Available online at www.sciencedirect.com
SCIENCE DIRECT®
Marine Pollution Bulletin 50 (2005) 768–777
MARINE POLLUTION BULLETIN
www.elsevier.com/locate/marpolbul

The effects of sand extraction on the macrobenthos of a relict sands area (northern Adriatic Sea): results 12 months post-extraction

R. Simonini [a,*], I. Ansaloni [a], A.M. Bonvicini Pagliai [a], F. Cavallini [a], M. Iotti [a], M. Mauri [a], G. Montanari [b], M. Preti [c], A. Rinaldi [b,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, Italy*
[c] *ARPA Emilia-Romagna, Ingegneria Ambientale, Vicolo Carega 10, Bologna, Italy*

Abstract

Sands for the nourishment of beaches along the Emilia-Romagna coast (northern Adriatic Sea) were dredged from an offshore area characterised by relict sands formed during the last Adriatic post-glacial transgression. The short-term effects of the sand extraction on macrozoobenthic communities were investigated before, during and 1, 6 and 12 months after dredging at three impacted stations and seven control stations. Sand extraction activities did not significantly influence the granulometry and %TOC in the sediment but caused almost complete defaunation at dredging stations. Yet, just 12 months after the extraction, the recolonisation of communities at the impacted stations was at an advanced stage. Unlike other studies on the effects of extraction of marine sand, no significant settlement of opportunistic species was observed. The limited impact of the sand extraction operation on the physical characteristics of the sediment and hydrological-sedimentary characteristics in the relict sand area should aid its rapid recovery and the restoration of the original community in a short period of time (2–4 years after dredging).

Keywords: Sand extraction; Macrozoobenthos; Recovery; Northern Adriatic Sea; Relict sands

1. Introduction

Since the second half of the 20th century, the Emilia-Romagna coast (Northern Adriatic Sea, Italy), thanks to the presence of broad beaches and modern tourist facilities, has become the site of one of the most important tourist seaside resorts in Europe. However, the reduction in the contribution of sand to the sea by rivers and the alteration of the coastal environment have caused an imbalance in the sedimentary regime of the beaches, increasing coastal erosion and the necessity for beach protection operations (Preti, 2000; ARPA Emilia-Romagna, 2002). Among the techniques that have been tried, nourishment with sand extracted from offshore marine deposits has proved to be a valid method for beach protection, often preferable to rigid defence structures, such as artificial cliffs and groynes (Clark, 1983; Preti, 2000; ARPA Emilia-Romagna, 2002; CIESM, 2002). In fact, the exploitation of offshore sand deposits is common practice in various European countries, such as Spain, the Netherlands and Denmark (Van Dalfsen et al., 2000; Sardà et al., 2000). The feasibility of sand extraction operations does not only depend on the availability of sand deposits, but also on the analysis of potential risks for the benthic ecosystem: sand extraction often causes complete defaunation of the seabed and the damage to the benthic community is directly proportional to the surface area that is dredged (Van Dalfsen et al., 2000). Extraction activities can also interfere

* Corresponding author. Tel.: +39 592055562; fax: +39 592055548.
E-mail address: simonini.roberto@unimore.it (R. Simonini).

0025-326X/$ - see front matter © 2005 Elsevier Ltd. All rights reserved.
doi:10.1016/j.marpolbul.2005.02.009

with the sediment characteristics and influence the ecological conditions of the seabed (De Groot, 1979). Other important aspects concern the loss of important benthic resources and the subsequent consequences for marine trophic chains and fisheries. In particular, it is necessary to protect nursery areas and particularly sensitive coastal ecosystems (such as *Poseidonia oceanica* meadows), as well as preventing the tendency for siltation of the dredged areas, which would favour colonisation by a community that is different from the initial one (Foreman et al., 1995; Sardà et al., 2000). It is therefore essential to carry out medium–long-term monitoring programs, in order to predict, evaluate and model the effects of extraction on the disturbed communities and seabeds. Most of the studies carried out until now on the effects of the extraction of offshore sand on macrozoobenthic communities in Europe have regarded the coastal sandy bottoms of the North Sea and Western Mediterranean Sea (along the Spanish coast, i.e. Van Dalfsen et al., 2000; Sardà et al., 2000). The "Programma pluriennale di monitoraggio dell'area a mare da cui sono state prelevate le sabbie per il ripascimento delle spiagge emiliano-romagnole" (Multiannual monitoring programme of the offshore area of sand extraction for the nourishment of the Emilia-Romagna beaches), funded by the Emilia-Romagna Region and carried out by ARPA (Regional Agency for Prevention and the Environment of Emilia-Romagna), has offered the opportunity to study the effects of sand extraction and the recovery process of macrozoobenthic communities in an offshore area of the Northern Adriatic Sea, which until now has been poorly investigated.

