

Activity 2: Study Of Environmental Aspects For The Use Of Marine Sand Deposit

**Specific methodological protocol for the
study of the environmental conditions
pertaining to the use of marine sand
dredgers and to the nourishment of the
beaches (BEACHMED-ENV1)**

Protocol shared by :



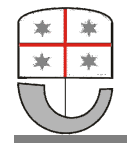
Regione Lazio (Italia)
Osservatorio Regionale dei Litorali



Generalitat Valenciana (Espagne)
Conselleria de Obras Publicas



Regione Toscana (Italia)
Dip. Politiche Territoriali e Ambientali



Regione Liguria (Italia)
Dip. Pianificazione Territoriale,
Paesaggistica e Ambientale



ICRAM

Central Institute for the Technological-Scientific Research Applied to the Sea



Introduction

Upon conclusion of the work involved in the project **BEACHMED**, the findings were included in the presentation, elaborated and developed by ICRAM, of the «**Specific methodological protocol for the study of the environmental conditions pertaining to the use of marine sand dredgers and to the nourishment of the beaches. (BEACHMED-ENV1)**»

This protocol (BEACHMED – ENV1) is particularly important as it is in cooperation with the Generalitat Valenciana, Regione Toscana, Liguria and Lazio and represents an indispensable point of reference for future legislation on the subject.

Actually, the document was considered a methodological protocol appropriate for the specific nature of this field of application, on the grounds of comparisons applied to different sectorial studies but, above all, of the experiences carried out in the field by different partners.



The study methodology of the environmental conditions for the utilization of marine sand deposits and for beach nourishment

ICRAM (Central Institute for the Technological-Scientific Research Applied to the Sea)

General aspects

The study and the evaluation of the environmental issues connected to the exploitation of off-shore sand deposits for beach nourishment projects must take into account the alterations to the environmental characteristics relating to all the concerned ambits (dredging area, transportation area and nourishment area).

In fact, during these activities phenomena of suspension of materials and morphological modifications of the seabed and shoreline occur, with consequent variation of the grain size characteristics of sediments, which could cause alteration to the existing ecosystems. At the same time effects due to bioturbation must be considered, in as much they can affect economic activities such as fishing.

Dredging operations aiming at nourishment involve direct impacts on the physical environment and on animal and vegetal organisms, which are concerned with such operations. These impacts are due essentially to the variations in the water quality caused by dredging, with the suspension of significant quantities of sediment, and on the bottom topography (morphological and bathymetric alteration of the seabed and shoreline, variation of textural and geotechnical characteristics of surface sediments).

From the experience carried out by the ICRAM in this area over the last years, in particular thanks to the studies performed along the continental shelf of Lazio, it has been stressed that in order to evaluate compatibility and possible impacts a knowledge framework is fundamental, and one of a sufficient degree of detail relating to the environment implicated in the project. For this purpose, the methods of study and investigation of marine environmental components involved in the dredging operation in the site selected for sand extraction and beach nourishment are reported below. Therefore, it was necessary to acquire information relating to the following parameters.

Morphology and characteristics of the seabed

The characterization of bottom morphology makes it possible to obtain an overall framework of the area where marine deposits are present, also in terms of the nature of the seabed, like the type of outcropping sediment, and highlights the possible presence of rock substrata and sensitive ecosystems, such as coral reef-building assemblages and/or *Posidonia oceanica* prairies. As far as the dredging area is concerned, once dredging operation was carried out, the physiographic characterization of the bottom is aimed at pointing out the morphological variations that were produced and to determine exactly the extent of the area subject to dredging. For this purpose, Side Scan Sonar and Multibeam soundings are performed, respectively regarding morphological and bathymetric aspects.

Instead, the investigations carried out on the particle-size characteristics of outcropping sediment in the area devoted to dredging operation make it possible to highlight the textural characteristics of the bottom and to estimate the fine fraction that could be moved to surface by dredging operations. The chemical analyses of sediments (metals and organic pollutants) provide information about the quality of the sediment that has to be moved. The fine sediment that often covers submerged marine deposits, in fact, because of its nature (large specific surface), in general represents a preferential environment to pollutant accumulation. For this reason the chemical analyses of the metals contained in the sediment must be able to define the origin (natural or secondary) of the metals that are present in the sample. In the absence of legal limits, it must be verified that the measured levels can be referenced to background concentration levels and that they are not bio available to the bio environment. Samples are collected by a box-corer that provides undisturbed samples, whose original sediment stratification is maintained. The grain size analysis must provide the description of the frequency distribution with an interval of 0.5 phi.



Hydrological and dynamical characteristics of water body

The movement on the bottom can produce, as described above, relevant effects on water quality, derived from the introduction of quite significant quantities of suspended sediment. For this reason it is important to know in the areas of interest both natural concentrations of suspended solid materials and the chemical physical (depth, temperature, salinity, solved oxygen, density and optical transmittance) and dynamical (current measurements) characteristics of the water column, in order to evaluate the diffusion patterns of suspended materials during dredging operations. The re-suspended sediment, brought on by currents, could reach also possibly present sensitive environments, such as prairies of *Posidonia oceanica*, with heavy damages to the ecosystem as a whole.

Benthic population

The study of benthic populations provides useful information about the general conditions of the environment. Moreover, benthic organisms represent a useful tool for studying the changes, both natural and anthropogenic, in marine systems thanks to their strict association with the sea bottom and to their scarce agility. For the sampling of macrobenthos a Van Veen grab sampler can be utilized, performing repeated operations for each station established by the sampling project. In the study of the benthic population settled along the shores, which are subject to nourishment, it will be necessary to pay particular attention to the fauna and molluscs of commercial interest. To this purpose, ad hoc samplings with traditional fishing equipment, like handheld rakes and turbo blowers, should be considered.

Ichthyic population

It is important to characterize the demersal fish population of the areas potentially suitable for the extraction of relict sand and of the adjacent areas in order to highlight particular situations such as the presence of sensitive species or critical phases relating to the biological cycle of commercial species in particular periods of the year. The strict association of demersal species with the bottom makes them more directly concerned with dredging activities. In the case of the dredging area, the investigations about fish population must be carried out every season with experimental campaigns of trawling, providing for a sampling plan stratified by depth, permitting to identify nursery areas and reproduction areas.

