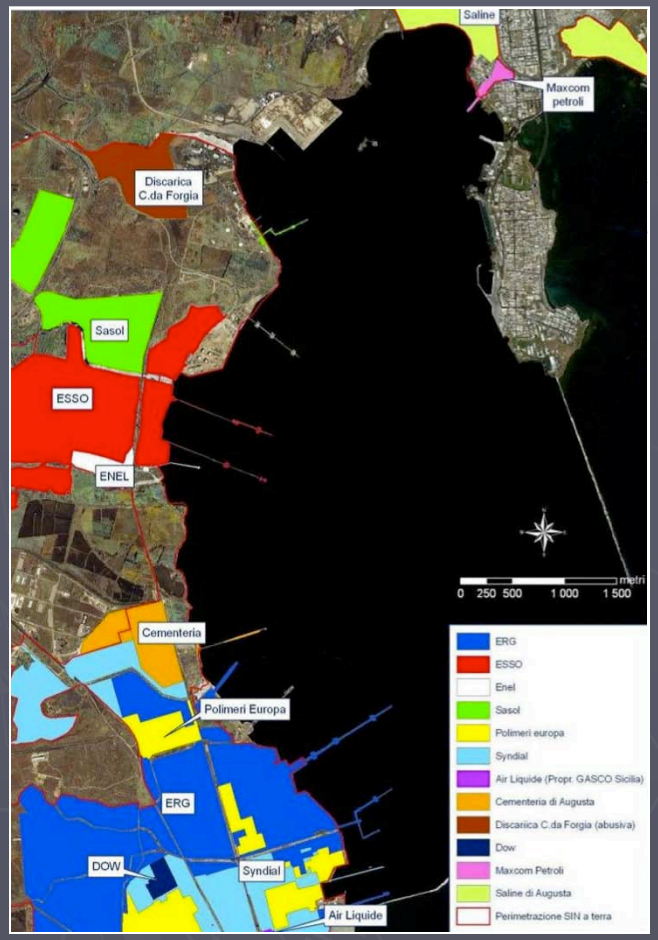
Sediment characterization of Augusta harbor (Sicily, Italy): modern benthic foraminifera in relation to grain-size and sediment contamination

Elena Romano, Luisa Bergamin, Maria Celia Magno, Antonella Ausili

ISPRA – Institute for Environmental Protection and Research

elena. romano@isprambiente.it

THE STUDY AREA



The Augusta harbor is affected by heavy anthropogenic impact mainly due to the activity of one of the largest Mediterranean petrochemical pole and in 2000 it was included in the "National Relevance Contaminated Site"

The petrochemical pole was built in the 1950s and it's still in activity including:

- ✓ Oil refineries
- ✓ Electric power plant
- ✓ Chemical and petrochemical plants
- ✓ Chlor-alkaly plant using Hg-cells technology
- ✓ Cement factory

But also:

- ✓ a commercial harbor
- ✓ a military base
- ✓ the Augusta town

So, it has been subjected to an environmental characterization for reclamation aim studying their morphological and bathymetrical features together with physic-chemical and ecotoxicological characteristics of sediments.

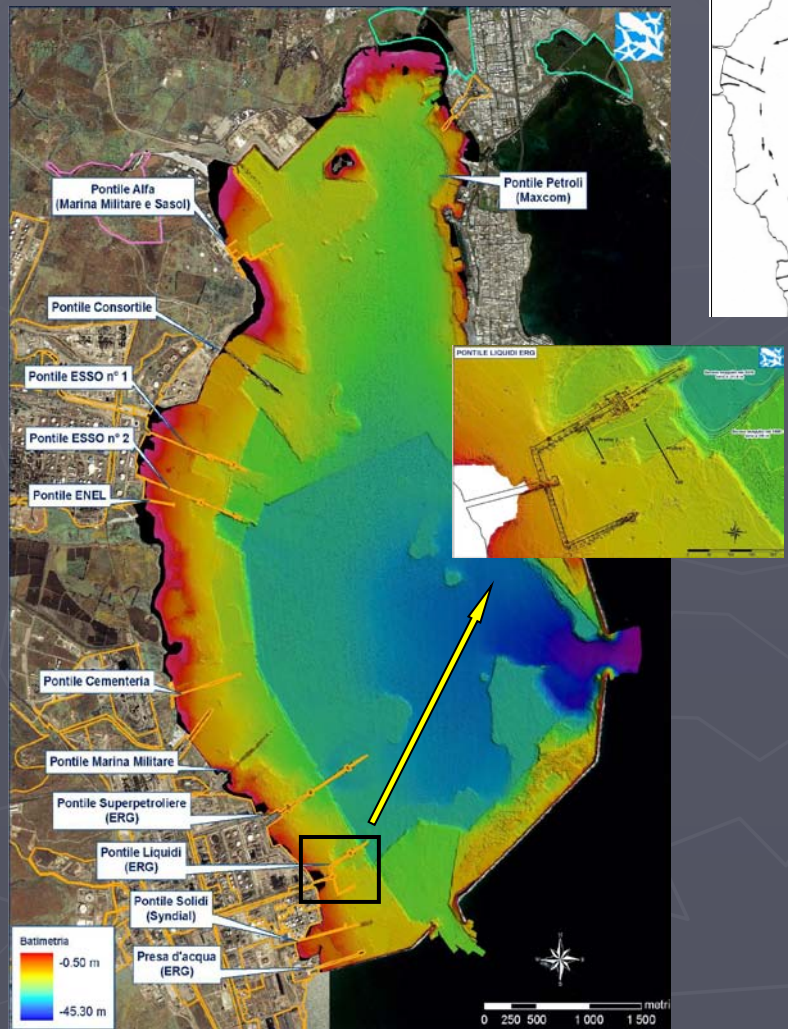
Benthic foraminifera were included in the environmental characterization as experimental tool to use as environmental indicators.

