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Cause-Consequence-Response Chains – DAPSI(W)R(M)

Authors: Michael Elliott, Jonathan Atkins and Gemma Smith

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Authors (alphabetical)	
Name	**Organisation**
Atkins, Jonathan	IECS Ltd
Elliott, Michael	IECS Ltd
Smith, Gemma	IECS Ltd

Acknowledgements/contributions (alphabetical)	
Name	Organisation

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1. Introduction

Environmental management, and especially that for marine and coastal areas, is essentially a risk assessment and risk management process which implicitly or explicitly involves a cause-consequence-response framework (Cormier et al., 2019; Elliott et al., 2020a, b). In this, the natural and anthropogenic causes of hazards to the natural environment and the resulting risks to society are determined and then management measures determined to either prevent, mitigate or compensate those adverse effects. In the case of EU marine management legislation, such as the Marine Strategy Framework, Water Framework, Habitats and Species, and Wild Birds Directives, the sum of the management responses are termed Programmes of Measures.

2. The DPSIR Framework and its evolution

Those consequences are regarded as effects on both the natural system and the way society uses the natural system, which then need management actions to alleviate, reduce or remove those consequences (Elliott and Wither, 2023). This approach has long been proposed (since the early 1990s) as the Driver-Pressure-State-Impact-Response (DPSIR) framework to link development and its pressures and impacts on the environment (Patricio et al., 2016) (Figure 1). The aim of the approach is to link human needs for the marine and estuarine systems, the consequences of those needs and the means of tackling any problems resulting from those needs and consequences. This cyclical framework considers the *Drivers* (human activities and economic sectors responsible for the pressures); *Pressures* (particular stressors on the environment); *State* (the characteristics and conditions of the environment); *Impacts* (changes in the natural and human system and the way in which we use the marine area), and *Responses* (the creation of different policy options and economic instruments to overcome the state changes and impacts). Hence, the five elements of DPSIR framework produce a valuable philosophy for tackling and communicating our methods of marine management (McLusky & Elliott, 2004; Patricio et al., 2016;Elliott 2011; Atkins et al., 2011).

To the DPSIR acronym we may also add Recovery (a reduction in the state changes as the result of these actions) this giving a 6th element in the DPSIRR framework (Elliott et al., 2007; Borja et al., 2010). Subsequently, the EU project KNOWSEAS replaced the I for Impact with W for Welfare (hence DPSWR), both to avoid the long-standing confusion and separate impacts on the natural system (the state changes) from impacts on the human system and also to reinforce the societal-ecosystem links.

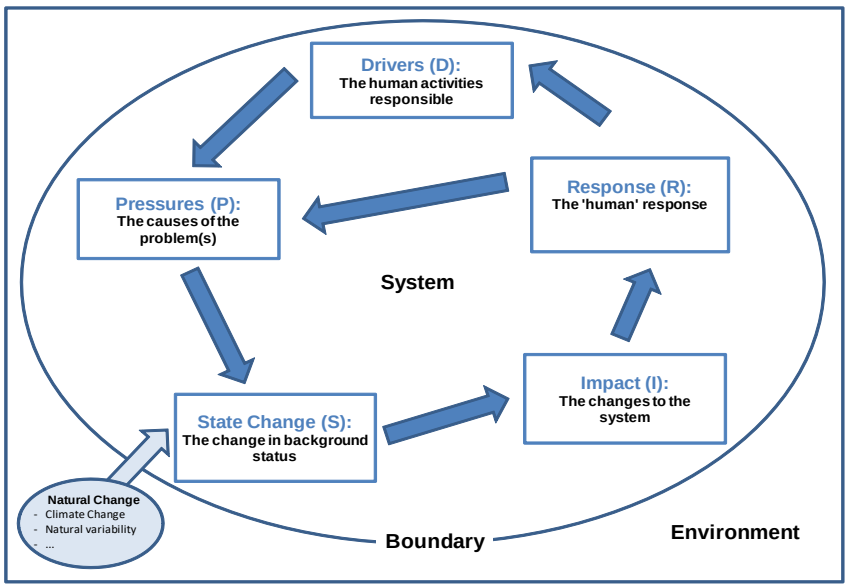


Figure 1. The DPSIR Cycle (from Atkins et al., 2011)