Sea constraints and uses

The individuation of sea uses, regarding exclusively the dredging area, makes it possible to identify the areas characterized by lawful uses of the sea not compatible with dredging (constraints) or which can limit or condition significantly such activities. Therefore, in the area of interest, it is necessary to point out the possible presence of protected marine areas, national parks and blue oases, areas for the dumping of harbour materials, cables and pipes, off shore terminals, not permitted areas for anchorage and fishing, artificial barriers and military shooting-range, as well as the belt within 3 nautical miles away of the coastline or alternatively the belt comprised within 50 m of depth (Law 963/1965¹ and DPR 1639/1968²).

¹ Legge 14/07/1965 n. 963 "Disciplina della pesca marittima"

² D.P.R. n° 1639 del 2 ottobre 1968 "Regolamento per l'esecuzione della Legge 14 luglio 1965, n. 963, concernente la disciplina della pesca marittima"

Procedures of investigation divided into phases

The experiences acquired by the ICRAM within the studies carried out for the nourishment projects of the lateral littoral made it possible to define a procedure for the investigations aiming at the assessment of environmental compatibility and of the possible impact induced by dredging and nourishing activities. In particular, such a procedure consists of a surveying program structured in three main phases, referred to as **Phase A**, **Phase B** and **Phase C**, each one with a specific objective.

Phase A, aiming at providing a framework as complete as much possible of knowledge presently available regarding the various subjects dealing with sea environment, is carried out on an area (named broad area) wide enough to encompass either intervention areas (nourishment sites and dredging areas) or surrounding areas over a wide extent and is concerned with the collection and critical analysis of existing literature.

During the **Phase B**, in order to provide a more detailed framework and to fill in the possible bibliographic gaps that came out during the A phase, the characterization of the broad area is carried out by direct surveys.

The **Phase C** comprises detailed surveys to be carried out before (**C1**), during (**C2**, control under operation) and after (**C3**) the activities of concern, either in the intervention site (all the sites where potentially exploitable deposits were located and the beaches to be nourished), or in the immediately surrounding areas. The goal is, once the intervention sites have been characterized in detail that of recording possible environmental changes due to sand movement activities and the possibility of restoration around both dredging and nourishment sites.

General characterization of the areas of interest (Phases A and B)

Before initiating dredging activities of submerged sand deposits for beach nourishment, it is fundamental to be provided possibly with a framework at a good degree of detail of the environmental characteristics (physical, chemical and biological) of a wide area around the marine deposit that was identified or the beach to be nourished, whose extent should be defined every time according to the specificity of the site.

Phase A (see the document developed for the Regione Lazio at www.osservatoriomare.lazio.it at the item "Studies-Seabed Habitats") is concerned, in relation to the broad area, with the collection and analysis of literature data about the following parameters: morphology and seabed characteristics (sediment particle size and chemistry), physical-chemical and dynamical characteristics of water body, suspended particulate, marine organisms (benthic and fish population) and lawful uses of sea.

In order to carry out this activity, essentially based on the integration and the comparison between not-homogeneous data afferent to different subjects, a planning multidisciplinary system is utilized, which, by the utilization of a GIS software, makes it possible either to visualize the data collected for the different subjects in a set of thematic maps or, by overlay techniques, to visualize those areas that result possibly not compatible with sand extraction and/or nourishment activities.

The GIS is a system comprised of software, displays, method and data capable to analyse, develop projects and manage environment and territory. The data of differing nature can be considered as layers of spatial information such to be recorded in a unique database, which can be integrated with other data. A GIS makes it possible to manage these layers, to combine them visually (cartography) and to utilize them for spatial correlations, analyses and processing, providing either an easier comprehension of complex phenomena or an evaluation of possible future sceneries (prediction), permitting the implementation of specific methodologies aimed to the analyses necessary for the planning and management of interventions on the territory.

The bibliographical data utilized for implementing GIS database make it possible to carry out, in the broad area, a specific analysis aimed at highlighting the presence of possible zones for which a particular attention is suggested as far as sand movement is concerned (environmental compatibility).

The possible reasons hampering such activities may be different, such as the presence of protected marine areas and national parks, the presence of zones devoted to harbour dumping, the presence of cables and pipelines, of off-shore terminals and of zones where anchorage and fishing are not permitted, the presence of protected zones, like the belt within 3 miles away of the coastline as well the presence of sensitive species and/or to be protected, such as *Posidonia oceanica*.

In particular, *Posidonia oceanica* prairie has been recognized as "priority habitat" in accordance with the 92/43 European Council Directive ("Habitat"), which has been absorbed in Italy by DPR 357/97 and subsequent modifications and integrations. Whenever in the broad area Sites of Community Interest (SIC) or Sites of Community Interest proposed (SICp), and, above all, priority habitats, possibly concerned with activities of sand movement, are present, the Incidence Assessment procedure should be initiated, in compliance with par.6 of DPR 120/03, and the guidelines of «Annexe G of DPR 357/97».

In the subsequent phase (**Phase B** - see the document developed for the Regione Lazio at www.osservatoriomare.lazio.it at the item Studies-"Seabed Habitats") the characterization of the broad area is initiated with direct surveys aiming at: particle-size analysis and chemistry of surface sediments; benthic populations; ichthyic populations; hydrological and dynamical characteristics of water column and suspended particulate. The goal is, therefore, that of filling up possible bibliographical lacks emerged during the phase A, providing a more detailed framework at the detail requested for the characterization and highlighting all those environmental characteristics of the zone, which could be affected by dredging activities.

Therefore, experimental targeted campaigns must be planned, with specific sampling programs characterized by a wide and regular grid, in order to in-depth characterize the area under investigation. The choice of the sampling stations should be made on the basis of either the characteristics of the area or the possible lacks emerged from phase A.

The integration of all the information gathered, completed with the data obtained from phase A utilizing a GIS software, makes it possible, finally, to acquire information about possible impacts that could derive either from dredging activities or from nourishment activities, in order to assess their feasibility. Moreover, such information can support the planning of the future control activities in the case of dredging or nourishment and of the subsequent monitoring activity to be carried out at the end of the works.

In particular, it should be taken into account that some parameters of those relating to the analysis of environmental compatibility are and/or could be subject to significant seasonal variations, like for example hydrology and dynamics of water body and composition and structure of benthic and ichthyic populations. Therefore, dredging operations should be limited to those periods of the year when the potential impact on all the species is minimum (*environmental windows*).

