Available online at www.sciencedirect.com
ScienceDirect
Marine Environmental Research 64 (2007) 574–589
MARINE ENVIRONMENTAL RESEARCH
www.elsevier.com/locate/marenvrev

Recolonization and recovery dynamics of the macrozoobenthos after sand extraction in relict sand bottoms of the Northern Adriatic Sea

R. Simonini [a,*], I. Ansaloni [a], P. Bonini [a], V. Grandi [a], F. Graziosi [a], M. Iotti [a], G. Massamba-N'Siala [a], M. Mauri [a], G. Montanari [b], M. Preti [c], N. De Nigris [c], D. Prevedelli [a]

[a] *Dipartimento di Biologia Animale, Università degli studi di Modena e Reggio Emilia, via Campi 213/D, 41100 Modena, Italy*
[b] *ARPA Emilia-Romagna, Struttura Oceanografica Daphne, via Vespucci, Cesenatico (FC), Italy*
[c] *ARPA Emilia-Romagna, Ingegneria Ambientale, Vicolo Carega 10, Bologna, Italy*

Received 16 June 2006; received in revised form 30 May 2007; accepted 11 June 2007

Abstract

The long-term effects of sand extraction on macrozoobenthic communities were investigated in an offshore area in the Northern Adriatic Sea characterised by relict sands formed during the last Adriatic post-glacial transgression. Surveys were carried out before, during and 1, 6, 12, 18, 24 and 30 months after extraction at three impacted and seven reference stations. The operations did not influence the physical characteristics of the sediment, but they caused almost complete defaunation at dredged sites. Univariate and multivariate analyses highlighted that the macrozoobenthic community responses to the dredging operations were (1) a rapid initial recolonisation phase by the dominant taxa present before dredging, which took place 6–12 months after sand extraction; (2) a slower recovery phase, that ended 30 months after the operations, when the composition and structure of the communities were similar in the dredged and reference areas. This pattern of recolonisation–recovery fits well with the commonly encountered scenario where the substratum merely remains unchanged after marine aggregate extraction.

Keywords: Environmental impact; Dredging; Sand extraction; Benthos; Recolonisation; Recovery; Northern Adriatic Sea; Relict sands

1. Introduction

The impact of marine sand extraction on the characteristics of the seabed and the changes in benthic fauna have been widely investigated (Newell et al., 1998; Sardà et al., 2000; Van Dalfsen et al., 2000). The dredging operations may influence the physical and biological characteristics of the impacted areas both directly,

* Corresponding author. Tel.: +39 59 2055562; fax: +39 59 2055548.
E-mail address: simonini.roberto@unimore.it (R. Simonini).

0141-1136/$ - see front matter © 2007 Elsevier Ltd. All rights reserved.
doi:10.1016/j.marenvres.2007.06.002

through removal, smothering and damage caused by the dredge head, and indirectly: surface and bottom plumes, changes in plankton bloom seasons, the release of nutrients and chemicals, as well as sound, can affect both the sea bottom and the water column in the immediate area around the dredging site (Boyd et al., 2005; Newell et al., 1998; Van Dalfsen et al., 2000).

Most studies concerning the impacts of sand dredging on macrozoobenthos were performed in shallow, dynamic sandy bottoms. In these cases, the recovery of the benthic assemblages appeared to be linked to the alterations in the seabed, in terms of grain size, organic content and morphology induced by sand extraction. Major alterations in the sediment and grain size characteristics over a long period favoured the settlement of benthic communities that were different in composition and structure from the pre-operational ones and this difference could be maintained for a long time (Boyd et al., 2003, 2005; Van der Veer et al., 1985). In contrast, when there was minimal variation in the seabed characteristics, benthic communities recovered within a few years in terms of biodiversity and biomass (Boyd et al., 2003; Kenny and Rees, 1994, 1996; Kenny et al., 1998; Robinson et al., 2005; Van Dalfsen and Essink, 1997).

The largest nourishment operation in the Mediterranean Sea took place in 2002, when approximately 800,000 m^3 of sand were dredged from off-shore relict sand deposits in the Northern Adriatic Sea. These were destined for the nourishment of several beaches along the Emilia-Romagna coast (Italy) (Simonini et al., 2005). Besides the geographical location, this operation was unusual because the seabed of the area (1) did not show active sedimentation, (2) was primarily composed of relict sand, (3) was far from the coast (55 km) and (4) at a greater depth (40–42 m) compared with the other previous dredging operations, where the maximum dredging depth was usually around 30 m (North Sea Foundation, 2005).

The analysis of the short-term impacts of sand extraction on sediment and macrozoobenthos during the first 12 months after dredging, highlighted that the activities did not significantly influence the granulometry and the total organic carbon content (%TOC) of the substratum, but caused almost complete defaunation at the dredging stations. Yet, at the end of this survey period, the recolonisation of the communities at the impacted stations was at an advanced stage (Simonini et al., 2005).

In the present paper, we analysed the impact of relict sand extraction on benthic communities and the degree of recolonisation of macrobenthos at the end of the monitoring program, up to 30 months after the completion of the dredging. The aim was to establish the recolonization–recovery state of the macrozoobenthos and obtain a reference model for the effects of sand extraction on relict sand bottoms.

2. Materials and methods

2.1. Study area and sampling

The dredged area is located approximately 55 km off the coast of Ravenna, in an area characterized by the occurrence of relict offshore sandy deposits (Fig. 1; Preti, 2000). These deposits, mainly composed of sand and coarse detritus, are the remains of coastal structures that were formed during the last Adriatic marine transgression. This area is outside the main current circuit of the Northern Adriatic, and as a result is characterized by a limited amount of sedimentation of fine material during the summer period that become resuspended and dispersed during the winter (Preti, 2000, 2002; Simonini et al., 2005). The tidal excursion is negligible and the currents are weak and with variable direction. In fact, the main factors that affect the sediment transport and re-suspension in the area are the storms driven by the NE and SE winds (Bora and Scirocco) that frequently occur in the Northern Adriatic Sea from December to late March and probably lead to significant sediment re-suspension (Matteucci and Frascari, 1997; Wang and Pinardi, 2003). Water temperature in the bottom showed marked seasonal variation ranging from 8 °C in February to 26 °C in August (Montanari and Pinardi, 2006).

The dredging operations took place in April–May 2002. The monitoring activities started in March 2001 and ended in December 2004. Eight sampling surveys were carried out: March 2001 (before extraction [B-Ex.]), April 2002 (during extraction [Ex.]), June 2002 (1 month after extraction [A-Ex. 1]), December 2002 (6 months after extraction [A-Ex. 6]), June 2003 (12 months after extraction [A-Ex. 12]), December 2003 (18 months after extraction [A-Ex. 18]), June 2004 (24 months after extraction [A-Ex. 24]) and December 2004 (30 months after extraction [A-Ex. 30]). Because of the lack of information