Marine Pollution Bulletin 86 (2014) 1–4

Contents lists available at ScienceDirect

Marine Pollution Bulletin

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

Editorial

Integrated marine science and management: Wading through the morass

1. Introduction

Many countries worldwide are now considering developing (or at least being required to consider developing) a holistic marine management planning framework which can encompass all the marine users and uses, the players and stakeholders, and the demands on the system (e.g. Borja et al., 2010). Given that there are many sectors involved in the marine environment (shipping, fishing, aquaculture, industries, recreation, etc.), there is the need for integrated management but within that multi-manager sectoral framework. Each sector usually has its own administrative body (e.g. Boyes and Elliott, 2014a) and often the complexity of the system means that one sectoral body, for example for conservation, is so preoccupied tackling its own conservation aspects that they pay less attention to others, such as fisheries.

The aim of that management framework should be to build on the previous history of marine management, for example in Europe and North America since the 1970s, and should not alienate legitimate sectoral planning bodies but rather build on existing expertise and linkages. Furthermore, for it to be successful requires an inclusive system involving stakeholder expertise and understanding. The pages of this journal have long recorded the different aspects of marine management although usually these are treated separately – hence the aim of this note is to attempt to integrate the aspects.

The underlying marine management can be usefully defined within the DPSIR framework, in which we consider the Drivers, as the main demands from the system, and the Pressures resulting from those demands (e.g. Table 1) (Atkins et al., 2011). It is suggested here that Activities (A) will then lead to the Pressures. These in turn, unless controlled, lead to State changes, on the natural systems which may be negative or positive, and then to Impacts on the human system. It is of interest that recently Cooper (2013) has suggesting replacing the I for Impacts by W for Welfare, hence DPSWR. It is suggested here that this perhaps not only replaces Impact but enhances it and should be termed 'Impacts on human Welfare', hence here I(W) is used here. Because of this, it is suggested here that DPSIR should perhaps more accurately become DAPSI(W)R.

In order to control those State changes and Impacts (or Impacts on human Welfare), we therefore require Responses. Those Responses may include bringing in technological advances (such as better fishing gear, habitat re-creation or water treatment plants), economic instruments (such as quotas or penalties) or laws administered by statutory bodies. Hence we need a management framework to accommodate and describe all the linked processes in this framework. Such a framework must then be aimed at what we may term the 'big idea' – '*that marine management is designed to protect and enhance the natural structure and functioning of the seas while at the same time ensuring the marine processes which deliver ecosystem services from which we then obtain societal goods and benefits*' (Elliott, 2011). Hence many of the Impacts in Table 1 relate to a loss of ecosystem services and societal benefits. Given the adage that '*if you don't know where you are going then any road will take you there*', then in order to set down the ultimate aim as a readily communicable message, this should be encapsulated in a vision for the seas, for example to achieve '*clean, healthy, safe, productive and biologically diverse oceans and seas*' as adopted by the UK government and others (Defra 2010).

Furthermore, it is argued that sustainable and successful marine management can then only be obtained by including all facets and players in the system, the so-called *10-tenets* (Elliott, 2013) in which the major players and responses are included. The latter suggest that our actions should be: Ecologically sustainable (identified as ecol. in the figures below), Technologically feasible (Tech.), Economically viable (Econ.), Socially desirable/tolerable (Soc.), Legally permissible (Leg.), Administratively achievable (Admin.), Politically expedient (Pol.), Ethically defensible (morally correct) (Ethic.), Culturally inclusive (Cult.) and Effectively communicable (Comm.). This discussion and its diagrams will therefore try to indicate the major steps in an integrated marine management framework while cross-referring to the elements D, P, S, I(W) and R and the 10-tenets.

