ELSEVIER

In Collaboration with the Royal Netherlands Institute for Sea Research

Journal of Sea Research 58 (2007) 302–312

JOURNAL OF SEA RESEARCH

www.elsevier.com/locate/seares

Effect of environmental conditions on variation in the sediment-water interface created by complex macrofaunal burrows on a tidal flat

Bon Joo Koo [a,*], Kae Kyoung Kwon [b], Jung-Ho Hyun [c]

[a] *Marine Ecosystem and Environment Division, Korea Ocean Research and Development Institute, Ansan P.O. Box 29, Seoul 425-600, Korea*
[b] *Marine Biotechnology Research Center, Korea Ocean Research and Development Institute, Ansan P.O. Box 29, Seoul 425-600, Korea*
[c] *Department of Environmental Marine Sciences, Hanyang University, 1271 Sa-dong, Ansan, Gyeonggi-do 426-791, Korea*

Received 27 October 2006; accepted 9 July 2007
Available online 7 August 2007

Abstract

We quantified the increase in the sediment-water interface created by the burrowing activities of the resident macrofaunal community and its variation with respect to the physical conditions of the habitat on a tidal fat. We investigated environmental factors and dimensions of macrofaunal burrows with respect to tidal height and vegetation during spring and summer at three sites. A resin-casting method was used to quantify the dimensions of all burrows at each site. The dimensions of macrofaunal burrows varied both temporally and spatially and the increase in the sediment-water interface reached a maximum of 311%, ranging from 20 to 255% under different habitat conditions. The sediment-water interface depended on the duration of exposure resulting from tidal height, increased temperatures resulting from seasonality, and marsh plant density. Burrows were deeper and more expansive at both higher tidal levels and higher temperatures in summer. Burrow dimensions were sharply reduced with the disappearance of adult macrofauna in areas where the roots of the marsh plant *Suaeda japonica* were dense. The significance of this study lies in quantifying the burrow dimensions of the entire macrofaunal community, rather than just a single population, and confirming their spatial and temporal variation with respect to physical conditions of the habitat. Environmental factors responsible for variation in burrow dimensions are discussed.

Keywords: Burrow; Environmental gradients; Macrofauna; Sediment-water interface; Tidal flat; West coast of Korea

1. Introduction

The increase in the sediment-water interface caused by complex macrofaunal burrows has implications for biogeochemical processes and associated microbial communities in marine sediments. Through their burrowing and feeding activities, macrofauna increase the surface area exposed to overlying water or air; they also modify the surface sediments, thereby increasing the supply of reactants such as electron acceptors and carbon substrates for microbially mediated diagenetic reactions while stimulating the removal of toxic metabolites such as dissolved sulfide (Aller, 2001; Kristensen, 2001). To understand biogeochemical processes associated with the pathways of organic matter mineralisation and to estimate material fluxes at

* Corresponding author. Tel.: +82 31 400 7724; fax: +82 31 408 5934.
E-mail address: bjkoo@kordi.re.kr (B.J. Koo).

1385-1101/$ - see front matter © 2007 Elsevier B.V. All rights reserved.
doi:10.1016/j.seares.2007.07.002

the sediment-water interface, it is important to quantify the increase in surface area resulting from complex burrow systems (Gribsholt et al., 2003; Furukawa et al., 2004). Although a great deal of information on the architecture and dimensions of macrofaunal burrows has become available during the last few decades, gaps remain in the quantification of the sediment-water interface within sediments (Kristensen and Kostka, 2005).

