

Developing an integrated conceptual model for health and environmental impact assessment

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Abstract

Different conceptual models to frame environment and human health impact assessment processes have been developed. They share similar concepts, but differ with regards to their scientific or policy focus, the methodologies underlying the causal chains represented, and the degree of complexity and scope captured in the relationships identified.

Some conceptual models such as the *Driver-Pressure-State-Impact-Response* (DPSIR) framework of the European Environment Agency and other institutions (EEA/OECD) or the *Integrated Science for Society and the Environment* (ISSE) framework are widely known and applied in policy appraisal and impact assessments. While DPSIR is generally applied across different policy domains and environmental media, the ISSE framework is mainly used in the area of Ecosystem Services assessments. Modifications and elaborations of these models have emerged. One example is the modified *Driver-Pressure-State-Exposure-Effect-Action* (DPSEEA) model, which extends the original DPSIR framework by separating *exposure* from *effect*, and adding *context* as a factor modifying the degree of and susceptibility to exposures due to socio-economic, demographic or other determinants. Practical applications of ISSE confirm the relevance of *context* favouring place-based assessments (rather than service- or habitat-based).

Despite the continuous evolution of conceptual frameworks and their application in policy appraisals, development mainly occurs within established discipline boundaries. But drivers and environmental states affect both human and ecosystem health. Policy measures targeted at, for instance, reducing emissions of air pollutants from a specific sector affect both human and ecosystem receptors. In addition, unintended consequences of policy actions may well spill over and are hardly ever constrained within discipline or policy silos. Thus, an integrated conceptual model to account for the full causal chain of both human and ecosystem health assessment processes is needed. We discuss the development and specific features of existing conceptual models, and the prospects for meaningful integration of health and ecosystem impacts.

Keywords: IA tools, conceptual framework, health, environment, ecosystem services

1 Introduction

Conceptual models are particularly useful tools for issue framing and to communicate complex relationships to a wider, non-specialist audience. And while these models are, by design, simplified representations of complex real-world relationships, the complexity of the underlying issues described often makes it difficult to agree on common conceptual models even within disciplines. This is further complicated when trying to establish such models which need to bridge across scientific disciplines and/or policy areas. Differences in specialist vocabularies and conceptual understanding of the “issue” often act as barriers to establishing a generally accepted model for issue framing. Conceptual frameworks, after all, are “Tools to think with” (McIntosh, 2007), in a similar way that complex environmental models help scientists understand and possibly predict interactions and functional relationships.

A variety of such conceptual models exists; those most relevant for this paper are introduced and discussed in Section 2. Here, we also discuss the similarities and differences of commonly used conceptual models, with a particular focus on the realms of health impact assessment (HIA) and ecosystem service assessment. Finally, in Section 3, we make a case for the development of a common conceptual framework with the objective to derive a robust approach for integrated impact assessment.

In this paper, the authors propose a new integrated and cross-disciplinary conceptual framework, bringing together experts in the field of HIA, EIA, ecosystem services, and public health. A unifying factor for ecosystem services and public health assessments is that human activity, including economic activity, acts as a direct and indirect *driver* of changes in the ecosystems on which humans rely for many services critical to health and well-being. Recognising that public health must embrace and operationalize this integration of social ecology with the ecology of the natural world, Rayner and Lang (2012) have called for a new “*Ecological Public Health*”. This, they believe, should be built on the core idea that “... *human health depends on the coexistence of the natural world and social relationships*....” Those with concerns about damage to ecosystems caused by humans have, in turn, realised that their arguments for measures to reduce or mitigate damage become much more persuasive when they also consider the harmful economic and social feedbacks which have been encapsulated in the ecosystem service approach. However, it is only recently that they have started to include consideration of wider impacts on human health and particularly how to operationalize them into the ecosystem service framework.

Set within the natural sciences community’s desire to minimise environmental damage, the use of an ecosystem services valuation based on the benefits people obtain from ecosystems (MA, 2005) to inform policy has generally focused on the interactions between ecosystem components and the more readily quantifiable direct economic benefits, with only recently attempts to value the cultural services and wider human health impacts being seriously considered.

Taking steps towards integration is without doubt timely. The existing historical division between scientific disciplines – with natural scientists, biologists and ecologists focusing on environmental impacts, while medical and public health experts working on human health is no longer fit for purpose and comes at a cost; these disciplinary “silos” prevent the development of efficient and effective policies to protect and improve the health and well-being of both humans and their environment.

