Estuarine, Coastal and Shelf Science 170 (2016) 102–111

Contents lists available at ScienceDirect

Estuarine, Coastal and Shelf Science

journal homepage: www.elsevier.com/locate/ecss

Evaluation of abiotic stresses of temperate estuaries by using resident zooplankton: A community vs. population approach

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ARTICLE INFO

Article history:
Received 21 May 2015
Received in revised form
9 December 2015
Accepted 3 January 2016
Available online 6 January 2016

Keywords:
Temperature
Salinity
Freshwater
Pielou's species evenness index (J)
Copepod
South Africa

ABSTRACT

By using permanently resident zooplankton, we assessed the ecological level (i.e. community and or population) that provides more in-depth indication of the stress related to salinity and temperature fluctuations in temperate estuaries. In the semi-arid warm temperate South Africa, the Gamtoos estuary experiences a full salinity gradient maintained by irregular but relatively frequent freshwater pulses, whereas the Kromme estuary is euhaline throughout its extent and receives only occasional freshwater inputs when the storage reservoir six km upstream overtops. Changes in the species evenness index of Pielou and the abundances of estuarine resident zooplankton species were modelled against salinity and temperature variations of respective estuaries. In the Gamtoos estuary, response of individual populations provided more in-depth information regarding zooplankton variability. However the most abundant resident zooplankton i.e. *Acartia longipatella* a copepod was not the best predictor of the salinity and temperature fluctuations. Conversely, the Kromme estuary study provided insights into the potential vulnerability of the resident estuarine zooplankton community to cold. Further, the population level study exposed responses of specific species against salinity changes. We discuss the pros and cons of designing ecological indicators of abiotic stress based on specific species, targeted to specific ecological level, and needs of considering the frequency and magnitude of fresh water inflow in an estuary. A suggestion is to use specific taxonomic group(s) (e.g. Copepods) to better understand the abiotic stress factors of specific set of estuaries (e.g. freshwater rich/starved) until a 'one size fits all' indicator is found for temperate estuaries.

1. Introduction

Estuaries are economically productive and biologically diverse, but often depleted, degraded and vulnerable because of numerous human interventions (dams, freshwater manipulation) that are affecting their natural gradients of salinity and temperature (Elliott and McLusky, 2002; Lotze et al., 2006; Elliott and Quintino, 2007; Schlacher et al., 2008; Whitfield et al., 2012). The search for indicators of such stresses is not new, but there is debate over whether the indication should adopt a more physical and/or biological (e.g. ecological) approach (Fairweather, 1999; Turpie et al., 2004; Elliott and Quintino, 2007). Since ecological aspects of estuarine studies are sometimes over-looked, especially at larger spatial-temporal scales, a 'one size fits all' ecological indicator remains elusive (Roy et al., 2001; Attrill, 2002; Elliott and McLusky, 2002). This study concentrates on temperate estuaries located in the semiarid parts of Southern Hemisphere, considering exclusively the resident zooplankton communities which inhabit mesohaline and polyhaline zones (Bulger et al., 1993).

Due to wide range of morphology, abiotic fluctuations of temperate estuaries in semi-arid regions could be extreme, on top, a lot of them are freshwater starved, which results in unique gradients of salinity and temperature, consequently the stress on resident species is possibly high (Elliott and McLusky, 2002; Lester and Fairweather, 2009; Gillett et al., 2015; Vieira et al., 2015). Therefore, an investigation is imperative of the ecological level(s), at which an indicator can be used effectively for assessment of the stress related to temperature and salinity fluctuations. Traditionally ecological diversity indices (e.g. Shannon–Wiener, Pielou, Simpson indices), and/or responses of population parameters (e.g. abundance) are used for the aforesaid purposes (Hilty and Merenlender, 2000; Borja and Dauer, 2008; Vieira et al., 2015). Since salinity and

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http://dx.doi.org/10.1016/j.ecss.2016.01.007
0272-7714/

