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Discussion

Drivers and pressures – Untangling the terms commonly used in marine science and policy

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ABSTRACT

In the marine sciences an increasing number of studies on environmental changes, their causes, and environmental assessments emerged in recent years. Often authors use non-uniform and inconsistent definitions of key terms like driver, threats, pressures etc. Although all of these studies clearly define causal dependencies between the interacting socio-economic and environmental systems in an understandable way, still an overall imprecise wording could induce misunderstanding at higher policy levels when it comes to integrated ecosystems assessments. Therefore we recommend using unified definitions for a better communication between science and management within national, regional and international environmental policies, for example the European Marine Strategy Framework Directive (MSFD). With this article we provide definitions compatible with the driver-pressure-state-impact-response (DPSIR) approach. Although most examples are MSFD related and thus have a marine focus the definitions are intended to be equally applicable for other systems and are usable world-wide. We suggest sticking to these definitions for an easy and simplified knowledge transfer from science to management, since DPSIR model is already accepted as a helpful tool for structuring and communicating ecosystem analyses.

1. Introduction

Worldwide human population is increasing while natural resources remain limited. Consequently, the usage and exploitation of available natural resources has been and will be intensified. In the oceans, increasing and diverse exploitation of marine resources has already led to augmenting human-induced alterations to ecosystems, particularly within sea shelf, coastal and estuarine environments (Kappel, 2005; Elliot, 2014). This has necessitated development of different regional and national legislative initiatives aimed at protection and restoration of marine ecosystems and further adequate and sustainable management of marine resources (Foster and Hawar, 2003; Parsons, 2007; Rutherford et al., 2005). One of the most recent important, the European Marine Strategy Framework Directive (MSFD) (EU-COM, 2008) requires all European marine waters to obtain and/or maintain good environmental status by 2020 (2008/56/EC). Herein, the MSFD required an ecosystem-based management approach (Borja et al., 2010, 2014), since it implies integrated management of human activities based on best available scientific knowledge about all ecosystem components (including humans), their dynamics and interactions, in order to achieve sustainable use of ecosystem goods and services and maintain ecosystem integrity (Elliot, 2011; Yanez-Arancibia et al., 2013). The ecosystem approach is vital for understanding causal dependencies between human activities and their various impacts on marine ecosystems, which has been identified as a major challenge within the contemporary marine science (Borja, 2014). It requires integration of knowledge across different ecosystem components, linking physical, chemical and biological aspects with existing and emerging anthropogenic factors. As a result, there is an exponential increase in marine studies focused on drivers of ecosystem change and assessment of associated pressures on the state of the ecosystem (Fig. 1).

But with the growing scientific interest in issues related to marine ecosystem-based management, inconsistency in usage of terms like '*driver*' and '*pressure*' also increases (cf. eg. Borja et al., 2006; Halpern et al., 2007, 2008; Kristensen, 2004; Link et al.,

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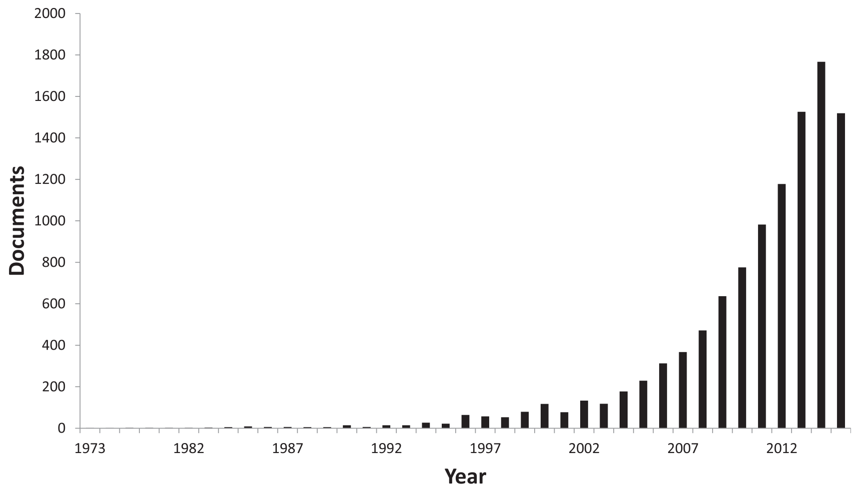

Fig. 1. Number of publications with the keywords 'ecosystem' and 'assessment' and 'marine' and 'pressure' or 'driver' over the past 45 years in the field of environmental science (Scopus Analyzer, 2015).