2 Conceptual frameworks for impact assessment

Evolution of full-chain approaches

On the most basic level, the conceptual models we discuss in this paper represent directional relationships between *cause* and *effect*. One example for a comparatively simple cause-effect chain, the *Impact Pathway Approach*, has been developed in the External Costs of Energy (ExternE¹) project series, and has been widely used to determine the (monetary) effects (benefits and costs) of different energy scenarios. However, this approach is rather generic; while helpful for a comprehensive scientific assessment of cause and effect, it does not lend itself easily to support a more general problem framing and impact assessment.

The *Pressure-State-Response* (PSR) model (Fig. 1) has been adopted by the Organisation for Economic Cooperation and Development (OECD, 1991 and 1993), and is itself based on an earlier “stress-response” model (Rapport and Friend, 1979). While the stress-response model rigidly established one-to-one relationships between stressors, environmental changes and societal response, the PSR framework mainly illustrates that human activities cause pressures (e.g. pollution emissions or land-use and land cover changes) on the environment, leading to potential changes in the state of the environment (e.g. pollution levels, biodiversity loss, drought). In addition to individual behaviour change, societal responses to these changes are policies (e.g. environmental, economic) or instruments (e.g. regulatory) to prevent, reduce or mitigate pressures or environmental damage.

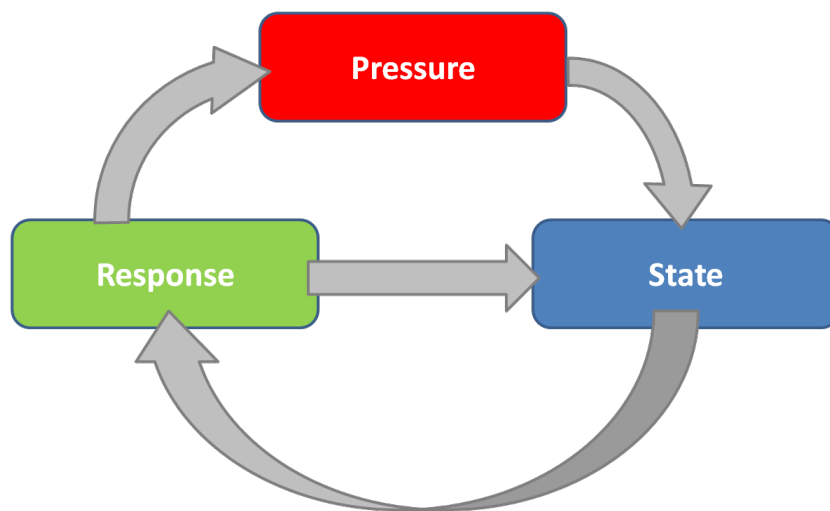


Fig. 1. Pressure-State-Response (PSR) model of environmental change (OECD, 1993)

A variation of the PSR model, the *Driving Force-State-Response* (DSR) Model (OECD, 1996) had a stronger focus on the linkages (between *pressure* and *responses*, *state* and *responses*, and *state* to *response*). In the late 1990s, the European Environment Agency introduced a further extension of the PSR model by adding *drivers* and *impacts* to create the *Driver-Pressure-State-Impact-Response* (DPSIR) framework (EEA, 1999; Fig. 2).

¹ http://www.externe.info/externe_d7/?q=node/46

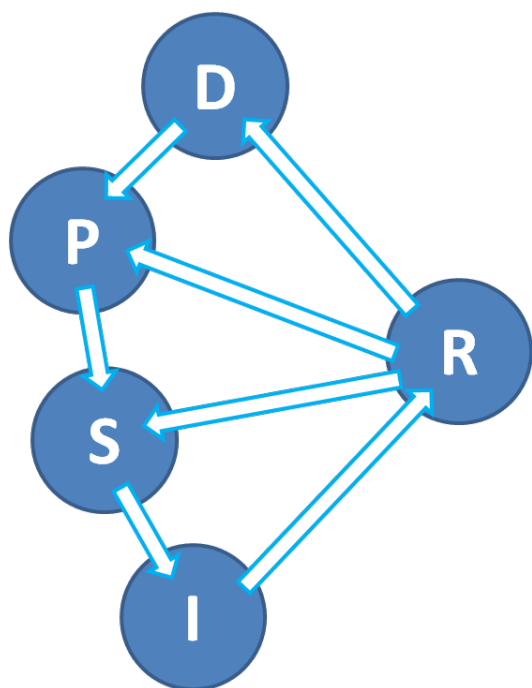


Fig. 2. Driver-Pressure-State-Impact-Response (DPSIR) framework for reporting on environmental issues (EEA, 1999)

The DPSIR model covers the following aspects in more detail than the PSR (see EEA, 1999):

- i. **D**riving forces and
- ii. the resulting environmental **P**ressures, on
- iii. the **S**tate of the Environment, and
- iv. **I**mpacts resulting from changes in environmental quality and on
- v. the societal **R**esponse to these changes in the environment.

