JAMP Guidelines for the Integrated Monitoring and Assessment of Contaminants and their effects

Contents

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 be able 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 of components of ecosystem health.

The marine environment receives inputs of hazardous substances through riverine inputs and direct discharges, as well as by 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 have the potential to cause metabolic disorders, an increase in disease prevalence and, potentially, effects on populations through changes in e.g. 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 by using 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 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 due to tributyltin (TBT) is a case in point.

This guidance document is intended to complete the development of JAMP guidance for integrated monitoring of chemicals and their biological effects. The original JAMP Guidelines for monitoring contaminants and biological effects in biota and sediment did not provide guidance for the optimum approach to monitoring and support the integrated assessment of concentrations and effects of contaminants across the OSPAR Maritime Area, although some of them contain references to supporting measurements (chemical data, physical data, biological data) which 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 JAMP Guidelines do not provide guidance on the specific substances which should be determined in order to be able 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 co-ordination of field sampling and sample handling techniques, utilising 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, since biological effects may be influenced by e.g. temperature, stage of maturation or size. Integration of effort in this way will yield additional information in a cost- effective manner, whilst also reducing the inter-annual 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.

The OSPAR Hazardous Substances Strategy

The objective of the OSPAR Hazardous Substances Strategy (OSPAR Agreement 2010-03) 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 man-made 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 manmade substances? How are the concentrations changing over time? Are the concentrations of either individual substances or mixture of substances such that they are not giving rise to pollution effects?

- How to improve and extend OSPAR's monitoring framework and better link it 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.

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 such that significant European Legislation incorporating marine waters and the lakes and rivers which 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 good ecological status for water bodies. This is described on the basis of biological quality elements, hydromorphological quality elements and physico-chemical quality elements. 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 and as such 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 eleven 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 set up by JRCA interpreted this as meaning that the concentrations of contaminants should not exceed established quality standards (e.g. EQSs, EACs) and that the intensity of biological effects attributable to contaminants should not indicate harm at organism or higher levels of organization. Commission Decision (2010/477/EU) noted that progress towards good environmental status will depend on whether 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 chemical and biological effects data into a single process.

Purpose of this JAMP Guideline

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) issues and the list of OSPAR priority chemicals. In addition, it provides the context for the associated Technical Annexes describing biological effects techniques include a list of the supporting parameters which are required in an integrated programme, as well as the chemical determinands relevant to the effects being studied.

The JAMP Guideline is 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 assessment criteria (Background Concentrations, Background Assessment Concentrations, and Environmental Assessment Criteria for chemical contaminants, and analogous assessment criteria for biological effects measurements).

Quantitative objectives; Temporal Trend and Spatial Programmes

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

- to assess status (existing level of marine contamination and its effect) and trends of hazardous substances across the OSPAR maritime area;

- to assess the effectiveness of measures taken for the reduction of marine contamination;

- to assess harm (unintended/unacceptable biological responses) to living resources and marine life;

- to identify areas of serious concern/hotspots and their underlying causes;

- to identify unforeseen impacts and new areas of concern;

- to create the background to develop prediction of expected effects and the verification thereof (hindcasting); and

- to 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 the chemical, physical and biological samples and data to be collected.

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

- Spatial Monitoring: monitoring to identify geographical variation within the OSPAR maritime area;

- Temporal Monitoring: monitoring aimed at identifying changes over time.

Although these two types of monitoring have been described separately, there is no reason why the two activities cannot be carried out simultaneously, as long as 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.

The integrated approach

The contribution made by the 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 will assist in 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 will provide an improved assessment due to the possible identification of the substances contributing to the observed effects. By bringing together monitoring disciplines which have tended to be conducted separately, an integrated assessment can further lead to an improved 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 amongst 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 enable the chemical concentrations, the biological effects data and other supporting parameters to be combined for assessment. The basic structure of an integrated programme is illustrated in Figure 1.

ECOSYSTEM COMPONENTS OF INTEGRATED ASSESSMENT

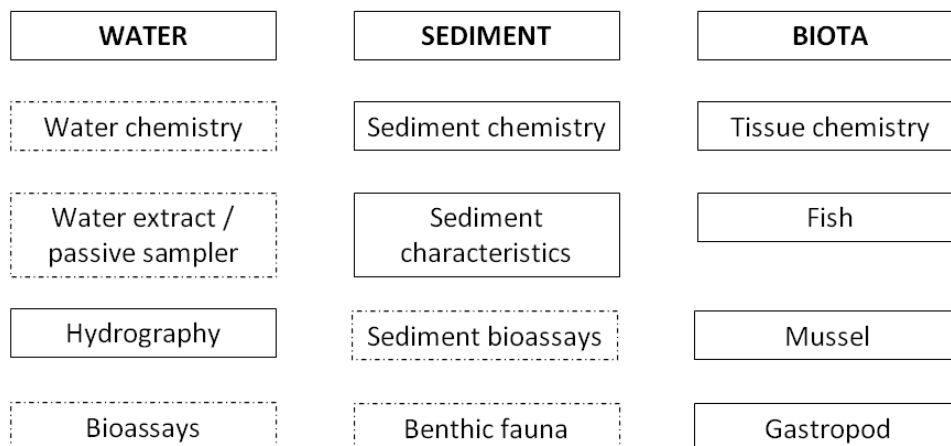| WATER	SEDIMENT	BIOTA
Water chemistry	Sediment chemistry	Tissue chemistry
Water extract / passive sampler	Sediment characteristics	Fish
Hydrography	Sediment bioassays	Mussel
Bioassays	Benthic fauna	Gastropod

Figure 1: Overview of components in a framework for the integrated monitoring programme 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 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:

1   the ability to separate contaminant-related effects from influence by other factors (e.g. natural variability, food availability, etc);

2   sensitivity to contaminants, i.e. provide "early warning";

3   the suite of methods used should cover a range of mechanisms of toxic action, e.g. estrogenicity/androgenicity, carcinogenicity, genotoxicity and mutagenicity;

4   the range of methods applied in an integrated programme should include at least one that measures the "general health" of the organism.

