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

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WP 7: Environmental Monitoring

Task 7.3.1: Guidelines for a Long-term Monitoring Programme

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Authors: Susana Moreira
Isabel Cunha
Lúcia Guilhermino

Responsible: Lúcia Guilhermino

Involved partners: CIIMAR

Approved by Steering Group on: ________

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1. Executive summary

In the case of an accidental marine pollution event, having long time series of well-validated baseline reference data is clearly important for assisting decision makers in analysing the environmental impact and recovery pattern, deciding on mitigation and remediation measures, and evaluating the damage to maximise the benefit from available compensation funds. However, the lack of baseline reference data was a recurrent observation in the environmental monitoring programmes for the impact assessment of the various accidents studied so far.

In this context, this task aims to define guidelines for the establishment of a long-term environmental monitoring programme in the Atlantic Arc Area. A systematic approach to setting up an environmental monitoring programme is essential in order to use funding and resources in an effective manner. In the present document, a brief introduction is first given to the definition and the rationale of long-term environmental monitoring programmes and the importance of baseline reference data sets. A set of steps for the implementation of a long-term monitoring programme is then described, from the definition of objectives and selection of monitoring strategies, to the protocol development and programme implementation phases.

Special attention is also given to quality assurance and cost considerations in the implementation of a long-term monitoring programme. Quality assurance of all procedures throughout the monitoring programme is considered an important step of long-term monitoring programmes in order to guarantee the consistence delivery of quality controlled results that allow the purpose of scientific assessments over time to be met. Any successful environmental monitoring programme must be cost-effective and, consequently, cost considerations should also be incorporated into the design and operation of long-term monitoring programmes.

2. Introduction

2.1. Context of the task and statement of the problem/ rationale of study

To assess the impact of an accidental marine pollution event such as an oil spill, it is important to know the historical contamination and the basal situation regarding the existing biological communities and the health status of the individuals and populations that constitute them. In this context, having long time series of well-validated baseline reference data is clearly important for assisting decision makers in analysing the impact and recovery pattern, deciding on mitigation and remediation measures, and evaluating the damage to maximise the benefit from available compensation funds (Hawkins *et al.*, 2002). The severity, duration and extent of chemical spills are very variable, and not all cause devastating and evident effects. Most environmental toxicity effects may be acute and extremely evident, but others may be chronic and only noticeable after a longer period of time and carefully planned detailed studies. Against this background it is difficult to establish the precise extent and duration of environmental damage caused by an oil spill and to distinguish such impacts from changes related with a variety of other factors, both natural (e.g. climatic or hydrographic) or man-made (e.g. other sources of contamination). Many case studies on oil spill impacts prove that the reality is sometimes different from the expected, with species and marine ecosystems being quite resilient due to their natural variability. This may compromise attempts to document environmental spill impacts and subsequent recovery.

The lack of baseline reference data was, in fact, a recurrent observation in the environmental monitoring programmes for the impact assessment of the various accidents studied so far. In this context, a work package dedicated to Environmental Monitoring (WP 7) was integrated into the EROCIPS project. Key outputs of this work package include the establishment of protocols or guidelines for environmental baseline reference data (i.e. protocols for selection of monitoring areas and sites and selection of sentinel species, and advice on selecting the type of monitoring and seasonality), and guidelines to determine pollution damage (i.e. guidelines to measure the damage caused by pollution to the different types of sensitive coastal habitats found in the Atlantic Area). A pre-spill analysis based on developed environmental base-lining protocols has been implemented on the Portuguese coast for over more than 1 year, employing sentinel species, biomarkers of exposure and effect at the sub-individual level, and the measurement of polycyclic aromatic hydrocarbons and metal levels in sediments and tissues. The present report presents guidelines for the setting-up of long-term monitoring programmes.

2.2. Aim of the task

This task aims to guide all EROCIPS partners, or other institutions, towards the establishment of a long-term environmental monitoring programme. The report is divided into several sections. The first three sections provide an introduction to the context, rationale, aim and geographical scope of this task, and to the EROCIPS context and framework. The fourth section briefly introduces the definition and the rationale of long-term environmental monitoring programmes and the importance of baseline reference data sets. The main section of this document delineates guidelines for the establishment of a long-term monitoring programme and comprises a set of steps from the definition of objectives and selection of monitoring strategies, to the protocol development and programme implementation phases. Another two sections are dedicated to quality assurance and cost considerations. Several recommendations for the setting up of a long-term environmental monitoring programme are put together in the last section.

