2 Guidelines for the integrated monitoring and assessment of contaminants and their effects

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2.1 General introduction

Our seas and oceans are dynamic and variable. They represent a fundamental component of global ecosystems and, as such, we need to be able to assess the health status of the marine environment. Furthermore, we need to be able to detect anthropogenically induced changes in seas and oceans and to identify the reasons for these changes. It is only through such understanding that we can advise on necessary and appropriate remedial responses, such as regulatory action, as well as report on any improvements resulting from OSPAR measures. There is a need to express clearly what is meant by the "health" of the marine environment, and for that purpose, we require indicators for the components of ecosystem health.

The marine environment receives inputs of hazardous substances through riverine inputs, direct discharges, and atmospheric deposition. The marine environment is the ultimate repository for complex mixtures of persistent chemicals. This means that organisms are exposed to a range of substances, many of which can cause metabolic disorders, an increase in disease prevalence, and, potentially, effects on populations through changes in, for example, growth, reproduction, and survival. There is general agreement that the best way to assess the environmental quality of the marine environment with respect to hazardous substances is to use a suite of chemical and biological measurements in an integrated fashion. In the past, monitoring to assess the "impact" of hazardous substances has been based primarily on measurements of concentration. This was because the questions being asked concerned concentrations of such substances in water, sediment, and biota, and such measurements were possible. However, in order to more fully assess the health of our maritime area, questions about the bioavailability of hazardous substances and their impact on marine organisms or processes are now being posed. Biological effects techniques have become increasingly important in recent years. The specific focus from OSPAR is on determining whether or not there are any unintended/unacceptable biological responses, or unintended/unacceptable levels of such responses, as a result of exposure to hazardous substances. Sometimes a biological response can be observed when the causative substance is below current chemical analytical detection limits; the development of imposex in gastropod molluscs as a result of tributyltin (TBT) is a case in point.

This guidance document is intended to complete the development of Joint Assessment and Monitoring Programme (JAMP) guidance for integrated monitoring of chemicals and their biological effects. The original JAMP guidelines for monitoring contaminants and biological effects in biota and sediments did not provide guidance for the optimum approach to monitoring or support the integrated assessment of concentrations and effects of contaminants across the OSPAR maritime area, although some contain references to supporting measurements (chemical, physical, and biological data) that aid the interpretation of monitoring data. Consequently, chemical analytical and biological effects data have usually been collected, reported, and assessed separately. Also, in some cases, the original guidelines do not provide guidance on the specific substances that should be determined in order to explicitly link concentrations and effects. An integrated approach to monitoring is based on the simultaneous measurement of contaminant concentrations (in biota, sediments, and, in some cases, water or passive samplers), biological effects parameters, and a range of physical and other chemical measurements so as to permit normalization and appropriate assessment.

Integrated monitoring of contaminants and their effects requires coordination of field sampling and sample-handling techniques, utilizing the same species/ population/individual for both types of measurement from the same area and sampled within the same time-frame. Furthermore, a set of supporting parameters should be measured at the same time, and such data have to be available for use in the final assessment, because biological effects may be influenced by factors such as temperature, stage of maturation, or size. Integration of effort in this way will yield additional information in a cost-effective manner, while also reducing the interannual variance of the data.

OSPAR has obligations to measure and monitor the quality of the marine environment and its compartments (water, sediments, and biota), the activities and inputs that can affect that quality, and the effects of those activities and inputs, and to assess what is happening in the marine environment as a basis for identifying priorities for action. OSPAR, together with HELCOM, have agreed on an ecosystem approach to managing the marine environment, under which OSPAR has committed to monitoring the ecosystems of the marine environment, in order to understand and assess the interactions between, and impact of, human activities on marine organisms. Integrated monitoring and assessment of contaminants in the marine environment and their effects will contribute effectively to the integrated assessment of the full range of human impacts on the quality status of the marine environment, as part of the ecosystem approach.

2.2 The OSPAR Hazardous Substances Strategy

The objective of the OSPAR Hazardous Substances Strategy (OSPAR Agreement 2003–2021) is to prevent pollution of the maritime area by continuously reducing discharges, emissions, and losses of hazardous substances, with the ultimate aim of achieving concentrations in the marine environment near background values for naturally occurring substances and close to zero for synthetic substances. The Hazardous Substances Strategy further declares that the Commission will implement this Strategy progressively by making every endeavour to move towards the target of the cessation of discharges, emissions, and losses of hazardous substances by the year 2020. In association with this and the other five OSPAR strategies, OSPAR has developed a Joint Assessment and Monitoring Programme (JAMP). This provides the basis for the monitoring activities undertaken by contracting parties to assess progress towards achieving OSPAR objectives. In relation to hazardous substances, the JAMP seeks to addresses the following questions:

- What are the concentrations of hazardous substances in the marine environment? Are those hazardous substances monitored at, or approaching, background levels for naturally occurring substances and close to zero for synthetic substances? How are the concentrations changing over time? Are the concentrations of either individual substances or mixtures of substances such that they are not giving rise to pollution effects?

