EROCIPS
Emergency Response to coastal Oil, Chemical and Inert Pollution from Shipping

ESPAÑA ESPACIO ATLÁNTICO
FRANCE ESPACE ATLANTIQUE
IRELAND ATLANTIC AREA
PORTUGAL ESPAÇO ATLÂNTICO
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WP 7: Environmental Monitoring

Task 7.4.2: Protocols for Monitoring Pollution Damage to Different Types of Sensitive Coastal Habitats

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TABLE OF CONTENTS

1. Introduction

1.1. Context and aims of the task

Environmental monitoring programmes may include different components such as monitoring of abiotic parameters, chemical contamination in different compartments (e.g., sediments, water and biota), and biological monitoring (i.e. monitoring the effects of environmental contaminants on the biota using toxicological and ecological approaches). Biological monitoring is an important component in monitoring programmes since it can demonstrate links between contamination and effects at several levels of biological organisation (sub-individual, individual, population, community and ecosystem), according to the measured parameters. Ideally, all the above monitoring strategies should be used in a multidisciplinary context, as part of a weight-of-evidence approach for increasing the ecological realism of environmental decisions and establishing causation in ecological risk assessment for specific impacted systems.

The collection and analysis of baseline reference data is of extreme importance for an accurate assessment of impact and recovery patterns in the event of a future spill. Establishing consistent baseline reference data is imperative to improve the knowledge of the natural spatial and temporal fluctuations of the biota, allowing distinguishing natural trends from human-caused changes in the environment. Within the Environmental Monitoring work package (WP 7), protocols or guidelines for environmental baseline reference data have been established, including protocols for selection of monitoring areas and sites and selection of sentinel species, and advice on selecting the type of monitoring and seasonality. Based on the developed environmental base-lining protocols a pre-spill analysis has been implemented on several coastal areas and estuarine systems along the Portuguese coast. It included the monitoring of abiotic parameters and chemical contamination in water and sediments, and the measurement of contamination levels and different biomarkers of exposure and effect on sentinel species. This report aims to provide guidance on monitoring pollution damage to different types of sensitive coastal habitats focusing mainly on an ecological approach, which has not been previously addressed within the biological component of the environmental monitoring programme.

Five coastal habitats, designated in Annex I of the EC Habitat Directive, have been selected including broad habitat types (Reefs, Intertidal mudflats and sandflats, and Shallow subtidal sandbanks) and physiographic features (Estuaries, Large shallow inlets and bays).

This document has been produced considering the expertise developed through the UK Marine SACs LIFE Project[1], which was set up as a European pilot project to help implement the Habitats Directive on marine sites (English Nature, Scottish Natural Heritage (SNH), Countryside Council for Wales (CCW), Environmental Environment and Heritage Service (EHS), Joint Nature Conservation Committee (UK) (JNCC) and Scottish Association for Marine Science (SAMS), 2001). In particular, the *Marine Environmental Handbook* (Davies *et al*., 2001), a key output of the UK Marine SACs Project, which provides guidance on best practices for monitoring Annex I habitats, has been broadly considered in the development of the present document.

1.2. Geographical scope of the task

The environmental monitoring programme reported in this document was performed along the Portuguese continental coast and estuaries, focusing mostly in the north-western coast of Portugal. However, as the selected sentinel species are common in the intertidal rocky coast and estuarine systems of the EROCIPS partners, the results have a wide geographical application all through the Atlantic Arc Area. The partners involved in the project are listed below (Figure 1).

[1] All information on the UK Marine SACs Project available on http://www.ukmarinesac.org.uk/.

UK: Devon County Council, Dorset County Council, Environment and Heritage Service, Pembrokeshire County Council, Devon Wildlife Trust.

France: Conseil Régional d'Aquitaine, Conseil Régional de Bretagne, Conseil Régional des Pays de la Loire, Conseil Régional de Poitou-Charentes, Le Cedre as the operational subcontractor for the French regions.

Spain: CETMAR Conselleria de Pesca y Asuntos Marítimos, Conselleria de Medio Ambiente, INTECMAR.

Portugal: CIIMAR, Instituto Superior Técnico, HIDROMOD.