Biological effects and chemical methods were selected for the biota matrix (separated as fish and mussel) using these criteria. In addition, some physiological characteristics of individual fish are required including gonad somatic index (GSI), liver somatic index (LSI) and condition factor, as described in supporting Technical Annexes. Similarly, spawning status is relevant for mussel effect assessment. General designs for integrated monitoring of fish are presented in Figure 2 and of mussel in Figure 3. Designs for water, sediment and gastropod monitoring are included as Figures 4, 5 and 6 respectively.
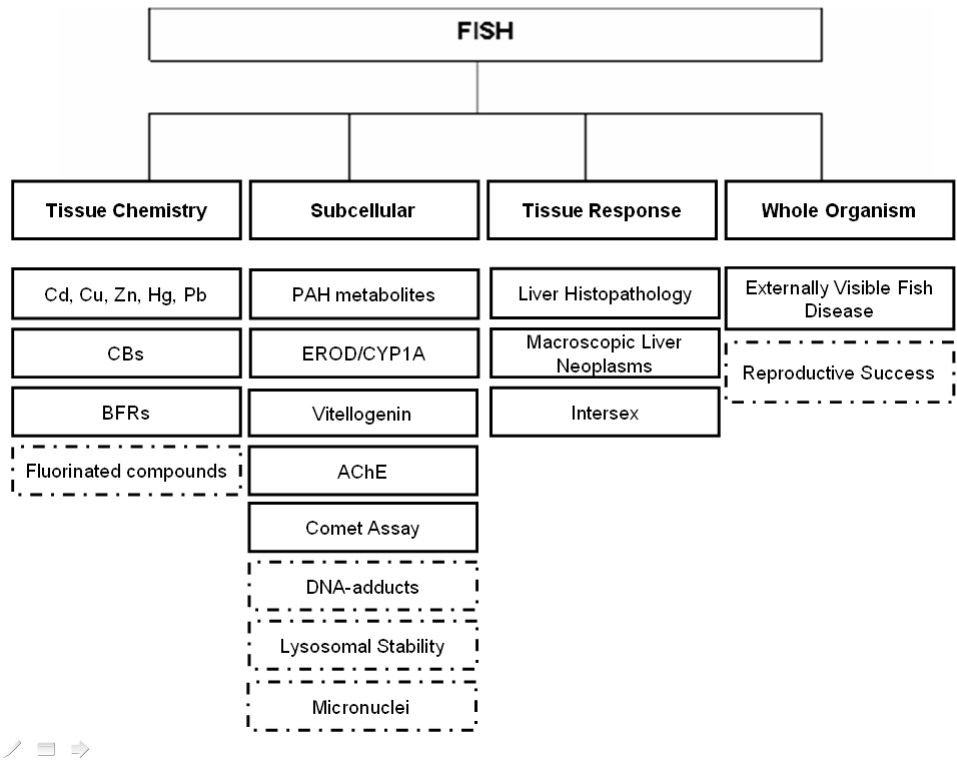
Figure 2: Methods included in the fish component of the integrated monitoring framework; solid lines – core methods, broken lines – additional methods.
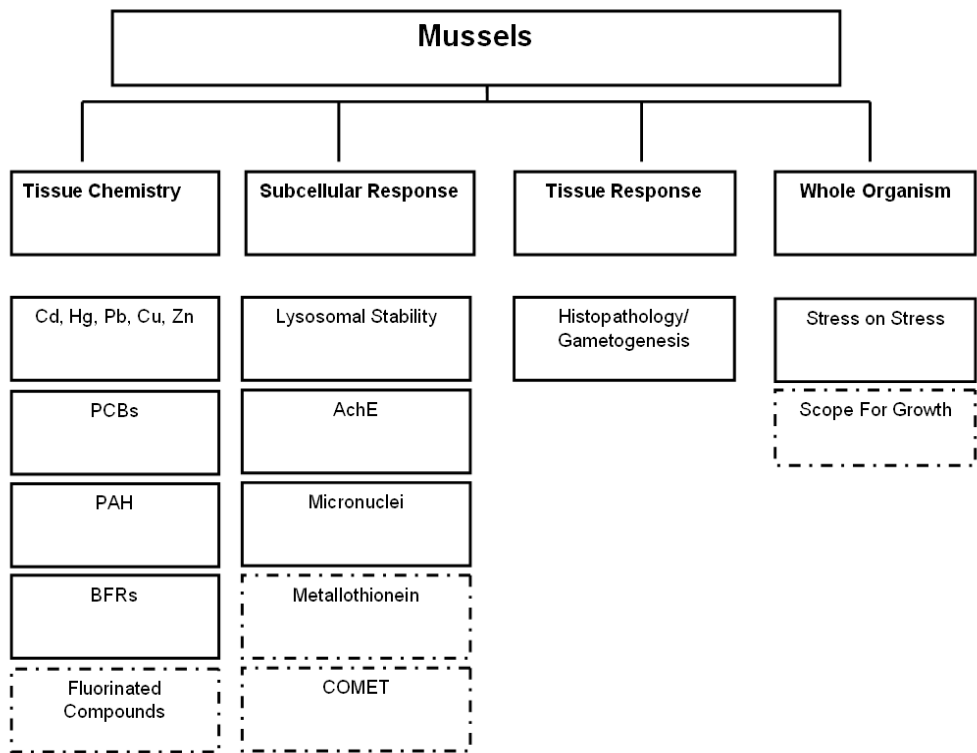

Figure 3: Methods included in the mussel component of the integrated monitoring framework; solid lines – core methods, broken lines – additional methods.
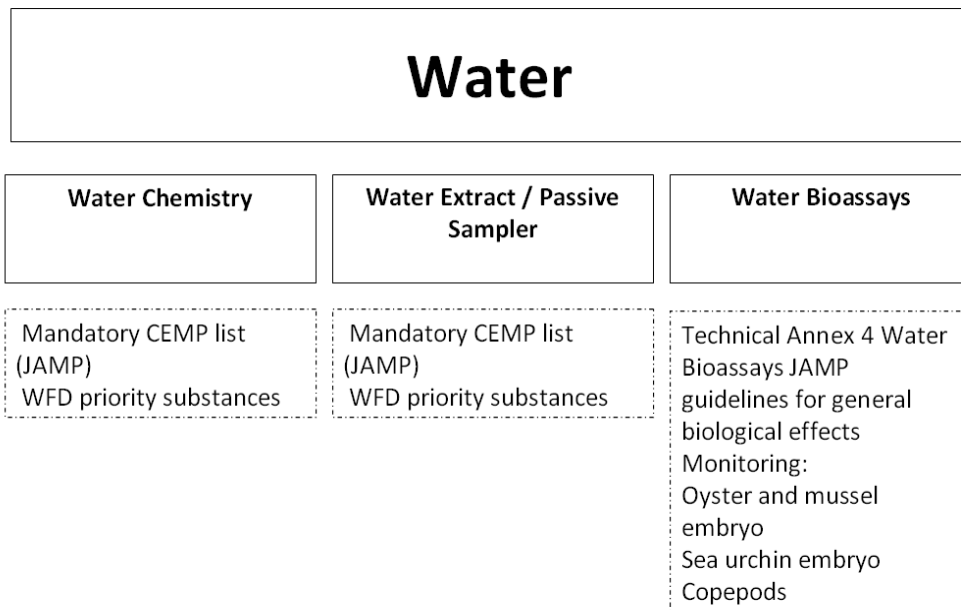
Figure 4: Methods included in the water component of the integrated monitoring framework; solid lines – core methods, broken lines – additional methods.
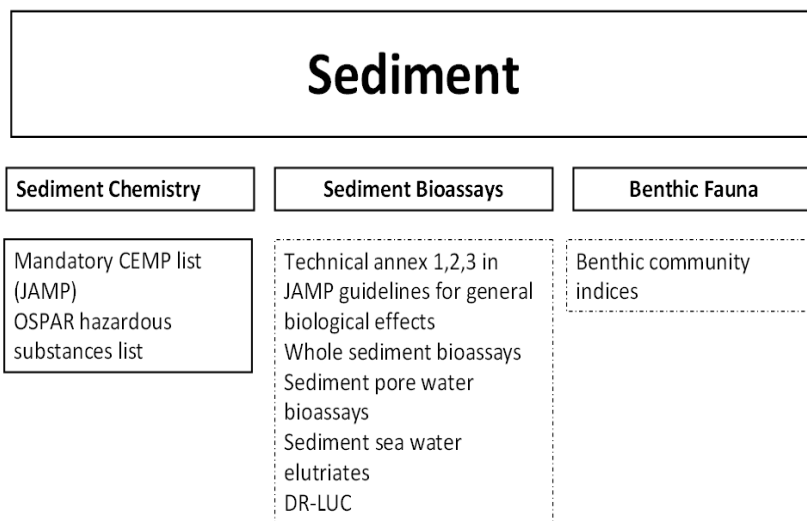