2.3. Geographical scope of the task

The guidelines for a long-term monitoring programme developed in the present task are applicable all through the Atlantic Arc Area (Figure 1).

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.

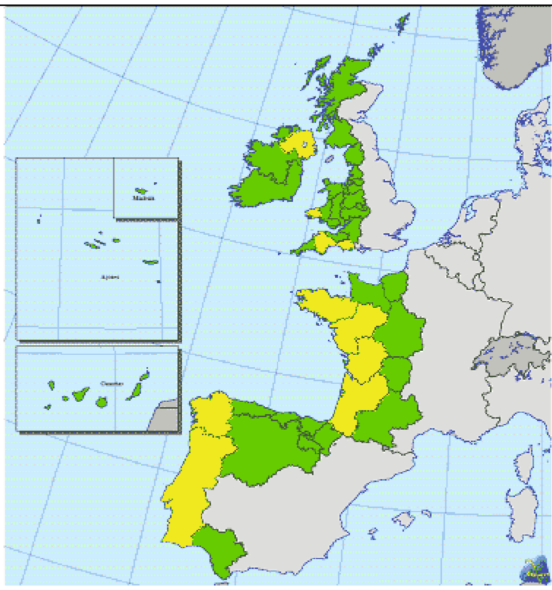

Figure 1. EROCIPS geographical scope and list of the partners involved per country.

3. Background

3.1. 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. Several partners from along the Atlantic Coast of Europe (Figure 1) 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.

A set of work packages (WPs) have been defined to address the following aspects of shoreline response to pollution: 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 to relevant bodies associated with coastal pollution, specifically those in the Atlantic Area (Figure 2). The present document falls within WP 7: Environmental Monitoring.

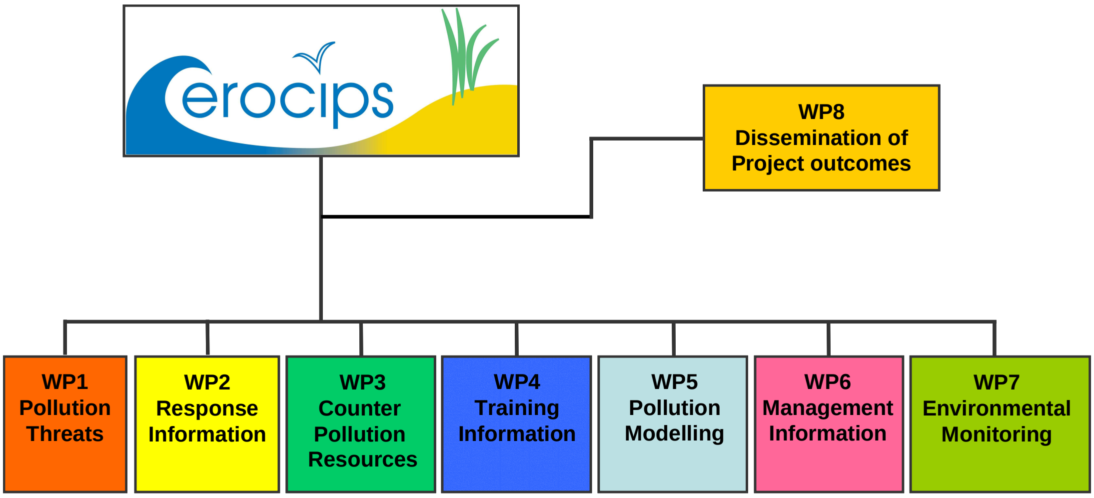

Figure 2. Graphical presentation of EROCIPS project work packages.

4. Long-term environmental monitoring programme

4.1. Definition and rationale

Monitoring programmes are designed to detect and evaluate changes in condition and progress towards meeting a pre-defined management objective. Environmental monitoring first involves the establishment of a baseline reference situation by collecting and analysing repeated observations or measurements through an integrated chemical, toxicological and ecological survey in a specific area and during a certain period.