The in-depth characterization of the zones of interest (Phase C1)

SAND DEPOSITS

During the **Phase C1** (see the document developed for the Regione Lazio at www.osservatoriomare.lazio.it at the item Studies-"Seabed Habitats") detailed environmental surveys are carried out for an area of an extent limited with respect to the broad area, encompassing the dredging site, in order to highlight specific obstacles to the activities connected with sand extraction. If obstacles to dredging do not occur, the acquired data constitute the bench of comparison with the data that will be acquired in the following phases, useful for assessing the possible effects induced by dredging operations and the times required for the restoring of the environment concerned.

The planning for the procuring of samples should be set up on the basis of the suppositions about possible impacts derived during phases A and B; anyway, the sampling stations should be placed within the extraction site and outside, at progressive distances.

The number of stations for sampling has to be established according to the size and the characteristics of each area under investigation; for quarries of extent of up to 1 km by 0.5 km, a minimum

number of 10 stations must be envisaged, among which at least 3 must be located within the dredging site. The number of stations must be proportionally increased for quarries of larger extent.

Afterwards the following information should be acquired:

- *Physical characteristics of the seabed.* Bathymetric and morphological characteristics (S.S.S. and Multibeam), particle-size and geochemistry (metals) of surface sediments and pollutants (polycyclic aromatic hydrocarbons and organic chloride compounds);
- *Chemical-physical characteristics of water column.* Thermohaline seasonal regimes with particular reference to the thermoclines and pycoclines distribution and to their in depth variation as a function of the season and of the meteorological conditions, fluorescence, turbidity, salinity, dissolved oxygen, pH, suspended particulate, primary productivity.
- *Benthic populations.* Main benthic assemblages.

THE BEACHES

The environmental characterization of the shorelines to be nourished aims at acquiring all the data necessary for highlighting the possible presence of specific obstacles to the nourishment itself, as well as evaluating all those aspects that can be affected significantly by nourishment activities.

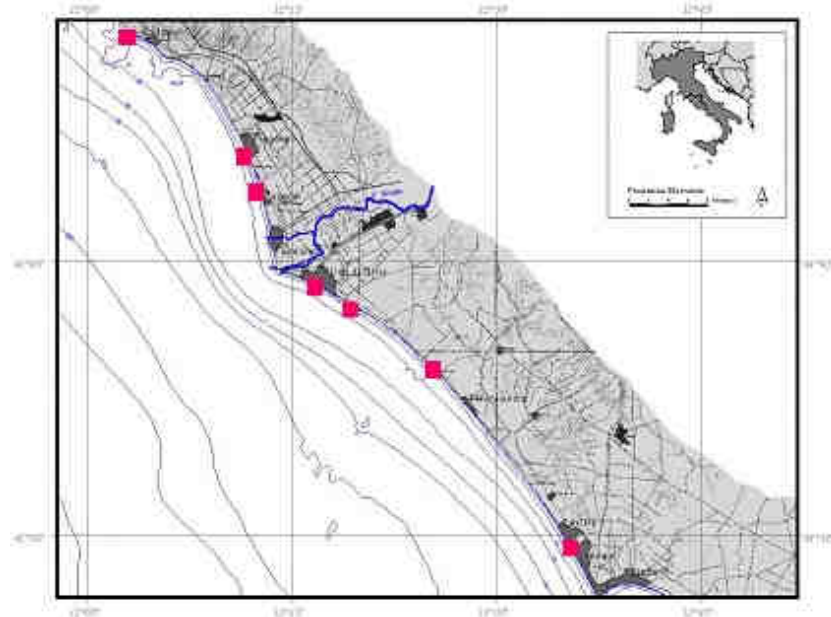
The main impacts produced by nourishment are those concerning benthos and demersal ichthyic populations, as well as fishing of commercial species, owing to the covering with sand and to the alterations to physical environment (substratum characteristics and water quality).

Generally, it is accepted as an immediate consequence of the beach nourishment, the loss of benthic assemblages living there due to burial and/or removal. Moreover, it must be considered that turbidity increase and remobilisation of the sediment just placed on the shorelines can generate effects on those sensitive ecosystems that may possibly be found there. (for example *Posidonia oceanica*). The effects deriving from the utilization of materials, characterized by particle-size and composition different from those relating to the original sediment, must be added. It must be pointed out that the problem of burial is conditioned particularly by the modalities of the carrying out of the project, above all duration and season of execution, and that its effects could be different to the various species involved. In fact, the retrieval of benthic assemblages occurs either through the migration of adult individuals from the adjacent areas or the settlement of larval forms, hence the rate of this recovery depends strictly on the seasonal period of the works.

The Case of the Bivalve Molluscs of Lazio

In order to assess the possible interactions between nourishment and coastal benthic populations, the ICRAM has recently carried out a study relating to the bivalve molluscs of commercial interest such as cockles (*Donax trunculus*) and clams (*Chamelea gallina*). These bivalve molluscs are subject to vocational fishing all over the coastal areas of Lazio and represent an important economic resource. Because of their specific life cycle, they are particularly sensitive to the alteration of sediment particle-size. If these conditions vary, for example due to the lack of equilibrium in the shoreline sedimentary regime, present populations could suffer the effects and quite disappear.

The study, carried out over two years (2002-2004) along various stretches of the latial coastline, provided for determining the present species and estimating their distribution, abundance, population structure and reproduction and recruitment periods. The survey was conducted on the sites of Ladispoli, Focene, Ostia1-Marechiaro, Ostia2-Venezia, Anzio, which had been concerned, during the period February-April of 2003, with offshore relict sand nourishment interventions, and on two reference sites, Fregene and Torvaianica, for which nourishment interventions had not been planned because of a better sediment stability.

