The Role of the DPSIR Approach and Conceptual Models in Marine Environmental Management: An...

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Editorial

The role of the DPSIR approach and conceptual models in marine environmental management: an example for offshore wind power

1. Complexity, the 6 tenets and the DPSIR approach

The marine system is arguably more complex than any other ecosystem with highly interrelated processes between its physical, chemical and biological components. Its study and management requires information on all aspects and an understanding of the structure and function of the systems. In addition, the increasing amount of national, supra-national and global legislation and agreements is producing the need to develop tools for the sustainable use of the marine environment, in particular management for conservation and biodiversity in order to protect habitat integrity. The paradox here is that the scientific community is mostly working on very detailed and more narrow aspects whereas the managers require a holistic and ecosystemic approach, not necessarily at a very high level of detail. It is suggested that, despite such a requirement, there are fewer and fewer scientists willing (and able) to take a broader, cross-disciplinary and multi-disciplinary approach to tackling the problems created by human activities.

There is an increasing need to demonstrate, quantify and predict the effects of human activities on the interrelated components in space and time, e.g. the air–water and water–substratum interfaces, aerial system, water column, sediment and hard substratum components. There is the need to demonstrate the bottom-up processes, for example the manner in which natural changes in the physical system creates the conditions which are colonised by the biota and the way in which Man influences those changes. Similarly, there is then the need to show the top-down responses in which the higher marine trophic levels are affected by changes in the lower components. Following all of this, there is the need to link this science to the causes of change and to the social, economic and legal responses by Man to that change.

This sequence can be summarised by the increasingly used DPSIR approach. A knowledge is required of the over-arching DRIVERS of change, e.g. the need for fisheries, energy, land for development and the causes of climate change. Following this, each of these creates particular PRESSURES, such as the effects of bottom trawling, the discharge of cooling water from power stations, coastal squeeze from sea-level rise, etc. The STATUS of the system then needs to be assessed thus covering the physical, chemical and biological conditions and this then leads to the definition of IMPACTS on each component. The latter then requires the definition of monitoring procedures and the use of indicators of change. Finally, there is the need to indicate the human RESPONSE to these changes in the marine system.

The human response to the changes resulting from our activities has to be defined is such a way as to meet what we may call 'six tenets for environmental management'. Our actions have to be:

environmentally sustainable (i.e. good for nature now and in the future);
technologically feasible (i.e. with appropriate methods and equipment);
economically viable (i.e. at a reasonable and tolerable cost);
socially desirable (i.e. wanted by our societies);
legally permissible (i.e. within our defined laws at national and international level);
administratively achievable (i.e. carried out by our system of departments, agencies and governments).

The first three of these have been well cited in national and international strategies but the latter three have been added here in order to ensure that solutions to environmental change sit within our developed systems.

These six tenets and the DPSIR approach can be applied to any particular stressor in the marine environment, for example offshore windpower. This fledgling industry involves the creation and siting of aerogenerators which harness winds in the nearshore area but sufficiently far away from the coastline to minimise public antagonism, reduce aesthetic concerns

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and be more cost-effective in utilising the more constant wind climate. The overall *drivers* are our desire for cost-effective electrical power against our concerns about global warming and climate change. The *pressures* resulting from the activity include the construction of the aerogenerators, the trenching for seabed cables, the noise and vibration of the turbines once operating, etc. The *status* relates to the nature of the seabed where the structures are sited, often subtidal sandbanks or natural or man-made reefs, the water column and the physical and biological features of these. The *impacts* potentially emanate from the disturbance of hydrographic and sedimentological patterns, the effects of a changing seabed on the benthic populations and their predators, and the effects on water column fish and sea mammals. Finally, the human *response* to such potential problems is to minimise these through siting and operation, use good practice during construction and operation, as well as the administrative and legal controls such as Environmental Impact Assessments and planning regulations. In addition, the monitoring protocols and the indicators for acceptable change also have to be defined once the potential impacts have been defined.