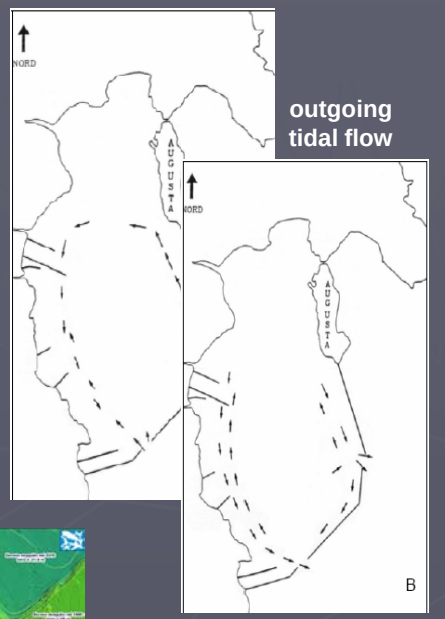
FEATURES OF THE AREA

The geophysical surveys (SBP, SSS, Multibeam) recognized:

- ✓ An irregular substrate constituted by rocks or overconsolidated clays potentially acting as barrier to vertical contamination transfer
- ✓ Soft sediments of variable thickness, broader in the northern and central sector and nearly thinner or absent in the southern part to define the potential contamination

A detailed Multibeam survey highlighted several morphological steps due to past dredging activities (1972 – 1990) and many grooves due to the ship berthing activity useful to define undisturbed areas for collecting sediment cores



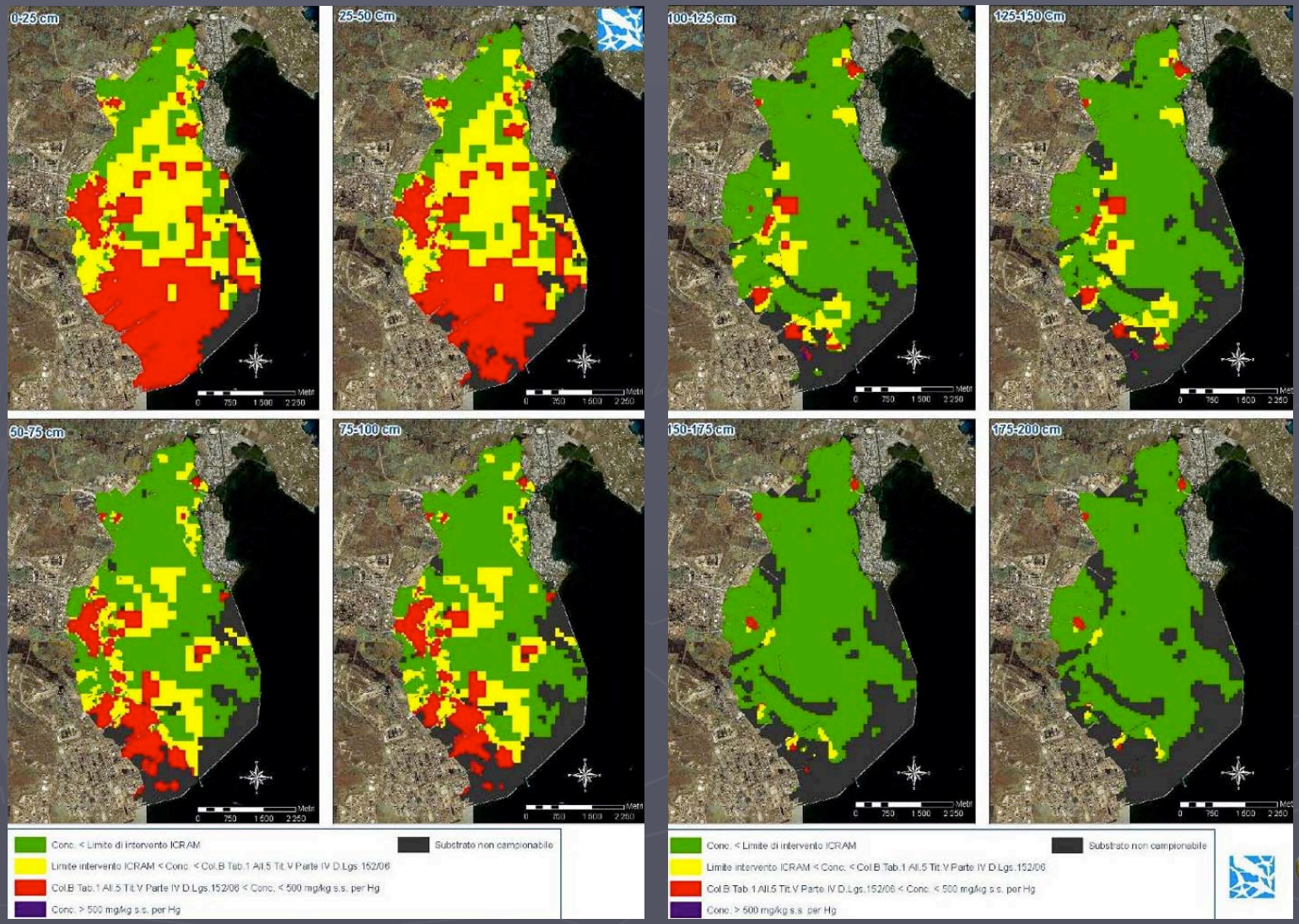


Water circulation is mainly located in the central-southern sector with cell having alternating directions in different tide conditions.

The highest water speed is of 5-6 cm/s in correspondence of the inlet.

