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**Biomarkers for assessing benthic pollution
impacts in a subtropical estuary,
Mozambique**

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Abstract

This thesis focuses on the marine environment in a subtropical estuary and particularly on exploring a suite of easy-to-use, cost effective and environmentally valid biological response tools (biomarkers). The main driving force of the thesis is the knowledge of the numerous anthropogenic impacts. Today, only scarce information is available in the Espírito Santo Estuary (ESE) in southern Mozambique on the effects of pollutants.

Links between behavioural disruption and neurological dysfunction, such as acetylcholinesterase (AChE) inhibition has been shown to be the most responsive biochemical biomarker at sites influenced by agricultural, urban and industrial activities. In **Paper I**, the enzymatic inhibition of AChE and butyrylcholinesterase (BChE) was measured in tissues (brain, liver and hepatopancreas) from barred mudskipper fish (*Periophthalmus argentilineatus*), Jarbua fish (*Terapon jarbua*), Indian white prawn (*Penaeus indicus*) and the clam *Meretrix meretrix*. In general, all species showed a significant decrease in the enzymatic activities. For *M. meretrix* the inhibition of BChE was most evident. In water of the Infulene River, tributary of ESE, 12 pesticides were found.

Besides the contaminants having a direct effect on burrowing behaviour, they also cause a sublethal physiological stress, reducing metabolic activity, growth rate and reproduction. In **Paper II**, integrated physiological assays were applied by using the scope for growth (SFG) method and condition index (CI) as tools for assessing the metabolic state in *M. meretrix* from the ESE and Incomati estuary (which is used as a comparison site). Low values of SFG ($<5 \text{ J h}^{-1} \text{ g}^{-1}$), as well as the low CI (that ranged from 0.80 ± 0.02 to 1.62 ± 0.10) in both investigated areas show symptoms of stress and impact of pollution as reflected in the clam *M. meretrix*. These results also show that SFG can be used as a tool to compare bioenergetic responses of clams to impacts of various environmental pollutants.

Locomotion is the most studied behaviour because it links fitness-related parameters, such as food seeking and predator avoidance and is also considered as an ecologically valuable individual biomarker of stress. In **Paper III**, the impaired burrowing activity as a signal of organismal behaviour was tested in two cross-toxicity assays using the clam *M. meretrix* (bivalvia, family Veneridae). Metals in sediments and clams were also analysed to assess the sediment quality according to international guidelines and human safety for clam consumption and. The burrowing times were different in the two experiments. This finding indicated that the metal contaminated sediments delayed the burrowing time. Based on the concentrations of metals in sediments we concluded that the northern margin of ESE is polluted principally by Cu, Ni, Cd, Co, Cr, Zn, As and Hg. As expected, sediment from the comparison site and those at the southern margin of ESE contained lower levels of these metals.

Paper IV presents the more ecologically relevant aspects of the adverse effects of pollutants on benthic communities in ESE and the nearby Incomati estuary. Community indicators, such as species richness and abundance were used in association with multivariate analyses of assemblage structure to assess the environmental status in three zones (i.e. the upper, middle and lower reaches) of ESE. Ecological groups and ranking of feeding strategies of benthic macrofauna were also used as bioindicators. The results showed clear differences in invertebrate density and population structure between ESE and the comparison estuary, while the three zones in ESE showed negligible differences from each other. The difference between the two estuaries was mainly due to the dominance of distinguished macrobenthic groups; polychaetes were common in ESE, while bivalves and amphipods were highly abundant in the Incomati estuary.

It is recognized that the need of integrative tools to assess ecosystem quality is very important from a scientific point of view, but simple and pragmatic information is also necessary for stakeholders and society to get useful assessments of the impact of human pressure in the estuaries and other coastal ecosystems.

KEYWORDS: subtropical estuary, contaminants, biological hierarchical biomarkers, scope for growth, burrowing response, acetylcholinesterase, benthic fauna, southern Mozambique.