- How can OSPAR's monitoring framework be improved and extended and better linked with the understanding of biological effects and ecological impacts of individual substances and the cumulative impacts of mixtures of substances?

There is a need to adopt an integrated approach to the monitoring of contaminants in the marine environment and the biological responses to the presence of hazardous substances. Such an approach would provide greater interpretative power in assessments of the state of the OSPAR maritime area with respect to hazardous substances and an improved assessment of progress towards achieving the objectives of the OSPAR Hazardous Substances Strategy.

2.3 EU Water Framework Directive and Marine Strategy Framework Directive

The marine environment is a precious heritage that must be protected, restored, and treated as such, with the ultimate aim of providing biologically diverse and dynamic oceans and seas that are safe, clean, healthy, and productive. It is in this context that the European Union has, over the last decade, developed its water policies so that now there is significant European legislation covering marine waters and the lakes and rivers that ultimately flow into our coastal ecosystems. The Water Framework Directive (Directive 2000/06/EC) establishes a framework for community action in the field of water policy, central to which is a good ecological status for water bodies. This is described on the basis of biological quality, hydromorphological quality, and physico-chemical quality. More recently, the European Union has implemented the Marine Strategy Framework Directive (Directive 2008/56/EC). At its heart is the concept of "Good Environmental Status" for all European waters and the provision of a framework for the protection and preservation of the marine environment, the prevention of its deterioration, and, where practicable, the restoration of that environment in areas where it has been adversely affected. "Good Environmental Status" (GES) will be assessed on a regional basis. The programmes of the various regional sea conventions, including OSPAR, will provide a valuable source of data for the assessments that will be required.

The Directive specifies that GES will be assessed against 11 qualitative descriptors. Descriptor 8 (Concentrations of contaminants are at levels not giving rise to pollution effects) has been interpreted as requiring assessments of contaminant concentrations and their biological effects.

A task group established by EC Joint Research Centre (JRC) interpreted this as meaning that the concentrations of contaminants should not exceed established quality standards (e.g. Environmental Quality Standards EQS, environmental assessment criteria (EAC)) and that the intensity of biological effects attributable to contaminants should not indicate harm at organism level or higher levels of organization. Commission Decision (2010/477/EU) noted that progress towards GES will depend on whether or not pollution is progressively being phased out (i.e. the presence of contaminants in the marine environment and their biological effects are kept within acceptable limits, so as to ensure that there are no significant impacts on or risk to the marine environment).

It is clear that assessment for Descriptor 8 will require both chemical and biological effects measurements. It is likely that a robust and holistic approach will seek to integrate the assessment of chemical and biological effects data into a single process.

2.4 Purpose of these guidelines

The purpose of this document is to provide guidance on integrated chemical and biological effects monitoring within the OSPAR area in the context of the Coordinated Environmental Monitoring Programme (CEMP) and the list of OSPAR priority chemicals. In addition, it provides a place for the associated technical annexes describing biological effects techniques, including a list of the supporting parameters that are required in an integrated programme, as well as the chemical determinands relevant to the effects being studied.

The guidelines are supported by associated background documents which provide information on the scientific background to the contaminants and biological effects measurements included in the programme, and on the derivations and values of the assessment criteria (background concentrations, background assessment concentrations, and environmental assessment criteria for chemical contaminants, and analogous assessment criteria for biological effects measurements).

2.5 Quantitative objectives; temporal trends and spatial programmes

The ultimate objectives of OSPAR monitoring activities relating to hazardous substances are to:

- assess the status (existing level of marine contamination and its effect) and trends of hazardous substances across the OSPAR maritime area;
- assess the effectiveness of measures taken for the reduction of marine contamination;
- assess harm (unintended/unacceptable biological responses) to living resources and marine life;
- identify areas of serious concern/hotspots and their underlying causes;
- identify unforeseen impacts and new areas of concern;
- create the background to develop predictions of expected effects and the verification thereof (hindcasting); and
- direct future monitoring programmes.

By being clear about the objective of the monitoring, the parameters for inclusion in the programme of work, the sampling strategy, methods of statistical analysis, and assessment methods can all be developed and specified. In the context of integrated monitoring, the planning aspect is crucial as it will ensure that operating procedures can be put in place that clearly detail all of the chemical, physical, and biological samples and data to be collected.

There is a need to perform monitoring to identify differences over time and across geographical space. This will be divided into two generic types:

- *spatial monitoring* to identify geographical variation within the OSPAR maritime area; and
- *temporal monitoring* aimed at identifying changes over time.

Although these two types of monitoring have been described separately, there is no reason why they cannot be carried out simultaneously, provided that this is incorporated into the design of the programme. The processes of integration for both these types of monitoring are closely related and hence should be developed simultaneously.