2. Source of adverse changes

The Pressures on the marine environment (e.g. Kennish and Elliott, 2011) can be regarded as coming from three sources – activities which remove materials and space from the system, activities which place materials into the system, and thirdly, external and wider pressures, such as global climate change, which emanate from outside the system (Fig. 1). The materials extracted include fish, shellfish, water, and seabed sands and gravels, and space is also removed, for example by occupying the seabed with harbours, windfarms, etc. The materials placed into the system include fisheries discards, land and vessel pollutants, structures such as wind turbine monopiles and gas rigs, discharged cooling water and also claimed land on previous wetlands. Both of these groups of activities, carried out by stakeholders what we can call the 'Inputters' and the 'Extractors', occur within the system being managed and so are regarded as Endogenic Managed Pressures, in which we need to control the causes and consequences. However, in the case of discharges to catchments (e.g. nutrients, persistent pollutants) outside the sea area being managed, these are also Exogenic Unmanaged Pressures in which we respond to the consequences without necessarily

http://dx.doi.org/10.1016/j.marpolbul.2014.07.026
0025-326X/

Table 1
Examples of vectors of change – from drivers through impacts to policy responses.

Driver	Pressure/Activity	State change	Impact (on human welfare)	Response
Increasing urbanisation, agriculture and industrialisation	Changes in temperature regimes and weather patterns (storminess)	Climate change and related impacts (natural and anthropogenic; effects on structure and functioning and on Ecosystem Services (ES))		Local adaptation, compensation; policy, economic & legal mechanisms
	Increased CO_2 and decreased pH	Ocean acidification	Reduced ecosystem services, ability for waste removal	Global agreements
	Diffuse and point source land-based pollution	Polluted components; Harmful Algal Bloom formation	Environmental and food quality reduction, reduced ES	Diffuse and point-source discharge controls
	Space removal	Loss of carrying capacity	Loss (& gain) of ecosystem services	Planning controls, Marine Spatial Planning
Demand for food	Capture fisheries	Changes to local populations, spawning sustainability, by-catch and habitat damage	Stock viability, ecosystem services reduction	Economic and legal instruments
	Aquaculture	Changes to local ecology	Ecosystem services (+ and −)	
Maritime transport (demand for movement of goods, etc)	NIS (non-indigenous species) introduction, infrastructure demands, pollution, dredging	Community change, habitat alteration	Pest introduction, invasive and nuisance species; effects on ecosystem services	Introduction of new ballast water technologies and practices
Energy demands	Infrastructure demands	Habitat loss and gain, energy/ hydrodynamic change	Effects on ecosystem services (+ and −)	Marine spatial planning, economic and legislative constraints
Tourism & recreation demands		Loss of natural habitats, reduction in resilience		Planning controls, coastal spatial planning
Total societal demands	Interactions between multiple users & sectors	Cumulative effects on natural structure and functioning	Effects on ecosystem services	Changes in policy

addressing the causes (Elliott 2011). Those 'Inputters' and 'Extractors' thus encompass the uses and users of the marine system. The third group of wider pressures such as global climate change will also be regarded as Exogenic Unmanaged Pressures, i.e. the cause is not within the sea or ecoregion being managed but globally although marine management and the response to the consequences of climate change, such as building sea-defences to accommodate increased storminess or water retention areas to accommodate relative sea-level rise, has to be within the management area.

3. Ecosystem Services & Societal Benefits

Marine management is required to deliver the Ecosystem Services which, following the input of complementary assets and human capital such as time, money, energy and skills, can then be translated into and deliver Societal Benefits (Atkins et al., 2011). For example, the marine system can maintain the ecological and hydrological processes to produce sediments, invertebrates and fish but society has to expend complementary assets (by building boats and infrastructure) to catch, process and consume those fish. Hence the uses and users may affect another major group of stakeholders ('Affectees'), for example by restricting the available area for other activities, but provide the goods and benefits for the 'Beneficiaries') (Fig. 2).