Given the above there is the need to explain, demonstrate and illustrate to environmental managers, politicians, and workers in other disciplines, the complexity of the system, the linking between components, the knock-on effects of activities and the responses at different levels of the system. Any one activity requires management in order to minimise deleterious effects. The activity will have an impact or impacts at one level or on one set of components and then there may be a knock-on effect to other levels, components, communities and systems. In particular there may be transboundary impacts which require management and thus environmental managers require to understand or at least be informed and aware of the interlinked nature of the effects especially on other uses and users of the marine system.

In many countries, there is a long history of a sectoral approach to marine management, i.e. the desire to concentrate on an area, a time, an activity or the system's response at one time. For example, the protection of bathing waters, the development of fisheries and shellfisheries, the control of water pollution, and the environmental impact assessment of an activity. The increasing realisation of the complex nature of the marine system and the effects of human activities is producing a movement away from this approach, to consider the integral management of all features, both natural and anthropogenic. Indeed, the concept of an ecosystemic approach is now being incorporated into agreements and legislation, for example the European Union's Water Framework Directive, Habitats and Species Directive and Common Fisheries Policy and the Oslo and Paris Commission's Annex V for the protection of marine systems.

It is of note that environmental legislation is becoming more complex and integrative, for example the above directives and the EU Strategic EIA Directive and the UNCED Earth Summits, such as at Rio de Janeiro and New York in the 1990s and Johannesburg later this year. Each of these require that a holistic and ecosystemic approach is taken to managing the marine environment. They also require scientists, environmental managers and politicians to take a wide view of the marine system. Furthermore, the dynamics of the marine system and the interlinked nature of our states requires mechanisms which bring together not only different scientific and technical aspects but also different socio-economic–political systems. For example, and especially within Europe, there is the need to unify each country's national, European and international obligations to major initiatives for the wise and sustainable management of coastal areas.

Given this development, it is important for managers to understand the nature of changes to the marine system even if they are not specialists in all fields. In addition, there is an increasing involvement by environmental lawyers, environmental economists and numerical modellers, many of whom are unlikely to be specialists in marine science, or even to have a science background, and thus they may be unaware of the interlinking and complexity of the marine system. This difficulty may be compounded by an increasing trend to bring in business managers to manage environmental organisations.

2. Approach to marine environmental management

I suggest a four stage approach to developing marine environmental management—to decide on priorities, to produce tools for general use, assemble background information, and define case studies as examples of good practice.

2.1. Deciding on priorities

This will set out the aims, decide which aspects are most important, what human influences should be considered and where possible produce a matrix of effects/responses. For example, all types of coastal power generation have an environmental impact but we have a sufficiently good understanding of the system to determine the advantages and disadvantages of each type and thus to set priorities to be addressed.

2.2. Tools for general use

We have many tools with which to define, quantify and address the marine problems created by Man. We can derive conceptual models for indicating responses for each human activity (see below); produce environmental quality classification schemes for estuaries, coasts and the open sea to indicate change; determine the value of schemes such as biotope classification and adapt/adopt these for areas; adapt/adopt and/or derive Ecological and Environmental Quality Standards and Objectives, and adapt/adopt/produce monitoring protocols for the main components of the system (benthos, fishes, birds, sediments, etc.). However, each of these increasingly is requiring a multi-disciplinary approach and thus a broader background knowledge of marine scientists and managers.

2.3. Background information

In tackling actual and potential problems caused by any stressor, there is the need to define the natural system and determine changes from it. This will require us (i) to characterise the system, for example by producing a catalogue of habitats, a biotopes matrix and mapping; (ii) to catalogue biological features in relation to the physical–chemical environment, (iii) to define the natural variability in the systems and to produce the means of quantifying that, (iv) to determine the signs and symptoms of change, e.g. for eutrophication and nutrient problems there is a choice between physico-chemical assessment (inputs of nutrients, water residence times, degree of chemical transformation) and biological consequences (development of macroalgal mats, anoxic areas, noxious microalgal blooms, disruption of predator feeding areas); (v) to determine/quantify what change is acceptable in allowing a sustainable use of an area and the maintenance of habitat/conservation integrity.