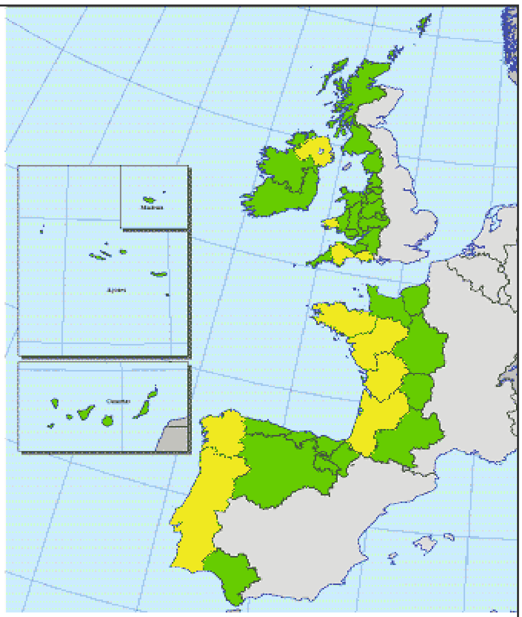

Figure 1. EROCIPS geographical scope and list of the partners involved per country.

2. Background

2.1. EROCIPS Context and framework

The Atlantic Area of the European Union has been the scene of a number of well-known shipping accidents over the last thirty years. These include the *Amoco Cadiz*, *Betelgeuse*, *Aegean Sea*, *Sea Empress*, *Erika* and *Prestige*. Each incident has demonstrated the strain that can be placed on regional and local government resources and management structures as responders attempt to limit the impact caused by the pollution on the shoreline assets of a coastal area.

The EROCIPS Project is the first transnational initiative to focus on the need for local and regional governments to pursue an integrated approach to emergency response for coastal pollution incidents. Partners from along the Atlantic Coast of Europe (UK, France, Spain and Portugal) have worked together with the aim of formulating a transferable methodology that communicates relevant information to responders and decision-makers involved in shoreline counter-pollution operations following a shipping incident.

Seven work packages (WPs) have been defined to address several aspects of shoreline response to pollution, namely, Pollution Threats, Response Information, Counter-Pollution Resources, Training Information, Pollution Modelling, Management Information and Environmental Monitoring. Another work package has been designed to disseminate the outcomes of the project in order to transfer these outputs to other bodies associated with coastal pollution, specifically those in the Atlantic Area and other European regions.

The present report falls within WP 7: Environmental Monitoring. The aim of WP 7 was to develop guidelines, protocols and databases for assessing contamination levels before, during and after pollution incidents in order to help in the restoration of damaged coastal environments. Other key outputs of this WP include the establishment of protocols or guidelines for environmental baseline reference data, including protocols for selection of monitoring areas and sites and selection of sentinel species, and guidance for the establishment of long-term monitoring programmes.

3. Broad habitat types

3.1. Reefs

Reefs are an Annex I habitat and defined under the EC Habitat Directive as *"Submarine, or exposed at low tide, rocky substrates and biogenic concretions, which arise from the sea floor in the sublittoral zone but may extend into the littoral zone where there is an uninterrupted zonation of plant and animal communities. These reefs generally support a zonation of benthic communities of algae and animals species including concretions, encrustations and corallogenic concretions"* (European Commission 2003).

Reefs are an also an integral part of the Annex I habitats: Estuaries, and Large shallow inlets and bays.

Two main types of reefs can be recognised: rocky reefs, where animal and plant communities grow or raise on protruding rock, and biogenic reefs, which are structures created by accumulations of organisms, usually rising from the seabed, or at least clearly forming a substantial, discrete community or habitat which is very different from the surrounding seabed (Hill *et al.*, 1998; Holt *et al.*, 1998). Overall, reefs contribute significantly to the increase of the structural diversity of the sea bottom by providing new physical spaces for many other organisms to attach and live, and form the basis for complex ecosystems by providing nursery and feeding areas.

Courtesy: I. Lima, CIIMAR

Figure 2. Intertidal reefs, North of Portugal.

Biological monitoring for condition assessment of reefs habitats should be based on several attributes[2] (Davies *et al.*, 2001), namely:

- Extent;
- biotope composition;
- distribution and spatial arrangement of biotopes.

[2] An attribute is defined as *"a characteristic of a habitat, biotope, community or population of a species which most economically provides an indication of the condition of the interest feature to which it applies"* (Davies *et al.*, 2001).