Earlier iterations then showed that there will be a single DPSIR cycle for each major driver (e.g., power generation is one cycle) but this interacts with cycles for wild capture fisheries, recreational fisheries, tourism, other industry etc. These ideas were expanded to require a set of 15 DPSIR-ES&SB (Ecosystem Services & Societal Benefits) postulates (see Atkins et al., 2011; Elliott 2011). As an example, a power station development fulfils the need for power by society (D) which in turn will lead to loss of space, requirement for cooling water and aggregates (P) which could change the ecological health of the benthos and the fish community (S). If not checked, these changes on the natural system would lead to a loss of amenity and fisheries (I). To prevent the latter then requires economic and legal instruments (R).

3. The DAPSI(W)R(M) Framework

Patricio et al. (2016) showed the evolution of the DPSIR approach and its many iterations and so, over time, various areas of confusion have developed in the use of DPSIR not least with social scientists using the elements in one way and natural scientists in another way. For example, a driver could be a human need, an activity, a sector of activities, or a stressor; a pressure could be an activity, a sector or a mechanism of change; state could be the characteristics of a system or the changes to those; impacts could be on the natural and/or social system, and responses were poorly defined. Hence DPSIR has been modified and refined into the most recent, and arguably a more complete, approach - the DAPSI(W)R(M) (pronounced *dap-see-worm*) framework (Figures 2 and 3) (Patrício et al., 2016; Elliott et al., 2017). The approach has now been used in many applications and areas (e.g., Lovecraft and Meek, 2019; Izar et al., 2022) as well as being merged with similar frameworks such as that produced by the AQUACROSS project (Elliott and O'Higgins, 2020).

The DAPSI(W)R(M) framework was designed to overcome anomalies and confusion in the previous iterations of the framework, especially the DPSIR approach (Table 1). In this, *Drivers* of basic human needs and values (such as the need for food and recreation) need to be fulfilled by *Activities* (e.g., fishing, tourism) that create *Pressures* (e.g., seabed abrasion, pollution); in turn, those Pressures, as the mechanisms of change, lead to *State changes* on the natural system (e.g., turbidity increase, oxygen depletion) and *Impacts (on human Welfare)* on the human system (e.g., biodiversity loss, ecosystem services provision depletion). The *Response (using management Measures)*, i.e. a policy response, then implies that society responds to those environmental and societal consequences, not least using a Programme of Measures, as defined in the EU Water Framework Directive and the EU Marine Strategy Framework Directive (Elliott et al., 2017). Those responses then need to range across the set of ecological, economic, technological, governance and other measures, summarised as the so-called 10-tenets (e.g., Cormier et al., 2022).

Table 1 The rationale for modifying the DPSIR framework to the DAPSI(W)R(M) framework (extracted from Patricio et al., 2016; Elliott et al., 2017)

Element	Differences in DAPSI(W)R(M) from DPSIR
Drivers	The original framework did not restrict drivers to high level human needs thereby making it difficult to link to the welfare aspects; this also confused overall drivers and activities; this led to the concept of sectoral drivers (such as fisheries, oil, and gas, etc.).
Activities	In the original framework, activities were merged *inter alia* with drivers and pressures, thereby adding confusion; drivers were not explicitly restricted to high level human needs
Pressures	In the original, pressures and activities were merged (e.g., fisheries was a pressure rather than an activity creating pressures). They were not defined as mechanisms of change.

State change	In DPSIR this was regarded by social scientists as State Change on the natural system whereas natural scientists regarded it as State of the natural system (as a condition at one time) so that Impact was then the change on both the natural and social aspects.
Impacts (on human Welfare)	Originally social scientists regarded this as changes to the societal system whereas natural scientists regarded it as changes to both the natural and social systems. It has only recently been linked to ecosystems services. The new system then separates ecosystem services from societal goods and benefits by addressing them in State Change and Impact (on Welfare) respectively.
Responses (using management Measures	In DPSIR, these were regarded as ways to respond but little detail was given. The inclusion of management Measures then harmonised the framework with legislation such as EU Directives which require countries to define 'Programmes of Measures'. The definition then explains what type of measures are possible to get a holistic response.
Links between the elements	The original framework had a simpler cycle with fewer linkages.