2.6 The integrated approach

The contribution made by an integrated programme involving both chemical and biological effects measurements is primarily that the combination of the different measurements increases the interpretive value of the individual measurements. For example, biological effects' measurements assist the assessment of the significance of measured concentrations of contaminants in biota or sediments. When biological effects measurements are carried out in combination with chemical measurements (or additional effects measurements), this provides an improved assessment allowing identification of the substances contributing to the observed effects. By bringing together monitoring disciplines that have tended to be conducted separately, an integrated assessment can improve our ability to explain the causes for hotspots detected during monitoring programmes. An integrated approach also has the advantage of combining and coordinating the various disciplines to achieve a greater understanding among those performing marine assessments of the contributions from the different components of a monitoring programme. This has the clear technical advantage that sampling of all relevant parameters at any particular sampling location will be assured. The economic benefit of an integrated approach comes from the fact that the samples and data are gathered during a single cruise and that the data can be directly compared/used with holistic assessment tools to provide truly integrated assessments.

The integration of sampling has four distinct connotations:

- sampling and analyses of same tissues and individuals;
- sampling of individuals for effects and chemical analyses from the same population as that used for disease and/or population structure determination at the same time;
- sampling of water, the water column (if included), and sediments at the same time and location as collecting biota; and
- simultaneous measurement of support parameters (e.g. hydrographic parameters) at any given sampling location.

Fundamental aspects of the design of an integrated programme include key environmental matrices (water, sediment, and biota), the selection of appropriate combinations of biological effects and chemical measurements, and the design of sampling programmes to allow the chemical concentrations, the biological effects data, and other supporting parameters to be combined for assessment. Some matrices/determinands are considered fundamental to the integrated assessment and are described as ”core methods”. Where additional matrices/determinands have been found to add value to the integrated assessment, these have been described as ”additional methods” and are not considered essential. The basic structure of an integrated programme is illustrated in Figure 2.1.

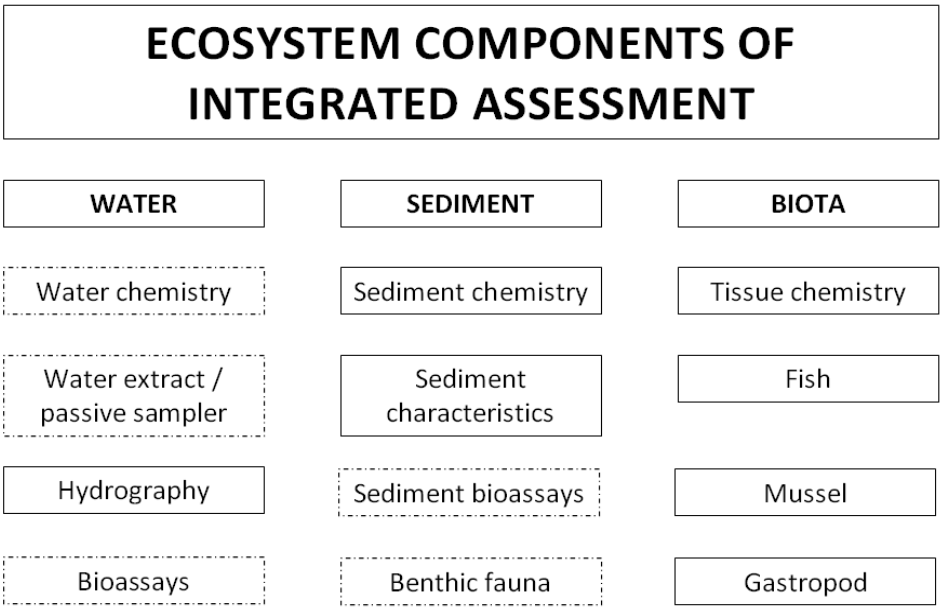

Figure 2.1. Overview of components in a framework for an integrated monitoring programme for chemical contaminants and their biological effects. Solid lines, core methods; broken lines, additional methods.

Chemical analyses to be included in an integrated programme for OSPAR purposes should cover the OSPAR priority hazardous substances. Analytical methods should be sufficiently sensitive to detect variation in environmental quality and should be supported by appropriate quality control and assurance. Biological effects methods to be included in an integrated programme have been identified by the ICES Working Group on the Biological Effects of Contaminants (WGBEC). They require the following characteristics:

- the ability to separate contaminant-related effects from influences caused by other factors (e.g. natural variability, food availability);
- sensitivity to contaminants (i.e. providing "early warning");
- a suite of methods that covers a range of mechanisms of toxic action (e.g. oestrogenicity/androgenicity, carcinogenicity, genotoxicity, and mutagenicity); and
- the inclusion of at least one method that measures the "general health" of the organism.