For specific biotopes that are considered as key structural components of the reef and particularly important for a specific site, condition assessment should also be based on the following site-specific attributes (Davies *et al*., 2001; JNCC, 2004a):

- extent of a specific biotope;
- species composition of a specific biotope.

3.1.1. Extent

This attribute aims to assess the area of the reefs against a baseline map/aerial image or through the review of any know activities that may have caused an alteration in extent. The extent of a non-biogenic reef is unlikely to change significantly over time unless due to some human damage activity. However, the extent of a biogenic reef is an important attribute in relation to the viability of the reef (Davies *et al*., 2001).

Feature attribute	Technique
Intertidal	- Intertidal resource mapping using aerial photographs
Subtidal	- Seabed mapping using acoustic ground discrimination interpreted with ground truthing - Sidescan sonar for seabed habitat mapping

Table 1. Possible techniques for measuring reef extent, provided in the *Marine Monitoring Handbook* (Davies *et al.,* 2001).

3.1.2. Biotope composition

This attribute aims to assess the overall biotope composition or a subset of specified biotopes identified for the site (number and occurrence/frequency). The biotope composition attribute may address a subset of biotopes identified for the following: overall biotope composition where the feature supports a diverse range of communities; specific biotopes indicative of the character of the site or of conservation interest; and biotopes which may be indicative of the condition of the feature with respect to the level of anthropogenic activity or input (JNCC, 2004a).

Feature attribute	Technique
Intertidal biotope richness	- Intertidal resource mapping using aerial photographs - In situ intertidal biotope recording
Subtidal biotope richness	- In situ survey of subtidal (epibiota) biotopes and species using diving techniques - Identifying biotopes using video recordings - In situ survey of sublittoral epibiota using hand-held video - In situ survey of sublittoral epibiota using towed sledge video and still photography

Table 2. Possible techniques for measuring biotope composition, provided in the *Marine Monitoring Handbook* (Davies *et al*., 2001).

3.1.3. Distribution of biotopes

This attribute aims to assess the geographical distribution and zonation pattern of all or specified biotopes identified for the site. The relative distribution of biotopes is an important structural aspect of the feature; changes in the extent and distribution may indicate long-term changes in the prevailing physical conditions at the site (Davies *et al*., 2001).

Feature attribute	Technique
Intertidal zonation/ spatial pattern of intertidal biotopes	- Intertidal resource mapping using aerial photographs - In situ intertidal biotope recording
Subtidal zonation/ spatial pattern of subtidal biotopes	- In situ survey of subtidal (epibiota) biotopes and species using diving techniques - Identifying biotopes using video recordings - In situ survey of sublittoral epibiota using hand-held video - In situ survey of sublittoral epibiota using towed sledge video and still photography

Table 3. Possible techniques for measuring distribution of biotopes, provided in the *Marine Monitoring Handbook* (Davies *et al.*, 2001).

3.1.4. Extent of a sub-feature or specific biotope

This attribute aims to assess the area of a sub-feature or representative/notable biotope (i.e. nationally rare or scarce biotopes, biotopes that are indicative of the "health" of the feature or the level of anthropogenic activity or input) from the site. The biotopes chosen should reflect the site-specific interest of the feature (JNCC, 2004a). This attribute may be of particular relevance to biogenic reefs, such as those created in the intertidal zone by the mussels *Mytilus* spp. and the polychaeta worms *Sabellaria alveolata*, and by *Sabellaria spinulosa* and *Modiolus modiolus* in the subtidal zone (Holt *et al*., 1998).

Feature attribute	Technique
Intertidal	- In situ intertidal biotope recording
Subtidal	- Seabed mapping using acoustic ground discrimination interpreted with ground truthing - Sidescan sonar for seabed habitat mapping

Table 4. Possible techniques for measuring extent of a specific biotope, provided in the *Marine Monitoring Handbook* (Davies *et al.,* 2001).

Figure 3. Intertidal *Mytilus galloprovincilais* beds.

Source: M. Weber (2005)

Courtesy: I. Lima, CIIMAR

Figure 4. Intertidal *Sabellaria alveolata* reefs, North of Portugal.