The definition of “long-term” is rarely made explicit. However, it is implicit that the time scale has to be long enough to enable indicators of environmental change to be distinguished from background noise, in general beyond the usual length of a scientific research programme. Long-term environmental monitoring places a set of demands on a sampling strategy not present in a survey designed for a single time period. Methods need to be statistically robust and include systematic, quantitative and carefully planned surveys to measure the amount of change over a specific period of time relative to the baseline reference situation or other reference situation.

4.2. The importance of baseline reference data

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 natural trends to be distinguished from human-caused changes in the environment. During a spill event, baseline data enables one to characterise the conditions before the incident providing a reference for the impact assessment and for comparison of alternatives and mitigation measures. It is used as a starting point in the detection of the impacts resulting from the spill and of naturally occurring changes in the environment, the objective of the mitigation and recovery measures being the return to the baseline situation. These baseline reference data sets may also contribute to a response to other international initiatives such as the European Framework Directive.

5. Setting up a long-term environmental monitoring programme

A systematic approach to setting up an environmental monitoring programme is essential in order to use funding and resources in an effective manner. Special attention should be given to the definition of objectives and to the selection of monitoring strategies to accomplish the stated objectives. Then, the setting up of a long-term monitoring programme involves two key phases, a protocol development phase and a programme implementation phase.

5.1. Definition of objectives

Defining the objectives is frequently the most difficult and critical phase of developing a monitoring programme. Objectives must be well defined, prioritised and approved by all the actors involved in the programme. Different objectives require a different selection of parameters to be monitored, different sampling frequencies and durations, and different statistical treatments. Objectives should include not only the general purpose of the programme, but also more detailed objectives such as how the resulting data will be used in the future. One of the most commonly defined objectives in environmental monitoring is to use data to enable managers to make better-informed management decisions (Silsbee and Peterson, 1993).

Once objectives are well defined and prioritised, selection of the monitoring strategy should be a straightforward process.

5.2. Selection of monitoring strategy

Depending on the objectives formulated, an environmental monitoring programme may include several monitoring strategies such as monitoring of abiotic environmental parameters, monitoring of 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).

Pollutants may have lethal consequences or cause sub-lethal effects on the organism at various levels, i.e. biochemical, sub-cellular, cellular, organs and whole organism. Effects may also be at higher levels of biological organisation (i.e. population, community and ecosystem). Biological monitoring is an important element in monitoring programmes since it can demonstrate links between contamination and the effects at several levels of biological organisation (sub-individual, individual, population, community and ecosystem), according to the measured parameters.

In general, monitoring is less demanding in terms of resources and budget when performed at lower levels of complexity, such as individuals or populations, than at higher levels, such as communities and ecosystems, and here results may be easier to interpret and to explain to managers and stakeholders. In the last few decades, support grows for inclusion of parameters commonly known as biomarkers, facilitated by rapid development of novel measurement tools. Biomarkers are measurements in body fluids, cells or tissues indicating molecular, biochemical or cellular modifications due to the presence and magnitude of toxicants, or of host response. In an environmental monitoring context, biomarkers offer promise as sensitive indicators, demonstrating that toxicants have entered organisms, have been distributed through the body and stored in certain organs or tissues, or have been eliciting a toxic effect at critical targets. Despite the questionable ecological relevance of sub-individual level responses, biomarkers have been applied intensively as early warning signals of contaminant exposure mainly because of their general acceptance amongst the earliest detectable toxicant-induced responses. Therefore, the detection of alterations at the sub-individual level may allow the adoption of preventive and/or mitigation measures at the beginning of the problem before serious effects are induced at higher levels of biological organisation (e.g. population, community and ecosystem). The use of these parameters may become particularly valuable once combined with higher-level assessments, in an attempt to clarify potential underlying toxicant-induced changes in key physiological functions and different modes of action of toxicants. Nevertheless, and depending on the objectives formulated, observable changes in population dynamics, community structure and ecosystem process functioning are more ecologically relevant and should also be considered in environmental monitoring programmes.

Ideally, all the above monitoring strategies (i.e. abiotic environmental parameter monitoring, chemical contamination monitoring and biological monitoring including the biomarker and the ecological approaches) 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 theoretic and practical approaches behind the selection of these different monitoring strategies are well documented in other deliverables of WP 7 (see particularly the following documents: Protocols for Type of Monitoring and Seasonality; Protocols for Monitoring Pollution Damage to Different Types of Sensitive Coastal Habitats; and Environmental Monitoring Report).