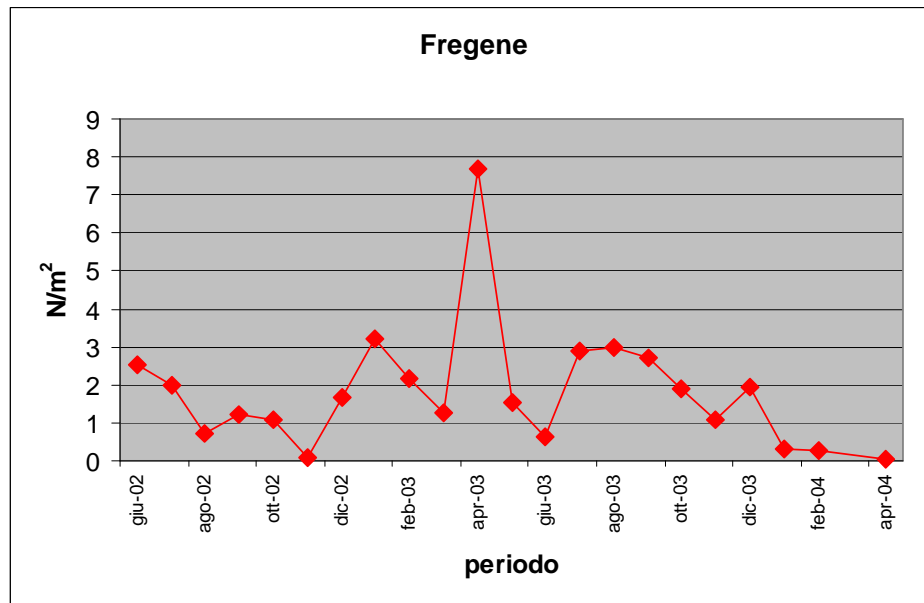


Samplings were executed with handheld rake at depth ranging from 0 to 1 m, and with turboblower dredge at higher depths.

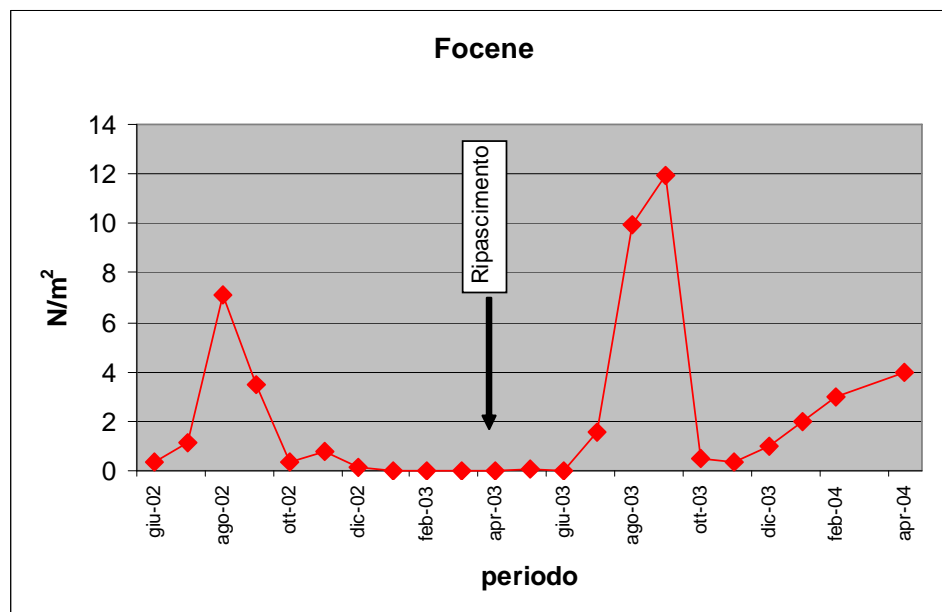
From the studies carried out, it resulted that cockle (*Donax trunculus*) is present in a bathymetric interval ranging from 0 to 2 m and in a quite wide particle-size distribution comprised between 0.125 mm and 0.250 mm. Generally, the results obtained highlighted a long period of recruitment (that is the arrival of young individuals on the seabed) lasting from April to October, sometimes prolonged up to the following winter. Recruitment occurs at depths ranging from 0 to -1.5 m and, as the individuals grow up, they move to depths of 1-1.5 m. The abundance of cockles resulted much variable over time and strictly connected with both meteorological and marine factors of strong intensity or variations in sediment grain-size.

As a consequence of the nourishment works executed on some beaches of latial littoral, cockles disappeared, buried by the new sand that had been placed on the seabed. Some of them succeeded in actively moving offshore or long shore in order to subsequently re colonize sea bottoms suitable from the bathymetric and particle-size point of view. Anyway, at a distance of a few months after the nourishment operation, after sediments had readjusted, and contemporary to recruitment period, almost every where the arrival of young individuals was observed, with a productivity increase.

For example, as for the reference site of Fregene, relating to the zone characterized by a greater stability of the shoreline and hence of the sediment grain size, cockle populations come out to be well-structured and with high rates of productivity. Only in winter months null productivity has been observed, jointly with severe sea-storms and remarkable water temperature decrease.



At Focene, a site characterized by the extreme instability of the shoreline and by strong variability of sediment particle size, populations resulted scarcely structured and very variable in productivity. In some cases, it was not possible to take samples owing to the presence on the sea bottom of gravel and pebbles hampering the rack-fishing. After the nourishment interventions (March – April of 2003), productivity begins to increase from the month of July, coinciding with sediment readjustment and summer recruitment. During the winter season a productivity rate near to zero was observed, while in the following spring season signs of recovery occurred.



Also at Ladispoli, Ostia2-Venezia and Anzio the new nourishment sand favoured the settlement of young individuals during the summer season, but the instability of this shoreline, characterizing these sites and observed since the autumn of 2003, did not allow the populations to settle.

In the site of Ostia1-Miramare, concerned in the past with numerous protection interventions (submerged parallel-to-the shoreline dike, nourishment projects with pebbles and sand) cockles have never been present. Also after the final nourishment works, recruitments suitable for the settlement of populations have not been observed.

Unlike what observed about cockle, clam (*Chamelea gallina*), occurring at depths ranging from 2 to 7 m on sandy bottoms, presented productivity rates more regular over time in almost all the sites studied. In the sites concerned with nourishment projects, not only productivity decrease has not been observed, but sometimes productivity occurred to increase.

From this study it results the importance of knowing the periods of recruitment and reproduction of the main bivalve species of commercial interest along the coastal belt, in order to minimize the impacts due to nourishment activities. A suggestion for coastal management could be that of executing nourishment projects before the recruitment period relating to the species of interest (that coincides with summer – autumn seasons for cockle in Lazio), in order to allow the sediment to reach an equilibrium suitable for the settlement of young individuals.

