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Benthic foraminiferal response to experimentally induced *Erika* oil pollution

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Abstract

Benthic foraminifera from an intertidal mudflat (Bay of Bourgneuf, France) have been exposed to different types of oil-polluted seawater in an experimental laboratory setting. The aim of this experiment was to study the response of foraminiferal faunas from the intertidal zone to oil spills, as observed after the wreckage of the *Erika* oil tanker in December 1999 on the French Atlantic coast. In the course of the experiment a saturated seawater mix (SSW) and a water accommodated fraction of the oil (WAF) were on several occasions added to a part of the mesocosms, and the response of the foraminiferal assemblages was monitored during 3 months after the start of oil treatments. Several potential effects of oil-pollution were studied: 1) foraminiferal standing stocks, 2) anomalous growth patterns resulting in deformed or abnormal foraminiferal tests, and 3) changes in the taxonomical composition of the assemblage.

The foraminiferal assemblages at the start of the experiment were dominantly composed of *Haynesina germanica*. The experimental results show a strong decline in density in all mesocosms (including the control mesocosms) over time. During the first 2 weeks of the experiment, this decline was stronger in the oil-treated mesocosms than in the control mesocosms. After the first 2 weeks, the replicates of the oil-treatments showed an extreme variability, whereas the control mesocosms showed less variability with densities steadily decreasing over time. In some of the oil-treated mesocosms, we observed strongly increased densities, indicative of reproductive events. In all other oil-treated mesocosms foraminiferal densities decreased more severely than in the control mesocosms. The different types of oil–seawater mixtures did not cause a significantly different response. After 3 months, some taxa that had not been encountered previously in the field samples or in the mesocosms (e.g., *Textularia earlandi*) appeared in the 63–125 μm fractions of the oil-treated mesocosms. We conclude that there is a dual response to oil-induced pollution: foraminiferal faunas may respond by a strongly increased mortality, and/or by an accelerated reproduction of some of the taxa.

Keywords: benthic foraminifera; mesocosm experiment; oil pollution; *Erika* wreckage; France

1. Introduction

Worldwide accidents and wreckages of oil tankers are a cause of great public concern, especially because of the clear visual ecological impact of such incidents. However, these accidents are not the major causes of oil

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dispersal in the marine environment. Of all oil released in the marine environment about 33% is generated by the transport of oil; only one quarter of this quantity (8% of all oil) is caused by accidents and major spillages (Kennish, 1992). Despite the fact that oil tanker accidents are not the major contributors to oil released in the natural environment, they have raised a wide public concern by showing that oil pollution has profound effects on the sea and its inhabitants. For example, accidents of the Amoco Cadiz, the Exxon Valdez, the *Erika* and the recent wreckages of the Prestige and the Jessica have had great impact on the awareness of the hazards involved in oil transports (e.g., Lee and Page, 1997; Baars, 2002; Marshall and Edgar, 2003; Zenetos et al., 2004). The more invisible release of oil and its toxic compounds in nature is probably of even greater concern to us, especially since about one third of all oil released is ultimately accumulating in estuaries (Kennish, 1992), that contain a wide range of very fragile environments.

Several studies have shown the impact of oil pollution on various benthic organisms, such as bivalves, gastropods, copepods, nematodes and sea urchins (Temara et al., 1999; Hamoutene et al., 2002; Lee et al., 2002; Le Hir and Hily, 2002; Suderman and Thistle, 2003; Martinéz-Jerónimo et al., 2005). Effects range from lethal, carcogenic and/or mutagenic effects. Different oils have specific compositions and the proportions of toxic components vary strongly (Singer et al., 2000; Tsvetnenko and Evans, 2002). Crude oils are composed of many thousands complex gaseous, liquid and solid organic compounds of which hydrocarbons are the most abundant (Kennish, 1992). Import constituents are the alkanes (parrafins), cycloalkanes (cycloparrafins, naphtalenes), alkenes, alkynes and the aromatic hydrocarbons including polynuclear or polycyclic hydrocarbons (PAHs). This last group forms the most toxic part of the oil and generally the toxicity increases from alkanes, cycloalkanes, and alkenes to the aromatics. Already in the first hours following oil spills the composition of the released oil changes significantly. A number of processes are responsible for this compositional change: spreading, evaporation, photochemical oxidation, dissolution, emulsification, sedimentation, adsorption and microbial degradation (Kennish, 1992; Kingston, 2002). After being released in the marine environment, it mostly takes at least a few hours to transport the oil into the coastal zone. During this time interval, the aforementioned processes will strongly affect the composition and toxicity of the oil.

In December 1999 the oil tanker *Erika* wrecked 80 miles off the coast of Brittany, France. This accident caused 5.8 million gallons of heavy fuel oil to be released in the marine environment. The transported oil was lowly volatile, had a poor solubility and a low dispersal potential (for a specific analysis of the *Erika* oil see IFP, 2003). In the weeks/months following the accident, the oil was washed ashore along a 400 km stretch of the French coastline.

Live foraminifera are increasingly used and studied for their value as bioindicators in a wide range of marine environments (e.g., Alve, 1991, 1995; Yanko et al., 1994, 1999; Debenay et al., 2001; Samir, 2000; Samir and El-Din, 2001; Armynot du Châtelet et al., 2004; Saraswat et al., 2004). Foraminifera are valuable since they respond fast to environmental changes, occur in high densities and produce a fossil record giving access to the pre-pollution background faunas. Since the degree of bioavailability of toxic compounds cannot be derived directly from analyses of sediments or waters, the study of foraminiferal faunas that give an integrated account of the effects of pollution is important. However, very few studies dealing with the effects of natural or anthropogenic oil pollution on benthic foraminifera have been performed until today (e.g., Vénec-Peyré, 1981; Yanko et al., 1994; Alve, 1995; Bernhard et al., 2001). Since January 2000 a field survey has been carried out in tidal mudflats and marshes in the Bay of Bourgneuf (French Atlantic coast), that were heavily affected by the *Erika* oil spill (see Baars, 2002), with the aim to study the effect of the *Erika* oil pollution on the benthic foraminiferal faunas (Morvan et al., 2004). Further, a series of monospecific cultures and in vitro experiments with specimens of *Ammonia tepida* were carried out under laboratory conditions (Le Cadre, 2003; Morvan et al., 2004). These experiments were designed to test the impact of different quantities of *Erika* oil mixed in seawater on populations of this taxon. The results of both field and laboratory studies urged the need for a series of complementary mesocosm experiments, in which an oil spill was simulated under controlled environmental conditions and in which foraminifera were kept as far as possible in natural conditions, i.e., in original sediments. For this purpose, 26 mesocosms were incubated and two different methods of introducing oil in the experimental environment were tested over a period of 4 months. We did not particularly intend to study a mono-specific assemblage as was performed in previous experiments with *Ammonia beccarii* (Le Cadre, 2003). However, these intertidal environments require special capacities from organisms experiencing regularly extreme environmental variability. In these environments only few foraminiferal taxa thrive and often the assemblages are