Marine Pollution Bulletin 62 (2011) 651–655

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

Editorial

Marine science and management means tackling exogenic unmanaged pressures and endogenic managed pressures – A numbered guide

1. The Ecosystem Approach

There is only ONE big idea in the management of marine areas, including coasts and estuaries – that we have to protect and maintain the natural ecological characteristics while at the same time deliver the services and benefits required by society. This can be regarded as The Ecosystem Approach *sensu stricto* (as defined by the UN Convention on Biological Diversity) which requires that marine scientists and managers have to take a multidisciplinary approach covering natural and social sciences. This article aims to guide readers through the increasingly complex debate.

There are TWO questions relevant to our science for management – '*what if*?' and '*so what*?' – the first refers to our ability to predict a change if we know the stressors and the underlying environmental characteristics; for example, what will happen to the system if sea level rises or contaminants are discharged into the sea. The second question concerns our ability to present our findings to the policy makers – as researchers we may often be preoccupied with *OUTPUTS* (number of papers, number of citations, number of students, etc.) whereas we should be preoccupied with *OUTCOMES* – i.e. did the research and monitoring do any good/achieve anything for society. Furthermore, our science should be separated into TWO categories – the '*nice-to-know*' and the '*need-to-know*' – of course as scientists we will have the curiosity to try to understand everything about the system but if we wish marine users to fund our research we will have to be honest and limit ourselves to those aspects needed to address applied questions. Accordingly our science has to fulfil at least TWO if not THREE requirements: to increasing knowledge, wealth creation and the quality of life.

The pressures likely to produce change in the marine environment, and for which we need good science, can be separated into TWO sets: those emanating from within the system under study (a sea area, an estuary) and which we can control and those emanating from outside the system (globally or from the catchment) which are not under our control when managing a particular system. Each of these requires an ability to detect, understand and manage change in the marine environment – therefore change is simply caused by these TWO: *endogenic managed pressures* and *exogenic unmanaged pressures*. In the case of the former, management has to respond to the causes and consequences of the pressures whereas it only responds to the consequences of the exogenic unmanaged pressures. For example, endogenic managed pressures will include the effects of a conventional power plant in an estuary or an offshore windfarm and we can control, through design and licensing, the causes and the consequences of those pressures. In the case of relative sea-level rise through global warming or isostatic rebound, however, we do not control the causes of this when managing an area but we do have to respond to the consequences, e.g. by building higher dykes or creating more wetland to absorb rising water levels, hence this is an exogenic unmanaged pressure. In contrast, nutrient inputs from agriculture may be an exogenic unmanaged pressure when we are attempting to manage an estuary but they become an endogenic managed pressure when we are managing the whole catchment from freshwaters to the sea.

The endogenic managed pressures can in turn be divided simply into TWO types – those things which we put into the system and those which we take out. For example, pollutants and infrastructure such as buildings and bridges go into the system (think of a bridge as a big particle!), and we take out physical resources such as aggregates and biological resources such as fisheries. These aspects, however, merge when we remove marine space by putting in land claim for urban expansion. Most importantly, this separation of the pressures affecting marine systems allows us to know and appreciate for human activities what, why and how we can and cannot manage.

We have to ensure that we have robust and defendable science to assess marine health and underpin marine management, hence be aware of the THREE aspects of science methodology – that we should define our Aims, as the big idea in the science, list our Objectives, as what we need to do to reach our Aims, and give our Hypotheses, as testable and scientifically rigorous questions. Following this, we can suggest there are THREE types of significance in our findings – firstly, and most easy to determine as long as we have sufficient data, is statistical significance. Secondly, and perhaps more importantly, is ecological or environmental significance, and thirdly we have the social significance of any change that we detect. For example, detecting the loss of a species amongst hundreds would be impossible statistically without a large and powerful statistical sampling design but that lost species could be ecologically relevant. Despite this, we might not be able to statistically or ecologically detect a change because of noise (inherent variability) in the system but if society thinks a change has occurred then it should have the highest significance (see Gray and Elliott, 2009). If society thinks there is a problem then by definition there is one even if science cannot detect it. Consequently, The Ecosystem Approach relies on good and proportionate (*fit-for-purpose*) science to provide an ecosystem health assessment (or monitoring) programme consisting of FOUR elements – (i) an analysis of main processes and structural characteristics of ecosystem; (ii) an identification of known or potential stressors; (iii) the development of hypotheses about how those stressors may affect each ecosystem; and (iv) the

doi:10.1016/j.marpolbul.2010.11.033

identification of measures of environmental quality and ecosystem health to test hypotheses.