Finally, it is appropriate to remark that, as a consequence of the nourishment of an eroding beach, with the restoration of the sand substratum, an improvement of the general environmental conditions could occur, deriving from the return of benthic species disappeared because of the exposure of different substrata due to erosion, as we had observed along the latial shoreline.

In the light of what is expounded above, the execution of specific surveys should be planned with regards to benthic populations, with particular reference to the species of commercial interest, and the grain size distribution of surface sediments, as well as the sensitive ecosystems close to the site (*Posidonia oceanica* etc.), according to the previous observations.

The experimental campaigns must include the following activities:

- Sampling of surface sediments (grain-size analyses);
- Sampling of benthic populations, with particular reference to the species of commercial interest
- Mapping of *Posidonia oceanica* and of existing sensitive ecosystems.

As for benthic populations, with particular reference to the species of commercial interest, the life cycle must be known, especially with regard to the reproduction and recruitment period.

Finally, as for the study of *Posidonia oceanica*, before initiating nourishment activities at least one side scan sonar survey must be conducted, together with R.O.V video imaging surveys, in order to obtain a map.

The characterization during and after the execution of nourishment works relating to the zones of interest (Phases C2 and C3)

SAND DEPOSITS

Control phase during the execution of the works

In this phase the possible significant variations of the environmental parameters, capable of compromising the natural setting of the area and its environmental restoration, must be verified. In particular, the physical effect (turbidity) produced by digging activities on water column must be assessed and the monitoring of the marine biota must be carried out, in order to evaluate its variations as a consequence of the stirring up of sand from the bottom.

The frequency of the activities and the number of the campaigns to be carried out are established every time on the basis of the impacts, predicted during the previous phases, and of the planning specifications regarding basically the duration of the activities.

In particular, during this phase, it is necessary to verify if overflow conditions occur, such to involve the present sensitive ecosystems. Therefore, specific investigations on the water column (physical-chemical characteristics, suspended particulate and dynamics) must be carried out. If during this phase patterns of sediment distribution, such to involve existing sensitive ecosystems, were highlighted, they should be subject to specific monitoring.

During this phase, Side Scan Sonar sounding may also be envisaged, in order to verify that during dredging activities the limits of the area allowed for this activity have been respected.

In detail the following investigations must be considered:

- Benthic populations
- Chemical-physical and dynamical characteristics of the water column
- Suspended particulate
- Bottom morphology (Side Scan Sonar)

Such investigations must be carried out in all the stations selected during the characterization phase C1. As far as macrobenthos sampling is concerned, it would be appropriate to ensure that at least a few sampling sites are located in the areas actually dredged. In particular, the behaviour of the plume of turbidity, derived from sand extraction from the quarry of Montalto di Castro, was studied, whose results are reported below.

In fact the ICRAM recently carried out specific studies along the continental shelf of Lazio, offshore Montalto di Castro (VT), utilizing an Acoustic Doppler Current Profiler and a multiparameter probe CTD (Conductivity, Temperature, Depth), matched to instruments suitable for measuring turbidity (transmittance meters or optical scatter meters).

The use of such a methodology provided for:

- Evaluating the distance within which the effects of dredging activities are clear, describing the spatial-temporal variability of the plume;
- Identifying the prevailing direction of dispersion of the plume and the relative persistence in function of local hydrodynamic conditions;
- Assessing the magnitude of the disturbance induced by dredging operation in terms of concentration of suspended sediments;
- Verifying the possibility that the *plume* reaches the sensitive areas (*Posidonia oceanica*), present near to the dredging site.

The sampling design envisaged the carrying out of surveys, along transects properly identified, aimed at the execution of measurements of the current and at the characterization of the suspended particulate and of the main hydrological parameters.

The measuring campaigns were conducted over a time interval of 4 consecutive days.

On the first day, before dredging activities had started, specific measurements were carried out through the execution of transects from the coastline out to sea in order to recognize the background value of turbidity (white).

Afterwards, in order to follow and quantify the extent of the plume generated by dredging, a set of transects variable in length and step were executed every operating cycle of the dredge. In real time, through the visualization of ADCP data, it was therefore possible to identify the zones reached by the *plume*.

In order to verify the possible impact on the sensitive areas present near shore (prairies of *Posidonia oceanica*) further surveys regarding current measurements, hydrology and suspended particulate were carried out, according to measuring transects from the origin of the plume to the zones of interest.

Finally, the temporal variability of the plume was analysed executing, approximately every hour for a total duration of 5 hours, a square-shaped transect, placed at an average distance of 250 m from the dredge. The execution of such transect made it possible the monitoring of an entire operating cycle of the dredge. The turbidity increase generated by dredging activities appeared to be of moderate intensity, also in proximity (250 m) of the dredge, where values of 5-6 mg/l were recorded, higher than the background levels of 1 mg/l. Such increase resulted short-lasting: even though the area was characterized by low-dynamism conditions, in approximately 2 hours (less than the time elapsing between two consecutive operations) conditions similar to the natural ones or slightly differing were restored in the dredging site.

It was observed how the perturbation generated by dredging activities is not constant over time but, on the contrary, is strongly pulsating and how it had concerned only limited portions of the water column. In particular, turbidity increases were recorded in well-defined layers: on the surface, as a direct consequence of overflow phase, by the thermocline for a thickness of 2-4 m and on the bottom, due to the direct effect of sand suction.

Finally, it was observed how, even at a distance of approximately 2 km, the turbidity increase due to dredging activity cannot be distinguished from the background level measured for the site and that the prairies of *Posidonia oceanica* present in the coastal areas located to east-northeast of the dredging area were not interested with turbidity increases attributable to the dredging operations.

It is important to point out that the results reported above cannot be generalized as site-specific: in fact, the spatial distribution and the evolution of the plume depend on the chemical-physical and dynamic conditions of the water column that characterize the area at the moment of dredging, on the particle-size characteristics of the moved sediment as well as on the technology utilized for sand extraction.