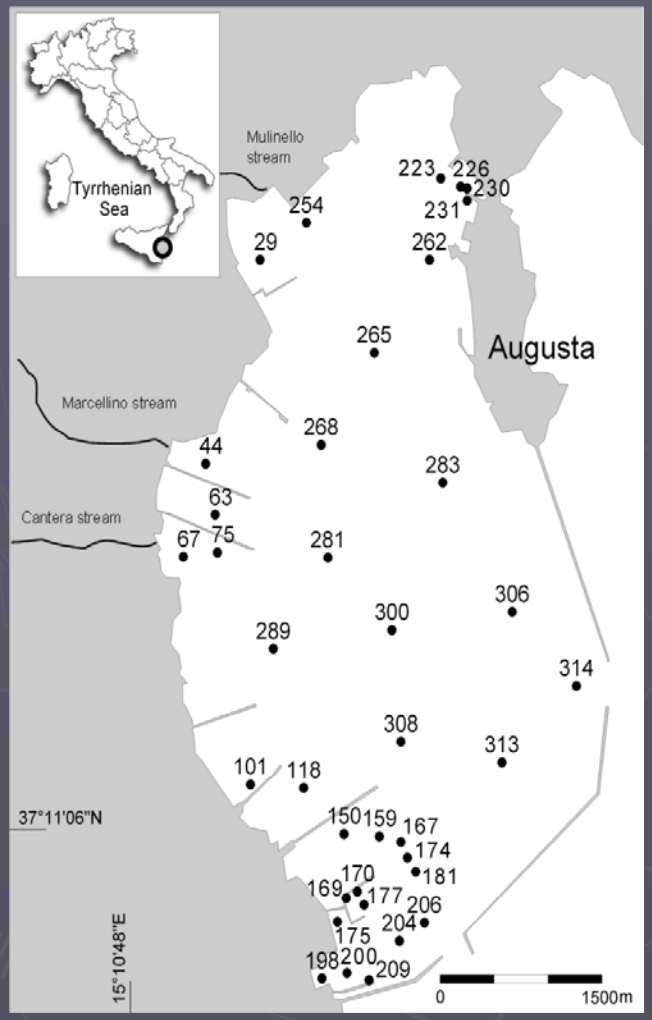
ENVIRONMENTAL CHARACTERIZATION

Chemical sediment characterization highlighted a strong contamination due to Hg, Pb, Cu, heavy hydrocarbons, PCBs, HCB and dioxins



BENTHIC FORAMINIFERA

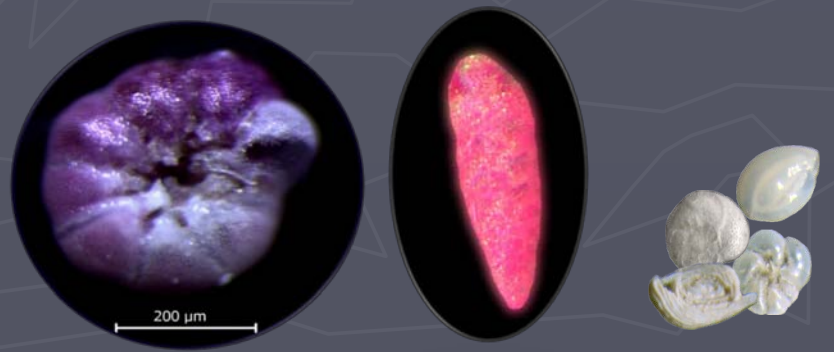
Benthic foraminifera assemblages were studied to highlight new reliable environmental indicators for areas affected by high anthropogenic impact through:



- ✓ Checking their response to sediment texture and geochemistry
- ✓ Recognizing the faunal parameters correlated to abiotic one and able to consider them as descriptors of the environmental quality

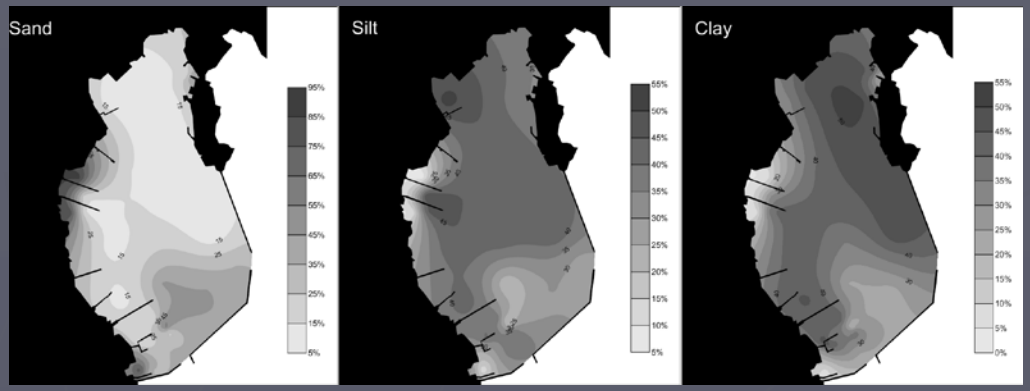
A total of 37 superficial sediment samples were collected by van Veen grab. A 2-cm thick sample was taken from the central most undisturbed sector of the grab to analyze:

- ✓ Grain size
- ✓ Metals and trace elements (Al, As, Cd, Cr, Cu, Fe, Hg, Ni, Pb, Zn,V)
- ✓ Polychlorobiphenyls, Polycyclic Aromatic Hydrocarbons
- ✓ Organic Carbon
- ✓ Foraminifera, stained with a Rose Bengal solution to identify living specimens



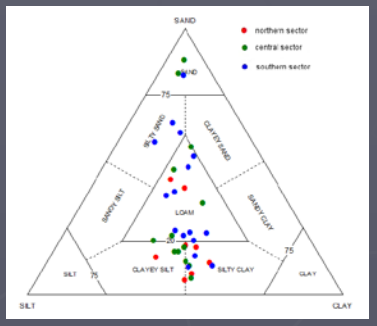
Romano et al., Environ. Sci.: Processes Impacts 2013, 15, 930-946