In managing the environment we can no longer just be concerned with single sciences – for example, we can take ideas from the business literature which suggests that the *environment* of an *organisation* is summarised by the FOUR categories of *PEST* (***P**olitical*, ***E**conomical*, ***S**ocial* and ***T**echnological* constraints) (Palmer and Hartley, 2008). This has been expanded to the *PESTLE* analysis which includes the FIFTH, ***Legal*** aspect. We can then juxtapose this to reinforce the idea that the *organisation* and management of an *environment* is subjected to the same constraints. This recognises that while as natural scientists we may want to emphasise the natural science, we have to be aware of (and work with) wider disciplines. These features are important in not only preventing the deterioration in ecosystem health but also in restoring and allowing a degraded ecosystem to recover (Elliott et al., 2007). The FOUR aspects of *PEST* and the FIVE of *PESTLE* were independently suggested and expanded in Elliott (2002) and Elliott and Cutts (2004) to emphasise that successful and sustainable management requires a set of SIX actions (the *6-tenets*) later expanded further as the SEVEN aspects called the *7-tenets* (see Box 1) (e.g. see also Mee et al., 2008).

By combining ideas on our needs for the marine systems, the consequences of those needs and the means of tackling any problems resulting from those needs and consequences, the FIVE elements of DPSIR framework give us a valuable philosophy for tackling and communicating our methods of marine management (McLusky and Elliott, 2004; Atkins et al., 2011). This cyclical framework considers the **D**riving forces (human activities and economic sectors responsible for the pressures); **P**ressures (particular stressors on the environment); **S**tate changes (in the characteristics and conditions of the natural environment); **I**mpacts (changes in the human system and the way in which we use the marine area) and **R**esponses (the creation of different policy options and economic instruments to overcome the state changes and impacts). To this we may also add **R**ecovery (a reduction in the state changes as the result of these actions) this giving a SIXTH element in the DPSIRR framework. We recently took the view that for this approach to be valid, it requires a set of FIFTEEN DPSIR-ES&SB (Ecosystem Services and Societal Benefits) postulates (see Atkins et al., 2011).

Box 1
7-Tenets of successful and sustainable environmental management (expanded from Elliott and Cutts, 2004; Mee et al., 2008).

Environmentally/ ecologically sustainable	That the measures will ensure that the ecosystem features and functioning and the fundamental and final ecosystem services are safeguarded
Technologically feasible	That the methods, techniques and equipment for ecosystem protection are available
Economically viable	That a cost-benefit assessment of the environmental management indicates viability and sustainability
Socially desirable/ tolerable	That the environmental management measures are as required or at least are understood and tolerated by society as being required; that societal benefits are delivered
Legally permissible	That there are regional, national or international agreements and/or statutes which will enable and/or force the management measures to be performed
Administratively achievable	That the statutory bodies such as governmental departments, environmental protection and conservation bodies are in place and functioning to enable successful and sustainable management
Politically expedient	That the management approaches and philosophies are consistent with the prevailing political climate and have the support of political leaders