Biological effects and chemical methods have been selected for the biota matrix (separated as fish and mussels) using these criteria. In addition, some physiological characteristics of individual fish are required, including gonadosomatic index (GSI), liver somatic index (LSI), and condition factor, as described in supporting technical annexes. Similarly, spawning status is relevant to mussel effect assessment. General designs for integrated monitoring of fish are presented in Figure 2.2 and of mussels in Figure 2.3. Designs for water, sediment, and gastropod monitoring are included as Figures 2.4, 2.5, and 2.6, respectively.

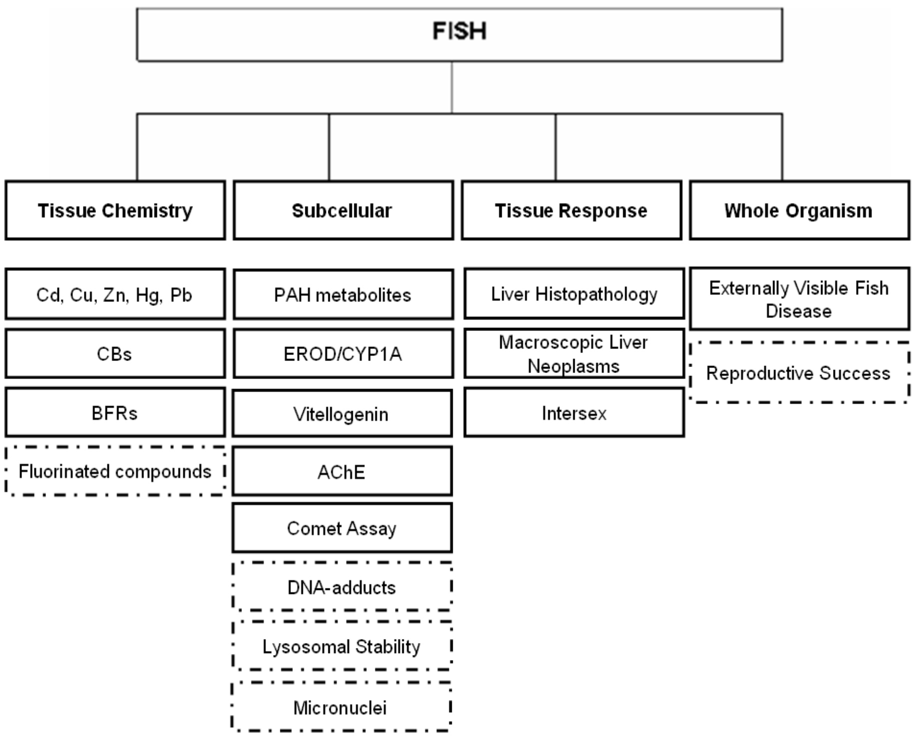

Figure 2.2. Methods included in the fish component of the integrated monitoring framework. Solid lines, core methods; broken lines, additional methods. CBs, chlorinated biphenyls; BFRs, brominated flame retardants; AChE, acetylcholinesterase.

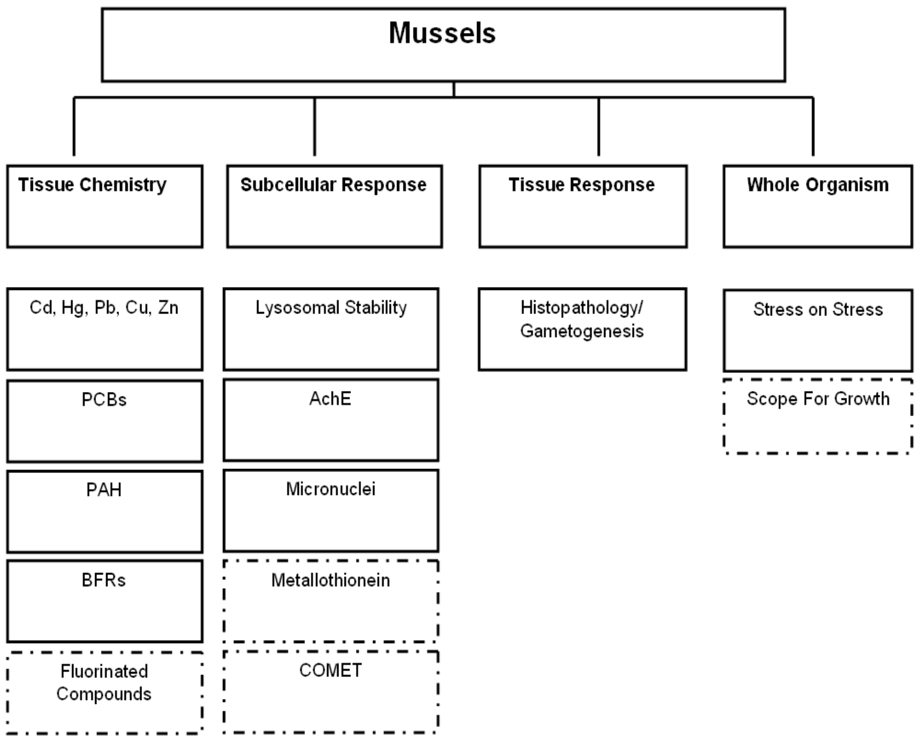

Figure 2.3. Methods included in the mussel component of the integrated monitoring framework. Solid lines, core methods; broken lines, additional methods. PCBs, polychlorinated biphenyls; PAH, polycyclic aromatic hydrocarbon; BFRs, brominated flame retardants; AChE, acetylcholinesterase.