Monitoring phase (C3)

The aim of the surveys conducted at the end of the dredging operations (see the document developed for the Regione Lazio at www.osservatoriomare.lazio.it at the item Studies-“Seabed Habitats”) is to provide information relating to the variations of the studied parameters, caused by the activities of sand movement on the sea-bottom and to estimate the times necessary for the restoration of the environment concerned. In particular, in the framework of the studies concerning the environment, monitoring makes it possible to understand how ecosystems react to the alterations of the environment due to such activities and to estimate possible damages, in order to assess advantages and/or disadvantages for the environment, involved by nourishment with marine sand.

The surveys being carried out in the monitoring phase concern various parameters and are articulated in different temporal cycles, which must be defined according to the type of environment where the dredging site is located.

Monitoring must make it possible to assess the times for restoration and cover a temporal period long 1 year at least.

The activities envisaged in this phase are concerned with:

- Morphology and bathymetry of the seabed (S.S.S. and Multibeam);
- Characterization of sediment grain-size;
- Chemical-physical characteristics of the water column;
- Suspended particulate;
- Benthic populations;
- Ichthyic demersal populations.

The results from monitoring activity should provide competent authorities with the technical information necessary for establishing:

- If the conditions for the authorizations have been respected (compliance and control);
- If the possible negative effects on the environment, due to the sand deposit exploitation and /or to the stirring up of pelitic coverage have been prevented;
- If, once the possible effects induced by the motion of sea-bottom materials and the time necessary for the restoration have been defined, further exploitations of the deposit are conceivable.

Whether unacceptable alterations to the environment and/or not naturally restorable were to be pointed out (that is alterations that involve a modification of the environmental conditions not compatible with a restoration to a biota similar or corresponding to the initial one, nor in the medium term nor in the



long term), procedures for the mitigation of the effects produced should be envisaged and carried out, besides environmental restoration works or possible compensations.

THE BEACHES

In the nourishment area, the control phase during the executions of the works is not envisaged.

Monitoring phase (C3)

The beach monitoring is carried out only if, during the phase relating to environmental compatibility assessment, the presence of benthic assemblages was pointed out.

Monitoring mainly aims at following the temporal evolution of the alterations produced by nourishment activities on the benthic assemblages occurring either in the submerged beach or in the immediate proximities, up to their disappearance or, at least, up to the reaching of new equilibrium conditions.

In accordance with what exposed above about the expected effects of nourishment activities on biological resources, monitoring will aim at following over time the effects induced on the populations of bivalve molluscs of commercial interest and on sensitive ecosystems.

As far as the monitoring of benthic populations, in particular of the species of commercial interest, is concerned, it is opportune to carry out a set of experimental campaigns for the collection of samples either of surface sediment or of the species investigated. Where prairies of *Posidonia oceanica* are present, monitoring campaigns (R.O.V. video imaging of the bottom and prairies mapping) must be carried out in order to verify their physical condition. The frequency of the activities and the number of experimental campaigns must be established every time and must be based either on the environmental characteristics or on the project specifications.

The Methodologic Protocol: Tables

PHASE A

Study of environmental compatibility

Preliminary evaluations at a regional level: dredging area

Area subject to investigation:

A broad enough area, comprising the present potential sand deposits and the surrounding areas over a wide range and, possibly, up to the shoreline.

Technical scientific information available from literature relating to:

Environmental characteristics of the area:

- bathymetry and morphology of the seabed
- particle size of surface sediments
- chemistry of surface sediments (As, Cd, Cr, Cu, Hg, Ni, Pb, Zn, V e Al as for metals, PCB, IPA, chemicals for plant diseases as for organic pollutants)
- chemical-physical characteristics of the water column (temperature, salinity. Turbidity, fluorescence and dissolved oxygen)
- suspended particulate (total and inorganic)
- water velocity measurements (current meter systems)
- benthonic populations (characterization of assemblages)
- demersal ichthyic populations (nursery areas)

Uses of the sea:

- protected areas:
 - archaeological marine areas
 - protected marine areas
 - protected natural marine areas (blue oases)
 - protected coastal land areas
 - not strictly protected areas of the Mediterranean Sea (ASPIM)
 - submerged archaeological parks
 - natural habitats (Natura 2000 - pSIC e ZPS)
- sensitive areas:
 - nursery areas of the main demersal ichthyic species
 - prairies of Posidonia oceanica
 - marine areas for repopulation
 - marine areas of biological protection
 - belt within 3 miles away from the coastline and/or bathymetric limit of 50 m
- Other lawful uses of the sea:
 - Areas devoted to mariculture (molluscs and ichthyic species)



Areas for the discharge of harbour materials
Submerged artificial barriers
Cables, pipelines and oil pipelines
Oil-terminals
Military shooting-ranges

Data processing

- Creation of a proper database (preferably implemented with a GIS system)
- Creation of thematic maps
- Visualization of the areas environmentally not compatible with dredging activities

Results

Preliminary compared assessment of *Environmental Compatibility* of dredging activities

Conclusions

- The existing literature data are not enoughi (→Phase B)
- The dredging activity is compatible (→Phase C1)
- The dredging activity is compatible only if suitable technical means are utilized (→Phase C1)
- The dredging activity is not compatible.

Phase A

Study of environmental compatibility

Preliminary evaluations at a regional level: nourishment area

Area subject to investigation

A broad enough area, comprising the shoreline stretch concerned with nourishment activities and surrounding areas.

Technical scientific information available from literature relating to:

Environmental characteristics of the area:

- Particle size and composition of surface sediments
- Benthonic population
- Demersal ichthyic population

Uses of the sea:

- protected areas:
 - archaeological marine areas
 - protected marine areas
 - protected natural marine areas (blue oases)
 - protected coastal land areas
 - not strictly protected areas of the Mediterranean Sea (ASPIM)
 - submerged archaeological parks
 - natural habitats (Natura 2000 - pSIC e ZPS)
- Sensitive areas:
 - nursery areas of the main demersal ichthyic species
 - prairies of *Posidonia oceanica*
 - marine areas for repopulation
 - marine areas of biological protection
 - belt within 3 miles away from the coastline and/or bathymetric limit of 50 m
- Other lawful uses of the sea:
 - Areas devoted to mariculture (molluscs and ichthyic species)
 - Areas for the discharge of harbour materials
 - Submerged artificial barriers
 - Cables, pipelines and oil pipelines
 - Oil-terminals
 - Military shooting-ranges

Data processing

- Creation of a suitable database (preferably implemented with a GIS system)
- Creation of thematic maps
- Visualization of the areas environmentally not compatible with nourishment activities



Results

Preliminary compared assessment of *Environmental Compatibility* of nourishment activities

Conclusions

- The existing literature data are not enough (→Phase B)
- The nourishment activity is compatible (→Phase C1)
- The nourishment activity is compatible only if suitable technical means are utilized (→Phase C1)
- The nourishment activity is not compatible

Phase B

Study of Environmental Compatibility

Characterization of the broad area: dredging area.