2010; Maxim et al., 2009; Oman et al., 2009, Sundblad et al., 2014), which potentially may lead to misapplication and therefore misunderstanding among researchers, managers, decision-makers and other stakeholders. An overall usage of concerted terminology is necessary to eliminate confusion hampering successful implementation of ecosystem-based management and integrated policy. Here we examine the variation in usage of the commonly accepted terms and propose a set of consistent and universally valid definitions which are understandable for different groups of potential users and are applicable for integrated ecosystems assessments within environmental policies. Our focus lays predominantly on examples from the marine realm referring to the Driver-Pressure-State-Impact-Response framework (DPSIR), yet the proposed definitions of the DPSIR terms are intended to be applicable for other ecosystems and different frameworks (e.g. PSR), and will support communication between researchers and policy-makers. To exemplify the usage of these terms we will focus on the MSFD which covers a wide range of ecosystem aspects and functions (2008/56/EC), being a good case for demonstrating the necessity of the consistent terminology. To successfully implement MSFD, all coastal member states of the European Union have to work together through interdisciplinary knowledge exchange of various fields of science and policy in order to achieve GES in their interconnected marine waters. Therefore, a huge amount of effort is necessary to align monitoring and measures between the member states requiring clear and coordinative understanding of driver-pressure-state-impact-response relationships and talking the same language is a crucial prerequisite for this.

2. Examples of inconsistent usage of the terms 'driver' and 'pressure'

As mentioned above the most confusing words of the DPSIR framework are 'driver' and 'pressure' which are elaborated in more detail in the following sections.

2.1. 'Driver'

A brief research on the usage of the term *driver* revealed rather diverse understanding of the 'drivers' in marine ecosystems. For example while some studies define climate change as a driver (MA, 2005), others refer to it as a pressure (Omann et al., 2009) or still others as a threat (Halpern et al., 2008). Confusion concerning the assignment to these three terms seems to be typical and might be related to the various contextual and conceptual frameworks used by the different authors. Within the marine-focused literature many studies consider only anthropogenic factors as drivers or driving forces (Maxim et al., 2009) related to the certain socio-economic activities (Patricio et al., 2014a), while others refer the term 'driver' to both natural and anthropogenic factors (Allen and Fulton, 2010; Harwell et al., 2010; MA, 2005).

More differences were revealed in regards to the level of detail. In most cases, drivers are studied within a specific context and are described with many details and several structural levels (Bulleri and Chapman, 2010). However some authors consider drivers at the highest level, as the overarching economic and social policies of governments or economic and social goals of major industries (Smith et al., 2014). This phenomenon could be correlated to the degree of knowledge about interactions within the ecosystem as well as the availability of relevant information. Some studies divide driving forces further into different categories. The MA (2005) for example, distinguishes between indirect and direct drivers. Hereby indirect drivers are considered to operate more diffusely, e.g. demographic, economic, socio-political, cultural or religious drivers plus science and technology. These indirect drivers include factors which influence the level of production and consumption of ecosystem services and the sustainable use of the resources. In most cases these factors exhibit multiple interactions. Thus a connection between a certain indirect driver and a particular change in the ecosystem is uncommon (MA, 2005). On the contrary, direct drivers like habitat change, over-exploitation, introduction of non-indigenous species, pollution, and climate change are considered to influence ecosystem processes more obviously (MA, 2005).

There are also studies with driving forces divided into more than two categories (Rodríguez-Labajos et al., 2009; Spangenberg, 2007). Spangenberg (2007) defined three categories of drivers; a) physical primary drivers (mainly resource consumption and pollution), b) secondary drivers (politics and policies) and c) tertiary drivers (structures incl. ideologies). Rodríguez-Labajos et al. (2009) differentiate two criteria, the direct linkage between the driver and a pressure and the long term influence of societal behaviour. Based on these criteria they further divide drivers into four categories. While the primary driver (economic activities with a direct pressure) and the secondary driver (policy level) are quite similar to the Spangenberg (2007) definition, the 'tertiary driving forces' represent the level of ideology and lifestyle and finally the 'base driving forces' involve the structural aspects (e.g. demographic patterns).

2.2. 'Pressure'

In various policy documents, scientific reports and research papers the term *pressure* is often synonymized with human activity or driving force (Patricio et al., 2014a) or impacts induced by human activities (Borja et al., 2013; Elliott et al., 2015). Occasionally confusion with the terms 'hazards', 'risks', 'driver', 'stressor' and 'state-change' occurs (Crain et al., 2008; Patricio et al., 2014a). Again, most authors refer to anthropogenic pressures, yet some distinguish a further category 'natural pressures' (Atkins et al., 2011), alternatively to natural drivers, specifying that the former are not directly manageable.