THE PHYSICAL-CHEMICAL RESULTS



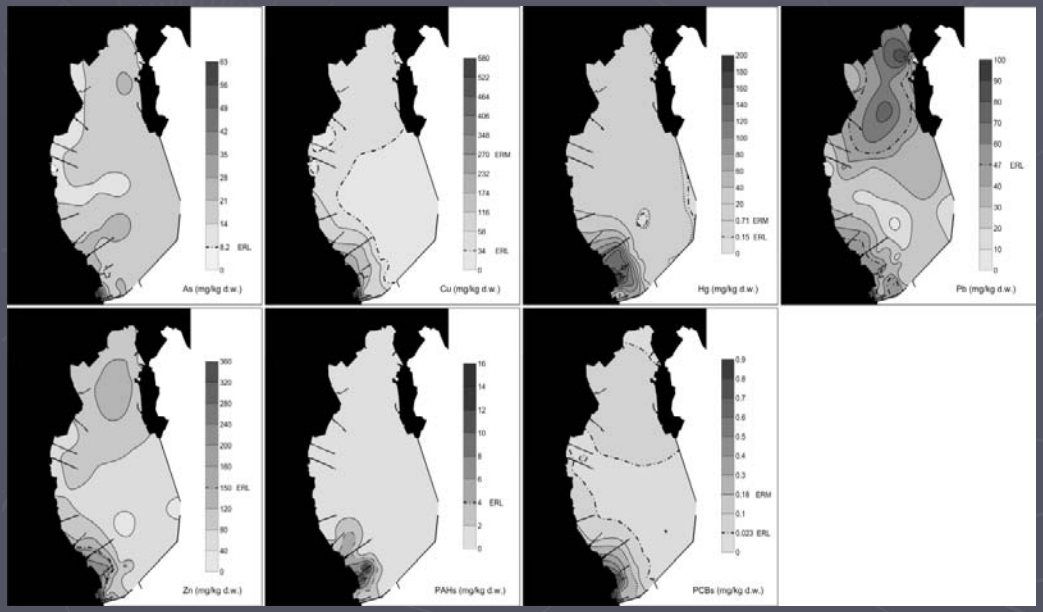
Celia Magno et al., Mar. Geol. 2012, 315–318, 143-161

Fine sediments, silt and clay, prevail. Their highest percentages are located in the northern sector. Instead of the highest percentages of sand are recorded close to the coast and to the inlet.



Romano et al., Environ. Sci.: Processes Impacts 2013, 15, 930-946

Sand is mainly constituted by bioclasts, included reworked foraminifera which were well recognizable from the recent ones and not included in the faunal analysis



Romano et al., Environ. Sci.: Processes Impacts 2013, 15, 930-946

Chemical concentration show their highest values mainly located in the southern sector and, some of these, exceed threshold values (Long at al., 1995):

- ✓Hg exceeds ERM* in all the samples: an adverse biotic effect is probable
- ✓PCBs and Cu exceed ERL** in most harbor area while exceed ERM* in the southern one

These are the contaminants expected to determine adverse effects on foraminifera

** Effects Range-Low concentration below which adverse effects rarely occur

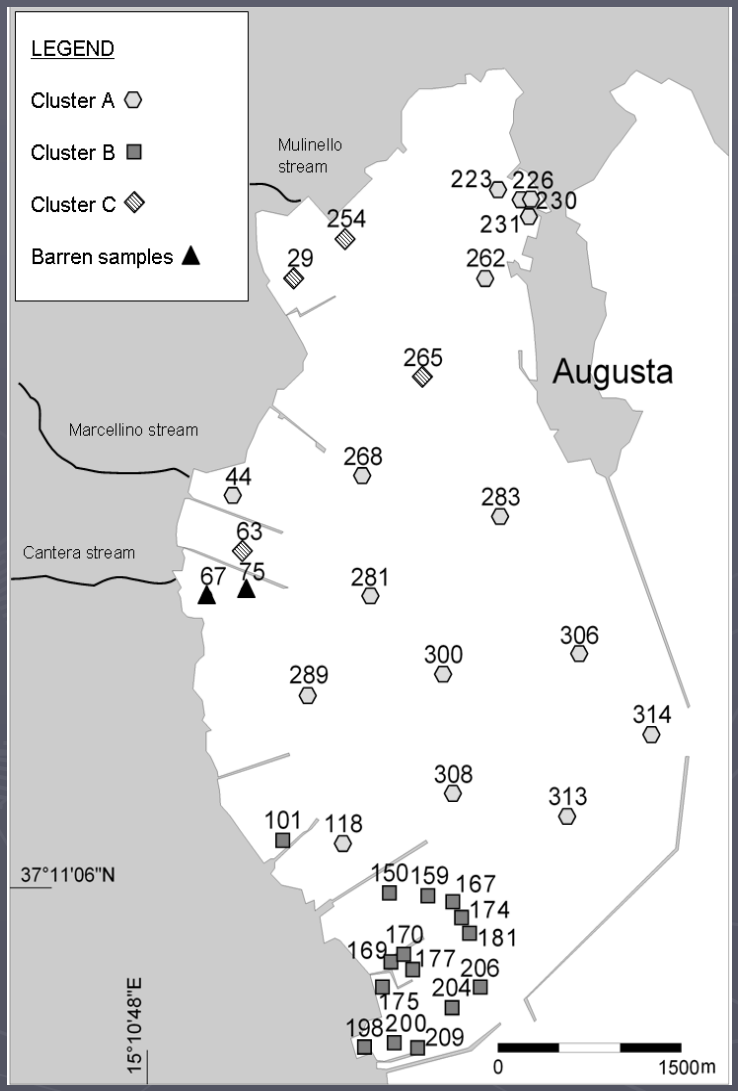
* Effects Range Median concentration above which adverse effects frequently occur

THE FORAMINIFERAL RESULTS (1/2)

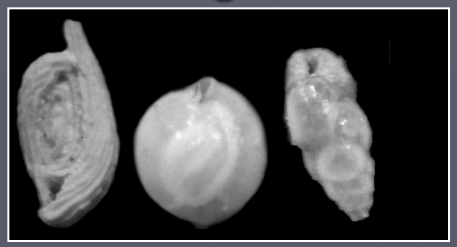
The assemblages were identified by means of Hierarchical Cluster Analysis

Assemblage C

Ammonia tepida 19%
Environment influenced by stream outflow with silty bottom and intermediate contamination levels.
Only 4 samples well localized in front of river mouths



Assemblage A

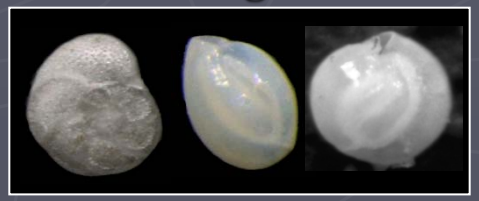


Sigmoilinita costata, Miliolinella subrotunda , Bulimina marginata 4%

Environment with muddy sea-bottom and the lowest sediment contamination.