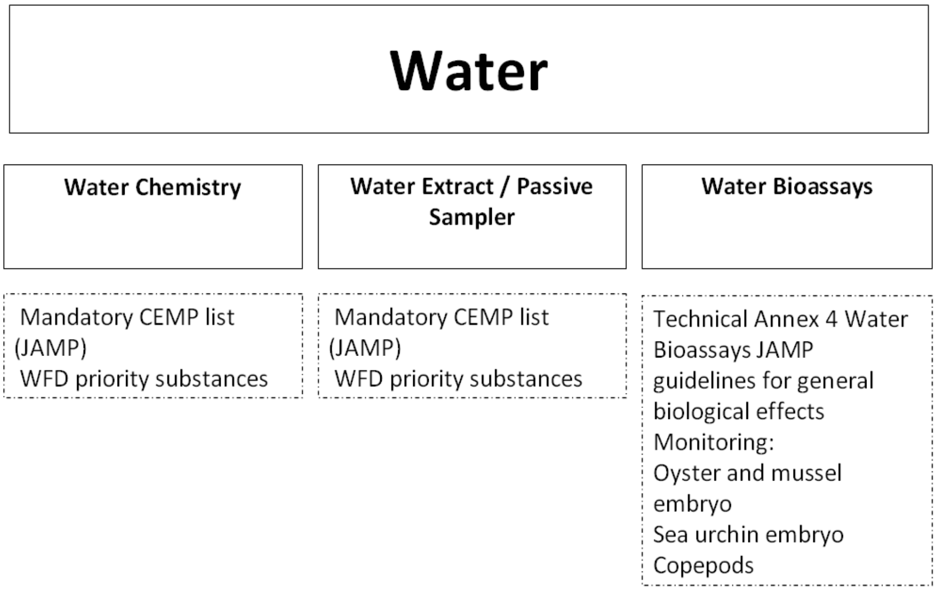

Figure 2.4. Methods included in the water component of the integrated monitoring framework. Solid lines, core methods; broken lines, additional methods.

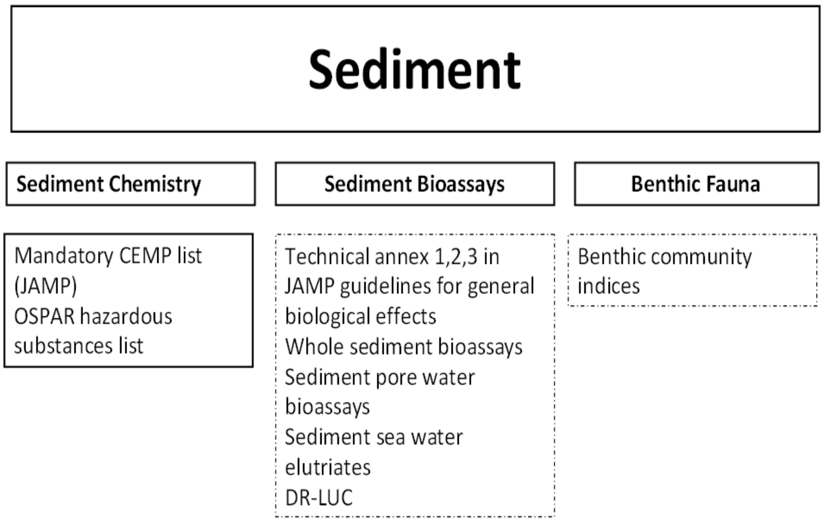

Figure 2.5. Methods included in the sediment component of the integrated monitoring framework. Solid lines, core methods; broken lines, additional methods.

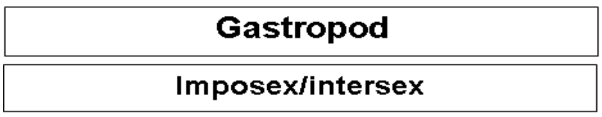

Figure 2.6. Methods included in the gastropod component of the integrated monitoring framework. Solid lines, core methods; broken lines, additional methods.

2.7 Sampling and analysis strategies for integrated fish and bivalve monitoring

The integration of contaminant and biological effects monitoring requires a strategy for sampling and analysis that includes:

- sampling and analyses of the same tissues and individuals;

- sampling of individuals for effects and chemical analyses from the same population as that used for disease and/or population structure determination at a common time;
- sampling of water, the water column, and sediments at the same time and location as collecting biota; and
- more or less simultaneous sampling for and determination of primary and support parameters (e.g. hydrographic parameters) at any given location.