DPSIR has been applied widely within the EEA and other European bodies for problem framing and as a guiding concept for policy impact assessment, for example when considering policies such as the Water Framework Directive², the Biodiversity Convention³, and general human health policies. One of the challenges that frequently occurs is to consistently distinguish between *Drivers* and *Pressures*. For the purpose of this paper, we define the *Drivers* as distal causes, *Pressures* as the intermediate causes of changes in *State*.

Around the same time, a modification of the DPSIR framework was established on behalf of the World Health Organisation (WHO), with the initial goal of developing health indicators (Corvalan *et al.*, 1996). With its roots in health impact assessment, the *Driver-Pressure-State-Exposure-Effect-Action* (DPSEEA) framework recognises that exposure to stressors may lead to different effects. Further to that, *Actions* ('A' in Fig. 3) directed at reducing or controlling adverse health effects can be targeted at each step of the causal chain. Depending on the stage at which actions aim, preventive or responsive measures may have different associated effectiveness and costs. More recently (Morris *et al.*, 2006 and 2010), DPSEEA has been modified to the "mDPSEEA" framework to account for the mitigating influence of socio-economic, demographic etc. context, on the individual or sub-population exposure and on susceptibility which in turn influences the likelihood and magnitude of health effects arising from the same (Fig. 3; Scottish Government, 2008 and 2011).

² http://ec.europa.eu/environment/water/water-framework/index_en.html

³ <http://www.cbd.int/doc/reviews/impact/information-guidelines.pdf>

A similar approach which has also been developed for the WHO, with a specific view on children's health, is termed the MEME-framework (*many-exposures-many-effects*, see Briggs *et al.*, 2003). MEME accounts for the non-linearity of causes and effects, and takes a less pollution-based view compared with previous frameworks. It also explicitly recognises the importance of behaviours and contextual aspects in determining exposures.