Figure 5: Methods included in the sediment component of the integrated monitoring framework; solid lines – core methods, broken lines – additional methods.
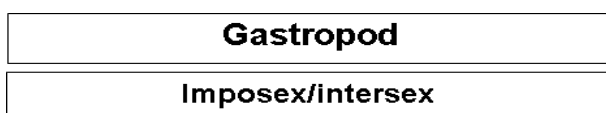

Figure 6: Methods included in the gastropod component of the integrated monitoring framework; solid lines – core methods, broken lines – additional methods.

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 the:

• 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 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 7 and 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 7: Sampling strategy for integrated fish monitoring.

Integrated site 'bivalves scheme'

Target species *Mytilus edulis* and *M. galloprovinialis*. Hybrid species present in certain locations therefore its is recommended speciation studies conducted at the outset. Other potential species include *Crassostrea gigas, Ostrea edulis*

Sediment & water taken from sites representative of the station

Mussel histopathology assessment
Sub sample 60 bivalves and follow ICES TIMES document for bivalve histopathology (in prep.)

Tissue contaminant analysis
A minimum of 60 bivalves in 3 batches of 20. Follow JAMP Guidelines for contaminants in biota (OSPAR 1999-2) and Fig. 4.1 to prioritise determinants

Sediment chemistry: (JAMP guidelines for monitoring contaminants in sediment OSPAR 2002-16).
Chemical determinants (as appropriate)
Physical characteristics (e.g. sediment PSA
Bioassays (e.g. CALUX, invertebrate embryo
Water Chemistry
Salinity, nutrients, oxygen
Chemical determinants (as appropriate)
Passive samplers

Sub sample 20 animals for biomarker analysis

Biomarkers: Enpoints driven by site specific factors and relevant integrated package(s)
Follow JAMP Guidelines for contaminant specific biological effects monitoring (OSPAR-2003-10) and Figure 4.1 to prioritise components