Examples of sampling strategies for the integrated fish and shellfish schemes are shown in Figures 2.7 and 2.8. In order to integrate sediment, water chemistry, and associated bioassay components with the fish and bivalve schemes, sediment and water samples should be collected at the same time as fish/bivalve samples and from a site or sites that are representative of the defined station/sampling area.

Additional integrated sampling opportunities may arise from trawl/grab contents, for example, gastropods for imposex or benthos, and these should be exploited where possible/practicable.

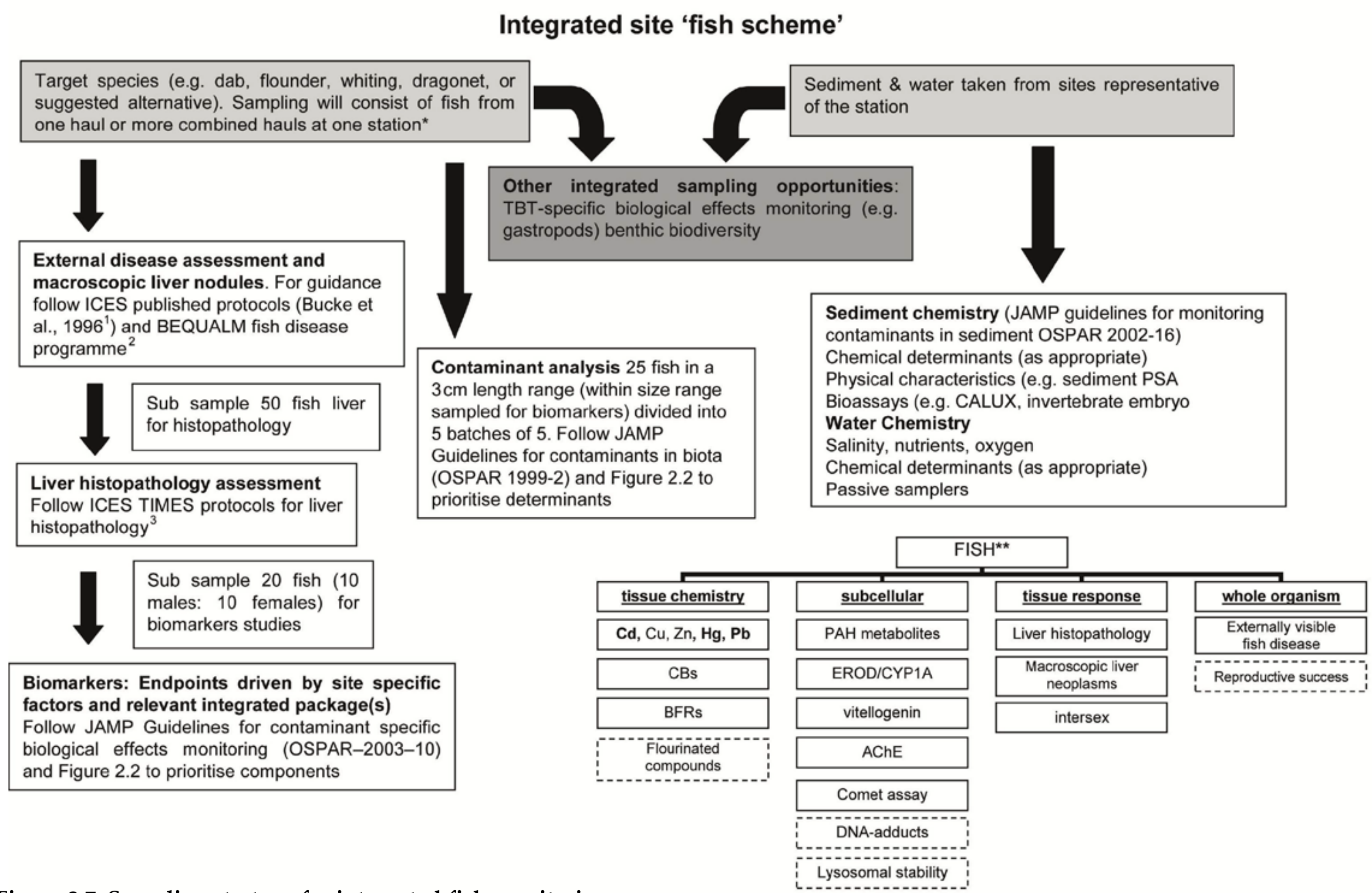

Figure 2.7. Sampling strategy for integrated fish monitoring.

**Figure 2.2 Overview of methods to be included in an integrated programme for selected fish species. (Solid lines – core methods, broken lines – additional methods).

1 Note: A station may be site specific or a larger defined area

2 Bucke, D., Vethaak, D., Lang, T., and Mellergaard, S. 1996. Common diseases and parasites of fish in the North Atlantic: training guide for identification. ICES Techniques in Marine Environmental Sciences, No. 27 pp.