5.3. Protocol development phase

5.3.1. Recommended content for long-term environmental monitoring protocols

Environmental monitoring protocols should be a key component of quality assurance in monitoring programmes, certifying that data meets defined standards of quality with a known level of confidence, and can be externally reviewed. They are essential in the assessment of trends of environmental change over time, to allow comparisons of data from different locations and institutions, and to minimise the variability of results due to turnover of personnel.

An effective long-term monitoring protocol should provide more than a detailed description of methodologies. Ideally, it should include a protocol narrative, a series of procedural guidelines or Standard Operational Procedures (SOPs), and a supplementary section of supporting materials (Oakley *et al*., 2003).

The protocol narrative must provide the rationale for why a particular environmental resource or resource issue was selected for monitoring and give background information concerning the environmental resource or resource issue of interest. It should also give an overview of the various components of the protocol including measurable objectives, monitoring strategy and methodologies, data analysis and reporting, operational and personnel requirements, and training procedures. An outline structure for a protocol narrative is described in Table 1 (adapted from Oakley *et al*., 2003).

Procedural guidelines or SOPs should contain a description of all operational procedures leading to the determination of each monitoring parameter. SOPs should be structured logistically by heading and sub-heading to cover the full sequence of procedures in field sampling and laboratory analysis. They should be written in the form of instructions with step-by-step details of procedures, taking into consideration the facts that substantial turnover of personnel is likely and personnel may not always be highly trained. A well-written SOP will help inexperienced personnel to quickly develop expertise consistent with past practice at the laboratory. An outline structure for a SOP, adapted from ICES (2004), is described in Table 2.

The preparation of SOPs to cover all field and laboratory activities defined in a monitoring programme is strongly recommended since it represents one of the most important practical steps to improve the quality and consistency of its scientific output. Interlaboratory comparisons of SOPs may provide a useful tool for promoting the harmonisation of methodologies at regional, national and international levels. Improving the comparability of data from different locations is crucial for an effective integration of environmental monitoring efforts, especially when results, as often, need to be used in trans-boundary accidental marine pollution impact evaluation.

Supplementary materials should include additional supporting material, including materials that cannot easily be formatted and included as part of the digital protocol document.

Such a modular organisation of protocols allows for a periodic review and revision in long-term monitoring programmes that should be regularly considered. It also facilitates export and adaptation of protocols across regional departments or institutions (Oakley *et al*., 2003).

1. Background and objectives
    - 1.1 Background and history including the description of the resource issue being addressed
    - 1.2 Rationale for selecting the resource issue to monitor
    - 1.3 Objectives
2. Monitoring strategy and sampling design
    - 2.1 Rationale for selecting the monitoring strategy
    - 2.2 Criteria for selecting the monitoring area
    - 2.3 Procedures for selecting the monitoring sites
    - 2.4 Recommended number of monitoring sites, and frequency and time period of sampling
    - 2.5 Level of change that can be detected for the defined monitoring strategy and sampling frequency
3. Field procedures
    - 3.1 Procedures for preparing a field survey including equipment set-up
    - 3.2 Recommended methodologies for collecting and post-collection processing of field samples
4. Laboratory procedures
    - 4.1 Recommended methodologies for processing field samples
5. Data handling, analysis and reporting
    - 5.1 Metadata procedures
    - 5.2 Overview of database design
    - 5.3 Recommended routine data summaries and statistical analyses to detect change
    - 5.4 Recommended reporting schedule and report format with examples of summary tables/figures
    - 5.5 Recommended methods for long-term trend analysis (e.g. every 5 or 10 years)
    - 5.6 Data archival procedures
6. Personnel requirements and training
    - 6.1 Qualifications and responsibilities of personnel
    - 6.2 Training procedures
7. Operational requirements
    - 7.1 Annual workload and schedule for field surveys
    - 7.2 Facility and equipments needs
    - 7.3 Safety aspects
    - 7.4 Quality assurance scheme
    - 7.5 Cost considerations
8. References

Table 1. Recommended content of the protocol narrative (adapted from Oakley *et al.*, 2003).