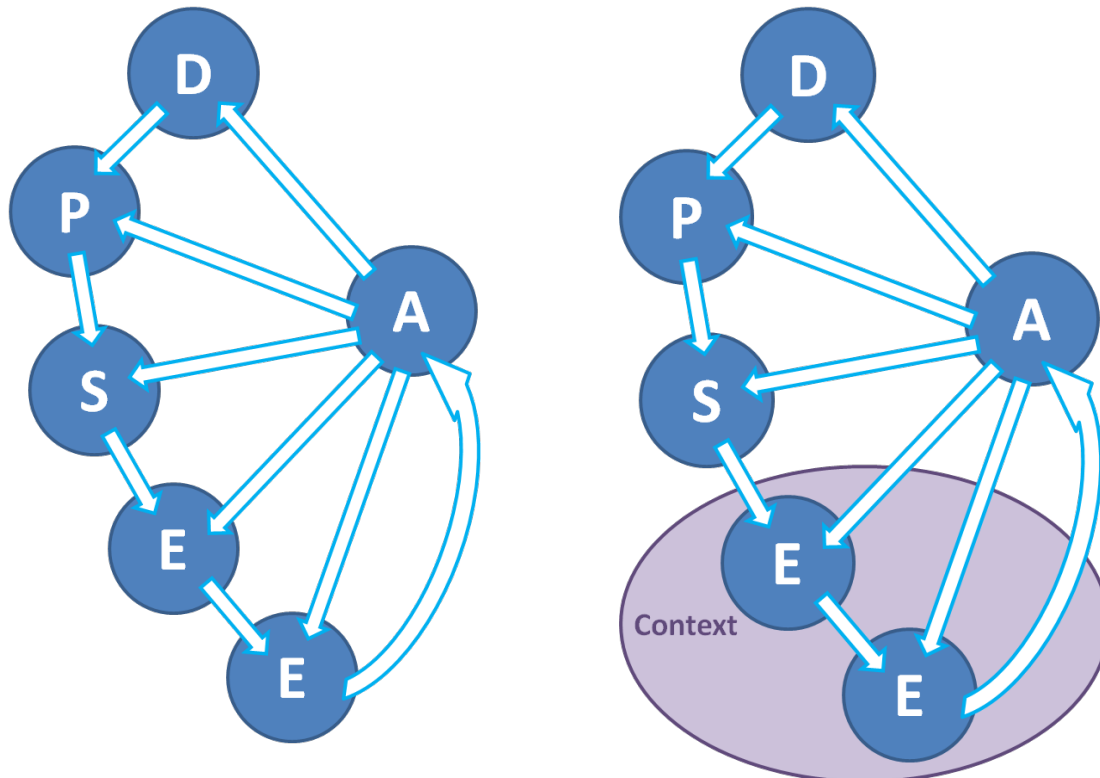


Fig. 3. Original Driver-Pressure-State-Exposure-Effect-Action (DPSEEA, left) and modified (mDPSEEA, right) models (Corvalán *et al.*, 1996; Morris *et al.*, 2006 and 2010)

Enter: Ecosystem services (ES)

The concept of ecosystem services (ES) has evolved over a long period of time (Ehrlich and Mooney, 1983; Daily, 1997), and can arguably be viewed as a further development of some aspects of the sustainable development agenda. In many respects the ecosystem service approach has arisen in the natural sciences (Collins, 2007; Potschin and Haines-Young, 2011) and has formed significant links with the environmental economics community (TEEB, 2010). The global Millennium Ecosystem Assessment (MA) methodology (MA, 2003) focused on linkages between ecosystem services and human well-being, and the influence of direct and indirect drivers of change. With the publication of the Millennium Assessment Report (MA, 2005), the concept of ecosystem services as a framework for all benefits supplied by ecosystems to humans has become a topic of international relevance, with research into ecosystem services serving as an important focus of national and international research funding agencies. The anthropocentric concept of ecosystem services focuses on those aspects of biodiversity, ecosystem functions and processes which, collectively as services, provide direct or indirect benefits to human beings (both related to directly affecting human health, or more generally human well-being and welfare). For the purpose of this paper, we focus on the ecosystem services which are directly related to human health. However, our conceptual approach takes the general ecosystem services framework into account. In our approach, we particularly address the lack of

explicit representation of public health and well-being in current ecosystem services research which leads to a paucity of relevant data (National Ecosystem Assessment, 2011).

In the ES context, there is a plethora of evolving conceptual frameworks, of which we will only briefly introduce a select few here. For example, the *Framework for Ecosystem Service Provision* (FESP) is based explicitly on the DPSIR framework (Rounsevell *et al.*, 2010), while the *Integrated Science for Society and the Environment* (ISSE) framework (Collins *et al.*, 2007) is more loosely based on DPSIR. More widely disseminated to policy makers and stakeholders, *The Economics of Ecosystems and Biodiversity* (TEEB) framework (de Groot *et al.*, 2010) and the approach taken for the UK *National Ecosystem Assessment* (NEA, UK National Ecosystem Assessment, 2011) are derived from the *Millennium Ecosystem Assessment* (MEA) framework. These approaches both largely omit the *Pressure* variable subsuming it within the *Driver* variable, and focussing more on the detail of the relationships between structural and process components of ecosystems and the different services and benefits they deliver to society.