Northern and central part of the harbor

Assemblage B



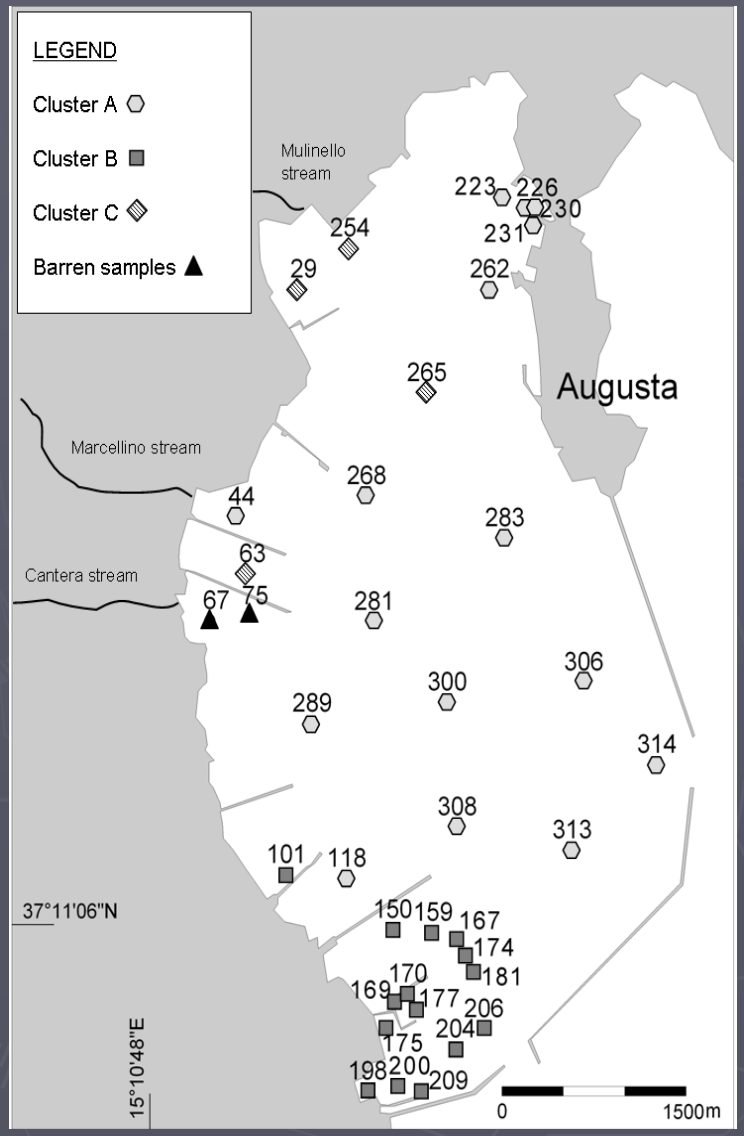
Rosalina bradyi 8%, *Quinqueloculina lata* 6%, *M. subrotunda* 5%.

Environment with mixed sediment and the highest contamination level.

Exclusive of the southern part of the harbor

Romano et al., Environ. Sci.: Processes Impacts 2013, 15, 930-946

THE FORAMINIFERAL RESULTS (2/2)



Romano et al., Environ. Sci.: Processes Impacts 2013, 15, 930-946

Faunal parameters indicative of species diversity, like as (Fisher α-index), Dominance (D) and foraminiferal density (Foraminiferal Number - FN), were considered as possible descriptors of environmental quality.

Assemblage A

The highest values of diversity, density and the lowest dominance

NO ENVIRONMENTAL STRESS

Assemblage B

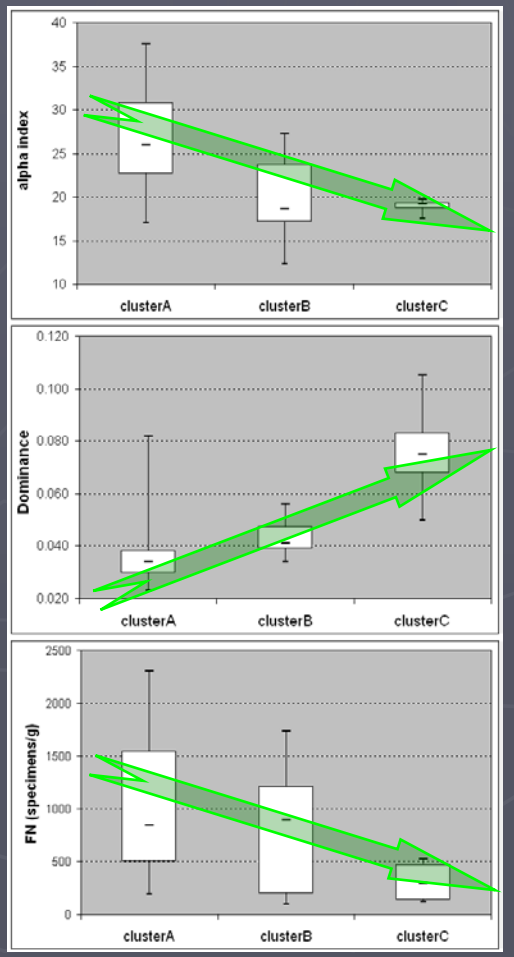
Intermediate values of diversity, density and dominance