MUSSELS

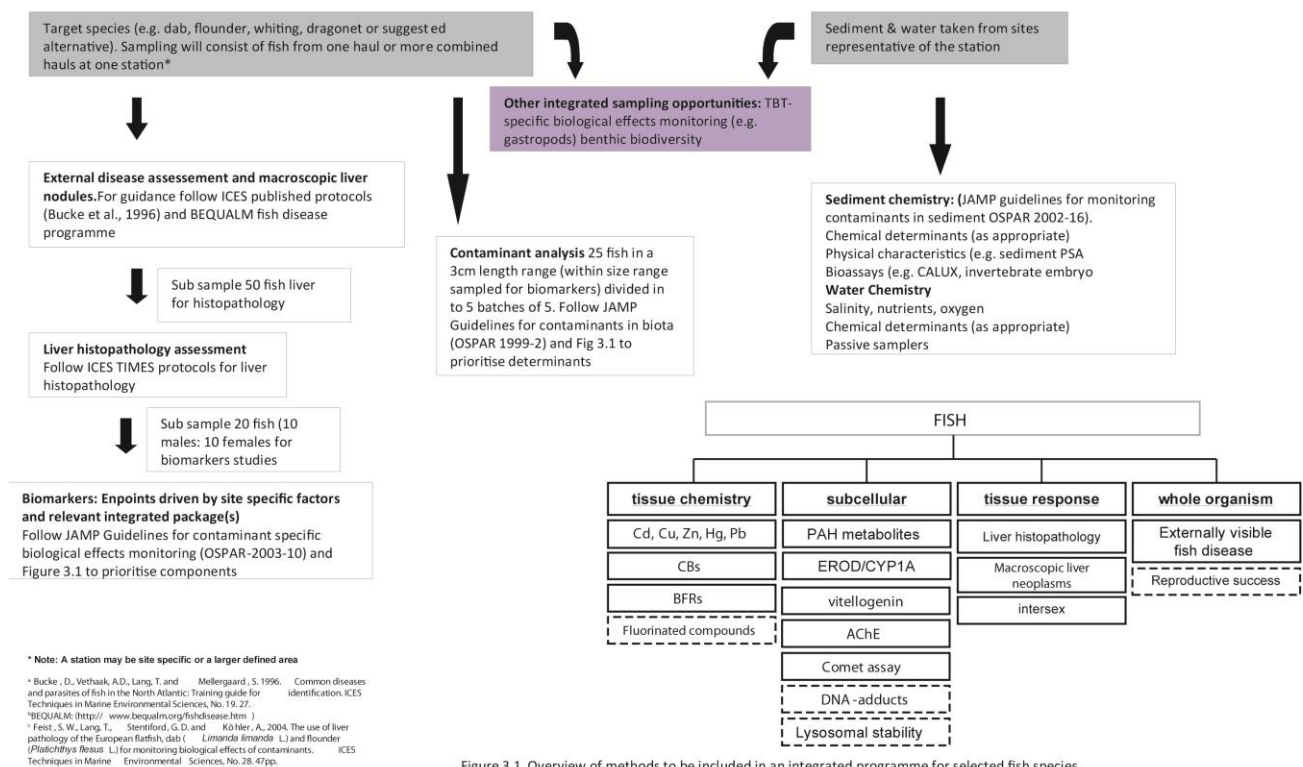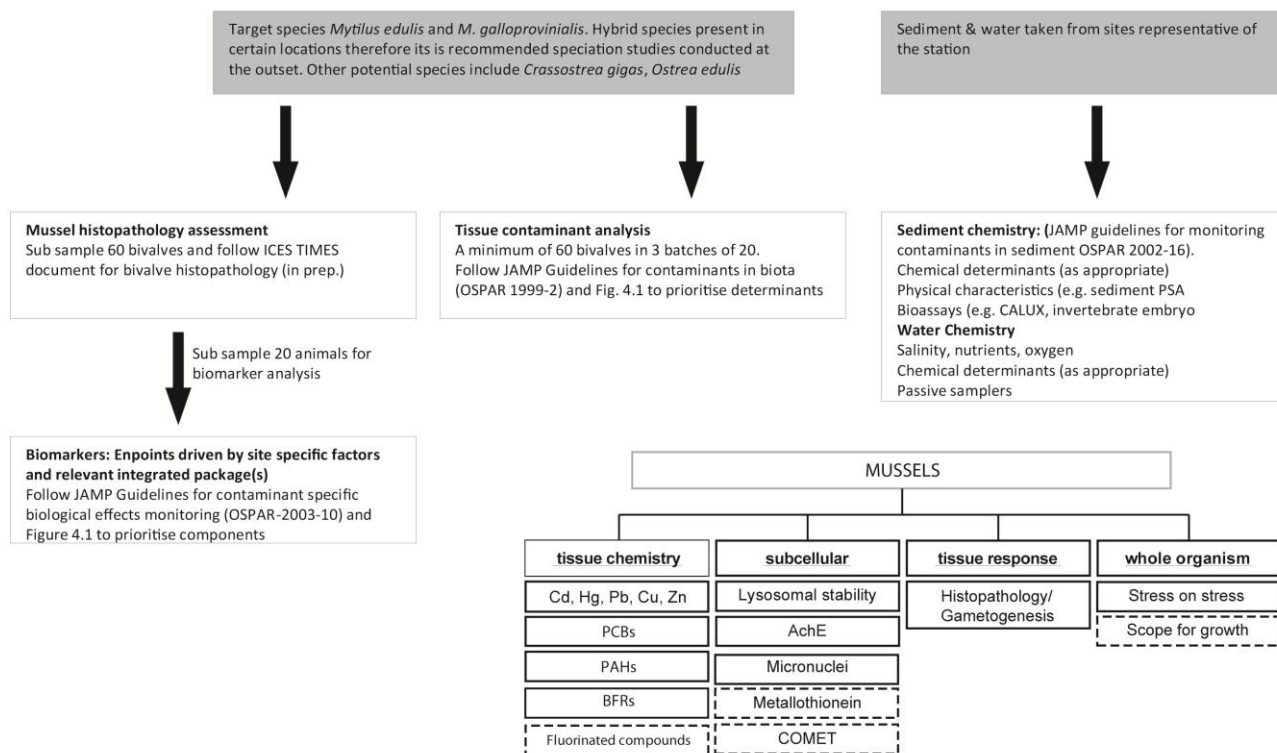| tissue chemistry	subcellular	tissue response	whole organism
Cd, Hg, Pb, Cu, Zn	Lysosomal stability	Histopathology/ Gametogenesis	Stress on stress
PCBs	AchE		Scope for growth
PAHs	Micronuclei		
BFRs	Metallothionein		
Fluorinated compounds	COMET		

Figure 4.1 Overview of methods to be included in an integrated programme for selected bivalve species. (Solid lines – core methods, broken lines – additional methods).

Figure 8: Sampling strategy for integrated bivalve monitoring

The integrated assessment

It is not sufficient simply to co-ordinate 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 standardise effect-variables, e.g. temperature or seasonal effects on biomarker responses. Similarly, normalisation procedures for the expression of contaminant concentrations in biota and sediment have been established, for example the use of defined bases (e.g. dry weight or lipid weight) for biota analyses, and normalization of sediment analyses to organic carbon or aluminium to minimize the influence of differences in bulk sediment properties. These are described in detail in the CEMP Monitoring Manual.

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 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 (BACs) and Environmental Assessment Criteria (EACs). 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 has been found to be applicable to all effects measurements. Assessment criteria analogous to

EACs, i.e. representing levels of response below which unacceptable responses at higher (e.g. organism or population) levels would not be expected, have been found to be applicable for some many 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 BACs and their biological analogues, and EACs 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 EACs and analogues represent similar levels of environmental risk. A table of the current assessment criteria for biological effects is presented as Appendix A to this JAMP Guideline. 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 9).
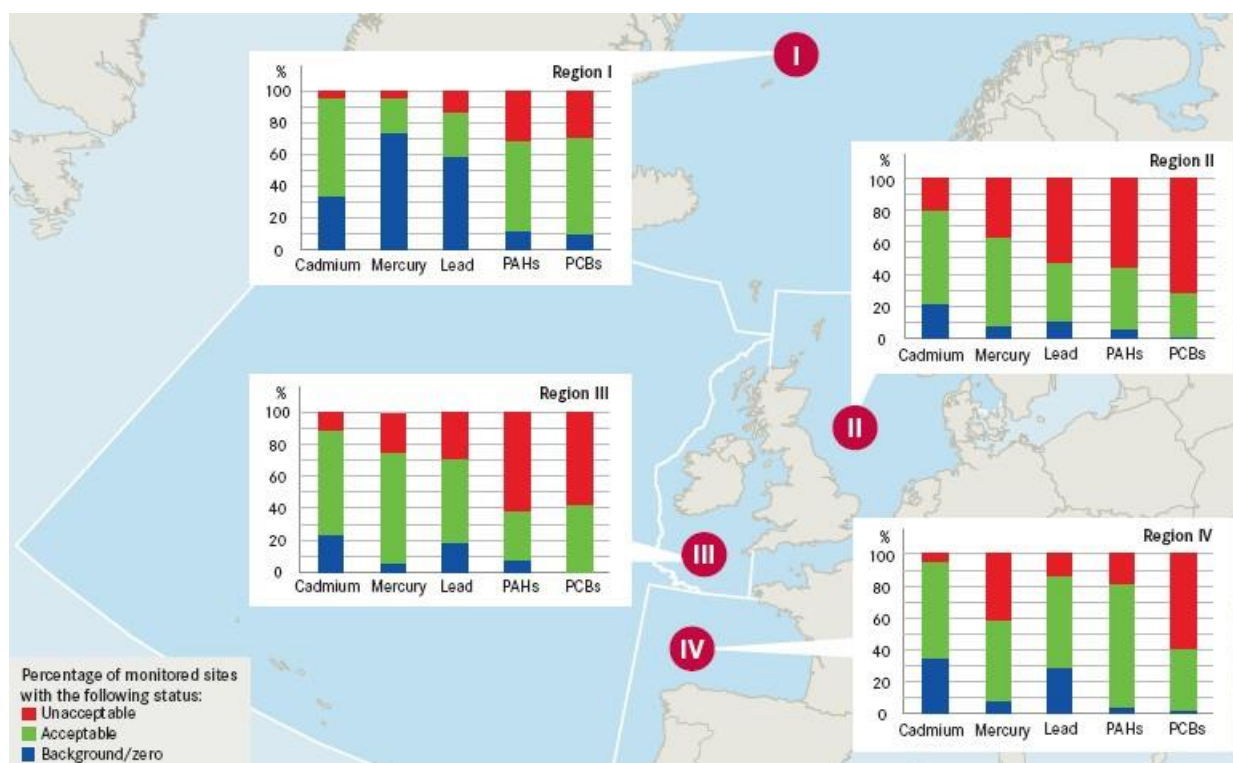