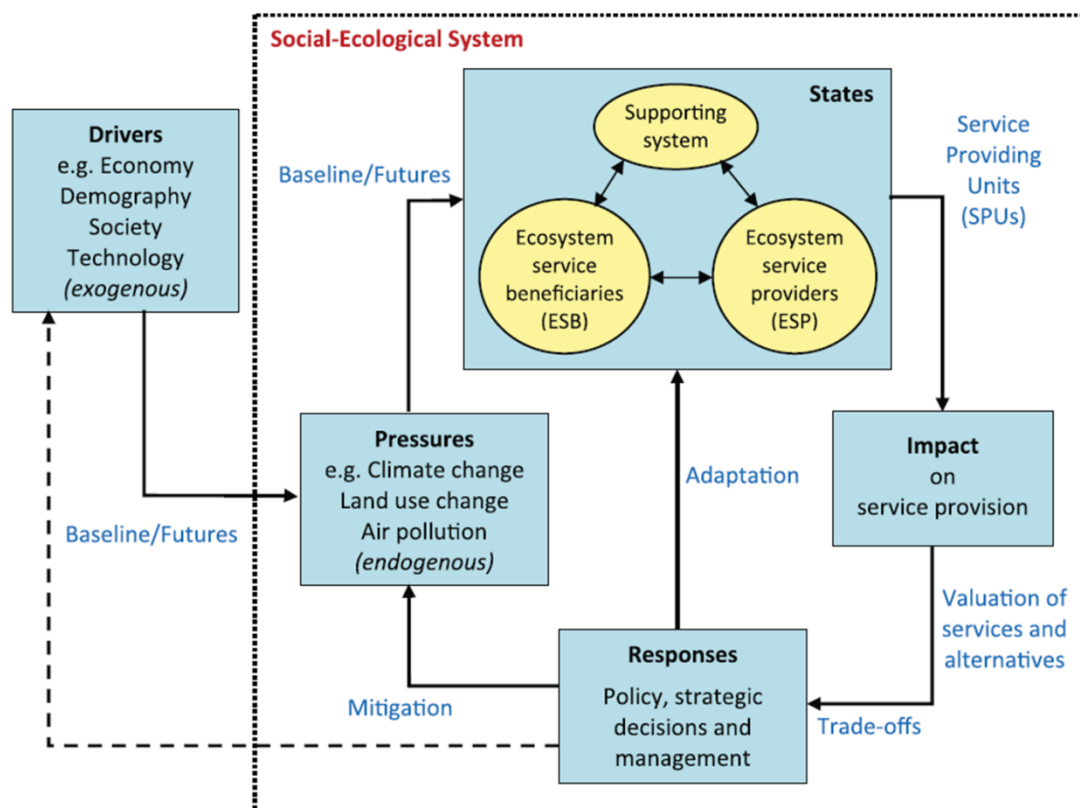


Fig. 4. A Framework for Ecosystem Service Provision (FESP) based on a modified Driver-Pressure-State-Impact-Response (DPSIR) framework (Source: Rounsevell *et al.*, 2010; see as well *Conservation of Biodiversity and Ecosystem Services in Europe: From Threat to Action*, by Paula A. Harrison and the RUBICODE consortium⁴)

The *Framework for Ecosystem Service Provision* (FESP) is also based on the DPSIR framework. FESP (Fig. 4) has been thoroughly discussed by Rounsevell *et al.* (2010). The main aspect to be noted is the expansion of the *State* to accommodate the different features of ecosystem services, both for ecosystem service providers (ESPs) and beneficiaries (ESBs), linked to the overall supporting system. In addition, the explicit definition of the *socio-ecological system* (SES, Dawson *et al.*, 2010) as a sub-

⁴ <http://www.rubicode.net/rubicode/summaryBrochure.html>

system of the DPSIR causal chain embeds humans as an integral part into the ecosystem. However, the separation of *Drivers* from the SES as an "exogeneous" factor may merit further discussion. Equally, the dotted line representing the influence of *Responses* on *Drivers* and a missing arrow representing a link from *Responses* to *Impacts* need further scrutiny.

The social ecological accounting framework *Driver-Pressure-State-Welfare-Response* (DPSWR) has been based on DPSIR and introduces the change in human *Welfare* due to changes in *State* (Cooper, 2012).

The ES frameworks have many similarities to DPSEEA, but tend to be focused on the system as a whole and the feedbacks through the system. For example, the ISSE framework (which arose from the USA long-term monitoring community) is based on a narrative approach focused around six questions (Collins, 2007). These link the biotic structure and ecosystem function directly to ecosystem services and feed through to human outcomes and human cognition, behaviours and institutions (depicted in Fig. 5). Human health is considered directly only as one of many aspects of human well-being. The narrative commonly starts with a recognition of a disturbance to the system and follows the impact through the various aspects depicted. The framework distinguishes between long-term drivers such as climate change (termed "a press disturbance") and short term pulse disturbances (for example a fire or a summer drought). The questions are commonly framed as:

- Q1: *How do long-term press disturbances and short-term pulse disturbances interact to alter ecosystem structure and function?*
- Q2: *How can biotic structure be both a cause and consequence of ecological fluxes of energy and matter?*
- Q3: *How do altered ecosystem dynamics affect ecosystem services?*
- Q4: *How do changes in vital ecosystem services alter human outcomes?*
- Q5: *How do perceptions and outcomes affect human behaviour?*
- Q6: *Which human actions influence the frequency, magnitude, or form of press and pulse disturbance regimes across ecosystems, and what determines these human actions?*

Such frameworks tend to see human health and ecosystem health in the one framework (Haines-Young *et al.*, 2011 a, b). The Ecosystem Services Framework (ESF, Daily *et al.*, 2000) integrates biophysical and socio-economic dimensions of environmental protection. It provides guidance to users in particular by making multidisciplinary information more readily accessible and reducing jargon, towards supporting institutional strategic choices.