2. Ecosystem management and indicators of health

Business management also takes the view that you cannot management anything unless you can measure it and that by setting quantitative objectives, you will know when your management has achieved something – the management of the environment is exactly the same and so we need *indicators* of health which needs to have the FIVE *SMART* characteristics: **S**pecific, **M**easurable, **A**chievable/**A**ppropriate/**A**ttainable, **R**ealistic/**R**esults focussed/ **R**elevant, **T**ime-bounded/**T**imely otherwise they cannot be used in measuring, monitoring and managing change. We need this type of indicators for the P, S and I parts of the DPSIR approach and, increasingly, we need environmental indicators which have THREE basic functions (Aubry and Elliott, 2006): *To simplify:* amongst the diverse components of an ecosystem, a few indicators are needed according to their perceived relevance for characterising the overall state of the ecosystem. *To quantify:* the indicator is compared with reference values considered to be characteristic of either 'pristine' or heavily impacted ecosystems to determine changes from reference or expected conditions (e.g. Hering et al., 2010). *To communicate:* with stakeholders and policy makers, by promoting information exchange and comparison of spatial and temporal patterns. The monitoring parameters and the indicators derived from them and adopted then have to cover EIGHTEEN characteristics in order to provide the information relevant to successful marine management (Box 2).

Marine management has the central aim of protecting the health of the system, whether that health relates to natural functioning or the wellbeing of Man. Therefore it is helpful to think of health as defined under FOUR categories: medical, biological, societal and economic, each of which requires protecting. If our main aim in marine management is to protect health then, as far as the biology is concerned, we can consider health at each of SIX different levels of biological organisation and judge changes in these against uncertainty and variability in the system (McLusky and Elliott, 2004; Borja et al., 2010a):

- Health of the cell – as functioning, at a molecular/biochemical level, maintenance of cellular processes; as structure as the integrity of the organelles.
- Health at the tissue level – its performance and the ability to absorb stress to cellular processes.
- Health of the individual – functioning in terms of physiology, reflecting impaired performance; structural health, e.g. anatomy and morphology in which changes will impair performance and fitness to survive.
- Health of the population as the sustainability and maintenance of the population.
- Health of the community as ensuring an appropriate assemblage but ensuring functioning of the community (to allow the maintenance of the relationships between different species, as shown by predator–prey relationships, maintenance of commensals, etc.).
- Health of the ecosystem – as ensuring protection against adverse symptoms of ecosystem pathology (see below), to allow a detection of things going wrong as well as the ability to withstand change.

In essence, the detection of change in health and consequent aim by management is to ensure those levels are *fit-for-survival*. We take the precautionary approach which assumes that stress will be transferred through the natural system but in reality the system can absorb stress, termed *environmental homeostasis* (Elliott and Quintino, 2007). As we go through each of these SIX levels, the complexity increases, it is more difficult to detect a response, a

Box 2
The required properties of indicators and monitoring parameters for successful marine management (developed from Holl and Cairns, 2002; McLusky and Elliott, 2004; Gray and Elliott, 2009).