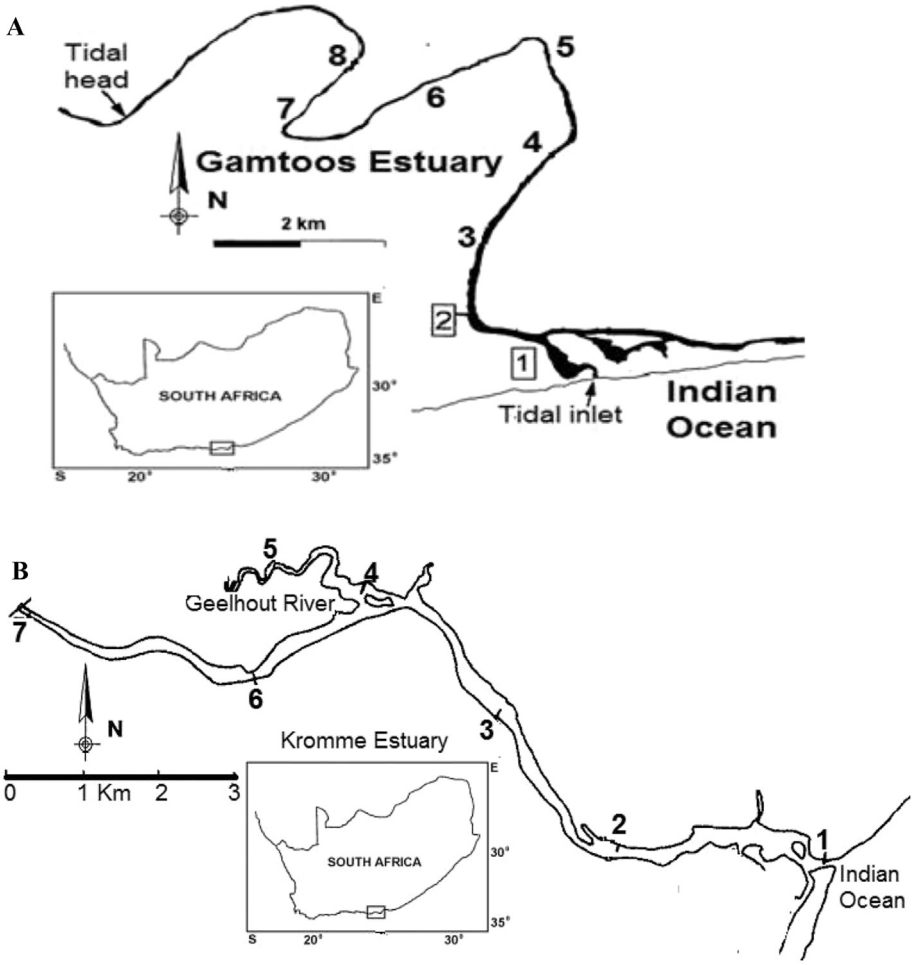

Fig. 1. A. Sampling sites within Gamtoos Estuary of South Africa (map modified from Schlacher and Wooldridge, 1996) used in the study. Numbers indicate the sampling locations. **B**. Sampling sites within Kromme estuary of South Africa (map modified from Emmerson and Erasmus, 1987) used in the study. Numbers indicate the sampling locations.

temperature together or singly often determine(s) the presence-absence and limit the abundances of numerous resident zooplankton species, consequently they are considered among the prime stressors in estuarine environment (Attrill, 2002; Daufresne et al., 2004; Vieira et al., 2015).

Temperate estuaries in semi-arid South Africa are highly variable in terms of salinity and temperature gradients which become exacerbated when exposed to periodic floods or droughts (Allanson and Baird, 2008). Further, the presence of dams, water abstraction schemes and flow regulations affect the salinity and temperature gradients of specific estuaries (Scharler and Baird, 2003; Whitfield et al., 2012; Vieira et al., 2015). As a working example, this study focuses exclusively on the resident zooplankton species (not on temporary residents or occasional intruders) of mesohaline and or polyhaline reaches (Bulger et al., 1993) in two of the permanently open Eastern Cape estuaries of South Africa. The Gamtoos estuary receives a relatively high proportion of its Mean Annual Runoff (MAR) and a full horizontal salinity gradient is evident, so

Table 1
List of permanently resident species and their representative groups that were sampled (at least once) exclusively from the meso- and polyhaline reaches of the Gamtoos estuary during the monthly survey of February 1989 to March 1991.

Estuary	Sampling year	Taxonomic group	Species sampled	Total Catch (n)
Gamtoos	February 1989–March 1991	Copepoda	*Acartia longipatella*	2797378[a]
			Acartia natalensis	924843
			Pseudodiaptomus hessei	1461952
		Mysidacea	*Gastrosaccus brevifissura*	10524
			Mesopodopsis wooldridgei	32824[a]
			Rhopalophthalmus terranatalis	27269
		Cumacea	*Iphinoe truncata*	18366
		Amphipoda	*Corophium triaenonyx*	1257
			Grandidierella lignorum	7173
		Anomura	*Upogebia africana*	40753
		Brachyura	*Hymenosoma orbiculare*	94256[a]

[a] Most common and abundant populations of different taxonomic groups.