2.4. Case studies

There is the need to define all of the above from actual scenarios and particular stressors but also for wider areas—we no longer only consider the management of small marine areas, within the ecological footprint of a stressor, but also for whole catchments, coastlines and sea areas. Thus we are now learning lessons from catchment and river-basin management plans, classification schemes, the use of quality status reports and cumulative impact assessments for complex coastal and brackish areas. As each of these areas represents a combination of several stressors and activities, there is the need to consider whether we understand the effects of that stressor both in isolation and in combination with others.

For any particular stressor or activity, we should aim towards predicting changes to the marine system, and indeed our success in managing the marine environment is only as good as our ability to predict the consequences of human activities. We have a good understanding of the changes to the system at the conceptual (and possibly qualitative) level but not necessarily such a detailed understanding at a quantitative level. It is questionable whether we will ever have fully validated numerical models which can adequately predict the ecological effects of an activity such as fisheries or a construction in the marine environment. However, the first step towards creating such models is the definition of the problem, hence the production of conceptual models.

3. Definition and role of conceptual models

Given the above features and trends in marine environmental management, there is an increasing needs for the development of conceptual models. These can be regarded as diagrams which bring together and summarise information from many areas. They provide the basis for communicating the main message to managers and developers as well as having an educational value. They provide the starting point for developing quantitative and numerical models, or for indicating the limitation of such models and the available scientific knowledge. Thus they can inform the need for further field and laboratory studies to fill the gaps in knowledge. In particular they allow a problem to be deconstructed as a precursor to each aspect being assessed, prioritised and addressed.

As an example, Figs. 1 and 2 indicate the dominant processes and responses for offshore windpower. A knowledge of the marine system, of the physical, chemical and biological interactions, and of the potential effects during the construction and operation of aerogenerators can be combined to produce the models (colloquially termed 'horrendograms' due to their complexity!). The potential effects of this activity, and thus the means of assessing and mitigating those affects, relies on an understanding of the bottom-up processes and the top-down consequences. The bottom-up processes relate to the construction and operation-induced changes in the physical system, such as a change to the seabed and water column. The top-down consequences then relate to the manner in which these affect the biota, especially the larger organisms (fishes, birds and sea mammals) which may also be the ones with greatest socio-economic and conservation significance.

Each part of the horrendogram requires an assessment of the likelihood of an impact and the means by which that could be mitigated for or compensated. Similarly, each arrow linking components implies a process which may occur over space or time. Those processes require to be measured and if possible modelled in order to denote the likelihood of adverse repercussions of the industry.

The relatively young nature of the offshore windfarm industry dictates that there are few case studies to produce fully quantified data either to support or refute

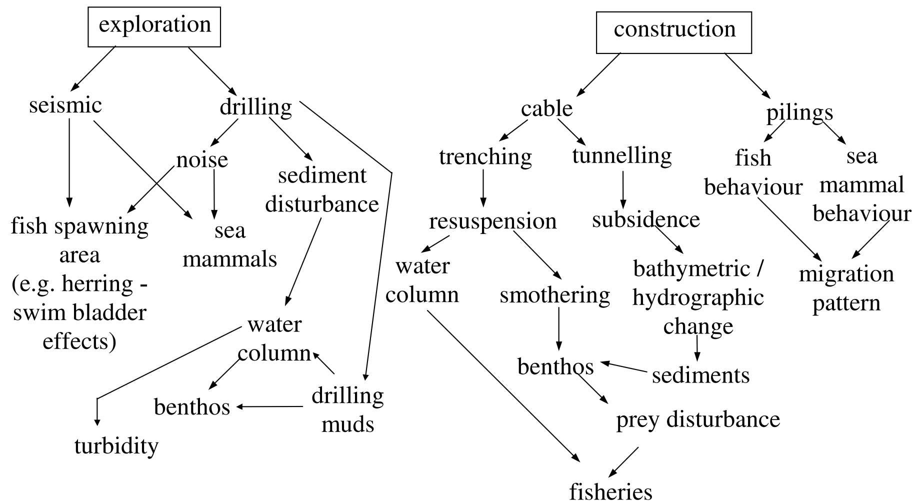

Fig. 1. Environmental consequences of offshore wind power generation I.