4. Marine governance at national, regional, international and global levels

The actions of the users and the repercussions of the uses are then controlled by a system of governance (defined here as the politics, policies, administration and legislation of the system) and particularly by the 'Regulators' as a blanket-term for all stakeholders involved in that governance. Such a governance needs to operate at levels from the local to the national to the regional to the wider ecoregion and ultimately to global scales and thus constitute the Response in DPSIR to the problems created (Boyes and Elliott, 2014b). Hence we need vertical integration throughout those levels of governance across the geopolitical levels – for example, within Europe, global agreements such as those emanating from the UN Law of the Sea or the International Maritime Organisation, will filter through Regional Seas Conventions such as the OSPAR or HELCOM and the European Commission down to national legislatures and even to local bylaws and agreements (Boyes and Elliott, 2014b).

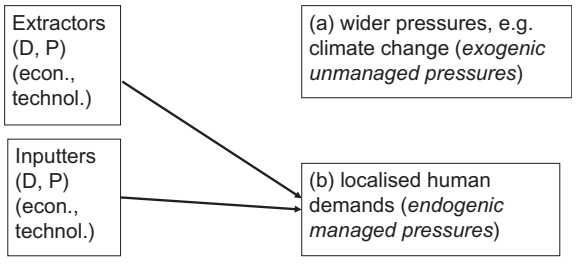

Fig. 1. The source of problems for which marine management is required.

5. Typology of stakeholders

The above indicates what we might consider elements of a generic typology of stakeholders to which we should also add the 'Influencers', i.e. those with an aim to raise awareness of the problems and consequences. Some of these 'Influencers' may be in government as politicians but also they include Non-Governmental Organisations, pressure groups and even members of society at large. Hence we have 6 types of stakeholders which have to be integrated horizontally (as they may all occur within one area) (Fig. 3). However, it is of note that certain elements in society can be placed in several of these categories – for example, local fishing bodies may extract fish and shellfish, input materials such as bycatch discards, be affected by other activities such as offshore windfarms, benefit commercially and socially from the activity, will influence policy and may regulate each other in an area through fisheries co-management.

6. Risk Assessment and Risk Management

The pressures emanating from the uses and users of the marine system and the wider influences on the system then in turn create hazards and risks which need to be understood and where possible controlled, if not at least accommodated, mitigated or compensated for under a system of adaptive management (e.g. Elliott et al., 2014).

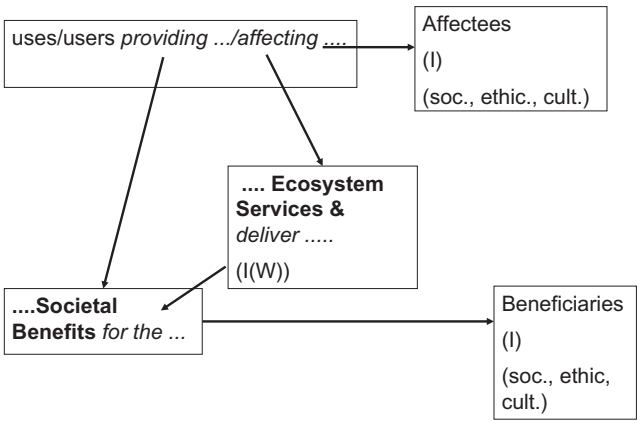

Fig. 2. The mechanism of producing Ecosystem Services and Societal Benefits and the receiving stakeholders.

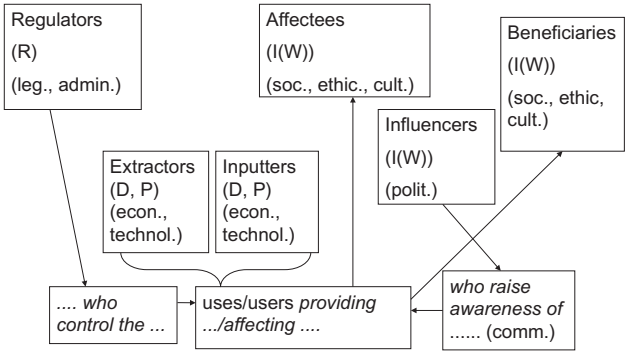

Fig. 3. The typology of stakeholders and the links between them.