Between April and May 2002, approximately 800,000 m^3 of sand destined for the nourishment of various beaches along the Emilia-Romagna coast was dredged from an area of approximately 100 ha (1 km^2) off Marina di Ravenna (Fig. 1). Besides the geographical location, this operation is also clearly different from those carried out until now regarding other aspects: the seabed of the area does not show active sedimentation and is primarily composed of relict sand; moreover, the dredged area was at a greater depth (40–42 m) and distance from the coast (55 km) compared with the other operations carried out until now in Europe (Preti, 2000). In this paper, we analyse the impact of sand extraction on benthic communities and the degree of recolonisation of macrobenthos 1 year after the completion of the extraction activities.

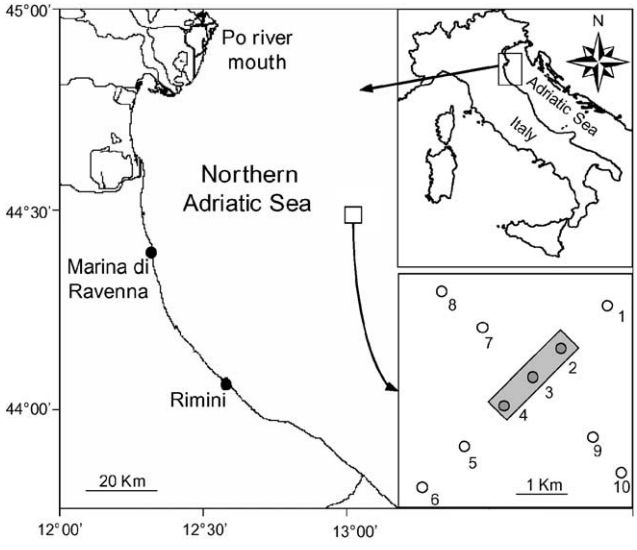

Fig. 1. Location of the sand extraction area and map of the sampling stations. Grey area = sand extraction area.

2. Materials and methods

2.1. Study area and sampling

The dredged area is located at approximately 55 km off the coast of Ravenna, on a seabed of 40–42 m depth, where relict offshore sandy deposits are present (Fig. 1). These deposits, mainly formed of sand and course detritus, are the remains of coastal structures that were formed during the last Adriatic marine transgression (that took place approximately 8000–11,000 years ago, at the end of the glaciation) and have subsequently been remodelled by marine erosion. The distance from the coast means that this area is outside the current circuit of the Northern Adriatic and receives a small amount of terrigenous contribution from the rivers that flow above all into the western side. The seabed is subject to weak erosion phenomena: in fact, there is a small and limited amount of sedimentation during the summer period, whereas during the winter the finer materials tend to become re-suspended and dispersed (Giani et al., 2001; Preti, 2000). Taking into account the hydrological and sedimentary characteristics of the area and the references to the effects of sand extraction operations on sea bottom and benthic assemblages (see Sardà et al., 2000; Van Dalfsen et al., 2000), we predicted that (1) the dredging activities would determine a marked reduction in the number of taxa and abundance of macrozoobenthos in the sand extraction area with respect to a nearby reference area; (2) the recolonisation of the bottom after dredging would take 12–18 months while the restoration of the original community would require 2–4 years.

Five sampling surveys were carried out in March 2001 (before extraction [Bef.-Ex.]), April 2002 (during extraction [Ex.]), June 2002 (1 month after extraction [Aft.-Ex. 1]), December 2002 (6 months after extraction [Aft.-Ex. 6]) and June 2003 (12 months after extraction [Aft.-Ex. 12]) in the extraction area as well in the nearby reference area. The sampling design provided for samples at three impacted stations within the extraction area and at seven control stations outside the area.