Figure 9: OSPAR regional level integration of the concentrations of priority contaminants in fish, shellfish and sediment, from the OSPAR QSR 2010, Hazardous Substances chapter.

A comparable approach can be used in the assessment of biological effects data, for which EACs and/or BACs have been developed. Furthermore, the coherence of assessment criteria across both chemistry 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 Appendix B to this JAMP Guideline.

Appendix A: Assessment Criteria for Biological Effects Measurements

Assessment criteria for biological effects measurements. Values are given for both background assessment levels (BAC) and environmental assessment criteria (EAC), as available.

Biological Effect	Applicable to:	BAC	EAC	Summary statistic for assessment
VTG in plasma; μg/ml	Cod	0.23		
	Flounder	0.13		
Reproductive success in fish Mean prevalence (%) of:	Eelpout, *Zoarces viviparous*			
	Malformed fry	1	2	
	Late dead fry	2	4	
	Early dead fry	2.5	5	
	Total abnormal fry	5	10	
EROD; pmol/mg protein pmol/min/ mg protein S9 * pmol/min/ mg microsomal protein	Dab (F)	178		
	Dab (M)	147		
	Dab (M/F)	680*		
	Flounder (M)	24		
	Plaice (M)	9.5		
	Cod (M/F)	145*		
	Plaice (M/F)	255*		
	Four spotted megrim (M/F)	13*		
	Dragonet (M/F)	202*		
	Red mullet (M)	208		
	Eelpout (F)	10		
PAHs Bile metabolites; [1] ng/ml; HPLC-F [2] pyrene-type μg/ml; synchronous scan fluorescence 341/383 nm [3] ng/g GC/MS * 1-OH pyrene ** 1-OH phenanthrene	Dab	16 [1] * 3.7 [1] ** 0.15 [2]	22 [2]	
	Cod	21 [1] * 2.7 [1] ** 1.1 [2]	483 [3] * 528 [3] ** 35 [2]	
	Flounder	16 [1] * 3.7 [1] ** 1.3 [2]	29 [2]	
	Haddock	13 [1] * 0.8 [1] ** 1.9 [2]	35 [2]	
	Eelpout	92 [1] * 7.9 [1] **		
	Herring	151 [1] * 4.5 [1] **		
DR-Luc; ng TEQ/kg dry wt, silica clean up	Sediment (extracts)	10	40	

DNA adducts; nm adducts mol DNA	Dab	1	4,0	
	Flounder	1	4,0	
	Long Rough Dab		4,0	
	Halibut		5,8	
	Herring and sprat		0,39	
	Cod	1.6	6,7	
	Haddock	3.0	6,7	
Bioassays; % mortality	Sediment, Corophium	20	60	
	Sediment, Arenicola	10	50	
	Water, copepod	10	50	
Bioassays; % abnormality	Water, oyster embryo	20	50	
	Water, mussel embryo	30	50	
	Water, sea urchin embryo	10	50	
Bioassay; % growth	Water, sea urchin embryo	30	50	
Lysosomal stability; minutes	Cytochemical; liver all species	20	10	
	Neutral Red Retention: all species	120	50	
Micronuclei; $^0/_{00}$ (frequency of micronucleated cells) [1] Gill cells [2] Haemocytes [3] Erythrocytes	*Mytilus edulis*	2.5 [1] 2.5 [2]		
	Mytilus galloprovincialis	3.9 [2]		
	Mytilus trossulus	4.5 [2]		
	Flounder	0.3 [3]		
	Dab	0.5 [3]		
	Eelpout	0.4 [3]		
	Cod	0.4 [3]		
	Red mullet	0.3 [3]		
Comet Assay; % DNA Tail	*Mytilus edulis*	10		
	Dab	5		
	Cod	5		
Stress on Stress; days	*Mytilus* sp.	10	5	
AChE activity; nmol.min^{-1} mg prot^{-1} [1] gills [2] muscle tissue [3] brain tissue * French Atlantic waters ** Portuguese Atlantic waters + French Mediterranean Waters ++ Spanish Mediterranean Waters +++ Baltic sea	*Mytilus edulis*	30 [1*]	21 [1*]	
		26 [1**]	19 [1**]	
	Mytilus galloprovincialis	29 [1+]	20 [1+]	
		15 [1++]	10 [1++]	
	Flounder	235 [2*]	165 [2*]	
	Dab	150 [2*]	105 [2*]	
	Red mullet	155 [2+] 75 [3++]	109 [2+] 52 [3++]	
	Eelpout	124 [2+++]	87 [2+++]	