Area subject to investigation:

Specific sampling plan on a broad area comprising the deposit to be cultivated.

Direct surveys relating to:

- particle size of surface sediments
- chemistry of surface sediments (As, Cd, Cr, Cu, Hg, Ni, Pb, Zn, V e Al as for metals, PCB, IPA, chemicals for plant diseases as for organic pollutants)
- chemical-physical characteristics of the water column (temperature, salinity. Turbidity, fluorescence and dissolved oxygen)
- suspended particulate (total and inorganic)
- water velocity measurements (current meter systems)
- macrobenthos population (characterization of biocoenoses)
- demersal ichthyic populations (nursery areas)

Data processing

- Integration of the data obtained with those derived from phase A
- Creation of updated thematic maps
- Visualization of the areas environmentally not compatible with dredging activities.

Results

Preliminary compared assessment of *Environmental Compatibility* of dredging activities

Conclusions

- The dredging activity is compatible (→Phase C1)
- The dredging activity is compatible only if suitable technical means are utilized (→Phase C1)
- The dredging activity is not compatible



Phase B

Study of environmental compatibility

Characterization of the broad area: nourishment area

Subject under investigation:

Specific sampling plan on a broad area including the beach to be nourished.

Direct surveys relating to:

- Particle size and composition of surface sediments
- Benthonic population
- Demersal ichthyic population

Data processing

- Integration of the data obtained with those derived from phase A
- Creation of updated thematic maps
- Visualization of the areas environmentally not compatible with nourishment activities.

Results

Preliminary compared assessment of *Environmental Compatibility* of nourishment activities

Conclusions

- Nourishment activities are compatible (→Phase C1)
- Nourishment activities are compatible only if suitable technical means are utilized (→Phase C1)
- Nourishment activities are not compatible

Phase C1

Study of Environmental Compatibility

Characterization of intervention sites: dredging area

Area subject to investigation

Area comprising the site envisaged for dredging.

Sampling stations will be located within the site envisaged for dredging and outside, at progressive distances, according to the hydrodynamic characteristics of the area and the possible presence of sensitive areas around.

Positioning and number of sampling stations:

- Area within the dredging site: 4 stations per square kilometres; at least 3 stations for areas of lesser extent
- Area outside the dredging site: 8 stations for sites of extent equal or lesser than 1 square kilometre, the number will be increased proportionally to the increasing of the site size.

Direct surveys relating to:

- Bathymetry and morphology of the seabed *
- Particle size analysis of surface sediment
- Chemistry of surface sediments * (As, Cd, Cr, Cu, Hg, Ni, Pb, Zn, V e Al as for metals, PCB, IPA, chemicals for plant diseases as for organic pollutants)
- Microbiological analyses of surface sediments (Coliforms (Escherichia coli), Enterococci (fecal), Salmonellae, Clostridia (Spores of clostridia sulphide reductant), Staphylococci, Mycete and Enterovirus)
- Grain size analysis and chemistry of deep sediments *** (As, Cd, Cr, Cu, Hg, Ni, Pb, Zn, V and Al)
- Chemical-physical characteristics of the water column (temperature, salinity, turbidity, fluorescence and dissolved oxygen)
- Suspended particulate (total and inorganic)
- Benthic communities

* Only in the stations within the dredging site

**Only in the stations within the dredging site in case the sands designed to nourishment appear on the surface and are lacking in pelitic covering

*** At least in 3 cores, taken within the dredging site, at significant levels in order to characterize the sand sediment to be dredged

Data processing

Critical analysis of the data obtained, integrated with those deriving from Phases A and B, according to:

- Geological and sedimentological characteristics of the sand deposit: location, extent, volume, average thickness, composition, presence of pelitic covering
- Method of dredging
- Duration foreseen for dredging operations

Expected results

Compared assessment about the *Environmental Compatibility* of dredging activities. Definition of procedures



intended for control activities during the executions of the works (Phase C2).

Conclusions

- The dredging activity is compatible (→Phase C2)
- The dredging activity is compatible only if suitable technical means are utilized (→Phase C2)
- The dredging activity is not compatible

Phase C1

Study of Environmental Compatibility

Characterization of intervention sites: transportation area

It is carried out only in case the presence of sensitive environments in the vicinity of the transportation area has been highlighted from phases A and B.

Area subject to investigation:

Area concerned with the navigation route of the dredge from the dredging site to the nourishment site, in particular the area where possible sensitive environments are present.

Direct surveys relating to:

- Chemical-physical characteristics of the water column (temperature, salinity, turbidity, fluorescence and dissolved oxygen)
- Suspended particulate
- Benthic communities (main biocenoses)

Data processing

Critical analysis of the data acquired, integrated with those deriving from Phases A and B, according to the technical characteristics of the dredger such as:

- Overflow phenomena
- Route envisaged
- Duration of the activities

Expected results

Compared assessment about the Environmental Compatibility of the activities of sand transportation from the dredging site to the nourishment site. Definition of the procedures intended for the control of the activities during the execution of the works (Phase C2).

Conclusions

- The dredging activity is compatible (→Phase C2)
- The dredging activity is compatible only if suitable technical means are utilized and/or suitable routes are selected (→Phase C2)
- The dredging activity is not compatible

Phase C1

Study of environmental compatibility

Characterization of the intervention sites: nourishment area

Area subject to investigation

Area concerned with nourishment activities.

Direct surveys relating to:

- Grain size analysis and chemistry of surface sediments
- Benthic communities

Data processing

Critical analysis of the data acquired, integrated with those deriving from Phases A and B, according to the technical characteristics of the nourishment project, such as:

- Size of the shoreline stretch to be nourished
- Grain size and composition of the sand that is intended to be used
- Foreseen quantities
- Shoreline advancement estimated
- Design of the new equilibrium profile
- Method of dewatering
- Duration of the activities

Expected results

Compared assessment about the Environmental Compatibility of nourishment activities. Definition of procedures intended for the monitoring phase.