As indicated by Maxim et al. (2009), the definition of pressure and its usage in the literature differs in at least four aspects: the objective of change, the relationship between the pressure and the changes induced, the character of the pressure and finally the specification level of the pressure. Indeed often it can be observed that various levels of specification are applied, which seems to depend on the amount of information available. For example, a well-known, complex pressure like extraction of living marine resources by fishing is often subdivided in regards to the range of fleets or methods used (like ground fishing, gillnet fishing, pelagic fishing etc.). In contrast, pressures with a vague or less known level of complexity are often described and analysed in a more generalized manner. This of course induces a risk of overweighting certain pressures within an assessment, if several are combined at a different specification level and merged unwarily.

Furthermore various studies show that it is important to take into account manageability of pressures. Some authors (Atkins et al., 2011; Borja et al., 2010; Elliot, 2011) distinguish pressures based on their scale and manageability: (i) local (inside the system) and manageable - endogenic managed pressures and (ii) those arising outside of the system, widespread and unmanageable - exogenic unmanaged pressures, which can only be regarded in management strategies. Within the marine scientific community there seems to be no complete agreement whether global phenomena such as climate change or ocean acidification should be treated as an exogenic unmanaged pressure (Elliott et al., 2015), or left beyond the pressures concepts and considered separately (Patricio et al., 2014b).

3. A framework for ecosystem assessment – a way to a better science communication

Ideally, within the environmental management or policy implementation, decision-makers will be advised by independent scientists to discuss different management options and come-up with the best possible solution for each considered environmental or social problem. Hence the scientifically-grounded advice is the basis for management decisions. A communication problem or misunderstanding of scientific recommendations could lead to uncertainty about which management option to choose and wrong conclusions, which might result in unpredicted consequences.

A relevant example refers to introductions of non-indigenous species and communication of the invasion biology related research. The inconsistent usage of terminology in this field has evoked unnecessary ethical and political debates resulting from misunderstanding of scientific vocabulary by managers and politicians (Larson, 2005). Even among experts there are diverging conceptual understandings of the non-indigenous species phenomena leading to the heterogeneity of expert judgements, inconsistency in risk assessments and consequently – impeded conservation management (Lodge and Shrader-Frechette, 2003; Humair et al., 2014). The need for enhanced communication of applied research in order to advance implementation of existing knowledge into policy and management is widely appreciated by both scientists and stakeholders (Lodge et al., 2006; Jones-Walters and Çil 2011). Consequently it urged the scientists to structure different aspects of biological invasions into coherent frameworks, thus reducing confusing range of concepts, terms and definitions and addressing the emerging management issues (e.g. Olenin et al., 2007; Blackburn etal., 2011; Heger et al., 2013).

For wider applications, a well-structured holistic framework is essential in order to standardize and unify the ecosystem-based analyses and to communicate and illustrate complex research results from different fields.

Between 2001 and 2005 the Millennium Ecosystem Assessment (MA) Board developed a conceptual framework for integrated environmental assessment focusing on the consequences of ecosystem change for human well-being. The framework assumes dynamic interaction between people and the ecosystem, with human condition directly or indirectly driving change in an ecosystem which has a reciprocal effect on human well-being. Thereby human condition is not assumed to be affected only by the environment and environmental change but also occurring due to the natural driving forces. The Millennium Ecosystem Assessment (MA) framework places human well-being as the central focus for managers, while recognizing that biodiversity and ecosystems also need to be protected due to their intrinsic values (MA, 2003).

Within this conceptual framework human well-being is considered to consist of multiple constituents, like security (personal safety, secure resource access, security from disasters, etc.), basic material for good life (adequate livelihoods, sufficient nutritious food, etc.), health (access to clean air and water, feeling well, etc.), freedom of choice and action (opportunity to be able to achieve what an individual values doing and being) and good social relations (social cohesion, mutual respect, etc.) (MA, 2003). Particular attention is paid on the linkage between human well-being and ecosystem services, the benefits humans obtain from nature. The MA categorizes ecosystem services as provisional (e.g. food, fresh water, fuel), regulating (e.g. climate regulation, water purification), cultural (e.g. aesthetic, spiritual, educational) and supporting (e.g. nutrient cycling, primary production). Human induced changes in the ecosystem are assumed to cause changes in ecosystem services thereby affecting human well-being (MA, 2003). Concerning such changes, the framework allows distinguishing whether these take place on rather local, regional or larger scales. Management response at each scale is intended to either minimize or prevent negative changes or to enhance positive (desirable) changes.