3 BEQUALM: http://www.bequalm.org/fishdisease.htm

4 Feist, S. W., Lang, T., Stentiford, G. D. and Köhler A., 2004. The use of liver pathology of the European flatfish, dab (Limanda limanda L.) and flounder (Platichthys flesus L.) for monitoring biological effects of contaminants. ICES Techniques in Marine Environmental Sciences, No. 38. 47 pp.

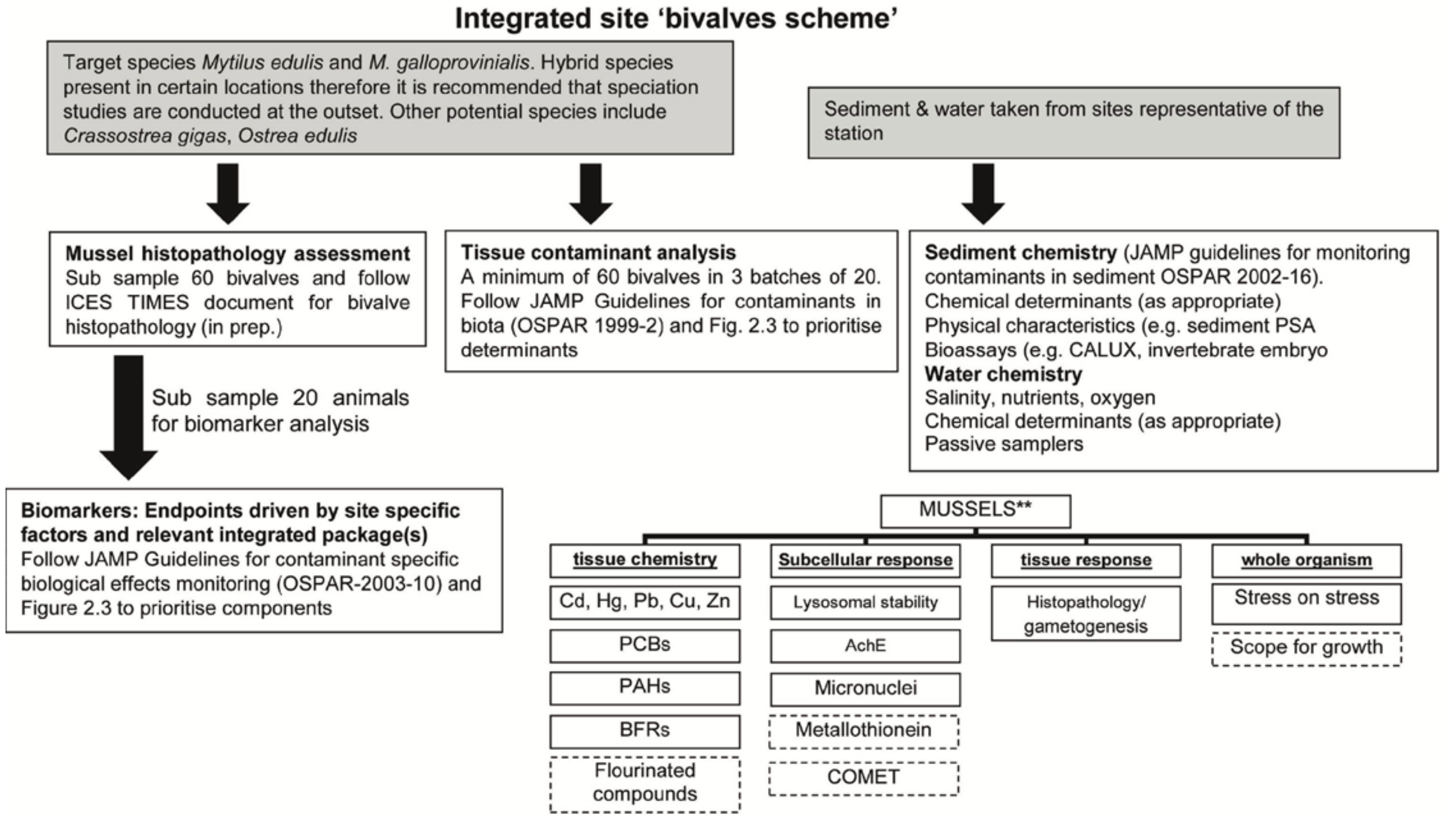

Figure 2.8. Sampling strategy for integrated bivalve monitoring.

** Figure 2.3 Overview of methods to be included in an integrated programme for selected bivalve species. (Solid lines – core methods, broken lines – additional methods).

2.8 The integrated assessment

It is not sufficient simply to coordinate sampling; integration must also involve a combined assessment of the monitored parameters, which must themselves be selected with the assessment aim in mind. Such a combined assessment may involve using environmental parameters as covariates in statistical analyses or they may be used to standardize effect-variables (e.g. temperature or seasonal effects on biomarker responses). Similarly, normalization procedures for the expression of contaminant concentrations in biota and sediment have been established. For example, defined bases (e.g. dry weight or lipid weight) are used for biota analyses, and sediment analyses are normalized to organic carbon or aluminium to minimize the influence of differences in bulk sediment properties. These procedures are described in detail in the OSPAR Co-ordinated Environmental Monitoring Programme (CEMP) Monitoring Manual (OSPAR, 2012).