3.1.5. Species composition of a specific biotope

This attribute aims to assess biotope quality through assessing species composition (frequency and occurrence/diversity index of composite species) from a biotope. Species composition is an important contributor to the structure of a biotope and therefore the reef as a whole (Davies *et al*., 2001). Any change in species composition should be assessed as an overall measure of community structure of the biotope rather than as an individual or indicator species. An assessment of species composition may be restricted to measure only the characterising species of a target biotope (JNCC, 2004a).

Feature attribute	Technique
Intertidal species composition/ richness	- In situ intertidal biotope recording - In situ survey of intertidal biotopes using abundance scales and checklists at exact locations (ACE surveys) - In situ quantitative survey of intertidal epibiota using quadrat sampling techniques - Littoral monitoring using fixed quadrat photography
Subtidal species composition/ richness	- In situ quantitative survey of subtidal epibiota using quadrat sampling techniques - In situ survey of subtidal (epibiota) biotopes and species using diving techniques - Sampling marine benthos using suction samplers - In situ surveys of sublittoral epibiota using hand-held video

Table 5. Possible techniques for measuring species composition of a specific biotope, provided in the *Marine Monitoring Handbook* (Davies *et al.,* 2001).

Source: M. Weber (2005)

Figure 5. Intertidal *S. alveolata* reefs monitoring using quadrat sampling techniques.

3.2. Intertidal mudflats and sandflats

Intertidal mudflats and sandflats are an Annex I habitat, designated under the EC Habitat Directive as *“Mudflats and sandflats not covered by seawater at low tide”* and defined as *”Sands and muds of the coasts of the oceans, their connected seas and associated lagoons, not covered by sea water at low tide, devoid of vascular plants, usually coated by blue algae and diatoms. They are of particular importance as feeding grounds for wildfowl and waders. The diverse intertidal communities of invertebrates and algae that occupy them can be used to define subdivisions of 11.27, eelgrass communities that may be exposed for a few hours in the course of every tide have been listed under 11.3, brackish water vegetation of permanent pools by use of those of 11.4.”* (European Commission 2003).

Intertidal mudflats and sandflats are also an integral part of the Annex I habitats: Estuaries, Large shallow inlets and bays, and Lagoons.

Sediment flats are highly productive areas in the Arc Atlantic Area, supporting diverse communities of animals, especially infaunal invertebrate species, seaweeds and seagrasses. They have a significant role in coastal ecosystems by providing roosting and feeding areas for wading birds and nursery areas for juvenile fish, and by forming natural coastal defences.

Anthropogenic activities such as oil spills and tanker accidents, industrial and domestic effluent discharge and organic enrichment have a high potential for deleterious effects to the biologic attributes of intertidal sediment flats (Elliott *et al.*, 1998). For example, oil covering intertidal mudflats can cause large-scale deterioration of intertidal communities due to infaunal death as a result of sediment anoxia (Elliott *et al.,* 1998).

Figure 6. Intertidal mudflat at Mira river estuary, Portugal.

3.2.1. Biological quality monitoring of intertidal mudflats and sandflats

Biological monitoring for condition assessment of intertidal mudflats and sandflats habitats should be based on several attributes (Davies *et al*., 2001), namely:

- biotope composition;
- distribution and spatial arrangement of biotopes.

For specific biotopes that are considered as key structural components of the intertidal mudflats and sandflats and particularly important for a specific site, condition assessment should also be based on the following site-specific attributes (Davies *et al.,* 2001; JNCC, 2004b):

- extent of a specific biotope;
- species composition of a specific biotope.

Other attributes such as the *Extent of the feature* and *Sediment character* should also be periodically monitored since they are considered essential structural components of intertidal mudflats and sandflats. However, since changes on these attributes are mainly attributable to natural coastal processes and not directly caused by an accidental pollution event, they were not included in this report. More information is available in Davies *et al.* (2001) and JNCC (2004b).

3.2.2. Biotope composition

This attribute aims to assess the overall biotope composition or a subset of specified biotopes identified for the site (number and occurrence/frequency). As for reef habitats, the biotope composition attribute may address a subset of biotopes identified for the following: overall biotope composition where the feature supports a diverse range of communities; specific biotopes indicative of the character of the site or of conservation interest; and biotopes which may be indicative of the condition of the feature with respect to the level of anthropogenic activity or input (JNCC, 2004b).