Other frameworks focus on causalities between human intervention and ecosystem state change, which implicitly also refer to human well-being but with practical emphasis on management options. For example, in the beginning of the 1990s, the Organisation for Economic Cooperation and Development (OECD) proposed a framework for combined assessment of pressure-, state-, and response-indicators for environmental performance evaluation, the so called pressure-state-response (PSR) framework (OECD, 1993). This framework is an extension of the Stress-Response framework developed in the late 1970s (Rapport and Friend, 1979). It was developed as a structuring and communication tool to provide policy-makers with easy-to-understand information on the key links between society and the environment. Later on, the PSR model was extended into the driver-pressure-state-impact-response (DPSIR) framework, which was adopted for ecosystem-based assessments by the European Environment Agency (Gabrielsen and Bosch, 2003). The central idea of both PSR and

DPSIR is the cause and effect continuum. In the case of PSR, human activities exert pressures on the environment leading to a change in quality or quantity of natural resources (state) thereby triggering a societal response (OECD, 1993). Within the extended DPSIR framework the driving forces induce pressures, which generate changes in the environmental state. This in turn leads to impacts on e.g. human health and ecosystem services and may trigger a societal response that feeds back to the driving forces, pressures, state or impact (Fig. 2, Smeets and Weterings, 1999). Of course the multiple nonlinear linkages have to be acknowledged as possible between and within PSR or DPSIR elements (Atkins et al., 2011, Fig. 2).

During the last years the DPSIR approach has become popular among scientists and policy-makers (Svarstad et al., 2008) as a conceptual framework for environmental assessments, providing a standardised methodology for traceability, replicability and accountability, facilitating the communication of the policy-relevant research outputs (Patricio et al., 2014a; Svarstad et al., 2008). It has found its application in different projects (e.g. ALARM – Assessing LArge scale Risks for biodiversity with tested Methods; DEVOTES – DEVelopment Of innovative Tools for understanding marine biodiversity and assessing good Environmental Status) and has been widely discussed by various scientists (e.g. Borja et al., 2006; Elliot, 2014; Maxim et al., 2009; Omann et al., 2009; Spangenberg et al., 2009). Nevertheless even under this well-established framework different definitions of the terms driver, pressure, state, impact and response are utilized (Sundblad et al., 2014). A reason might be that DPSIR is a conceptual framework allowing for divergent interpretations depending on case-specific research and management questions (Cooper, 2013; Sundblad et al., 2014) or different attitudes (Svarstad et al., 2008) and adjustments for specific needs (Cooper, 2013; Maxim et al., 2009; Spangenberg et al., 2009). The inconsequent application of the DPSIR concept and its terms, however, exacerbates communication and understanding, and restrains its usability in environmental assessments and ecosystem management (Spangenberg et al., 2009).

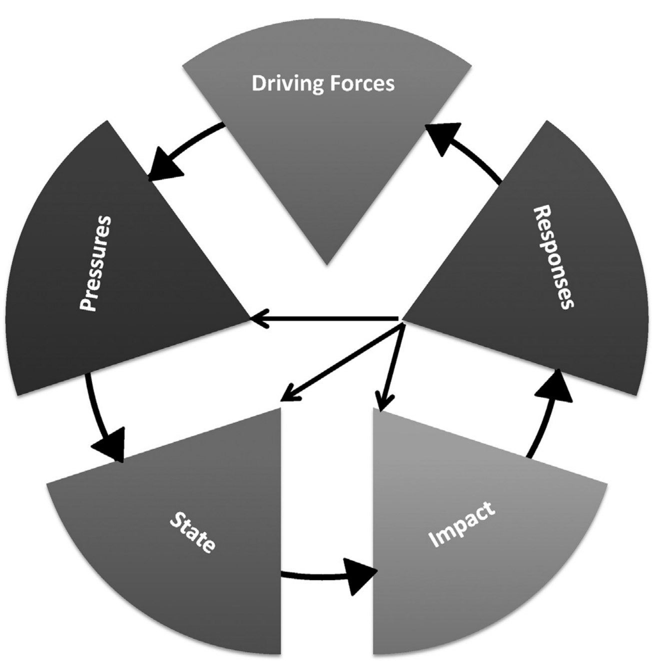

Fig. 2. The Driving Force – Pressures – State – Impacts - Responses framework (DPSIR) modified after Gabrielsen and Bosch (2003).

