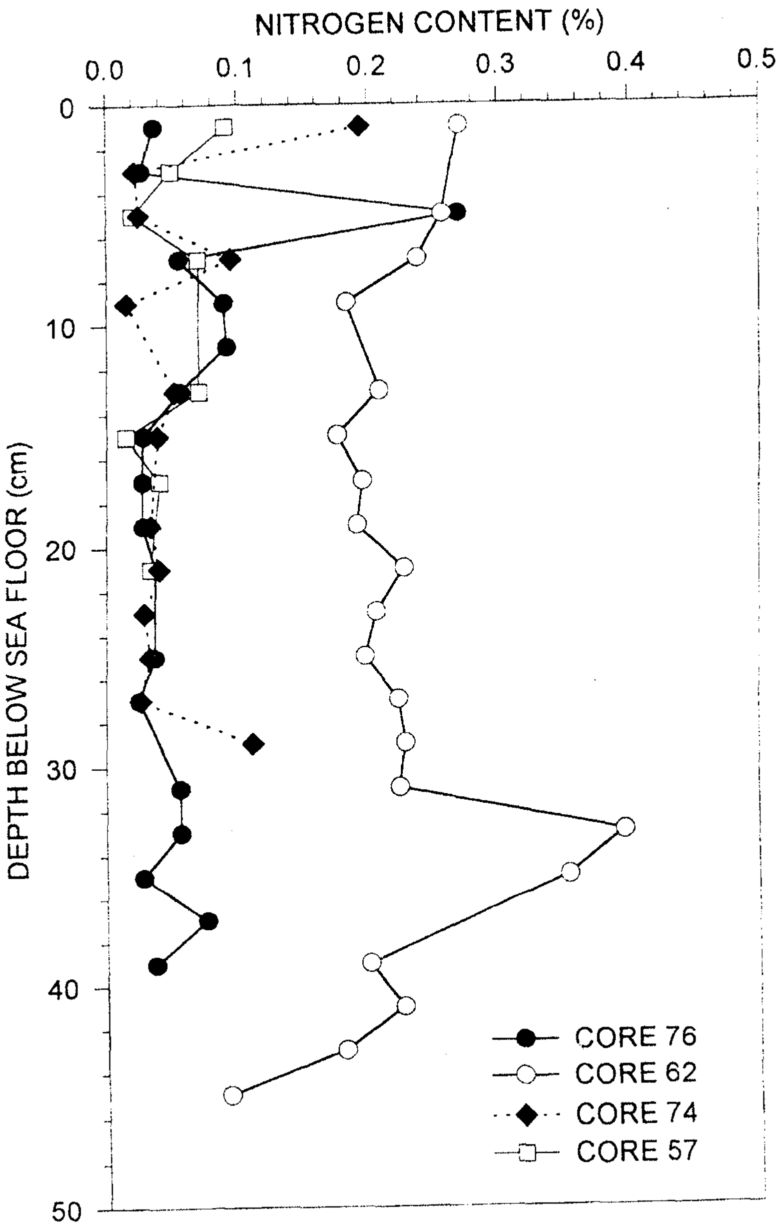

Fig. 5: Down-core variation in the content of nitrogen at different sites

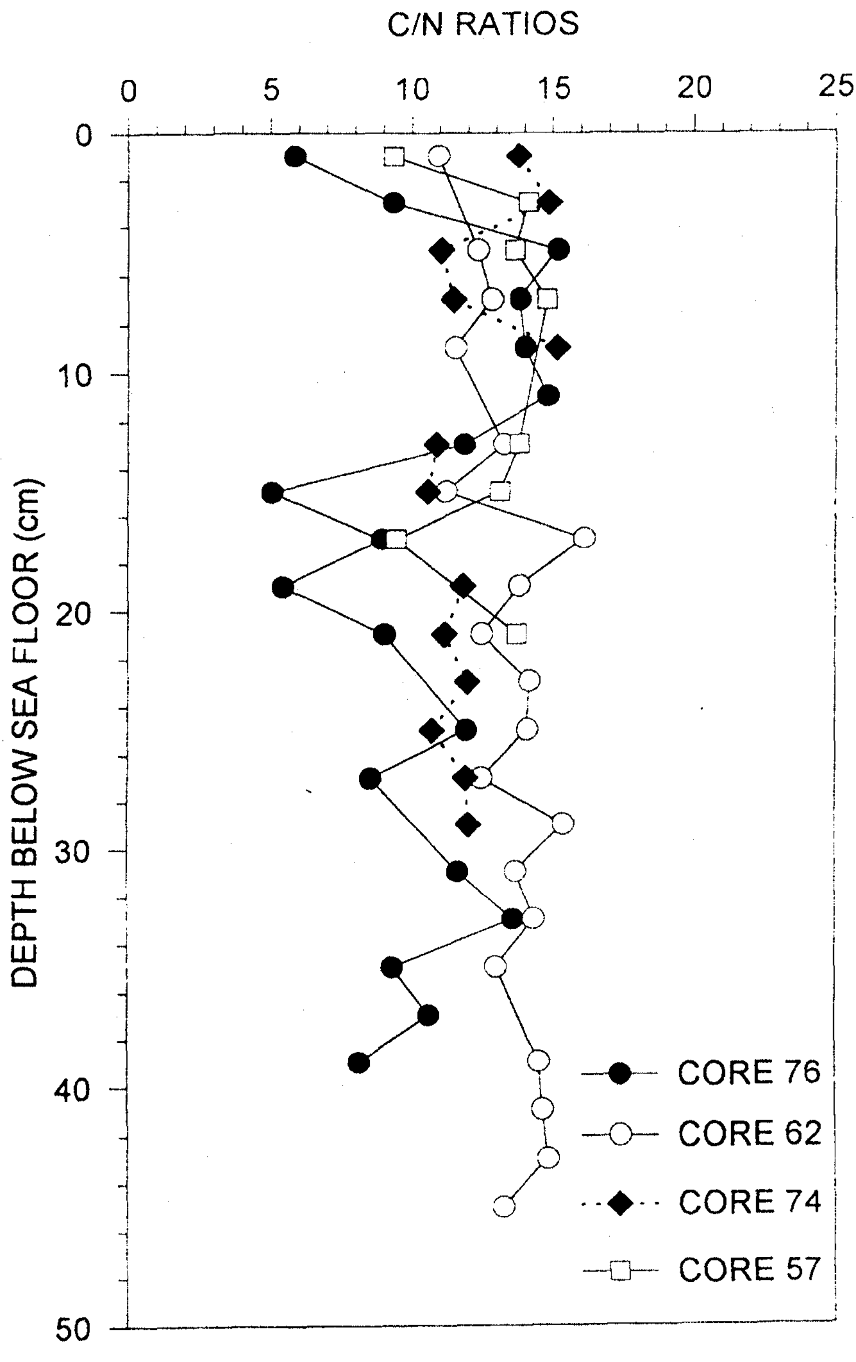

Fig. 6: Down-core variability in C/N ratio values at different sea locations off the City of Dar es Salaam, Tanzania

DISCUSSION

The stable carbon and nitrogen isotope compositions of OM observed in this study show a slight downcore decrease (Figs. 2 and 3). A similar dowoncore trend in these two parameters has been observed elsewhere (Spiker & Hatcher 1984, Velinsky *et al.* 1991, McArthur *et al.* 1992, Muzuka 1996, Muzuka & Hillaire-Marcel 1999). Although some workers have suggested absence of alteration of isotope composition in the course of diagenetic alteration of OM (Dean *et al.* 1986, Sackett 1989, Meyers 1994), others have associated downcore decreases or increases with diagenetic changes (Spiker & Hatcher 1984, Velisky *et al.* 1991, McArthur *et al.* 1992, Muzuka 1996, Muzuka & Hillaire-Marcel 1999). This is particularly supported by the fact that the stable isotope compositions of various components of organic material such as amino acids, carbohydrate, lignin as well as their quantity and degree towards diagenesis vary (Degens 1969). Therefore, this trend which is associated with a decrease in the contents of OC and nitrogen (Fig. 4 and 5) could be due to diagenetic changes resulting from diagenetic loss of compounds such as amino acids and carbohydrates that are enriched in ^{13}C and ^{15}N (Degens 1969, Macko *et al.* 1983, Marco & Estep 1984). Furthermore, since the C/N ratios of most marine plants is less than 10 (Hedges *et al.* 1986, Meyers 1994), C/N values greater than 10 observed in this study particularly at site WO57 could be a result of preferential loss of nitrogen bearing compounds over that of carbon.