Hence the next major concern is whether those hazards and risks have reduced the health of the seas or at least increased our concerns and demands for actions – in Tett et al. (2013), we argue that the assessment and maintenance of human and ecological health is the ultimate aim of adaptive management.

Risk Assessment and Risk Management therefore plays a major role in determining the severity of the problems and then tackling them (Cormier et al., 2013). In essence, if integrated marine management is successful then following the implementation of the combined Responses, the Drivers, Activities and Pressures should not produce State changes and Impacts (on societal Welfare) (Fig. 4). Determining the risks and hazards therefore leads to the need for monitoring systems, indicators of change, and targets against which the change is judged. In turn this requires syntheses

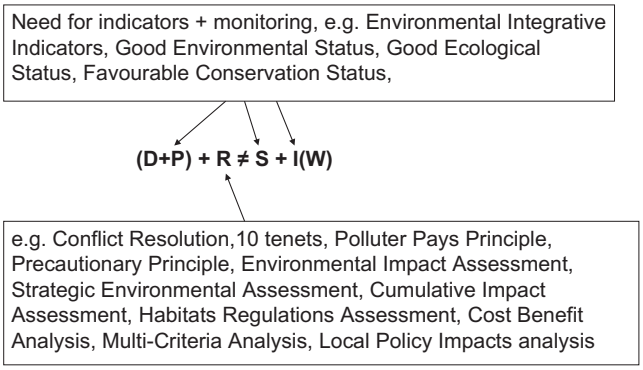

Fig. 4. Risk Assessment and Risk Management approaches.

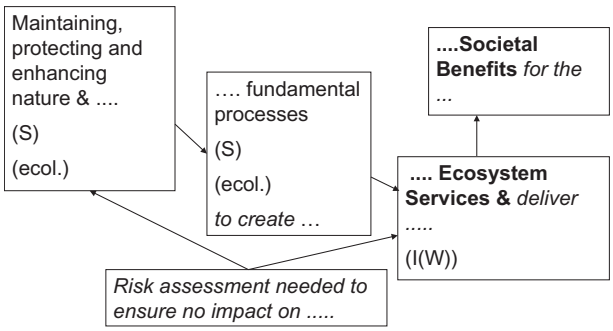

Fig. 5. The Ecosystem Approach aimed at protecting the natural system and delivering societal needs.

of the status of the area with and without the pressures and then ultimately to action plans being created (e.g. Aubry and Elliott, 2006; Borja et al., 2010, 2013).

The Response to the risks and hazards then is manifest through economic instruments and mechanisms, but first requires methods of assessment of the risk and hazard from the project level (Environmental Impact Assessment) through the combined projects (Cumulative Impact Assessments) to the wider sea area (Strategic Environmental Assessment). It needs to encompass underlying principles such as the Polluter (Developer) Pays Principle and the Precautionary Principle and methods of conflict resolution across the various players and stakeholders; any area in which the uses and users coincide spatially and/or temporally is likely to produce conflicts which need resolving.

7. The Ecosystem Approach

It is emphasised here that the main idea in marine management, to protect nature while delivering what society requires, can be summarised as The Ecosystem Approach and its 12 principles, as laid down in the UN Convention on Biological Diversity (e.g. Elliott et al., 2011) (Fig. 5). While there is a tendency to talk about an 'Ecosystem-based approach', this seems a misnomer as by definition the approach is based in the ecosystem and so does not need qualifying. Similarly, while some areas refer to, for example, an 'ecosystem-based approach to fisheries management' (Pikitch et al., 2004) then again by definition this is not a true Ecosystem Approach as it is sectoral in relating to one use, fishing, rather than covering all sectors.