Ultimately, the purpose of an integrated monitoring programme is to provide the necessary data to facilitate integrated assessments so that the status of the marine environment in relation to hazardous substances can be described as a contribution to general assessments of the quality status of the OSPAR maritime area (e.g. OSPAR Quality Status Reports – QSRs). In order to assess progress towards the objectives of the OSPAR Hazardous Substances Strategy, OSPAR has developed assessment criteria for contaminant concentration data. These are background concentrations (BCs), background assessment concentrations or criteria (BAC), and environmental assessment criteria (EAC). The use of these in data assessment, on both local and large (OSPAR Convention area) scales, is described in the CEMP Manual. The Manual also describes the statistical approaches to be used in comparing field data with assessment criteria to ensure rigorous and consistent assessments.

In the same way, OSPAR, with assistance from ICES, has more recently developed coherent sets of analogous assessment criteria for biological effects measurements. The concept of a background level of response is applicable to all effects measurements. Assessment criteria analogous to EAC (i.e. representing levels of response below which unacceptable responses at higher, e.g. organism or population, levels would not be expected) are applicable for some biological effects measurements, and these have been termed "biomarkers of effect". In other cases, the link to higher level effects is less clear, and these measurements have been termed "biomarkers of exposure", in that they indicate that exposure to hazardous substances has occurred. Importantly, the processes used to derive both BAC and their biological analogues and EAC and their analogues have been applied consistently to all chemical and effects measurements. The consequence is that the OSPAR objective of achieving background or near-background concentrations/effects represents targets based upon the same criteria across all parameters, and that EAC and their analogues represent similar levels of environmental risk. A table of the current assessment criteria for biological effects is presented in Section 30.

This coherence across the broad range of assessment criteria forms the basis for integrated assessment schemes. Progress towards the objectives of the Hazardous Substances Strategy was demonstrated in the QSR 2010 document, in that the status of all OSPAR priority contaminants could be presented in directly comparable "traffic light" formats (Figure 2.9).

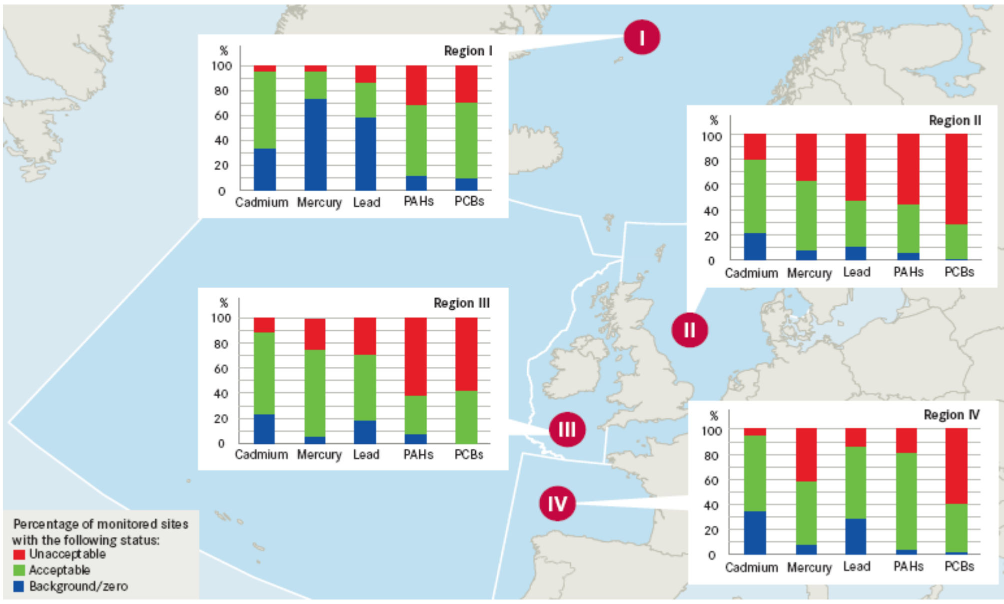

Figure 2.9. OSPAR regional-level integration of the concentrations of priority contaminants in fish, shellfish, and sediment from the OSPAR QSR 2010, Hazardous Substances chapter (OSPAR, 2010).

A comparable approach can be used in the assessment of biological effects data for which EAC and/or BAC have been developed. Furthermore, the coherence of assessment criteria across both chemical and biological effects measurements allows these two types of data to be brought together into a single integrated assessment scheme. The "traffic light" presentation is equally applicable to biological effects data and can be used to present data integrated on a range of geographical scales from the single sampling site to the regional scale, as required under MSFD. The application of this approach is described in Section 30.