The mean $\delta^{13}C$ and $\delta^{15}N$ values for the black-greasy layers observed at Site WO 76 are -22‰ and 5‰, while that of light coloured layers averages -18‰ and 5‰ respectively (Figs. 2 and 3). Lower ^{13}C values in black-greasy layers relative to the light coloured layers could be a result of mixing between oils and other allochthonous terrestrial material. The stable isotope compositions of OC for unaltered petroleum have been observed to range from -34‰ to -18‰ and averaging -28‰ (Faure 1986, Hoefs 1987 for review). Other naturally occurring organic materials that have similar isotope values include that of C_3 terrestrial material and high latitude phytoplankton (Fontugne & Duplessy 1978, 1981, Deines 1980, Faure 1986, Hoefs 1987, Rau e*t al.* 1989, Muzuka 1999a). For a shallow coastal tropical waters, where the core was collected, it is unlikely that large component OM was derived from phytoplankton debris, which averages -20‰ in low latitude (Fontugne & Duplessy 1978, 1981, Deines 1980, Faure 1986, Hoefs 1987, Rau *et al.* 1989 for review). Because of greasy character it is likely that large component of the material was derived from oils, but definitely mixed with terrestrial C_3 and C_4 type of organic material and other organic material derived from the marine environment particularly seagrasses and algae. Because of lack of distinct isotopic compositions between terrestrially derived C_3 organic material and petroleum, it is not possible to estimate relative contribution of each source.

The presence of black-greasy layers further suggests that there is a human influence in the type of material deposited in the area. The black-greasy layers, might have originated from garages and deposited there during rainy seasons where the level of runoff was high.