As with DPSIR, the DAPSI(W)R(M) framework can be presented as a set of interlinked cycles within a management area, each cycle for a major sector (fisheries, energy production, etc.), and where the activities produce the endogenic managed pressures (EnMP); the latter require management of both their causes and consequences within the management area (Figure 4). That management area, however, is also subject to exogenic unmanaged pressures (ExUP) in which the causes, such as of climate change, require management outside the management areas whereas the consequences and their management (such as sea-level rise) occur within the management area (Figure 4). The overall marine, coastal and estuarine system and their catchment can be shown as a set of interlinked DAPSI(W)R(M) cycles (Figure 5), thereby showing the complexity of the environmental management system, which requires the need for systems analysis and the development of a multifaceted Simple social-ecological system (Gregory et al., 2023). Briefing Paper 4 on Marine Processes and Functioning and Ecosystem Services presents an integrated ecosystem model based on DAPSI(W)R(M) (from Elliott, 2023).

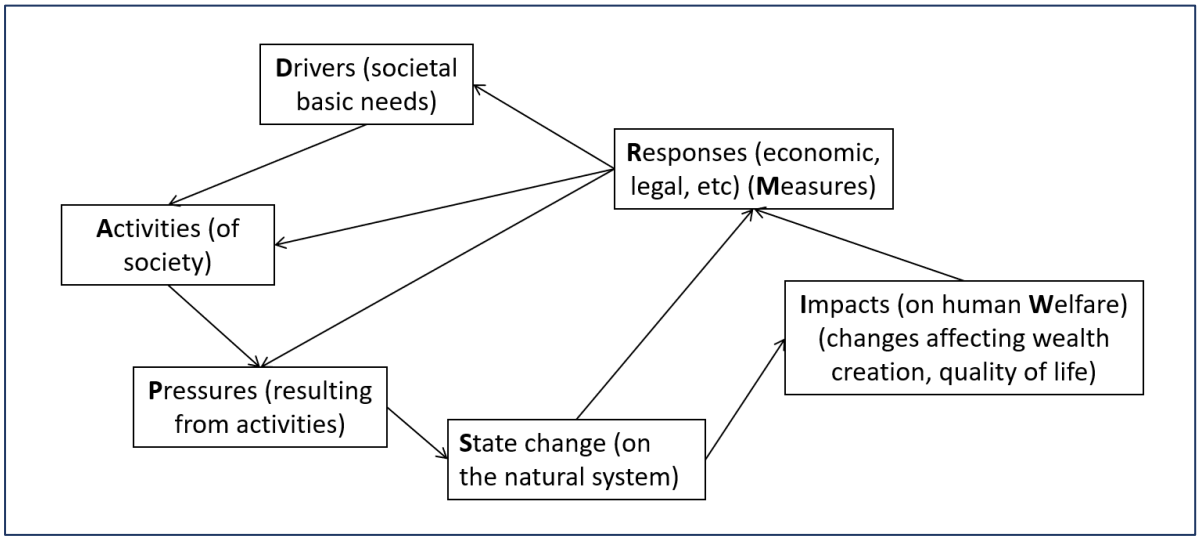


Figure 2. The DAPSI(W)R(M) Framework

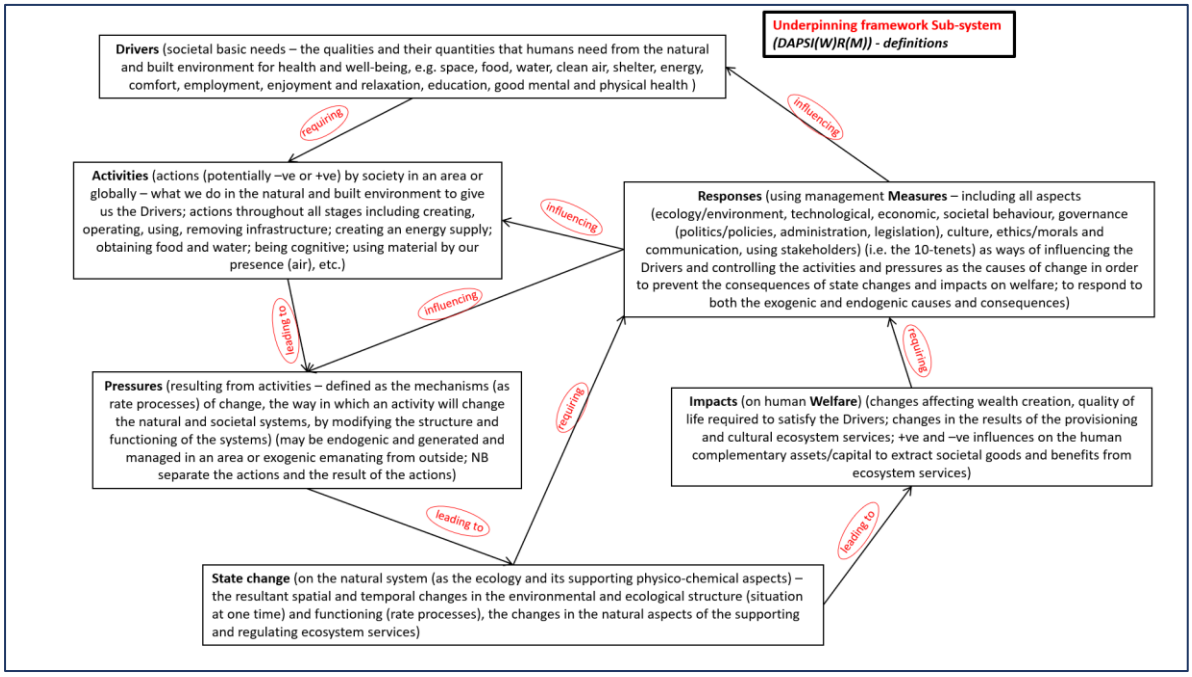
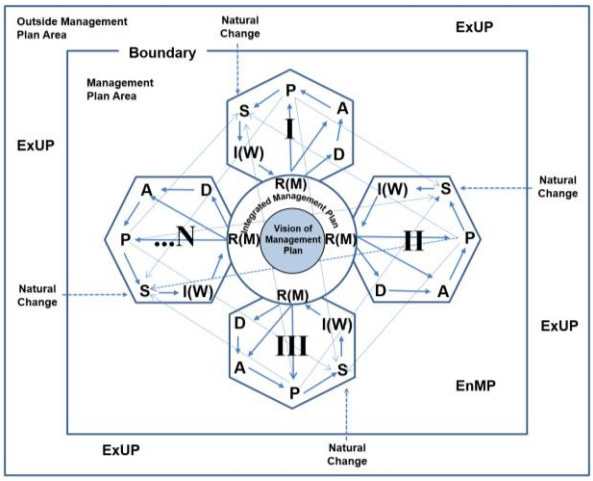


Figure 3. The DAPSI(W)R(M) Framework - the description of each element and the links between them



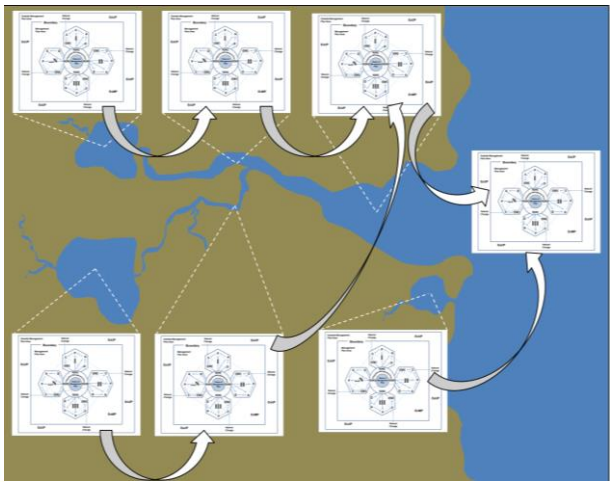


Figure 4 (Left). The DAPSI(W)R(M) cycles for each sector of endogenic managed pressures within a management area (the inner box) and surrounded by the exogenic unmanaged pressures and natural change (the outer box) (from Elliott et al., 2017)

Figure 5 (Right). The DAPSI(W)R(M) framework (Figure 4) shown for each area within a catchment and at sea showing the connectivity links between them.

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