Property	Explanation
Anticipatory	Sufficient to allow the defence of the precautionary principle, as an early warning of change, capable of indicating deviation from that expected before irreversible damage occurs
Biologically important	Focuses on species, biotopes, communities, etc. important in maintaining a fully functioning ecological community
Broadly applicable and integrative over space and time	Usable at many sites and over different time periods to give an holistic assessment which provides and summarises information from many environmental and biotic aspects; to allow comparisons with previous data to estimate variability and to define trends and breaches with guidelines or standards
Concrete/results focussed	We require indicators for directly observable and measurable properties rather than those which can only be estimated indirectly; concrete indicators are more readily interpretable by diverse stakeholders who contribute to management decision-making.
Continuity over time and space	Capable of being measured over appropriate ecological and human time and space scales to show recovery and restoration.
Cost-effective	Indicators and measurements should be cost-effective (financially non-prohibitive) given limited monitoring resources, i.e. with an ease/economy of monitoring. Monitoring should provide the greatest and quickest benefits to scientific understanding and interpretation, to society and sustainable development. This should produce an optimum and defensible sampling strategy and the most information possible.
Grounded in theory/relevant and appropriate	Indicators should reflect features of ecosystems and human impacts that are relevant to achieving operational objectives; they should be scientifically sound and defensible and based on well-defined and validated theory. They should be relevant and appropriate to management initiatives and understood by managers.
Interpretable	Indicators should reflect the concerns of, and be understood by stakeholders. Their understanding should be easy and equate to their technical meanings, especially for non-scientists and other users; some should have a general applicability and be capable of distinguishing acceptable from unacceptable conditions in a scientifically and legally defensive way
Low redundancy	The indicators and monitoring should provide unique information compared to other measures
Measurable	Indicators should be easily measurable in practice using existing instruments, monitoring programmes and analytical tools available in the relevant areas, to the required accuracy and precision, and on the time-scales needed to support management. They should have minimum or known bias (error), and the desired signal should be distinguishable from noise or at least the noise (inherent variability in the data) should be quantified and explained, i.e. have a high signal to noise ratio. They need to be capable of being updated regularly, being operationally defined and measured, with accepted methods and Analytical/Quality Control/Quality Assurance and with defined detection limits
Non-destructive	Methods used should cause minimal and acceptable damage to the ecosystem and should be legally permissible
Realistic/attainable (achievable)	Indicators should be realistic in their structure and measurement and should provide information on a 'need-to-know' basis rather than a 'nice-to-know' basis. They should be attainable (achievable) within the management framework
Responsive feedback to management	Indicators should be responsive to effective management action and regulation and provide rapid and reliable feedback on the findings. Such feedback loops should be determined and defined prior to using the indicator.
Sensitive to a known stressor or stressors	The trends in the indicators should be sensitive to changes in the ecosystem properties or impacts, to a stressor or stressors which the indicator is intended to measure and also sensitive to a manageable human activity; they should be based on an underlying conceptual model, without an all-or-none response to extreme or natural variability, hence potential for use in a diagnostic capacity
Socially relevant	Understandable to stakeholders and the wider society or at least predictive of, or a surrogate for, a change important to society
Specific	Indicators should respond to the properties they are intended to measure rather than to other factors, and/or it should be possible to disentangle the effects of other factors from the observed response (hence having a high reliability/specificity of response and relevance to the endpoint)
Time-bounded	The date of attaining a threshold/standard should be indicated in advance. They are likely to be based on existing time-series data to help set objectives and also based on readily available data and those showing temporal trends
Timely	The indicators should be appropriate to management decisions relating to human activities and therefore they should be linked to that activity; thus providing real-time information for feedback into management giving remedial action to prevent further deterioration and to indicate the results of or need for any change in strategy

greater level of stress is needed to create a response and the response times increase. We assume, through the precautionary principle, that the effects at one biological level, e.g. cell, will be transmitted to another, e.g. population if the stress is not removed although systems have an inherent ability to reduce or remove the effects of stress (individual or environmental homeostasis) (Elliott and Quintino, 2007).

We can then adopt the language of health for wider environmental change and the means of addressing problems: hence we can regard adverse change as SEVEN symptoms of marine ecosystem pathology for wider use and identify a few indicators of change for a wide and general application across human-derived problems (Box 3). It is interesting that the determination of unhealthy ecosystems is analogous with medicine which uses diagnosis, prognosis, treatment and prevention which can be directly translated to environmental systems in which we carry out FIVE stages: of assessment, prediction, remediation/creation/restoration, recovery and prevention. We manage in order to deliver a healthy system which we can define as a system *fit-for-purpose* – i.e. the big idea fulfilling ecology and social-economy. Taking ideas from the human, medical system, we can show the similarities in approach whereby we make a diagnosis of change or a prognosis of future change – if the system becomes or is likely to become degraded then we bring in treatment or prevention of change, we may even have to restore the system to health by various measures (Elliott et al., 2007; Borja et al., 2010a). This may rely on an understanding of what is good, hence including societal views as well as ecological views (see Mee et al., 2008). Furthermore, Odum (1985) described stress in the system as a set of EIGHTEEN adverse characteristics and so a healthy system by definition should be the converse of those characteristics (see Elliott and Quintino, 2007).

3. Monitoring to management

The management of an ecosystem and an understanding of the way in which it changes under human influences requires a large amount of data, information and knowledge about the structure and functioning of the system; this can be described as NINE stages which then allows management decisions to be made (Box 4; McLusky and Elliott, 2004). Such a framework, which is sufficiently generic to cover all human activities, will encourage managers to obtain the appropriate information for management. By accumu-

Box 3
SEVEN indicators of ecosystem pathology (modified from Harding, 1992).