1. Identification
    1.1 Issue number, title, date and name(s) of the author(s)
2. Introduction
    2.1 Description of the objective
    2.2 Parameter to be measured
    2.3 Scope and principle of the method
3. Equipment, material and reagents
4. Procedures
    4.1 Specification of working conditions required for effective field sampling (e.g. tide level)
    4.2 Description of procedure/method with respect to the following aspects:
        i) Field sampling and sample treatment, labelling, handling, transport and storage of samples, preparation of laboratory analysis
        ii) Laboratory analysis for measurement of parameter
        iii) Analytical equipment control and calibration
        iv) Recording of data
    4.3 Criteria to adopt or reject results, including assessment of uncertainty of measurements
    4.4 Data to be recorded and statistical methods for data analysis
5. References

Table 2. Recommended content of a Standard Operational Procedure (adapted from ICES, 2004).

5.4. Programme implementation phase

5.4.1. Pilot study

Once monitoring approaches have been selected, a pilot study should be conducted to determine whether the monitoring programme can rationally meet the objectives defined formerly. Analysis of preliminary data allows a first estimate of temporal and spatial variability of the monitoring parameters, and of what precision of results and statistical power to detect change is needed. Of most significance, conducting a pilot study allows a more realistic and accurate evaluation of the resources and costs involved than any advance estimate. If preliminary data analysis reveals that the available budget is sufficient to attain the objectives, then it is reasonable to proceed with the implementation of the programme. If not, further refinement is needed before monitoring begins. This refinement can involve reducing the area or number of parameters to be monitored, and eliminating lower priority objectives (Silsbee and Peterson, 1993). In any case, reducing the costs must not come at the expense of data quality assurance (see Section 6).

It is important to consider that the programme will have to be sustained for many years and, most probably, through changes in funding priorities. Any effort spent in the evaluation and refinement of the monitoring programme during the pilot study will generally be compensated for by improved cost-effectiveness over the long term. Then, the programme can be implemented with the confidence that its results will accomplish the objectives prioritised in advance.

5.4.2. Report and store data

Data should be summarised and reported on a regularly basis, following an effective pre-defined report format. The maintenance of consistent and objective standards in data reporting is best addressed through systems of peer review. Moreover, support should be given to the publication of outcomes in the conventional peer-reviewed literature. However, recognising that the level of detail required in the reporting of many monitoring outcomes (especially at the international level following synthesis of data from various sources, as for example after a trans-boundary accidental marine pollution incident) may preclude such conventional publication routes, the use/establishment of expert groups to serve this need is recommended (ICES, 2004).

Reporting and disseminating monitoring results should be a key issue for all the actors involved in any monitoring programme dealing with the impact assessment of accidental marine pollution, including scientists and authorities. In this case, the method of provision of such results of environmental impact assessment should involve a permanent informative dossier, clearly defined step-by-step synthesis reports (short-term, medium-term and long-term impact assessment reports) and thematic workshops. Operational guidelines for information management during ecological surveillance of aquatic accidental pollution have been produced by Girin (2001).

Standard databases and geographical information systems (GIS) database tools for reporting and storing data should be used. The advantages of GIS are clear when compared with older methodologies used for storing data: the access to the data is rapid and the updating is simple, scaling is automatic, and storing capacity is fairly unlimited.

6. Quality assurance

The acquisition of reliable data is an important component in any monitoring programme associated with marine environmental impact assessment and protection. To obtain such reliable data, the whole analytical process must proceed under a well-established quality assurance programme. Quality assurance guidelines should be defined across the full range of activities, i.e. from the initial definition of programme objectives and sampling designs of field surveys, through to the collection of field samples, post-collection processing in the laboratory leading to the generation of raw data and, finally, compilation, analysis and storing of data. All procedures must be evaluated and controlled on a regular basis in order to ensure the consistence delivery of quality-controlled results that allow the purpose of scientific assessments over time to be met. This includes the use of SOPs, and regular intercalibration proficiency exercises within each laboratory and between laboratories. The ICES have defined the principal topics in the quality assurance of a biological monitoring programme (*ICES Techniques in Marine Environmental Sciences, Biological monitoring: General Guidelines for Quality Assurance*), and these are transcribed following short modifications in Table 3.

7. Cost considerations

Any successful environmental monitoring programme must not only be ecologically relevant and statistically credible but also cost-effective. Programmes that neglect cost-effectiveness will face problems and likely not succeed. One way to incorporate cost considerations into the design and operation of long-term monitoring programmes will be to search for input and review by resource economists.