The Marine Strategy Framework Directive is a recent example of international political initiative, where different stakeholders interact and is closely related and attributable to the DPSIR framework in particular. In order to reach the good environmental status, the MSFD requires the EU coastal member states to take particular actions and conduct several steps which are strongly aligned with the DPSIR logics. This includes an evaluation of the current environmental status compared to the defined good environmental status, an assessment of predominant pressures and impacts involved, as well as a socio-economic analysis of anthropogenic use of the marine ecosystem. Consequently member states shall implement management measures (responses) in order to obtain or maintain the good environmental status. Nevertheless, despite its strong linkage to the DPSIR concept, no strict definition is given within the MSFD for the terms involved.

Consequently it is no wonder that within the EU-wide evaluation of the first MSFD implementation phase (finished in 2012), the European Commission had to adversely recognize that adequacy, consistency and coherence within and between the different marine regions are too low to fulfil the overall goals of the MSFD (EU-COM, 2014). Apparently, since the good environmental status has to be obtained at a comparable level across all European marine waters, the agreement of the member states on definition and understanding of major terms is an important prerequisite for efficient implementation of the MSFD in general.

Here we acknowledge the importance of a consistent agreement about terminology in environmental management and policy and suggest coherent definitions compatible with the DPSIR approach usable within the framework of the MSFD (to provide an example with high policy relevance) and beyond. These definitions are well suited for a wider application, addressing the needs of other policies, frameworks and ecosystems world-wide.

4. Proposal for consistent definitions within the DPSIR framework

In general terms, a **driver** causes a particular phenomenon to happen or develop (Griffiths and Lambert, 2013). Traditionally within the DPSIR framework a driver is understood as a demand from the system/society (Elliot, 2014). In order to remain in concert with the DPSIR concept yet overcoming the ambiguities related to the drivers' typology, we propose to define *driver as a superior complex phenomena governing the direction of the ecosystem change, which could be both of human and nature origin*. The term 'superior complex phenomena' is used to put emphasis on the inescapability of drivers which are beyond direct control or management. Thereby the anthropogenic drivers are based on economic, social and political fundamental needs (demands) like food, health, clean water, employment, energy, reproduction or the wish for re-election. Natural drivers on the other hand are majorly independent from anthropogenic causes and could be referred to as "force majeure", like for example earthquakes, volcanic eruptions or tectonic drift (Fig. 3). Therefore both anthropogenic and natural drivers are not manageable in a broader sense.

As regarding the **pressure** definition, it can be formally described as *a result of a driver-initiated mechanism (human activity/natural process) causing an effect on any part of an ecosystem that may alter the environmental state*. By accepting such definition, there will be no conflict in attributing widespread complex phenomena (such as climate change) to pressures' category, disregarding the uncertainties about their causes (natural or anthropogenic).

Unlike drivers, management can have a direct influence on intensity and direction or even the occurrence of pressures. However it is important to distinguish between manageable (endogenic)

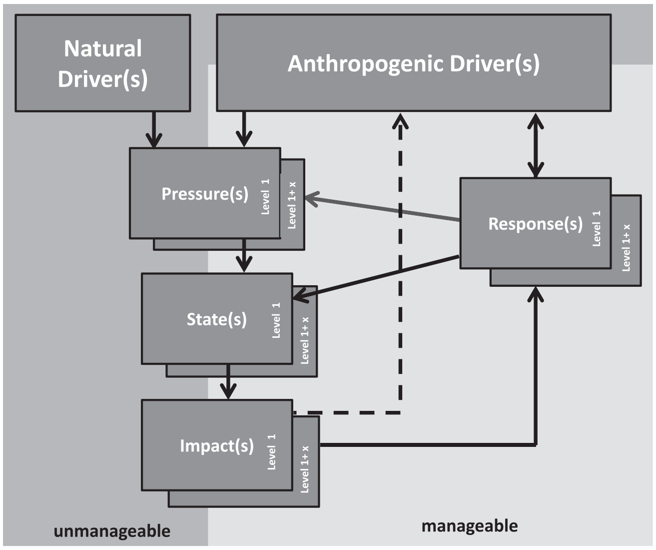

Fig. 3. The Driving Force – Pressures – State – Impacts - Responses framework (DPSIR) modified after Gabrielsen and Bosch (2003). It is distinguished between anthropogenic and natural drivers which lead to manageable and unmanageable pressures, respectively.

pressures arising from human activities due to anthropogenic demands and unmanageable (exogenic) pressures caused by natural drivers and/or created outside of the system which management can only take into account but not respond to (Borja et al., 2010). It should be noticed however that these categories are not mutually exclusive, e.g. when the pressure arises from different drivers simultaneously. An example for this is climate change, which can result both from human activities (CO^2 emissions) and natural phenomena (e.g. solar activity, volcanic eruptions or internal climate variability). Such pressures could be treated as semi-endogenic/semi-exogenic.