Feature-specific attribute	Technique
Biotope richness	- Intertidal resource mapping using aerial photographs - In situ intertidal biotope recording - Quantitative sampling of intertidal sediment species using cores

Table 6. Possible techniques for measuring biotope composition, provided in the *Marine Monitoring Handbook* (Davies *et al*., 2001).

3.2.3. Distribution of biotopes

This attribute aims to assess the relative spatial distribution of all biotopes, or a range of specified biotopes identified for the site, and should highlight any progressive loss or change in the biological integrity of the feature. As for reef habitats, the relative distribution of biotopes is an important structural aspect of the feature; changes in the extent and distribution may indicate long-term changes in the physical conditions at the site (Davies *et al*., 2001).

Feature-specific attribute	Technique
Spatial pattern of intertidal biotopes	- Intertidal resource mapping using aerial photographs - In situ intertidal biotope recording - Fixed viewpoint photography

Table 7. Possible techniques for measuring distribution of biotopes, provided in the *Marine Monitoring Handbook* (Davies *et al*. 2001).

3.2.4. Extent of a sub-feature or specific biotope

This attribute aims to assess the area of a sub-feature or a representative/notable biotope from the site. Where present, the area of seagrass is an important structural component of sediment flats, and provides a long-term integrated measure of environmental conditions across the feature. Eelgrass (*Zostera noltii* beds and *Z. marina* beds on the lower shore) primary production supports a rich, resident fauna and it is recognised to provide important refuge, spawning and nursery areas for many species of fish, including commercial species. Eeelgrass beds also increase rates of sedimentation and reduce erosion (Jones *et al*., 2000). A more complete review of measurable attributes of *Zostera* sp. biotopes, other then biotope extent and species composition, and appropriate methods has been reported by Davison and Hughes (1998). Areas of mussel beds are also an important structural component of sediment flats since they may play an important functional role within the feature, e.g. by stabilising sediments (Davies *et al.*, 2001).

Feature-specific attribute	Technique
Biotope extent	- Intertidal resource mapping using aerial photograph - In situ intertidal biotope recording

Table 8. Possible techniques for measuring extent of a specific biotope, provided in the *Marine Monitoring Handbook* (Davies *et al.,* 2001).

3.2.5. Species composition of a specific biotope

This attribute aims to assess biotope quality through assessing species composition (frequency and occurrence/diversity index of composite species) from a biotope. The determination of species diversity gives an indicator of the quality of the biotope, and a change in diversity may indicate a cyclic change or trend in sediment communities (Davies *et al*., 2001; JNCC, 2004b). As for reef habitats, any change in species composition should be assessed as an overall measure of community structure of the biotope rather than as an individual or indicator species. An assessment of species composition may be restricted to measure only the characterising species of a target biotope (JNCC, 2004b).

Feature - specific attribute	Technique
Intertidal species composition/ richness	- In situ survey of intertidal biotopes using abundance scales and checklists at exact locations (ACE surveys) - Quantitative sampling of intertidal sediment species using cores

Table 9. Possible techniques for measuring species composition of a specific biotope, provided in the *Marine Monitoring Handbook* (Davies *et al.,* 2001).

3.3. Shallow subtidal sandbanks

Shallow subtidal sandbanks are an Annex I habitat, designated under the EC Habitat Directive as *"Sandbanks which are slightly covered by seawater all the time"* and defined as *"Sublittoral sandbanks, permanently submerged. Water depth is seldom more than 20 m below Chart Datum. Non-vegetated sandbanks or sandbanks with vegetation belonging to the Zosteretum marinae and Cymodoceion nodosae"* (European Commission 2003).

Shallow subtidal sandbanks are an integral part of the Annex I habitats: Estuaries, and Large shallow inlets and bays. Subtidal sandbanks are often mobile and tend to occur in relatively exposed sites with high-energy hydrodynamic regimes. The diversity of species in subtidal sandbanks is determined by sediment type and a variety of other physical factors. Shallow sandy sediments are typically colonised by a burrowing fauna predominantly of worms, crustaceans, bivalve molluscs and echinoderms. In more sheltered and lower-energy conditions, seagrass communities may also occur. Shallow sandy sediments may be important nursery areas for fish and fishing grounds for seabirds (Davies *et al*., 2001).