ANTHROPOGENIC STRESS

Assemblage C

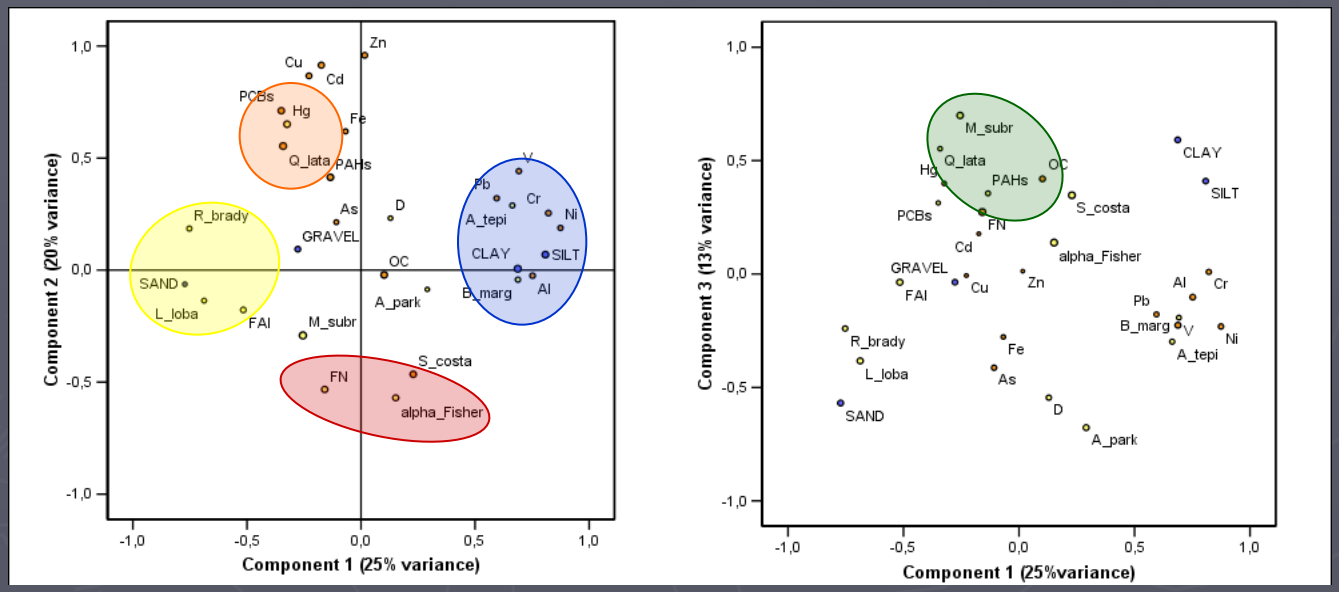
The lowest values of diversity, density and the highest dominance

ANTHROPOGENIC + NATURAL STRESS



CORRELATION WITH ENVIRONMENTAL DATA

The Principal Component Analysis was applied to compare species distribution and faunal parameters with environmental data



Romano et al., Environ. Sci.: Processes Impacts 2013, 15, 930-946

- ✓ Fine sediments are correlated with trace elements of natural origin
- ✓ Some species are correlated to selected sediment fractions: *B. marginata* is correlated to fine sediments, while *R. bradyi* and *L. lobatula* are correlated to the sandy fraction
- ✓ *Q. lata* is correlated to PCBs and Hg and then it is considered as a pollution-tolerant species
- ✓ FN and α-index are negatively correlated to anthropogenic pollutants
- ✓ FN as well as *Q. lata* and *M. subrotunda* are correlated to the Organic Matter

SEDIMENT CORE

We focused our attention on the southern most contaminated area of the harbor.

The study of foraminifera in a sediment core allows to reconstruct changes of environmental quality

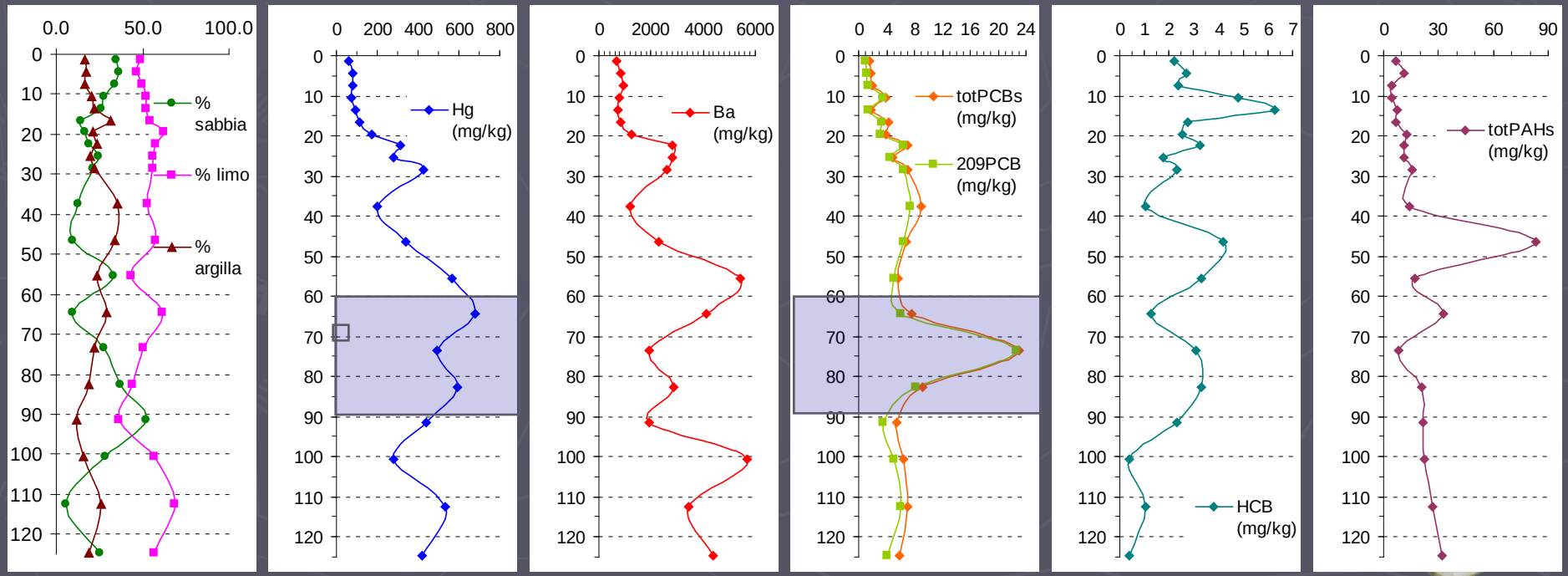
The sediment core AU10 was collected by means of a gravity corer (SW 104) from the southern most contaminated area. A total of 127 cm were recovered. A total of 20 sub-samples (3 cm thick) were taken by extrusion.