The effects on the 'state' of the environment emanating from the particular pressure emerge in the ecosystem elements (e.g. species, environmental conditions) and are related to the functions these elements fulfil (Gabrielsen and Bosch, 2003, Kristensen, 2004). Hence, the **state** *is the actual condition of the ecosystem and its components established in a certain area at a specific time frame, that can be quantitatively-qualitatively described based on physical* (e.g. *temperature*, *light*), *biological* (e.g. *genetic-*, *species-*, *community-*, *habitat-levels*), *and chemical* (e.g. *nitrogen level*, *atmospheric gas concentration*) *characteristics* as highlighted also in the MSFD itself, Annex III, Table 1 (EU-COM, 2008). The 'state' and 'pressure' concepts should be unambiguously distinguished for the sake of DPSIR application, since only a proper understanding of specific pressure-state-relationships can lead to successful ecosystem-based management. Therefore in the recent MSFD-related documents there are also suggestions on the more precise differentiation between state and pressure indicators (e.g. Patricio et al., 2014a; Teixeira et al., 2014).

Impacts can be defined as *consequences of environmental state change in terms of substantial environmental and/or socio-economic effects which can be both, positive or negative*. While environmental impacts can be detected by monitoring as a 'signal' over the environmental 'noise' – the natural ecosystem turnover (Maxim et al., 2009; Patricio et al., 2014b), socio-economic impacts ultimately affect human health, wellbeing and performance of society (Kristensen, 2004). It should be noted that an environmental or socio-economic impact may evoke some modifications to human awareness which could lead to changing societal interests/demands (see Fig. 3). However generally it leads to response actions that are aimed at the cause of impact (pressure) to mitigate unwanted impacts.

Thus a detected and defined impact will trigger a **response** by policy and management. We suggest defining 'response' as *all management actions seeking to reduce or prevent an unwanted change or to develop a positive* (*desirable*) *change in the ecosystem*. Thereby management ability to influence the strength and direction of change is restricted to manageable endogenic pressures driven by anthropogenic activities while unmanageable exogenic pressures can only be reacted upon or taken into account when considering major interrelationships.

However, it is important to keep in mind that the framework is not two-dimensional. It is rather multi-dimensional since one driver can cause one or more pressures and one pressure can be based on one or more drivers as we will demonstrate in the following examples. In marine ecosystems there is also a substantial lack of knowledge on causal links between pressures and impacts on particular ecosystem components that might also handicap the straight-forward application of the framework and timely implementation of adequate response measures.

4.1. Example 1: fishing

One of the major drivers in human society is demand for food, which is realized by several different mechanisms/human activities. One of those is fishing, which results e.g. in the pressure 'selective extraction of species from the ecosystem' (Fig. 4). In this case the measurable state could e.g. refer to the size spectrum or spawning stock biomass of the extracted species. On the ecosystem level, the consequence of such state change may impact the reproduction capacity of the species. Simultaneously impacts could also affect human well-being e.g. in terms of preservation of food supply or fishing opportunities. Management response might be the adaptation of the 'Total Allowable Catch' (TAC) or technical regulations concerning the gear. Note, that each category within DPSIR can be described in more detail which might be helpful for "fine tuning" of the management strategy; e.g. a higher level of detail is important due to the fact that there are generally multiple pressures arising from the same mechanism which may require