Primary production, i.e. the organic production of a system which may be overstimulated through increased sewage inputs
Nutrients (fate and effects), i.e. the increase in concentration as the result of increased diffuse and point source discharges but also as the cause of eutrophication
Species diversity (abiotic areas), i.e. the removal of species which are intolerant of change under stressful conditions and the encouragement of tolerant species
Community instability (biotic composition), i.e. the increase in biological turnover due to the dynamics of stress-tolerant species
Size and biomass spectrum, i.e. the tendency towards smaller, r-strategist organisms under stressed conditions
Disease/anomaly prevalence, i.e. the reduced tolerance of organisms to infection and pathological anomalies under stress
Contaminant uptake and response, i.e. the increased accumulation of conservative contaminants and perhaps the production of detoxification mechanisms after exposure

Box 4
The NINE stages in the provision of data, information and knowledge needed for management (modified from McLusky and Elliott, 2004).

Stage	Topic	Information produced
1	Behaviour/characteristics of the system	Of the intertidal, subtidal, lagoonal, estuarine, open coastal areas, etc.
2	Physical/chemical nature of system	Its hydrography, topography, bathymetry, salinity regime, nutrient status, etc.
3	Physical and chemical behaviour of additives to system	Their dispersion in a solid or liquid phase, solubility, transport, sequestration, etc.
4	Behaviour/characteristics of an activity in the environment	e.g. Whether there is a barrier to the flow of materials and biota, or the disruption of processes
5	Habitat at risk from modification or materials addition	e.g. Whether there is a surface feature (monolayer), or effects in the water column, water–substratum interface, sediment, supralittoral, intertidal, circalittoral, infralittoral, shelf
6	Inert or biologically effective action	Whether there is a direct toxic nature, secondary toxic nature (after modification in or of habitat)
7	Biotic and non-biotic component(s) at risk	e.g. Which of the phytoplankton, zooplankton, pelagic nekton, demersal nekton, hyperbenthos, epifauna, infauna, microphytobenthos, macroalgae, saltmarsh, reedbeds, wading birds and wildfowl are at risk
8	Behaviour of contaminants within organisms	e.g. Their uptake, sequestration, storage, excretion, passage to progeny and passage to prey
9	Structure and functioning of biological system	The response at any of the levels of biological organisation

lating information in progressing from Stage 1 to Stage 9, conservation and environmental protection bodies can then determine the effects of human activities on the marine system. Each of the 'decisions' relates to the way in which the ecosystem functions and the behaviour of materials or activities placed in the environment. For example, the placing of dredged material into the sea after dredging will have an effect which depends on the nature of the receiving environment (i.e. whether it has water currents above a threshold speed), and on the nature of the material being dumped (e.g. whether it is sand or mud). However, The Ecosystem Approach is necessary to ensure that all aspects are taken into account and thus that the overall health of systems and the ecosystem services that they deliver are recognised and protected.

To detect change then requires monitoring the system – when to assess and what to assess – although we have further complicated this to result in TEN types of monitoring:

- Surveillance monitoring – a 'look-see' approach which begins without deciding what are the end-points followed by a post hoc detection (*a posteriori)* of trends and suggested management action.
- Condition monitoring – used by nature conservation bodies to determine the present status of an area; it could be linked to biological valuation (e.g. Derous et al., 2007).
- Operational monitoring – used by industry for business reasons (e.g. for a dredging scheme linked to aims for management and to determine if an area requires further dredging).
- Compliance monitoring – used by industry and linked to licence (or permit/authorisation/consent) setting for effluent discharge, disposal at sea, etc.
- Self-monitoring – being carried out by the developer/industry under the 'polluter pays principle' but often sub-contracted to an independent and quality-assured/controlled laboratory.
- Check monitoring – where an Environmental Protection Agency checks self-monitoring to ensure that a developer is performing appropriate monitoring.
- Toxicity testing – as a predictive approach needed for licence setting, used by regulators to determine compliance of the licence conditions with required standards.
- Investigative monitoring – applied research on cause-and-effect, to explain any deviation from perceived or required quality.
- Diagnostic monitoring – determining effects but link to cause, synonymous with investigative monitoring.
- Feedback monitoring – real time analysis, linked to predetermined action; e.g. monitoring during dredging on condition that the activity is controlled/prevented/stopped if a deleterious change is observed; this relies on acceptance that any early-warning signal will be related to an ultimate affect (Gray and Elliott, 2009).

