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Foraminiferal microhabitats in a high marsh: Consequences for reconstructing past sea levels

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Abstract

The foraminiferal faunas of the high marsh of Plougoumelen, in the western part of the Gulf of Morbihan on the French Atlantic coast, have been studied in three successive sample sets taken in weekly intervals in April 2001. Each sampling day, four cores have been taken in different marsh environments, with or without vegetation, in order to determine the microhabitat of the major species and the eventual influence of a vegetation cover. Physico-chemical parameters have been surveyed during each sampling day. The foraminiferal faunas are similar to other faunas described from temperate salt marshes. We have distinguished three groups of taxa with different microhabitats: (a) *Jadammina macrescens* is found in comparable numbers down to about 9 cm depth; (b) shallow infaunal taxa, such as *Miliammina fusca* and *Trochammina inflata*; and (c) deep infaunal taxa, such as *Haplophragmoides wilberti* and *Arenoparrella mexicana*. Although these deep infaunal taxa have to cope with low oxygen concentrations, or even anoxia, life at depth in the sediment appears to provide ecological advantages. Our survey of the physico-chemical parameters shows an extreme variability at the surface, in comparison with much more stable conditions deeper in the sediment. These more stable conditions, demanding smaller tolerance ranges for several parameters (temperature, salinity, water content), appear to be advantageous to deep infaunal taxa. For the species *J. macrescens*, the microhabitat depth appears to be controlled by the water content of the sediment that strongly fluctuates in function of the meteorological conditions. During dry periods, when the water content of the sediment is lower, *J. macrescens* displays a much shallower microhabitat than during more humid periods. At the sediment surface, the presence of vegetation appears to have a positive influence on the density of the foraminiferal faunas by providing a shelter to desiccation during low tide, or more prolonged dry periods. Important differences exist between the live faunas found in the uppermost centimetre of the sediment, and those of the total, 9 cm deep sediment cores. Therefore, data inventories of living faunas, based on the superficial centimetre alone, can not be used as a basis for paleo-environmental reconstructions without correction for these microhabitat effects.

Keywords: Living benthic foraminifera; Microhabitat; Ecology; Salt marsh; French coast; Sea level

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1. Introduction

The ecology of salt-marsh foraminifera has been investigated since the 1950s (e.g. Phleger and Walton, 1950). Especially the spatial distribution and abundance of modern benthic salt-marsh foraminifera (living or total assemblages) have been the subject of numerous publications (e.g. Phleger, 1964, 1965a,b, 1970; Bradshaw, 1968; Murray, 1971, 1973, 1991; Goldstein and Frey, 1986; Hayward and Hollis, 1994; De Rijk, 1995; De Rijk and Troelstra, 1997; Sen Gupta, 1999; Debenay et al., 2000; Debenay and Guillou, 2002). In most of these papers, an attempt is made to relate the spatial distribution of foraminifera to environmental factors: temperature, salinity, pH, oxygen, flooding frequency, substrate, turbidity, vegetation or food availability. Foraminifera do not only have to tolerate the extreme (minimum and maximum) values of these parameters, but also the daily and seasonal range of variation, that tends to be extreme (Parker and Athearn, 1959; Phleger, 1965a). The small scale characteristics of the sample point, such as the presence of vegetation or of small ponds, may also have a strong impact on the live faunal composition and the density of the foraminiferal standing crops (Lee et al., 1969).

A model describing the foraminiferal distribution in salt marshes in function of vertical elevation has been established, in order to reconstruct former sea level changes (Scott and Medioli, 1978, 1986; Scott et al., 2001; Gehrels, 2002). Elevation is directly correlated with the duration and frequency of tidal flooding. However, other parameters than vertical elevation have also a potential impact on the foraminiferal distribution. Therefore, numerous studies comparing the foraminiferal distribution with elevation as well as with other environmental parameters have been undertaken in a wide array of marsh environments (Scott and Medioli, 1980, 1986; Scott et al., 1981; Williams, 1989, 1994, 1999; Patterson, 1990; Jennings and Nelson, 1992; Gehrels, 1994, 2002; Hayward et al., 1999; Horton, 1999; Horton et al., 1999). In tropical environments, vertical elevation has only a minor influence on the distribution of foraminiferal assemblages (Debenay et al., 2004).

The application of a recent distributional model to the fossil record has also to consider taphonomical processes, such as transport, selective preservation, admixture of older and/or infaunal foraminifera by bioturbation and diagenetic processes (De Rijk and Troelstra, 1999; De Stigter et al., 1999). The most studied phenomena intervening at the transition of the biocoenosis to the taphocoenosis in superficial sediments are selective preservation, that especially affects calcareous species in low pH salt marsh environments (Bradshaw, 1968; Murray and Alve, 1999a; Le Cadre et al., 2003), and the admixture of infaunal foraminiferal taxa to the superficial assemblages (Goldstein and Harben, 1993; Goldstein et al., 1995; Goldstein and Watkins, 1998, 1999; Ozarko et al., 1997; Saffert and Thomas, 1998; Patterson et al., 1999; Hippensteel et al., 2000).

Although generally a rapid drop of oxygen content, pH, and Eh, occurs in the first few millimeters of the sediment (Bradshaw, 1968), living salt-marsh foraminifera have been found down to 60 cm depth (Hippensteel et al., 2000, 2002). Unfortunately, very few studies deal with the vertical distribution of salt marsh foraminifera within the sediment, and in none of these, environmental parameters have been monitored. Until now, only speculations have been proposed to explain the occurrence of salt-marsh foraminifera deep in the sediment, such as the presence of "oxygen oases" around animal burrows and plant roots (Steineck and Bergstein, 1979; Goldstein et al., 1995), and/or passive transport by bioturbating macrofauna (Saffert and Thomas, 1998). Since many recent distributional studies are exclusively based on the living fauna of the topmost centimetres, addition of infaunal taxa may cause considerable differences between live and fossil assemblages. Therefore, a better knowledge of the distribution of foraminifera within the sediment, and the parameters influencing this distribution is required to complete the foraminiferal distribution model.

The aim of the present study is to examine the density, composition and vertical distribution of salt marsh foraminifera, and their changes over a short, weekly time scale, under different tidal ranges, in areas with and without vegetation. Collecting samples over a short period is the only way to point out the behaviour of foraminifera in response to rapidly changing local conditions. Seasonal samplings, on the contrary, should rather be affected by more long-term, systematical variations in mortality and reproduction (Alve and Murray, 2001). Therefore, short-term and