SEDIMENT ANALYSES

- ✓ Grain-size
- ✓ Metals (Hg, Ba)
- ✓ Polychlorobiphenyls (PCBs)
- ✓ Hexachlorobenzene (HCB)
- ✓ Polycyclic Aromatic Hydrocarbons (PAHs)
- ✓ Foraminifera

PHYSICAL-CHEMICAL RESULTS

- ✓ Silt is the prevailing sediment fraction in all analyzed levels. No significant changes of sediment texture were recognized along core depth.
- ✓ Chemical parameters show high concentrations in all the analyzed levels to indicate that pre-industrial condition was not recovered. Except HCBs, all parameters show a significant decrease from -30 cm to the core top.
- ✓ Concentration profiles of Ba and Hg have high similarity especially in the upper part of core. Also PCBs show a similar decreasing pattern.



Mean crustal concentrations: Hg 0.08 mg/kg - Ba 578 mg/kg

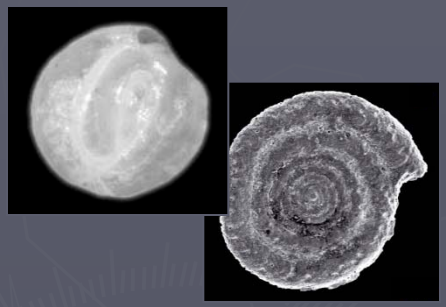
FORAMINIFERAL ASSEMBLAGES

Three distinct assemblages were identified by means of Hierarchical Cluster Analysis. *Miliolinella subrotunda* , a species demonstrated by previous studies to be pollution-tolerant, is prevailing in all the assemblages