3.3.1. Biological monitoring of shallow subtidal sandflats

Biological monitoring for condition assessment of shallow subtidal sandflats habitats should be based mainly on the following attribute (Davies *et al*., 2001):

- distribution of biotopes.

For specific biotopes that are considered as key structural components of the reef and are particularly important for a specific site, condition assessment should also be based on the following site-specific attributes (Davies *et al*., 2001; JNCC, 2004c):

- extent of a specific biotope;
- species composition of a specific biotope.

Other attributes such as the *Extent of the feature*, *Topography* and *Sediment character* should also be periodically monitored since they are considered essential structural components of shallow subtidal sandbanks. However, since changes in these attributes are mainly attributable to natural coastal processes or anthropogenic effects (e.g., dredging, aggregate extraction) but not likely to be caused by an accidental pollution event they were not included in this report. More information is available in Davies *et al.* (2001) and JNCC (2004c).

3.3.2. Distribution of biotopes

This attribute aims to assess the relative distribution of biotopes, or a range of specified biotopes identified for the site, and should highlight any progressive loss or change in the biological integrity of the feature. The biological character of inshore sublittoral sediment depends on their structure and may consist of one or many biotopes (Davies *et al.,* 2001). A subset of the biotopes may be addressed for the following: overall biotope composition where the feature supports a diverse range of communities; specific biotopes indicative of the character of the site or of conservation interest; and biotopes which may be indicative of the condition of the feature with respect to the level of anthropogenic activity or input

Feature-specific attribute	Technique
Spatial pattern of biotopes	- The application of side scan sonar for seabed mapping (with mosaicing) - Mapping extent using point samples (e.g., from Grab sampling) - Mosaicing side scan sonar images to map seabed features - In situ survey of sublittoral epibiota using towed sledge video and still photography

Table 10. Possible techniques for measuring distribution of biotopes, provided in the *Marine Monitoring Handbook* (Davies *et al.,* 2001).

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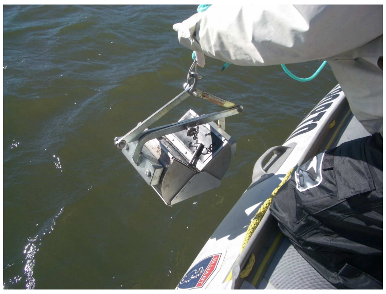

Courtesy: Laboratory of Hydrobiology ICBAS/CIIMAR

Figure 7. Grab sampling.

3.3.3. Extent of a sub-feature or specific biotope

This attribute aims to assess the area of a sub-feature or a representative/notable biotope from the site. The extents of seagrass, brittlestar beds and, in specific sites, maerl beds are key structural components of shallow subtidal sandbanks. In sheltered areas, seagrass provides a long-term integrated measure of environmental conditions across the feature whereas brittlestar beds represent major concentrations of benthic biomass and may play an important role in local carbon and nutrient cycles (Hughes, 1998; JNCC, 2004c). Maerl beds are created by a particular group of slow-growing and free-living red coralline seaweeds, and have a considerable conservation value due to the very high diversity of organisms, some being more or less confined to the beds. Even though relatively rare, changes in the extent and distribution of maerl beds may indicate long-term changes in the physical conditions influencing the feature (Birkett *et al*., 1998).

Feature-specific attribute	Technique
Biotope extent	- Seabed mapping using acoustic ground discrimination interpreted with ground truthing - The application of side scan sonar for seabed mapping - Mosaicing side scan sonar images to map seabed features - Mapping extent using point samples (e.g., from Grab sampling)

Table 11. Possible techniques for measuring extent of a sub-feature or specific biotope, provided in the *Marine Monitoring Handbook* (Davies *et al.,* 2001).

Source: L. Saldanha (1997)

Figure 8. Brittlestar bed (*Ophiocomina nigra*), Portugal.

3.3.4. Species composition of a specific biotope

This attribute aims to assess biotope quality through assessing species composition (frequency and occurrence/diversity index of composite species) from a biotope since it is considered as an important contributor to the structure of some biotopes (Davies *et al*., 2001). As for the other habitats previous referred to, an assessment of species composition may be restricted to measure only the characterising species of a target biotope (JNCC, 2004c).