As emphasised here, the aim of marine management is to protect the whole system although, again as shown here, this is

Box 5
The European Marine Strategy Framework Directive Descriptors of Good Environmental Status (from Borja et al., 2010b).

(1) Biological diversity is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climatic conditions
(2) Non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystems
(3) Populations of all commercially exploited fish and shellfish are within safe biological limits, exhibiting a population age and size distribution that is indicative of a healthy stock
(4) All elements of the marine food webs, to the extent that they are known, occur at normal abundance and diversity and levels capable of ensuring the long-term abundance of the species and the retention of their full reproductive capacity
(5) Human-induced eutrophication is minimised, especially adverse effects thereof, such as losses in biodiversity, ecosystem degradation, harmful algae blooms and oxygen deficiency in bottom waters
(6) Sea-floor integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected
(7) Permanent alteration of hydrographical conditions does not adversely affect marine ecosystems
(8) Concentrations of contaminants are at levels not giving rise to pollution effects
(9) Contaminants in fish and other seafood for human consumption do not exceed levels established by Community legislation or other relevant standards
(10) Properties and quantities of marine litter do not cause harm to the coastal and marine environment
(11) Introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment

Box 6
Relationships between the 12 principles of The Ecosystem Approach (as per the UN Convention for Biological Diversity) and the 7 tenets of environmental management (E = explicit, I = implicit).

	Env.	Econ.	Tech.	Soc.	Leg.	Admin.	Polit.
Societal choices		I		E			E
Subsidiarity					E	E	I
Inter-ecosystem effects	E		E		I	I	I
Economic management		E	I				E
Maintain ecosystem services	E	E	I	I			
Maintain ecosystem functioning	E						
Appropriate spatial and temporal scales	E				I	I	
Long-term management	E			I		I	I
Manage for variability	E						
Manage to conserve and use biodiversity	E	E		E			I
Use best practice, all 'data'	E	E	E				
Stakeholder input, incl. science	E	E	E	E	E	E	E

complex achievement. Given this complexity, we often deconstruct the ecosystem into a set of component parts, assess each of them in relation to any stressors and then aim to recombine our assessments to give the management of the whole system – this is what we previously called a 'deconstructing structural approach' as used for the European Water Framework Directive (Borja et al., 2010b). The WFD, adopted in 2000, concentrated on assessing deviation from Good Ecological Status by FIVE Biological Quality Elements (phytoplankton, macroalgae, macrophytes, benthic fauna and fishes) plus the chemical and physical characteristics. In perhaps realising that this could not give a complete picture of the complexity of the marine system's response to human activities, the 2008 European Marine Strategy Framework Directive then increased this to include ELEVEN descriptors (Box 5) to determine Good Environmental Status which we consider takes a more functional, holistic approach reflecting The Ecosystem Approach (Borja et al., 2010b).

As mentioned at the start of this article, our aims, actions and outcomes have to fulfil The Ecosystem Approach as defined by the UN Convention for Biological Diversity which is based on TWELVE principles (see Box 6). It is notable that the first 4 of these relate to societal desires, economics and management and, in the order they were written, we have to get to number 5 before ecology is mentioned. Perhaps this reinforces that the economic and social aspects of marine management may have equal or perhaps even greater weight than ecological aspects, especially in these financially difficult times. Because of this, we are increasingly emphasising to stakeholders and policy makers the need to consider the ability of the marine environment to deliver a set of fundamental and final ecosystem services leading to societal benefits (Atkins et al., 2011). Given that these 12 principles then map onto the 7 tenets (Box 6) shows the complexity of the system but in particular the need for a multidisciplinary approach linking natural and social sciences, especially the ability to protect Ecosystem Services and deliver Societal Benefits.