Assemblage A

Miliolinella subrotunda 9%, *Bolivina punctata* 9%

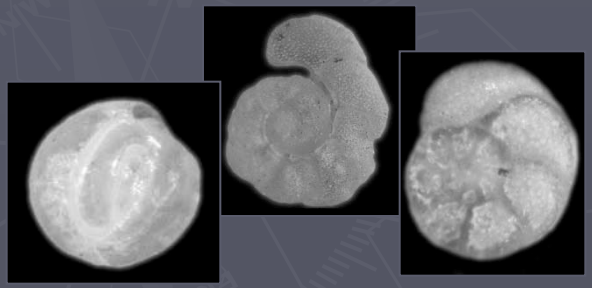
α-index 16.5; H 3.29; FN 1744



Assemblage B

M. subrotunda 15%, *Spirillina vivipara* 10%.

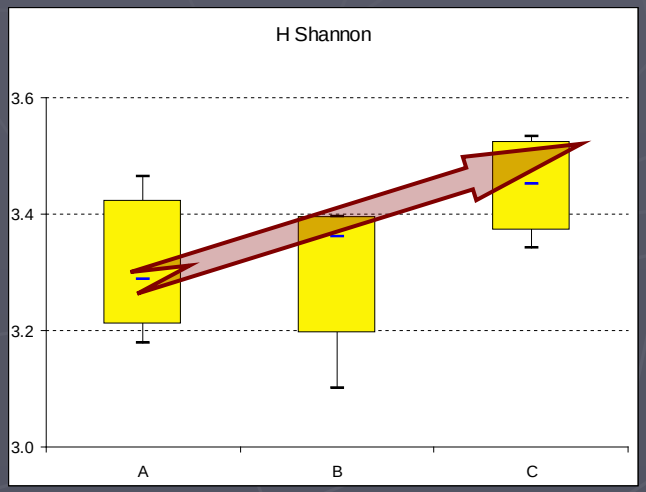
α-index 14.4; H 3.36; FN 483

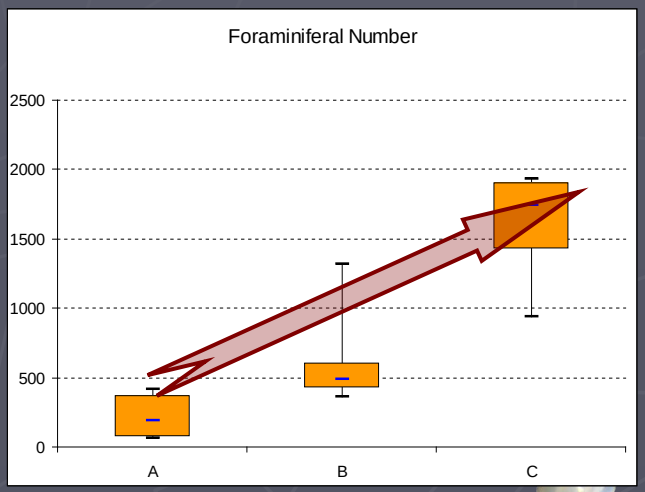


Assemblage C

M. subrotunda 9%, *Lobatula lobatula* 7%, *Rosalina bradyi* 6%.

α-index 14.9; H 3.45; FN 186

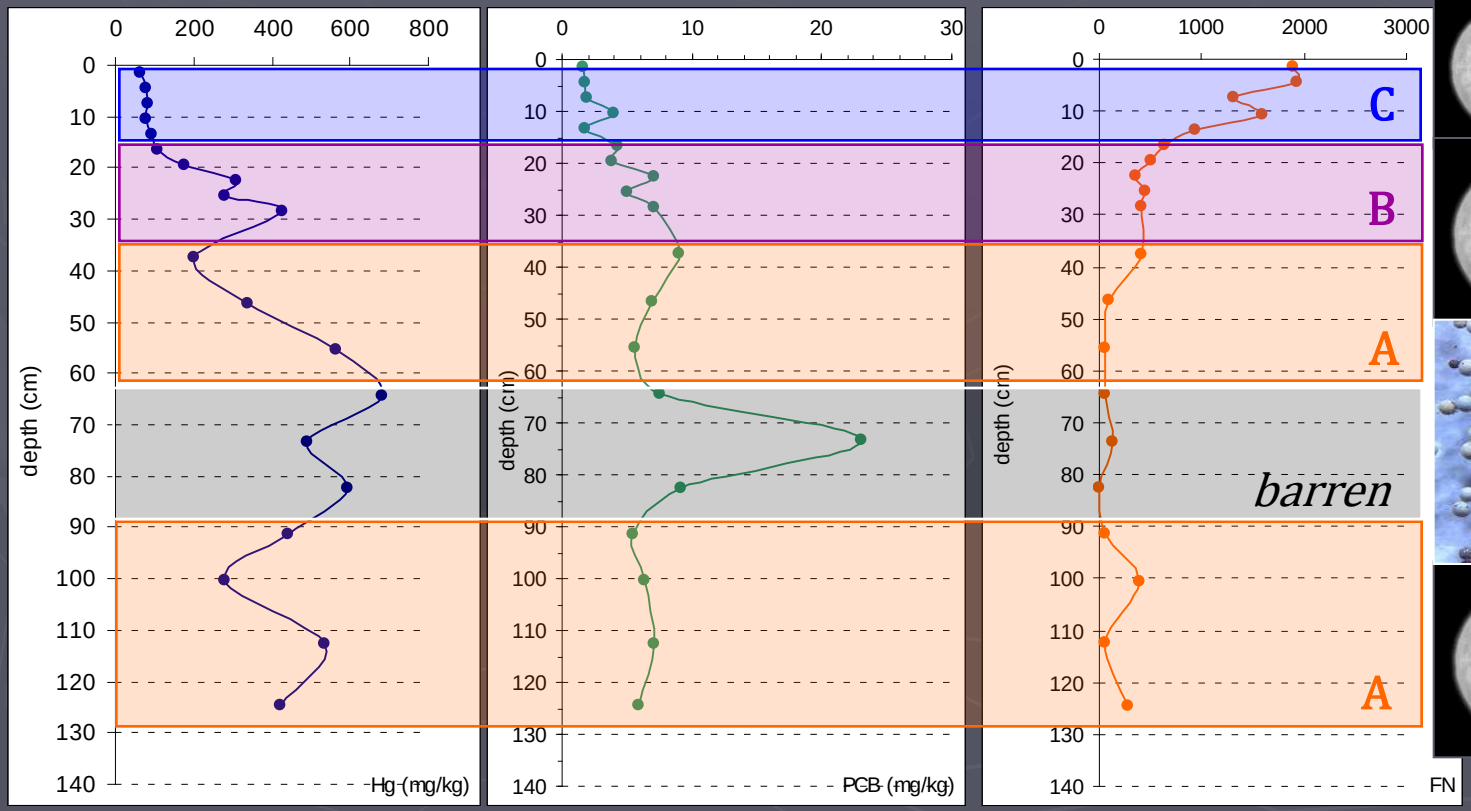




Increasing faunal diversity and density testify the increasing of environmental quality from assemblage A to C

ASSEMBLAGE DISTRIBUTION

- ✓ The turnover from assemblage A to B and then to C from the core bottom to the top is indicative of improvement of environmental quality, testified by the increasing of FN and the decreasing of pollutant concentrations.
- ✓ A barren interval is present in correspondence of the highest pollutant concentrations (Hg 493-680 mg/kg d.w.; PCB 7.57-22.98 mg/kg d.w.). In this interval the highest frequency of anthropogenic grains was found.



CONCLUSIONS

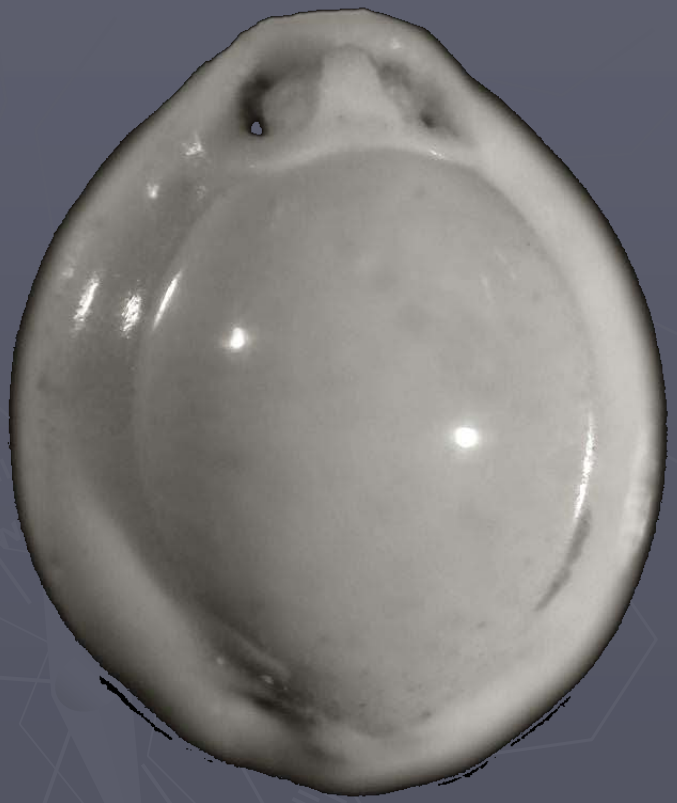
1) Sediment grain-size is an important factor influencing distribution of foraminifera even in heavily polluted areas such as Augusta harbor .

2) Also contamination have evident effects on foraminiferal assemblages: Hg and PCBs concentration influence the assemblage composition and structure reducing diversity and density. Moreover they promote the increase of pollution-tolerant species

3) Foraminifera demonstrated high tolerance degree to sediment contamination and disappeared only in extremely polluted conditions. Therefore they can be used as environmental indicators in highly impacted areas, where other potential bio-indicators disappeared due to contamination.

5) The high diversity of foraminiferal assemblages allowed a diversified response of species to different pollutants.

Foto ISPRA



Thank you for your attention

elena.romano@isprambiente.it