Conclusions

- Nourishment activities are compatible (→Phase C2)
- Nourishment activities are compatible only if suitable technical means are utilized (→Phase C2)
- Nourishment activities are not compatible



Phase C2

Study of Environmental Impact

The control under works execution: the dredging area

Area subject to investigation

The same area and the same stations as those identified in the C1 Phase.

Direct surveys relating to:

- Chemical-physical characteristics of the water column (temperature, salinity, turbidity, fluorescence and dissolved oxygen)
- Suspended particulate
- Benthic communities

Data processing

Critical analysis of the data acquired, in order to verify if phenomena of overflow are associated to the carrier and if they may affect the existing sensitive ecosystems.

Expected results

Environmental Impact Assessment of the dredging activities. Definition of the times and modes required for the post-opera monitoring (Phase C3).

Conclusions

- The dredging activity can prosecute (→Phase C3)
- The dredging activity can prosecute, provided for specific technical provisions (→Phase C3)
- The dredging activity can not prosecute, with subsequent immediate stoppage of activities (→Phase C3)

Phase C2

Study of Environmental Impact

The control under works execution: the transportation area

Area subject to investigation

The same area as that considered in Phase C1. During this phase more check campaigns can be envisaged: the frequency of activities will be established according to either the characteristics of the area and the dredging techniques utilized or the results already obtained in the previous phases.

Direct surveys relating to:

- Chemical-physical characteristics of the water column (temperature, salinity, turbidity, fluorescence and dissolved oxygen)
- Suspended particulate
- Current measurements

Data processing

Critical analysis of the data acquired, in order to verify if phenomena of overflow are associated to the carrier during the transportation and if they may affect the existing sensitive ecosystems.

Expected results

Environmental Impact Assessment of the activities of sand transportation from the dredging site to the nourishment site. Definition of the times and modes required for the post-opera monitoring (Phase C3) to be carried out whether patterns of the suspended sediment distribution resulted such as to involve sensitive ecosystems.

Conclusions

- The dredging activities can prosecute
- The dredging activities can prosecute, provided for specific technical provisions and/or opportune alternative routes for the transportation (→Phase C3)
- The dredging activities can not prosecute, with subsequent immediate stoppage of activities (→Phase C3)

Phase C2 Study of Environmental Impact

The control under works execution: the nourishment area

It is carried out only in case it has been pointed out from phase C1 that present sensitive environments and/or species may be affected by sand placement (for example prairies of *Posidonia oceanica*). Otherwise, the monitoring phase C3 is directly initiated.

Area subject to investigation

The same as in Phase C1.

Direct surveys relating to:

- Sensitive environments and/or species

Data processing

Critical analysis of the data acquired in order to verify if nourishment activities may negatively affect the present sensitive ecosystems

Expected results

Environmental Impact Assessment of nourishment activities. Definition of the times and modes suitable for the post-opera monitoring (Phase C3).

Conclusions

- The nourishment activities can prosecute
- The nourishment activities can prosecute, provided for specific technical provisions and/or opportune alternative routes for the transportation (→Phase C3)
- The nourishment activities can not prosecute, with subsequent immediate stoppage of activities (→Phase C3)

Phase C3

Study of Environmental Impact

The post-opera monitoring: the collection area

Area subject to investigation

The same area and the same stations as those identified in Phase C1.

The same times as those resulted from phases C1 and C2.

Direct surveys relating to:

- bathymetry and morphology of the seabed (SSS and Multibeam)
- particle size characterization of surface sediments
- chemical-physical characteristics of the water column (temperature, salinity, turbidity, fluorescence and dissolved oxygen)
- suspended particulate
- benthonic populations
- demersal ichthyic populations

Expected results

Environmental Impact Assessment of nourishment activities. Evaluation of the times and modes required for the area restoration.

Expected conclusions

The results derived from the monitoring should provide the competent authorities with the technical information necessary for determining:

- If the conditions for the authorizations to the sand uptake have been respected (compliance and control);
- The times and the modes required for the restoration of the dredged area;
- If the possible negative effects on the environment, due to the sand deposit exploitation and/or to the stirring up of pelitic covering, have been prevented;
- If, once the possible effects induced by the dredging operation and the times required for the restoration have been defined, further exploitations of the deposit are thinkable.

Phase C3
Study of Environmental Impact
The monitoring: transportation area

It must be carried out in case patterns of the distribution of the sediment suspended during the transportation resulted, such as to affect sensitive ecosystems.

Area subject to investigation

The same area as in phase C1 and C2. Surveys must be conducted in all the stations identified during the characterization phase (C1 and C2). The frequency of the activities will be determined according to either the characteristics of the area and the dredging techniques utilized or to the results already obtained from the previous phases.

Direct surveys relating to:

- chemical-physical characteristics of the water column (temperature, salinity, turbidity, fluorescence and dissolved oxygen)
- suspended particulate
- benthonic populations

Expected results

Environmental Impact assessment of the occurring sensitive ecosystems concerned with overflow phenomena occurred during the transportation. Evaluation of the times and modes required for the area restoration.

Conclusions

The results derived from the monitoring should provide the competent authorities with the technical information necessary for determining:

- If the conditions for the authorizations have been respected (compliance and control);
- The times and the modes required for the restoration of the area involved;
- If the possible negative effects on the environment, due to the sand transportation, have been prevented;
- If, once the possible effects induced by the sand transportation and the times required for the restoration of the environment have been defined, opportune alternative pathways for the transportation are advisable.



Phase C3

Study of Environmental Impact

The monitoring: nourishment area

Area subject to investigation

The same area and the same stations as in Phase C1. The same times as those resulted from phases C1 and C2.

Direct surveys relating to:

- particle size of surface sediments
- benthic communities

Expected results

Environmental Impact Assessment of the nourishments activities. Evaluation of the times and modes required for the area restoration.

Conclusions

The results derived from the monitoring should provide the competent authorities with the technical information necessary for determining:

- If the conditions for the authorizations have been respected (compliance and control);
- The times and the modes required for the restoration of the involved area;
- If the possible negative effects on the environment, due to the beach nourishment activities, have been prevented;