8. A unified and integrated/interlinked management system

The challenge here is to indicate that all of the above principles, philosophies, mechanisms, approaches, characteristics and players can be combined and linked into a unified system indicating holistic and adaptive environmental management (Fig. 6). While this may be a personal view, it covers the main aspects and hopefully guides the reader through the morass which has developed for managing a complex marine system. The need for and ability to achieve vertical and horizontal integration of the governance and stakeholders respectively is the essence of such management while ensuring the protection of the natural system and delivery of ecosystem services and societal benefits. This requires an understanding of Risk Assessment and then the tools and actions in Risk Management and then feedbacks from that management into ensuring the delivery of Ecosystem Services and societal goods and benefits as well as protecting the natural structure and functioning.

In showing such an integrated marine management framework, it becomes apparent that it can only be achieved by having sectoral

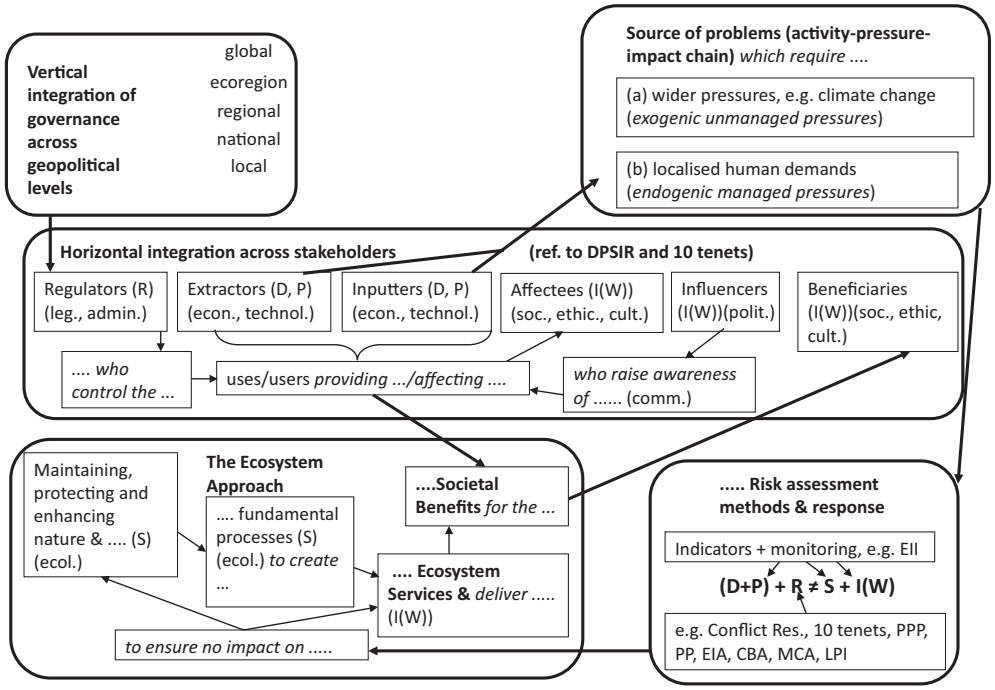

Fig. 6. A unified marine management framework *(thick arrows denote linkages between topics; thin arrows denote direction of influence).*

managers willing to think across the vertical and horizontal levels of integration. Secondly, we require statutory agencies which have the competency and capability to accommodate all the above aspects. Finally, we should always emphasise that marine educators should be required to produce graduates willing and able to link the natural and social sciences otherwise such an integrated framework and understanding cannot be achieved.

Acknowledgements

This paper is a result of prompting from colleagues within the European Union FP7 Collaborative projects: VECTORS (THEME Ocean.2010-2, Vectors of Change in Oceans and Seas Marine Life, Impact on Economic Sectors, Grant Agreement No.: 266445, www.marine-vectors.eu), and DEVOTES (DEVelopment Of innovative Tools for understanding marine biodiversity and assessing good Environmental Status, 'The Ocean of Tomorrow' Theme (Grant Agreement No.: 308392), www.devotes-project.eu). Thanks also to Dr. Bob Earll (CoastMS) for extremely helpful comments on the figures.

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. Mar. Pollut. Bull. 62 (2), 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. Mar. Pollut. Bull. 53 (1–4), 175–185.