Feature - specific attribute	Technique
Species composition/ richness	- Quantitative sampling of sublittoral sediment biotopes and species using diver-operated cores - Quantitative sampling of sublittoral sediment biotopes and species using remote-operated grabs - Sampling marine benthos using suction samplers For biotopes with large epibenthic species: - Identifying biotopes using video recordings - In situ surveys of sublittoral epibiota using hand-held video - In situ survey of sublittoral epibiota using towed sledge video and still photography

Table 12. Possible techniques for measuring species composition of a specific biotope, provided in the *Marine Monitoring Handbook* (Davies *et al*., 2001).

4. Physiographic features

The Atlantic Arc Area has a particularly large number of *estuaries* and *large shallow inlets and bays*. These physiographic features encompass the broad marine habitat types referred to in the previous section (i.e. reefs, intertidal mudflats and sandflats, and shallow subtidal sandflats).

4.1. Estuaries

Estuaries are an Annex I habitat, defined under the EC Habitat Directive as *"Downstream part of a river valley, subject to the tide and extending from the limit of brackish waters. River estuaries are coastal inlets where, unlike large shallow inlet and bays there is generally a substantial freshwater influence. The mixing of freshwater and sea water and the reduced current flows in the shelter of the estuary lead to deposition of fine sediments, often forming extensive intertidal sand and mud flats. Where the tidal currents are faster than flood tides, most sediments deposit to form a delta at the mouth of the estuary "* (European Commission 2003).

Estuaries are among the most productive marine ecosystems in the world and are critical to the life and development (e.g., rearing, feeding, migration routes and nursery grounds) of many aquatic species (Chapman and Wang, 2001). The intertidal and subtidal sediments of estuaries support biological communities that vary according to geographical location, the type of sediment, tidal currents and salinity gradients within the estuary (Davies *et al.,* 2001).

The specific monitoring guidelines indicated above for the individual features of *reefs*, *intertidal mudflats and sandflats*, and *shallow subtidal sandflats* should be considered for biological condition assessment of estuaries.

Saltmarshes, defined as intertidal areas of fine sediment transported by water and stabilised by vegetation, should be regarded as an important sub-feature of estuaries. They are characterised by a range of salt-tolerant plant species of terrestrial origin such as *Spartina* sp., *Salicornia* sp. and *Puccinellia*. In addition to the many plant and animal species that are directly associated with the saltmarsh itself, there are other species that benefit indirectly from saltmarshes. Tidal saltmarshes have been identified as areas of high productivity providing a source of organic matter and nutrients for fish and a variety of invertebrates in adjacent marine habitats. They also provide feeding, roosting and nesting areas for a wide range of bird species (Boorman, 2003). The protection of this sub-feature should be afforded a high priority at an early stage in oil spill response since the vegetation offers a large surface area for oil absorption and cleaning of oiled vegetation is very difficult and may cause more damage than the oil itself (IPIECA, 1994).

Figure 9. Saltmarsh at Minho river estuary, North of Portugal.

4.2. Large shallow inlets and bays

Large shallow inlets and bays are an Annex I habitat, defined under the EC Habitat Directive as *"Large indentations of the coast where, in contrast to estuaries, the influence of freshwater is generally limited. These shallow indentations are generally sheltered from wave action and contain a great diversity of sediments and substrates with a well developed zonation of benthic communities. These communities generally have a high biodiversity. The limit of shallow water is sometimes defined by the distribution of the Zosteretea and Potametea associations. Several physiographic types may be included under this category provided the water is shallow over a major part of the area: embayments, fjards, rias and voes"* (European Commission 2003).

Shallow inlets and bays are highly variable in habitat and species diversity according to the local geology and hydrodynamic regime. Intertidal rock communities may be dominated by species of *Fucus* spp, particularly in more sheltered locations, while extensive beds of *Mytilus* spp. may be present on mixed substrata. Communities of crustaceans and polychaetes may be present in less exposed sediment shores, while shores of fine sand and mud are characterised by polychaetes and bivalve communities and beds of *Zostera* spp. In the sublittoral zone, rocky coasts may support forests of the kelp *Laminaria* spp., soft corals, sea anemones, sponges and sea fans while finer sediments may support communities of sea pens and burrowing megafauna. In tide-swept areas, such as rias, suspension-feeding communities such as hydroids, bryozoans and brittlestars beds may be dominant (Davies *et al*., 2001).

