Comparing recent and abandoned shell middens to detect the impact of human exploitation on the intertidal ecosystem

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Abstract
Abandoned and recent shell middens were compared from Inhaca island, Mozambique, to investigate the impact of human exploitation. The growing human population was expected to increase the exploitation pressure, decrease the mean shell size, and increase the species diversity. Moreover, exploitation-vulnerable species were expected to disappear from recent middens. 29252 shells were collected from 6 recent and 8 abandoned middens, comprising 78 species, the majority bivalves. Pinctada nigra was the most abundant. The mean shell size was significantly smaller in recent middens, and the conspicuous, surface-dwelling gastropod Terebralia palustris showed the largest size reduction. Size reduction was related with the life history of the species. Older, abandoned middens had a larger species richness, refuting the intermediate disturbance hypothesis. The species composition of recent and abandoned middens was relatively similar, which was probably caused by low human exploitation pressure and the substrate characteristics. The disappearance of the mussel Perna perna was thought to be related to overexploitation.

Introduction
Man has exploited intertidal resources in Africa for at least the last 100,000 years (Barradas, 1967; Parkington, 1976; Voigt, 1975; Volman, 1978; Morais, 1988; Thackeray, 1988; Siegfried et al., 1994; Griffiths & Branch, 1997). Shellfish gathering still contributes considerably to the present diet, especially in terms of protein (Bigalke, 1973; Bailey, 1978; Hockey et al., 1988; Lasiak, 1993; Siegfried et al., 1994; Kyle et al., 1997ab). The impact of people on the intertidal resources, and human diet choice can be studied by analysing shell remains in middens (Swadling, 1976; Bailey, 1978; Mellars, 1978; Anderson, 1981; Deith, 1986; Hockey & Bosman, 1986; Lasiak, 1991a).

The pressure on the intertidal resources has increased in Mozambique due to a rapidly growing human population (Lopes, 1985, 1991) and a concentration of people in coastal zones, partly in a reaction to the civil war (1978–1992). People living on Inhaca Island collect crabs, bivalves, and gastropods from intertidal areas during low tide (de Boer & Longamane, 1996). A higher exploitation level can lead to changes in the intertidal community, such as changes in organism size, and species composition (Siegfried, 1994). To determine the impact of human exploitation on the intertidal community, the contents of contemporary middens were compared with those of older, abandoned middens.

People prefer larger shells (de Boer & Longamane, 1996). The consequence of this selectivity can be a reduction of mean animal size (Branch, 1975; Blake, 1979; McLusky et al., 1983; Siegfried et al., 1985; Hockey & Bosman, 1986; Keough et al., 1993; Robertson, 1996; Dye et al., 1997; Fernandez & Castilla, 1997; Griffiths & Branch, 1997). It is therefore expected that the mean shell size is smaller in
recent middens, especially in those species which are the most conspicuous at low tide.

Exploitation of certain species could change the abundance and, likewise, the availability of species (Siegfried et al., 1985; Hockey & Bosman, 1986; Adessi, 1994; Branch & Moreno, 1994), and possibly change the community structure as a whole (Moreno et al., 1984; Durán & Castilla, 1989; Menge & Farrell, 1989; Lasiak & Field, 1995; Menge, 1995; Griffiths & Branch, 1997; Lasiak, 1998; Sharpe & Keough, 1998).

The impact of the exploitation does not depend only on the exploitation pressure, but also depends on the vulnerability of the species regarding exploitation. Griffiths & Branch (1997, see also Robertson, 1996) showed that a decrease of the mean size of a certain prey species can negatively effect fertility, because of the relatively larger contribution of larger shells to the total reproductive output of the species. Removing only the larger shells can therefore decrease the population size. Some species, such as Oysters (Saccostrea spp.), seem particularly vulnerable to exploitation (Catterall & Poiner, 1987), due to their inability to escape depredation and their large size at maturity. Also rarer species, or stressed species found at the limits of their distribution range, are expected to be more affected by exploitation (Catterall & Poiner, 1987; Swadling, 1976; Lasiak, 1991a). Species such as Anadara spp. and Strombus spp. which are abundant, able to hide in the mud, and have high growth rates are believed to be less vulnerable to depletion. Therefore, we predict that the difference in species composition between old and recent shell middens is a result of the disappearance of these exploitation-vulnerable species.

Human exploitation can be regarded as a disturbance factor for the ecosystem. Intermediate levels of disturbance could increase the species richness of the community (Hockey & Bosman, 1986) by creating patches with different stages of succession. The so-called Intermediate Disturbance Hypothesis (Connell, 1978) will be tested in this paper.

Study area

The general ecology of Inhaca Island (lat. 26°07’, long. 32°56’) is well described by Kalk (1995). Annual rainfall is 880 mm and mean air temperature is 23 °C. There is a hot, rainy summer (November–April), and a colder, drier winter (March–October). The present human population is estimated at 8000 inhabitants, living in three settlements: Ridjene, In-

Materials and methods

An inventory of recent and old shell middens was made on Inhaca Island. The age of the abandoned middens was unknown, but an estimated age was obtained by interviewing people living in the vicinity. All abandoned middens could be traced back and were in use at least several generations ago. In order to decrease the influence of climate changes or fluctuations in sea level, middens older than approximately 200 years were excluded from the analysis. In order to avoid the problem of determining the middens’ age, we classified the middens in only two groups: used ($n=6$), and abandoned middens ($n=8$; Figure 1). Five different surface samples were taken from each midden. One sample was collected from the middle of the midden. From this point four lines were drawn to North, East, South, and West boundary of the midden. Four samples were collected at the middle of each line. A steel quadrat of 0.5 x 0.5 m was inserted at each sample point, and the whole substrate, including shells, removed up to 0.3 m in depth. Samples were sieved over a 2 mm mesh and species were identified, and measured to the nearest mm using a digital vernier calliper connected to a computer. The five subsamples of each midden were lumped, to reduce the impact of differences originating from the spatial variation in the shell middens (see Lasiak, 1992). The resulting sample was compared among middens.

Analysis

Differences in size per species between recent and abandoned middens were analysed using one-way ANOVA, for those species with a sample size >10 per midden category. The assumptions of the ANOVA