Borja, Á., Elliott, M., Carstensen, J., Heiskanen, A.-S., van de Bund, W., 2010. Marine management – towards an integrated implementation of the European Marine Strategy Framework and the Water Framework Directives. Mar. Pollut. Bull. 60, 2175–2186.

Borja, A., Elliott, M., Andersen, J.H., Cardoso, A.C., Carstensen, J., Ferreira, J.G., Heiskanen, A.-S., Marques, J.C., Neto, J., Teixeira, H., Uusitalo, L., Uyarra, M.C., Zampoukas, N., 2013. Good environmental status of marine ecosystems: what is it and how do we know when we have attained it? Mar. Pollut. Bull. 76, 16–27.

Boyes, S.J., Elliott, M., 2014a. The excessive complexity of national marine governance systems – has this decreased in England since the introduction of the Marine and Coastal Access Act 2009? Mar. Policy. http://dx.doi.org/10.1016/j.marpol.2014.07.019.

Boyes, S.J., Elliott, M., 2014b. Marine legislation – the ultimate 'horrendogram': international law, European Directives and national implementation. Mar. Pollut. Bull. 86, 39–47.

Cooper, P., 2013. Socio-ecological accounting: DPSWR, a modified DPSIR framework, and its application to marine ecosystems. Ecol. Econ. 94 (2013), 106–115.

Cormier, R., Kannen, A., Elliott, M., Hall, P., Davies, I.M. (Eds.), 2013. Marine and Coastal Ecosystem-based Risk Management Handbook. ICES Cooperative Research Report, No. 317, March 2013. International Council for the Exploration of the Sea, Copenhagen, 60pp., ISBN 978-87-7472-115-1.

Defra, 2010. UK Marine Science Strategy: Shaping, Supporting, Co-ordinating and Enabling the Delivery of World Class Marine Science for the UK: 2010–2025. The Department for Environment Food and Rural Affairs, London, UK, <http://www.defra.gov.uk/environment/marine/science/mscc.htm>.

Elliott, M., 2011. Marine science and management means tackling exogenic unmanaged pressures and endogenic managed pressures – a numbered guide. Mar. Pollut. Bull. 62, 651–655.

Elliott, M., 2013. The *10-tenets* for integrated, successful and sustainable marine management. Mar. Pollut. Bull. 74 (1), 1–5.

Elliott, M., Cutts, N.D., Trono, A., 2014. A typology of marine and estuarine hazards and risks as vectors of change: a review for vulnerable coasts and their management. Ocean Coastal Manage. 93, 88–99.

Kennish, M.J., Elliott, M. (Eds.), 2011. Human-induced problems (uses and abuses) in Estuaries and Coasts. In: Wolanski, E., McLusky, D.S. (Eds.), Treatise on Estuarine & Coastal Science, vol. 8. Elsevier, Amsterdam, pp. 315.

Pikitch, E.K., Santora, E.A., Babcock, A., Bakun, A., Bonfil, R., Conover, D.O., Dayton, P., Doukakis, P., Fluharty, D., Heheman, B., Houde, E.D., Link, J., Livingston, P.A., Mangel, M., McAllister, M.K., Pope, J., Sainsbury, K., 2004. Ecosystem-based fishery management. Science 305, 346–347.

Tett, P., Gowen, R., Painting, S., Elliott, M., Forster, R., Mills, D., Bresnan, E., Capuzzo, E., Fernandes, T., Foden, J., Geider, R., Gilpin, L., Huxham, M., McQuatters-Gollop, A., Malcolm, S., Saux-Picart, S., Platt, T., Racault, M.-F., Sathyendranath, S., Molen, Jvd, Wilkinson, M., 2013. Framework for understanding marine ecosystem health. Mar. Ecol. Progr. Ser. 494, 1–27 (+ suppl. material).

Michael Elliott *
Institute of Estuarine and Coastal Studies (IECS), University of Hull, Hull HU6 7RX, UK
* Tel.: +44 1482 464558; fax +44 1482 464130.
E-mail address: Mike.Elliott@hull.ac.uk