Externally visible diseases*** Ep,Ly,Ul Ep,Ly,Ul Ac,Ep,Fi,Hp,Le,Ly,St,Ul,Xc Ac,Ep,Fi,Hp,Le,Ly,St,Ul,Xc Ac,Ep,Hp,Le,Ly,St,Ul,Xc Ac,Ep,Hp,Le,Ly,St,Ul,Xc Italics: ungraded, bold: graded NA: Not applied	Dab	Fish Disease Index (FDI): F: *1.32*, 0.216 M: *0.96*, 0.232 F: *1.03*, 0.349 M: *1.17*, 0.342 F: *1.09*, 0.414 M*: 1.18*, 0.398 M: males F: females	Fish Disease Index (FDI): F: *NA*, 54.0 M: *NA*, 47.7 F: *50.6*, 19.2 M: *38.8*, 16.1 F: *48.3*, 21.9 M: *35.2*, 16.5	
Liver histopathology-non specific	Dab	NA	Statistically significant increase in mean FDI level in the assessment period compared to a prior observation period *or* Statistically significant upward trend in mean FDI level in the assessment period	
Liver histopathology-contaminant-specific	Dab	Mean FDI <2	Mean FDI ≥ 2 A value of FDI = 2 is, e.g., reached if the prevalence of liver tumours is 2% (e.g., one specimen out of a sample of 50 specimens is affected by a liver tumour). Levels of FDI ≥ 2 can be reached if more fish are affected or if combinations of other toxicopathic lesions occur.	
Macroscopic liver neoplasms	Dab	Mean FDI <2	Mean FDI ≥ 2 A value of FDI = 2 is reached if the prevalence of	

			liver tumours (benign or malignant) is 2% (e.g., one specimen out of a sample of 50 specimens is affected by a liver tumour). If more fish are affected, the value is FDI > 2.	
Intersex in fish; % prevalence	Dab Flounder Cod Red mullet Eelpout	5		
Scope for growth Joules/hr/g dry wt.	Mussel (*Mytilus* sp.) (provisional, further validation required)	15	5	
Hepatic metallothionein ìg/g (w.w.) [1] Whole animal [2] Digestive gland [3] Gills * Differential pulse polarography	*Mussel edulis*	0.6 [1*] 2.0 [2*] 0.6 [3*]		
	Mytilus galloprovincialis	2.0 [1*] 3.9 [2*] 0.6 [3*]		
Histopathology in mussels	VVbas: Cell type composition of digestive gland epithelium; $\mu m^3/\mu m^3$ *(quantitative)*	0.12	0.18	
	MLR/MET: Digestive tubule epithelial atrophy and thinning; $\mu m/\mu m$ *(quantitative)*	0.7	1.6	
	VVLYS & Lysosomal enlargement; $\mu m^3/\mu m^3$ *(quantitative)*	VvLYS 0.0002	V>0.0004	
	S/VLYS: $\mu m^2/\mu m^3$	4		
	Digestive tubule epithelial atrophy and thinning *(semi-quantitative)*	STAGE ≤1	STAGE 4	
	Inflammation *(semi-quantitative)*	STAGE ≤1	STAGE 3	
Imposex/intersex in snails VDSI	***Nucella lapillus***	**<0.3**	**<2**	VDSI

***: Assessment criteria for the assessment of the Fish Disease Index (FDI) for externally visible diseases in common dab (*Limanda limanda*). Abbreviations used: Ac, *Acanthochondria cornuta;* Ep, Epidermal hyperplasia/papilloma; Fi, Acute/healing fin rot/erosion; Hp, Hyperpigmentation; Le, *Lepeophtheirus sp.*; Ly, Lymphocystis; St, *Stephanostomum baccatum*; Ul, Acute/healing skin ulcerations; Xc, X-cell gill disease

Full details of the assessment criteria and how they were derived can be found in the SGIMC 2010 and SGIMC 2011 and WKIMON 2009 reports on the ICES website and in the OSPAR Background Documents for individual biological effects methods.

Data for biomarkers in some northern fish species have been obtained through the IRIS BioSea IiP programme (funded by Total E&P Norge & EniNorge) and the Biomarker Bridges programme (funded by Research Council of Norway) and have been used to develop EAC and BAC values for Arctic fish.

Appendix B: Integrated Assessment Framework for Contaminants and Biological Effects

The development of a framework with which to assess contaminant and biological effects data together is essential for the delivery of integrated monitoring and assessment. A multi-step process is proposed which follows on from experience of the assessment of contaminants data for sediment, fish and shellfish in OSPAR contexts. The process is informed initially by the individual assessment of determinands (contaminants or effects) in specific matrices at individual sites against the defined assessment criteria (BAC and EAC). Such assessment criteria for biological effects have been developed over recent years and are included in OSPAR Background Documents, and for contaminants have been used by OSPAR groups, for example in the QSR 2010. Initial comparisons determine whether the determinand and site combinations are <BAC (blue), between the BAC and EAC (green) or >EAC (red). This summarised indicator of status for each determinand can then be integrated over a number of levels: matrix (sediment, water, fish, mussel, gastropod), site and region and expressed with varying levels of aggregation to graphically represent the proportion of different types of determinands (or for each determinand, sites within a region) exceeding either level of assessment criteria.

Such an approach has several advantages. The integration of data can be simply performed on multiple levels depending on the type of assessment required and the monitoring data available. The representation of the assessment maintains all the supporting information and it is easy to identify the causative determinands that may be responsible for exceeding EAC levels. In addition, any stage of the assessment can be readily unpacked to a previous stage to identify either contaminant or effects measurements of potential concern or sites contributing to poor regional assessments.

This approach builds on the OSPAR MON regional assessment tool developed for contaminants. The development of BAC and EAC equivalent assessment criteria for biological effects, which represent the same degree of environmental risk as indicated by BACs and EACs for contaminants, allows the representation of these monitoring data alongside contaminant data using the same graphical representation approach. The inclusion of biological effects data to the system adds considerable value to the interpretation of assessments. Where sufficient effects monitoring data are available, confidence can be gained that contaminants are not having significant effects even where contaminant monitoring data are lacking. In instances where contaminant concentrations in water/sediment are >EAC, a lack of EAC threshold breach in appropriate effects data can provide some confidence that contaminant concentrations are not giving rise to pollution effects (due for example to lack of availability to marine biota). Similarly, the inclusion of effects data in the assessment framework can indicate instances where contaminants are having significant effects on biota, but have not been detected or covered in contaminant-specific chemical monitoring work.

Application to determination of GES for Descriptor 8 of MSFD

The assessment framework described below provides an appropriate tool for assessment of environmental monitoring data to determine whether Good Environmental Status is being achieved for Descriptor 8 of MSFD (concentrations of contaminants are at levels not giving rise to pollution effects). Determinands with EAC or EAC equivalent assessment criteria provide appropriate indicators with quantitative targets. The assessment of contaminant and effects monitoring data against these EAC-level assessment criteria provides information both on concentrations of contaminants likely to give rise to effects and the presence/absence of significant effects in marine biota.

Due to the relatively large number of determinands monitored under the integrated approach, it is inappropriate to adopt an approach whereby EAC level failure of a single determinand results in failure of GES for a site or region. A more appropriate approach would involve the setting of a threshold (%) of proportion of determinands that should be <EAC to achieve GES. Such an approach would avoid the failure of sites or regions due to occasional outlying, erroneous results for particular determinands. The setting of an appropriate threshold for overall regional assessment for MSFD will require consideration and revision in

the light of testing the framework described here with real monitoring data, however an initial threshold of 95% <EAC (to ensure that the vast majority but not all contaminants/effects measurements should be <EAC) is proposed here for the purposes of testing the system.