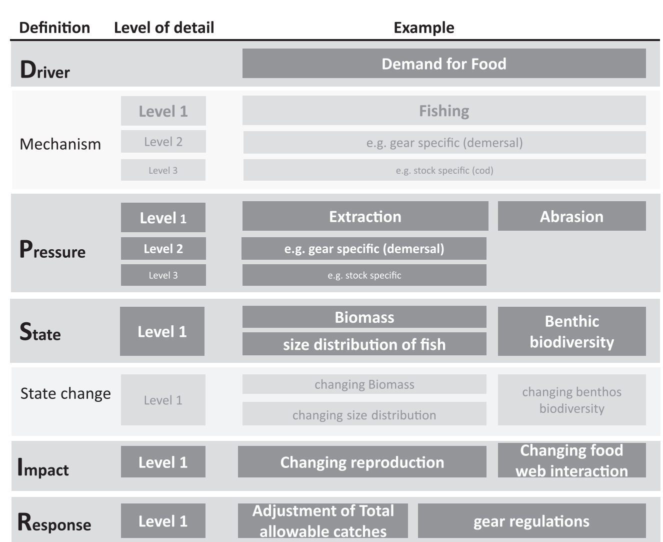

Fig. 4. Some potential dependencies as an example of using the DPSIR framework for fishing. Notice that the different level of detail is only shown for the *Mechanisms* and *Pressures* and could be continued for the other entire row as well.

different types of responses. In this example one could think of abrasion of the sea floor (Fig. 4) as effect of demersal gears. Furthermore response measures like TAC can be adjusted stock-specifically or technical measures are implemented gear-specifically. In addition, the example illustrates the importance of understanding the cross-linkages of all drivers and pressures to a certain impact when thinking about appropriate management measures which requires an interdisciplinary approach. For instance, reproduction might be impaired due to other reasons next to or even instead of fishing, for example environmental effects or interspecies relationships. Therefore the knowledge of as much as possible DPSIR linkages and interactions within the ecosystem is vital for successful implementation of an ecosystem based management.

4.2. Example 2: non-indigenous species

In this example we present a case with one pressure emerging from multiple drivers. The major driving forces for introduction of non-indigenous species (NIS) are maritime transport (or demand for transporting goods and humans), demand for food, demand for tourism and recreation. There can be several mechanisms involved including (but not limited to) shipping, mariculture, boating activities and fishing (Fig. 5). All of them can be subdivided to subcategories or particular vectors of NIS translocations across ecosystems. In relation to the pressure, the state characteristics can be assessed at communities, habitats or entire ecosystem levels (e.g. alteration of energy and trophic webs). The possible responses to the adverse impacts of NIS on different ecosystem elements and socio-economies are quite limited though and mostly restricted to those listed at the bottom of the scheme (Fig. 5). It is important to note, that different response measures are applicable at different stages of the NIS introduction process. They can't be interchangeable and are much more efficient when address the causes (i.e. aimed at prevention of the arrival) rather than associated state change or impacts (i.e. population control, containment, eradication, restoration; Sakai et al., 2001). Therefore the consistent use of terminology is essential for efficient communication of scientific advice and appropriate managerial response. Clear differentiation between the 'pressure' and 'impacts' as well as understanding of the major operating driving forces, can help to strategically focus the effort on prevention of new invasions and mitigation of their spread rather than eradication of the already established NIS (costly and seldom effective measure; Piola et al., 2009; Forrest and Hopkins, 2013).

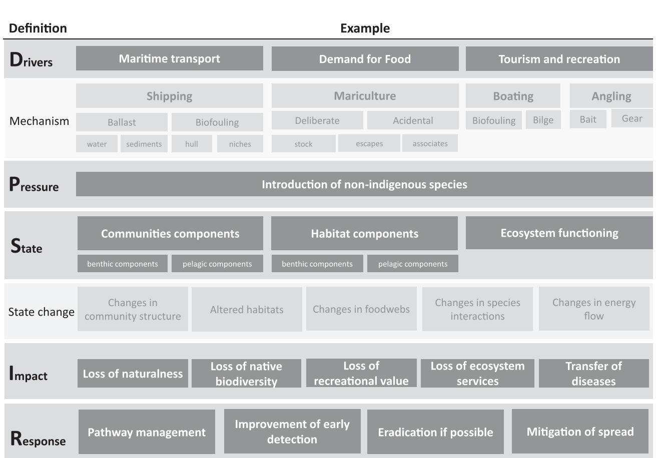

Fig. 5. Theoretical example about the usage in terms of one *Pressure* ,Introduction of non-indigenous species' based on different *Drivers* and some different levels of detail exemplarily.