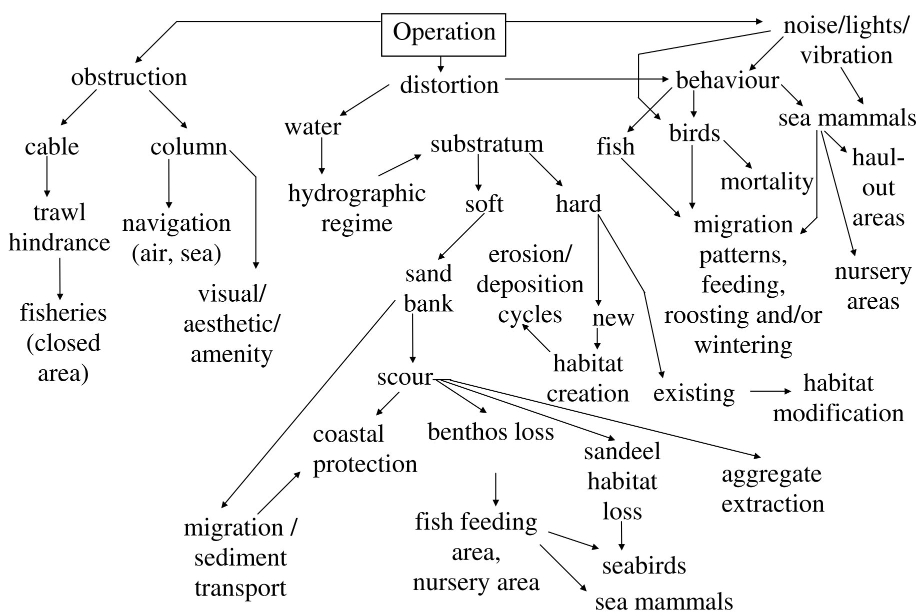

Fig. 2. Environmental consequences of offshore wind power generation II.

fully the potential effects indicated by the conceptual models. However, the consensus from EIA for windfarms suggests that whereas the potential effects may be predicted, many are either unlikely or are likely to be minimal. Indeed, when environmental groups describe offshore windpower as environmentally benign then it must be gaining acceptance as a green source of energy.

Such a view of offshore windpower has resulted in an increasing use of this form of alternative energy generation in many developed countries, for example the UK and Denmark. Whereas the latter has a well-developed offshore windpower industry, the UK has only recently agreed to its widescale development. Indeed in April 2002, a windfarm of 38 2-MW turbines was given the go-ahead for the Scroby Sands area off Eastern England. The conceptual models, such as those presented here, may therefore be viewed as a set of hypotheses for testing either by existing information from related activities (e.g. the seabed impacts of telephone cables) or field surveys of existing offshore windfarms.

4. The way ahead

It is necessary to be aware of the spatial and temporal links in the marine system coupled with the diverse nature of stressors on the systems. The latter will require conceptual models to be linked together and further developed towards numerical and predictive models. It is likely that such fully quantified and predictive models will not be possible for many of the stressors on the system and so decision makers will have to rely on quantitative relationships and expert judgement.

The marine assessment and management community will have to come to terms with considering the wide-scale nature of human activities. It may not be valuable or even possible to separate the changes within the hinterland, catchment, river–estuary system, coastline, near coast and out to sea. For example, as decided by the December 2000, Greenpeace case in the British High Court against the UK Government, the agreed legislation and especially European Directives will have to be enacted out to 200 nm not just in nearshore areas.

Scientists will be increasingly required to consider the whole marine system, to continue to derive conceptual models and to attempt quantitative, numerical predictive models and decision support systems. However, they will have to educate managers and politicians to the view that the marine system is so complex that it is unlikely that we will ever be able to fully and quantitatively predict all natural and anthropogenic changes and so best (expert) judgement will have to be relied on for decision making.

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