References

Atkins, J.P., Burdon, D., Elliott, M., Gregory, A.J., 2011. Management of the marine environment: integrating ecosystem services and societal benefits with the DPSIR framework in a systems approach. Marine Pollution Bulletin 62, 215–226.

Aubry, A., Elliott, M., 2006. The use of Environmental Integrative Indicators to assess seabed disturbance in estuaries and coasts: application to the Humber Estuary, UK. Marine Pollution Bulletin 53 (1–4), 175–185.

Borja, Á., Dauer, D.M., Elliott, M., Simenstad, C.A., 2010a. Medium- and long-term recovery of estuarine and coastal ecosystems: patterns, rates and restoration effectiveness. Estuaries and Coasts 33, 1249–1260.

Borja, Á., Elliott, M., Carstensen, J., Heiskanen, A.-S., van de Bund, W., 2010b. Marine management – towards an integrated implementation of the European Marine Strategy Framework and the Water Framework Directives. Marine Pollution Bulletin (2010 electronic version).

Derous, S., Agardy, T., Hillewaert, H., Hostens, K., Jamieson, G., Lieberknecht, L., Mees, J., Moulaert, I., Olenin, S., Paelinckx, D., Rabaut, M., Rachor, E., Roff, J., Stienen, E.W.M., van der Wal, J.T., van Lancker, V., Verfaillie, E., Vincx, M., Węsławski, J.M., Degraer, S., 2007. A concept for biological valuation in the marine environment. Oceanologia 49 (1), 99–128.

Elliott, M., 2002. The role of the DPSIR approach and conceptual models in marine environmental management: an example for offshore wind power. Marine Pollution Bulletin 44 (6), iii–vii.

Elliott, M., Cutts, N.D., 2004. Marine Habitats: loss and gain, mitigation and compensation. Marine Pollution Bulletin 49, 671–674.

Elliott, M., Quintino, V., 2007. The Estuarine Quality Paradox, Environmental Homeostasis and the difficulty of detecting anthropogenic stress in naturally stressed areas. Marine Pollution Bulletin 54, 640–645.

Elliott, M., Burdon, D., Hemingway, K.L., Apitz, S., 2007. Estuarine, Coastal and Marine Ecosystem Restoration: confusing management and science – a revision of concepts. Estuarine, Coastal and Shelf Science 74, 349–366.

Gray, J.S., Elliott, M., 2009. Ecology of Marine Sediments: Science to Management. OUP, Oxford. 260pp.

Harding, L.E., 1992. Measures of marine environmental quality. Marine Pollution Bulletin 25 (1–4), 23–27.

Hering, D., Borja, A., Carstensen, J., Carvalho, L., Elliott, M., Feld, C.K., Heiskanen, A.S., Johnson, R.K., Moe, J., Pont, D., Solheim, A.L., van de Bund, W., 2010. The European Water Framework Directive at the age of 10: a critical review of the achievements with recommendations for the future. Science of the Total Environment 408 (19), 4007–4019.

Holl, K.D., Cairns Jr., J., 2002. Monitoring and appraisal. In: Perrow, M.R., Davy, A.J. (Eds.), Handbook of Ecological Restoration, vol. 1. Cambridge University Press, Cambridge, pp. 411–432.

McLusky, D.S., Elliott, M., 2004. The Estuarine Ecosystem; Ecology, Threats and Management, third ed. OUP, Oxford. p. 216.

Mee, L.D., Jefferson, R.L., Laffoley, D.d'A., Elliott, M., 2008. How good is good? Human values and Europe's proposed Marine Strategy Directive. Marine Pollution Bulletin 56, 187–204.

Odum, E.P., 1985. Trends expected in stressed ecosystems. Bioscience 35, 419–422.

Palmer, A., Hartley, B., 2008. The Business Environment, sixth ed. McGraw-Hill Higher Education, London.

Michael Elliott
Institute of Estuarine and Coastal Studies,
University of Hull,
Hull HU6 7RX,
UK
E-mail address: Mike.Elliott@hull.ac.uk