4.3. Example 3: constructions

Yet another example of complex pressures arising from multiple drivers through a particular mechanism refers to the building and operation of marine constructions. Different coastal and offshore constructions emanate as a result of increasing demand for energy, maritime transport, urbanization, food production etc. (Mineur et al., 2012). The pressures arising from the associated mechanism can be various, involving (but not limited to) abrasion, siltation or noise emission and can evoke both short-term and long-term consequences to the marine environment. In most cases the pressures will affect habitat status and hydrological processes in the area (Fig. 6). The particular effect and impact magnitude will vary depending on the location, type, scale and longevity of the artificial structures deployed in the sea. The negative effect of constructions can be addressed by appropriate environmental impact assessments prior to building and further mitigation by encouraging use of "green technologies", restoration or compensation of lost habitats, enhanced control of operation-related risks etc. (Anastasopoulos et al., 2011). It is also important to consider the pressures arising from constructions within the overall environmental context – local and regional, as there most likely will be interactions with other pressures present. For example, building and operation of underwater constructions is expected to contribute to marine pollution (Henderson et al., 1999; Carstensen et al., 2006). Any temporal or permanent marine installation is linked by vessel movements to other localities within the region and beyond. Therefore increase of shipping-related pressures can be anticipated as well. Moreover, addition of artificial substrates can favor the establishment of non-indigenous species and serve as a reservoir or stepping-stone for their further spread (Tyrell and Byers, 2007; Mineur et al., 2012; Atalah et al., 2016). Such inter-linkage of drivers, pressures and impacts should be taken into consideration when designing the response strategies. Hence, a competent scientific advice on the overall regional context and local environmental peculiarities is highly desirable for better understanding of the complex pressures. It will be even more advantageous, if such advice is provided using the pre-agreed terms and following a well-structured framework.

4.4. Example 4: climate change

Climate change is one of the most discussed phenomena whether it is a driver or a pressure and whether it is caused by

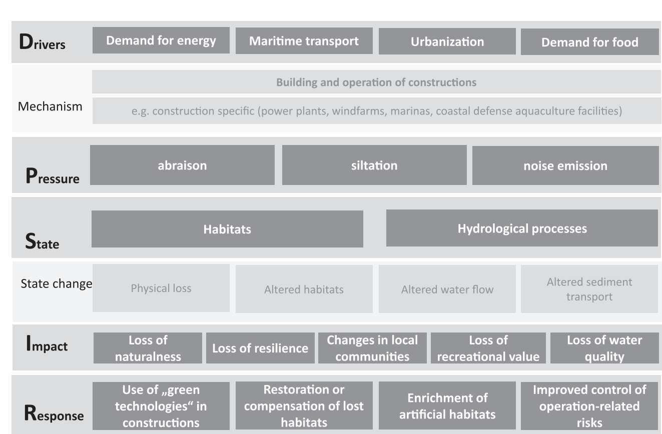

Fig. 6. Example based on the pressure 'constructions' resulting from different drivers.

humans or nature. By accepting our definition, climate change is attributed to pressures categories and results from both anthropogenic and natural drivers. In general terms, climate change is a global phenomenon and therefore should be treated as exogenic pressure disregarding the particular drivers involved. This pressure cannot be completely eliminated or effectively addressed by any short-term response measure. Still it cannot be excluded from the regional and international policies as completely “unmanageable”, as it can be (at least partly) affected through the shifts in anthropogenic drivers and underlying mechanisms. For example, by raising public awareness and changing human attitude, the transport or food production related CO_2 emissions can be reduced; by adopting cleaner production approaches pollution of atmosphere with aerosols can be minimized and energy can be produced by windpower stations and solar systems instead of nuclear power plants or coal fired power stations etc. These alterations in the driving forces will eventually feed back to the pressure (climate change) strength, but not as straight-forward and with a longer lag comparing to the cases when pressure can be affected directly.

5. Conclusion

In conclusion we want to highlight that an isolate definition and usage of the terms ‘driver’, ‘pressure’, ‘state’, ‘impact’ and ‘response’ does not make any sense and that an integrative understanding and communication of the causal links and mechanisms involved are essential. For this purpose the expanded pressure-state-response framework, the so called DPSIR framework, appears to be the most suitable. Initially developed to provide decision-makers with simplified knowledge of interacting social and political structures in the ecosystem, the advantages for communication are weakened by the fact that understanding of terms diverge among different stakeholders. We appeal for a consistent agreement on the DPSIR terminology in order to communicate scientific results in a coherent way. Scientists and policymakers will benefit from our proposed definitions due to the clear differentiation of manageable and unmanageable elements that facilitate a quick decision making process and advance the management strategies. By embedding these definitions within the DPSIR framework we provide a comprehensive approach to understand and illustrate the linkages between the different terms and establish the causalities of the observed status changes in the ecosystem. The definitions of the terms ‘driver’, ‘pressure’, ‘state’, ‘impact’ and ‘response’ suggested herein, are relevant to a wide range of ecosystems and have implications for environmental management, scientific communication and implementation of current environmental policies.

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