As with estuaries, the specific monitoring guidelines indicated above for the individual features of *reefs*, *intertidal mudflats and sandflats*, and *shallow subtidal sandflats* should be considered for biological condition assessment of large shallow inlets and bays.

Brittlestar beds and sea pens and burrowing megafauna should be regarded as important sub-features of large shallow inlets and bays.

Source: L. Saldanha (1997)

Figure 10. Example of seapen specie (*Halicornaria montagui*), Portugal.

5. Recovery of coastal habitats after pollution from shipping

In the context of a pollution event, biological recovery may be defined as the "re-establishment of a health biological community in which the plants and animals characteristic of that community are present and are functioning normally" (Clark, 1989). However, the re-establishment of a healthy biological community does not mean that the community will have exactly the same composition or age structure as that which was present before the damage. Moreover, considering natural temporal and spatial variability patterns, it is impossible to evaluate if an ecosystem recovering from an impact event will present the same community structure that it would evidence in the absence of a pollution event (IPIECA, 1991).

Depending on the quality and quantity of product spilled, the weather and sea conditions, the season of release, the geology of the affected area, the cleaning methods used and the sensitivity of the ecosystems affected, and many other factors, the recovery periods may vary from some years or months to various decades. Following an oil spill, for example, recovery rates tend to be rapid in exposed rocky shores, due to vigorous wave action, whereas in more sheltered shores recovery times tend to be longer because of oil persistence. In sedimentary shores, oil may persist for relatively long periods if it penetrates into the sediments. The extent to which penetration occurs varies with substratum type, oil viscosity and drainage; for example, penetration is generally greater for low-viscosity oils on coarser and well-drained sediments. However, greater oil penetration may be encountered in sheltered sand and mud shores where infaunal mixing of sediments, plant root channels or large established animal burrows are present (IPIECA, 1991, 2000). The biological recovery of an ecosystem is expected to be initiated when the contamination levels are tolerable for the organisms that make up the biological communities. The settling of the new species depends on the time of the year, on the biological availability of larvae and on the physicochemical properties of the water (Schratzberger *et al.,* 2003).

Recovery of the ecosystem may also be dependent on the clean-up and rehabilitation efforts. Clean-up efforts can decrease or increase damage and, therefore, before any clean-up measure is attempted there should be an assessment of the net environmental benefit (IPIECA, 1991, 1995). Clean-up efforts should focus on the best available techniques which minimise the environmental impacts and promote the natural restoration. Therefore, clean-up techniques which remove bulk oil without causing severe physical or chemical damage (i.e. use of dispersants) are preferable. For example, following the *Torrey Canyon* oil spill in 1967, long-term studies have detected that on areas where dispersants had been intensively applied recovery took from 10 to 15 years whereas in areas that were not exposed to dispersants recovery took no longer than 2 to 3 years (Hawkins *et al*., 2002). The main cause for long recovery periods in shore exposed to aggressive clean-up methods has been the extensive removal of keystone species, especially long-lived species, which take many years to become re-established. The choice of a technique and the extent to which it is applied should be decided on a site-by-site basis using, when available, a set of sensitivity maps for the area (see the project outcomes of Task 2.1: Coastline Resource Sensitivities and Clean-up Methodologies).

The experience gained from previous large spills, such as the *Torrey Canyon*, the *Exxon Valdez*, the *Braer*, the *Sea Empress* and, more recently, the *Prestige*, emphasises the need for long-term studies to monitor recovery patterns from pollution incidents such as oil and chemical spills and to help to provide guidelines for future remediation work after such incidents.

A restoration scheme may need to be considered in habitats where it is predicted that natural recovery will take an unacceptability long time or where aggressive cleaning has included stripping of vegetation and sediments. It may comprise a set of voluntary measures to enhance natural recovery, including precautionary measures to prevent further pollution damage, implementation of techniques to facilitate natural recovery, and acceleration of recovery by implants and re-introductions (Workshop on Environmental Restoration and Ecological Monitoring, 2002). There have been successful rehabilitation programmes in saltmarshes, undertaken after removal of bulk oil or when oil toxicity had been lost through natural weathering (IPIECA, 1994).

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