Lack of differences in the nitrogen stable isotope compositions between black-greasy and light coloured layers could be a result of similar isotope composition between oil and terrestrial OM. The nitrogen stable isotope compositions for the Tanzanian coastal flora averages 5% (Muzuka 1999a), a value that might be similar to that of oil. Although no average value has been reported, reported nitrogen stable isotope composition for petroleum range from 0.7% to 8.3% (Faure 1986).

Low isotope values at Site WO 62 may be attributed to a significant contribution of allochthonous material in the area. Assuming that the terrestrial end member value is -28% (Muzuka 1999a), and that the major contributors of the organic material in the coastal area are seagrasses and macro-algae with a mean isotope value of -12% (Gearing 1988), allochthonous contribution in the harbour would be more than 60%.

Reported global nitrogen stable isotope values for terrestrial organic material range from 0% to 4% and average 2% (Létolle 1980, Macko 1981, 1983, Kaplan 1983, Gearing 1988). Thus, elevated values of ^{15}N observed in the Dar es salaam harbour and off Msimbazi river would suggest that contribution of terrestrial material is minimal. However, the stable isotope composition of nitrogen for coastal Tanzanian flora and Amboseli National Park (Kenya) averages 5% (Muzuka 1999a), suggesting that the material deposited in coastal areas is indeed of terrestrial source. A similar observation of higher stable isotope values for material that reflect high proportion of terrestrial material has been observed else where (Gearing 1988 for review). Therefore, the observed low isotope compositions of OC in association with high ^{15}N values may still be an indication of anthropogenic input of OM to the area.

There is inter-site differences in the stable isotope compositions of OC and nitrogen with a site that is located in the Msasani Bay having the most depleted ^{15}N and enriched ^{13}C. Such a difference could be a result of inequalities in the relative proportion of terrestrial material. As pointed out above, sites located in the Harbour and off Msimbazi river, have relatively high proportion of terrestrial material than in the Msasani Bay. Low input of terrestrial material in the Msasani bay is supported by the work of Fay *et al.* (1992) who observed lack of $CaCO_3$ dilution just 1 km off shore indicating that siliciclastic materials are only transported parallel to the shoreline by longshore current. High proportion of autochthonous organic material in the Msasani bay is not derived from phytoplankton which have $\delta^{13}C$ values that are lower than -19%, but rather from seagrasses and macro algae. This is because, plants that have stable isotope compositions values that are higher than -16% include land grasses, seagrasses, algae and coral tissues (Gearing 1988, Yamamuro *et al.* 1995). Therefore, the observed enrichment in ^{13}C values in the Msasani Bay that averages -15% associated with low ^{15}N values is probably high proportion of OM derived from seagrasses and macro algae. Lower nitrogen isotope values are due to the fact that synthesized organic material by seagrasses and macro algae result from the utilization of fixed atmospheric nitrogen, which is isotopically not significantly different from that of atmospheric nitrogen (0%).

There is a preferential preservation of OC and nitrogen in the Dar es salaam harbour relative to other sites (Figs. 4 and 5). Preferential preservation could be a result of enhanced primary productivity (Pedersen & Calvert 1990, Pedersen *et al.* 1992). However, preferential preservation could also be related to the rate of tidal sediment deposition and removal as well as preferential deposition of more resistant terrestrial material towards diagenesis. Tides in the harbour are asymmetrical with high velocity during flood and lower velocities during ebb periods (Shaghude, personal communication). Such tidal pattern allows preferential deposition of particulate matter in the harbour, and that is why dredging activities need to be carried out regularly. Sedimentation rate has been pointed out as one of the causes of preferential preservation of OM (Canfield 1994). Although data on sedimentation rates in the harbour are lacking, most likely, the harbour is currently experiencing high sedimentation rate owing to the fact that particulate materials are being derived from the surrounding land mass and offshore resulting from asymmetrical tidal current pattern.

CONCLUSION

The values of stable isotope compositions of OC for sedimentary material preserved in the Msasani Bay is high relative to that deposited off the Msimbazi river and the Dar es salaam harbour. In contrast the Msasani Bay has the lowest stable isotope composition of nitrogen. The observed trend could be due to the fact that organic material preserved in the Msasani Bay is mainly derived from seagrasses and algae, and contribution of this source is high. Owing to the lack of major rivers in the Msasani Bay, capable of transporting significant amounts of land based material, there is little influence of terrestrial OM in the Bay.

Sediments preserved in the Dar es salaam harbour and off the Msimbazi river entrance are characterized by low OC isotope values and high nitrogen isotope values relative to that of the Msasani Bay. Such a difference between the two areas suggest that there is a significant quantity of allochthonous material in the Dar es salaam harbour and off Msimbazi river than in the Msasani Bay. Off the Msimbazi river in particular, human influence is high and material deposited there is of multiple sources.

Preferential preservation of OM is currently taking place in the Dar es salaam harbour with other areas experiencing high rate of diagenetic alteration of OM. Furthermore, diagenetic alteration of OM may have contributed to a slight downcore decrease in the contents of OC and stable isotope compositions of OC and nitrogen.

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