Example application of the integrated assessment framework

In order to best demonstrate how monitoring data (assessed against BAC and EAC) can be integrated for matrices, sites and regions and ultimately provide an assessment that could be useful for determination of GES for Descriptor 8, a worked example is provided below following a five step process.

Step 1 Assessment of monitoring data by matrix against BAC and EAC

All determinands available for a specific site assessment are compiled with results presented by monitoring matrix and expressed as a colour depending on whether the value exceeds BAC or EAC. In the example provided below, determinands and their status are provided for illustrative purposes only, to show how subsequent integration can be performed. A red classification indicates that the EAC is exceeded, blue indicates compliance with the BAC, while green indicates concentrations or levels of effects are between the BAC and EAC.

Step 2 Integration of determinands by matrix for a given site

For each of the five matrices, the results of the individual determinand assessments are aggregated into categories: contaminants, exposure indicators, effects indicators and for sediment/water matrices also passive sampling and bioassay categories. It is necessary to separate the biological effects measurements into different categories depending on whether an EAC-equivalent assessment criterion (AC) has been set or not. Otherwise aggregated information on the proportion of determinands exceeding the separate AC will be incorrect. For simplicity, these categories have been termed 'exposure indicators' (where an EAC has not been set) and 'effects indicators' where an EAC (equivalent to significant pollution effect) has been set for the measurement. On subsequent aggregation / integration of these indicators across matrices for a specific site, bioassays are considered 'effects indicators' as EAC are available. It should be possible to include data from passive sampling in both the water and sediment schemes when assessment criteria have become available. They are nominally included in the example here to show how they could be

included.

The integration by matrix and category of determinand can be expressed by tri-coloured bars showing the proportions of determinands that exceed the BAC and EAC as shown below. Note that for mussels in this instance, no exposure indicators are used, since all the biological effects measurements have EAC available.
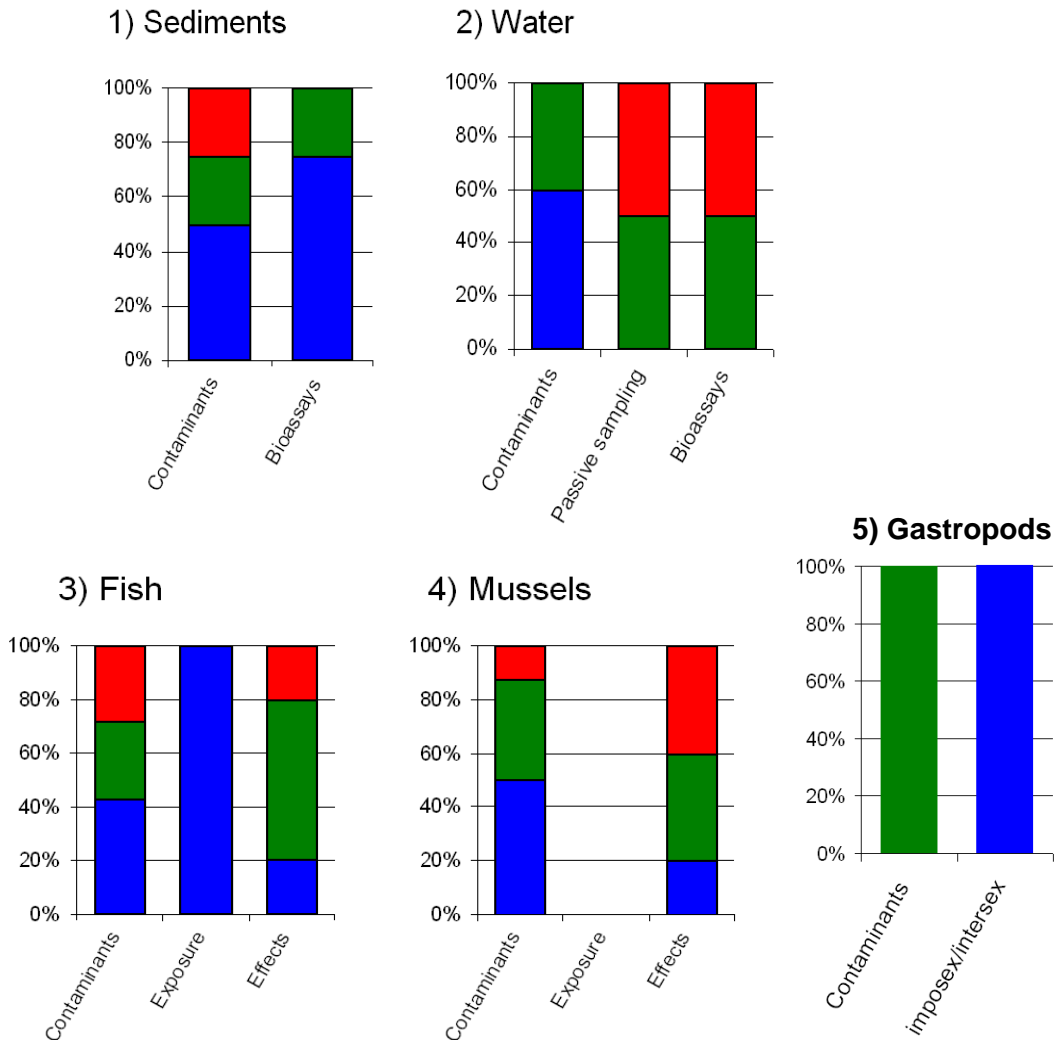
Step 3 Integration of matrices for a site assessment

In order to express the results of assessment for a particular site simply, information can be aggregated across matrices and expressed by determinand category as shown below. In order to achieve this, results from passive sampling from sediment and water categories could be integrated into the contaminant indicator graphic and bioassays and gastropod intersex/intersex integrated into 'effects indicators'. Thus the outcome of assessment of all determinands from all matrices can be expressed for a whole site. For some assessments, this will be the highest level of aggregation required. However, for assessments covering larger geographical areas (sub-regional, regional, national, regional seas for MSFD, etc) where assessments need to be undertaken across multiple sites, a further level of integration is required (steps 4 and 5).