Despite our well-developed understanding of burrows as microenvironments of chemical significance to sediment-water exchange processes, it is difficult to generalise a quantity for the sediment-water interface created by macrofaunal burrowing and feeding activities. Since the development of resin-casting techniques, the description of macrofaunal burrows has become widespread (e.g., Atkinson et al., 1982; Swinbanks and Luternauer, 1987; Griffis and Suchanek, 1991; Lee and Koh, 1994; Nickell and Atkinson, 1995; Stamhuis et al., 1997; Bird and Poore, 1999; Dworschak, 2002). The burrow morphology of macrofauna living in coastal sediments, especially deep-burrowing decapods, has been preferentially revealed using these methods. For example, Pemberton et al. (1976) found that the burrows of a thalassinidean mud-shrimp reached as deep as 2.5 m in sediments. Extensive burrows of another mud-shrimp, *Callianassa truncata*, can increase the total area of the sediment-water interface by roughly 400% in a shallow bay off the Italian coast of the Mediterranean Sea (Ziebis et al., 1996). Recently, sectioning sediment profiles using computer-aided tomography (CT) has been used to analyse biogenic structures in the sediment (e.g., Perez et al., 1999; Mermillod-Blondin et al., 2003; Rosenberg and Ringdahl, 2005). The CT technique, however, is limited in that it cannot cover the extensive areas required to obtain representative communities on tidal flats, especially in the upper tidal zone, which is inhabited by relatively large species.

Most previous studies have focused on the sediment-water interface created by the population of a single macrofaunal species (e.g., Katz, 1980; Kristensen, 1984; Griffis and Chavez, 1988; Davey, 1994; Fenchel, 1996; Coelho et al., 2000), which does not represent the space occupied by the whole community. In addition, physical gradients and seasonal variation in the environment, which may force intertidal macrofauna to form widely different burrow structures and dimensions, have rarely been considered in any detail. The same holds for bioturbation studies, with a few exceptions. Therefore, this study was designed to investigate the increase in the sediment-water interface and its variation with environmental gradients, focusing on all macrofaunal burrows on a tidal flat.

2. Study area

This study was conducted in the upper intertidal zone of the Ganghwa tidal flat at the northeastern end of Gyeonggi Bay on the west coast of Korea (see Koo et al., 2005: Fig. 2). The study area is almost surrounded by the two islands of Ganghwado and Donggeomdo, and a small tributary channel that branches from a main tidal channel extends into the area. This area has a semidiurnal macrotidal regime with a tidal range between 8.6 m at spring tide and 6.4 m at neap tide. In the main tidal channel during spring tide, flood-current velocities range between 1.4 and 2.4 m s^{-1} and ebb-current velocities range between 1.2 and 1.7 m s^{-1}. Surface sediments become finer eastward across the Ganghwa tidal flat and in the study area consist principally of mud, with a mean grain size of 6.0 to 7.0 φ (Woo and Je, 2002). The halophyte *Suaeda japonica* is distributed along the coast of Donggeomdo and extends into small tidal channels. Numerous biogenic structures of crabs, *Cleistostoma dilatatum* and *Macrophthalmus japonicus,* and polychaetes, *Periserrula leucophryna* and *Perinereis aibuhitensis*, are scattered on the flat (Koo et al., 2005). These species have conspicuous mounds or openings that are easily distinguished from each other.

3. Methods and materials

Three sites were selected for the investigation of environmental conditions and dimensions of macrofaunal burrows according to tidal height and vegetation (see Fig. 2 of Koo et al., 2005; their sites 1B, 1A, and 2 are named VMF1, VMF2, and UMF, respectively, in the present study). Sites VMF1 and VMF2 were established on a vegetated mud flat and site UMF was established on an unvegetated mud flat. Site VMF1 was located at the highest position from mean sea level (MSL) and site VMF2 was at the lowest point. Field surveys were conducted at low tide during spring tides in spring (April) and in summer (August) 2005.

Air temperature was measured 1.5 m above the surface sediment during the daytime on two survey occasions. The measurements were continued for three days at 1-h intervals. Sediment temperature was also measured by placing a thermometer directly at different sediment depths at site VMF1 at 13:00 h during each survey. The water content of the sediment was determined from the difference between the wet and the dry weight of cored sediment samples (N = 2). The elevation from MSL was measured using a real-time kinematic differential global positioning