1. A knowledge of the purpose of the survey, which is essential to establish the required data quality
2. Provision and optimisation of appropriate laboratory facilities and analytical equipment
3. Provision and regular updating of taxonomic keys and supporting literature for identification of biological specimens
4. Selection and training of personnel for the sampling and analytical procedure in question
5. Establishment of definitive instructions for appropriate collection, preservation, storage and transport procedures to maintain the integrity of samples prior to analysis
6. Use of suitable pre-treatment procedures prior to analysis of samples, to prevent cross-contamination and loss of the determinant in the samples
7. Validation of appropriate analytical methods to ensure that measurements are of the required quality to meet the needs of the survey
8. Conduct of interlaboratory checks on the accuracy of routine measurements, by the analysis of appropriate reference material, to assess whether the analytical methods are correctly employed and remain valid
9. Participation in interlaboratory quality assessments (proficiency testing schemes, training courses) to provide an independent assessment of the laboratory's capability to produce reliable measurements
10. The preparation and use of written instructions, laboratory protocols, etc., so that specific analytical data can be traced to the relevant samples and vice versa
11. The establishment of national/regional lists of all species likely to be encountered in surveys of marine communities, employment of up-to-date nomenclature and recognised coding systems
12. The management of the information in a suitable certified database/information system

Table 3. Principal topics in the quality assurance of a biological monitoring programme, as defined by ICES (transcribed from Rees (2004)).

1. Have clear objectives been defined and prioritised?
2. Has an adequate pilot study been budgeted for?
3. Have sampling designs been optimised?
4. Have the costs of a Type II error been considered?
5. Have all budgetary costs for operational monitoring programme elements been taken into account? Are scientific oversight, training, data management and reporting, quality assurance scheme, etc., provided for in the budget?
6. Have the financial bounds (high, medium and low) of the budget available to operate the monitoring programme been identified?
7. Has a cost–benefit or cost-effectiveness analysis been performed?

Table 4. Checking list items for taking cost considerations into account (adapted from Caughlan and Oakley, 2001).

8. Conclusions and recommendations

Monitoring programmes that incorporate a large up-front investment in defining objectives (including how monitoring results will be used), selecting monitoring strategies and developing monitoring protocols are more likely to succeed over the long-term. Periodic review and revision of long-term monitoring programmes are to be expected, and changes and improvements in such things as field methodology and approaches to data analysis and reporting should be regularly considered. In this context, a modular organisation of protocols, consisting of a protocol narrative, a series of SOPs and a supplementary section of supporting materials, facilitates periodic review and revision. It also facilitates data comparability within regional and national institutions. Improving the comparability of data from different locations is crucial to an effective integration of environmental monitoring efforts, especially when data, as often, need to be used in trans-boundary accidental marine pollution impact evaluation. The conducting of a pilot study prior to the full implementation of a long-term monitoring programme is highly recommended in order to determine if it can rationally meet the objectives and to have an advance estimate of resources and costs. Ideally, whole the analytical process must proceed under a well-established quality assurance programme in order to ensure the consistence delivery of quality-controlled results that allow the purpose of scientific assessments over time to be met.

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Rees, H. (ed.) (2004). *Biological Monitoring: General Guidelines for Quality Assurance (ICES Techniques in Marine Environmental Sciences*, *No. 32*). ICES, International Council for the Exploration of the Sea, 44 pp.

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Oakley, K.L., Thomas, L.P. and Fancy, S.G. (2003). Guidelines for long-term monitoring protocols. *Wildlife Society Bull.* **31**(4), 1000–1003.

Silsbee, D.G. and Peterson, D.L. (1993). Planning for implementation of long-term resource monitoring programs. *Environ. Monitor. Assess.* **26**, 177–185.

Further reading

International Council for the Exploration of the Sea: The ICES Techniques in Marine Environmental Sciences (www.ices.dk).

OSPAR Commission for the Protection of the Marine Environment of the North-East Atlantic: *Strategy for a Joint Assessment and Monitoring Programme (JAMP),* monitoring guidelines (www.ospar.org).

Workshop on Environmental Damage – Final Technical Implementation Report, 11–13 July 2005, Vigo, Spain (http://193.144.36.199/mgm/index.html).