For transparency, each determinand grouping is labelled with the matrices from which it is comprised. Thus it can quickly be determined whether the site assessment is comprised of all or just a sub-set of the monitoring matrices. In the example below, all five matrices have been used to determine the overall site assessment, however only for fish (matrix 3) were there any effects measurements that did not have available EAC for assessment. Therefore the exposure indicators graphic is labelled to show that only matrix 3 contributed to the site assessment.
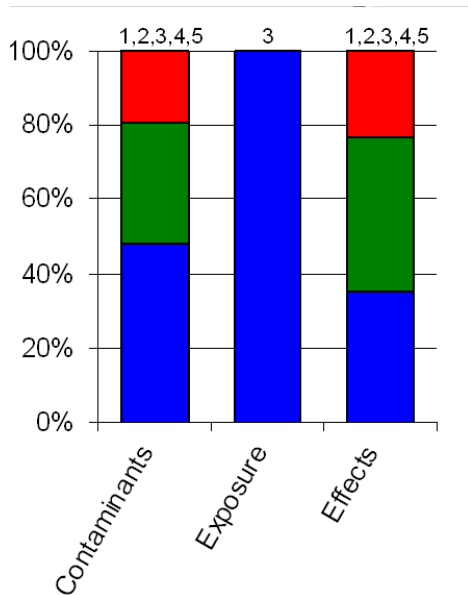
Step 4 Regional assessment across multiple sites

This can be done at multiple levels (aggregation of data at the sub-regional, regional and national levels) in different ways to express both the overall assessment of proportion of determinands (across all matrices) exceeding both assessment thresholds (BAC/EAC) (approach A) and by determinand for the region showing the proportion of sites assessed in the region that exceed the thresholds (approach B). Both approaches show the overall proportion of determinand/site incidences of threshold exceedance. However approach A shows most clearly which determinands are responsible for any EAC exceedance, while approach B shows a more aggregated, summarised representation of the same information by determinand category. Both can be constructed directly from the output of Step 1.
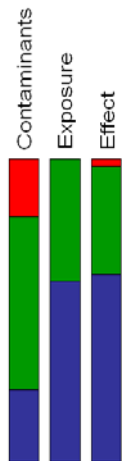
4A Regional assessment of sites by determinand

This shows a graphical representation of the proportion of sites falling into each status class for each determinand across all relevant matrices (many determinands are only relevant to one or some of the matrices.
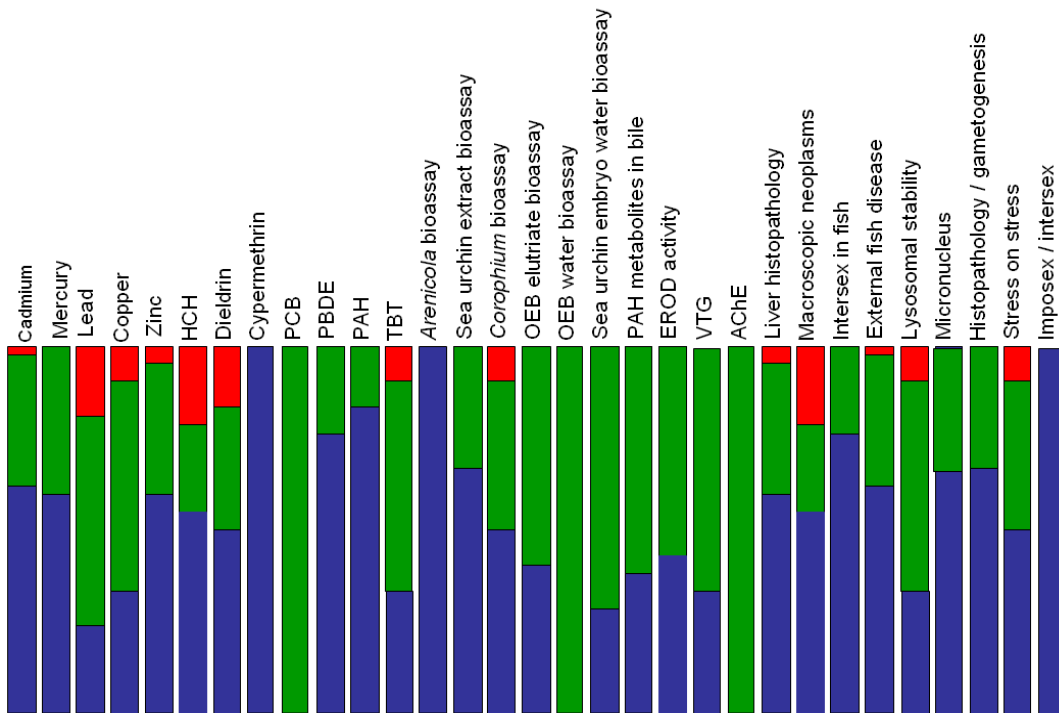
4B Regional assessment of sites by determinand category

The above regional assessment can be summarised by determinand category as was demonstrated in step 3 for the site assessment and shown below.

Step 5 Overall assessment

The assessment by region can be aggregated further into a single schematic showing the proportion all determinands across all sites that exceed BAC and EAC. This can be used for the purposes of an overall assessment and it is proposed that a simple threshold figure (e.g. 95%) <EAC is used to determine whether Good Environmental Status for Descriptor 8 is met in this assessment. The overall assessment can be easily unpacked through the steps above to determine which sites and determinands (effects types or contaminants) are contributing to, for example, the proportion of red (greater than EAC) data, and thereby potentially leading to failure to achieve GES for a region.
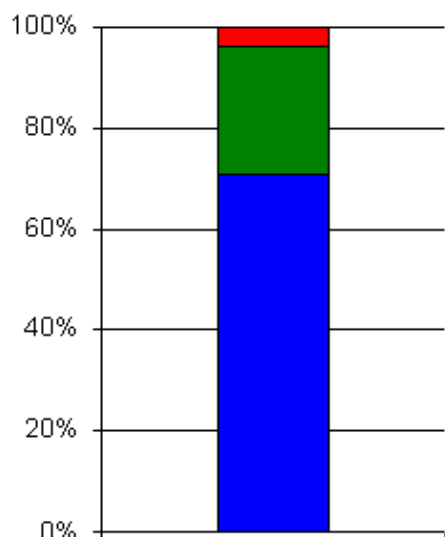
Conclusion

An assessment framework has been presented which integrates across contaminant and biological effects monitoring data and allows assessments to be made across matrices, sites and regions. It is simple and transparent and allows for multiple levels of aggregation for different assessment requirements. Such an approach has been used with success for a wide range of contaminants data in the OSPAR QSR 2010, and can be extended to include other chemical and biological effects measurements through the application of a coherent set of assessment criteria. This approach can provide a suitable approach for the assessment of GES for Descriptor 8 of the MSFD. Current research projects and the initial assessment for MSFD due in 2012 provide opportunities to gain experience in its use.