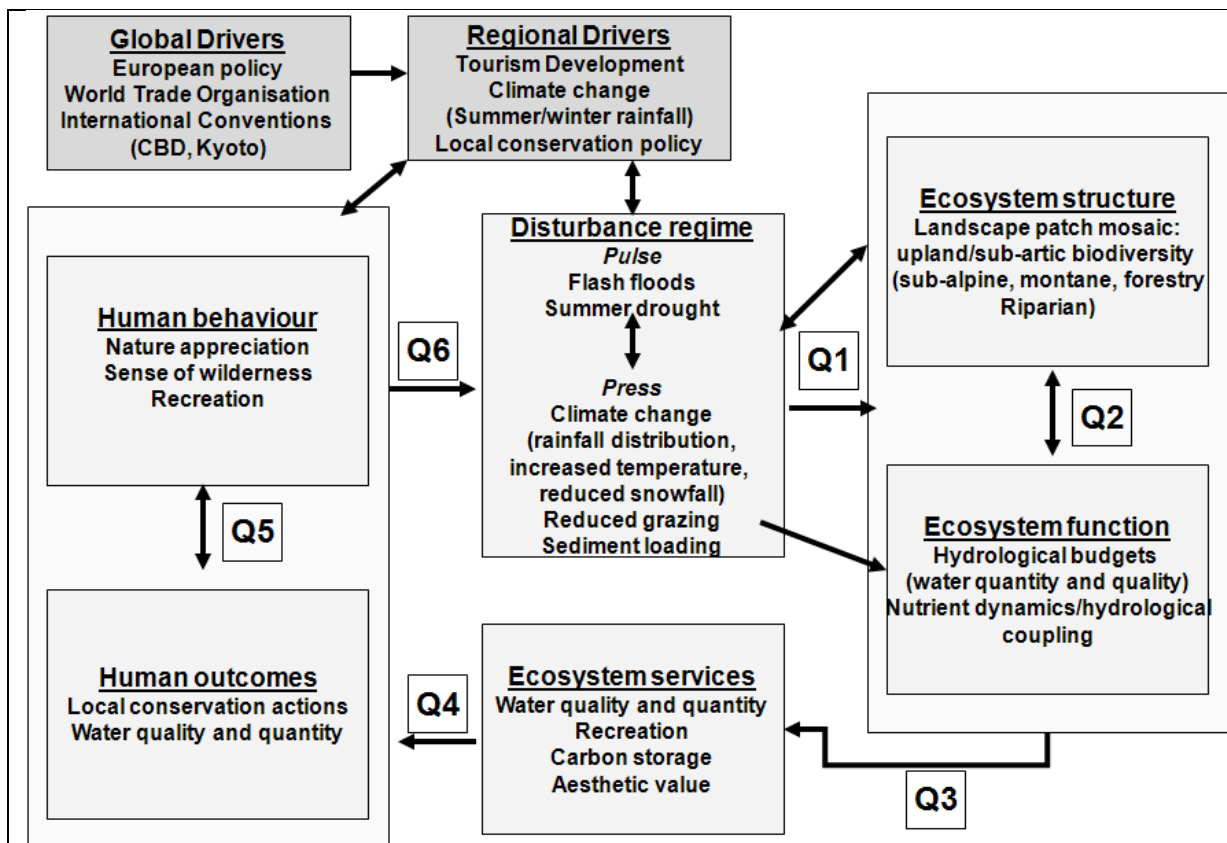


Fig. 5. Examples of a socio-ecological centred analysis describing the change in economic, ecological and social assessment of the Allt a’Mharcaidh catchment in Cairngorms, Scotland following the land purchase by the SNH Government body responsible to Scottish Government Ministers (Source: Ecosystem services and associated concepts, Dick et al , Environmetrics 22 598-607, Copyright © 2011, John Wiley & Sons Ltd.)

A major trend in the ecosystem service research community is a focus on valuing the ecosystem services to humans in which the costs to human health are explicitly acknowledged. For example, see the UK Valuing Nature Network (VNN) framework (Fig. 6).

Conceptual Framework

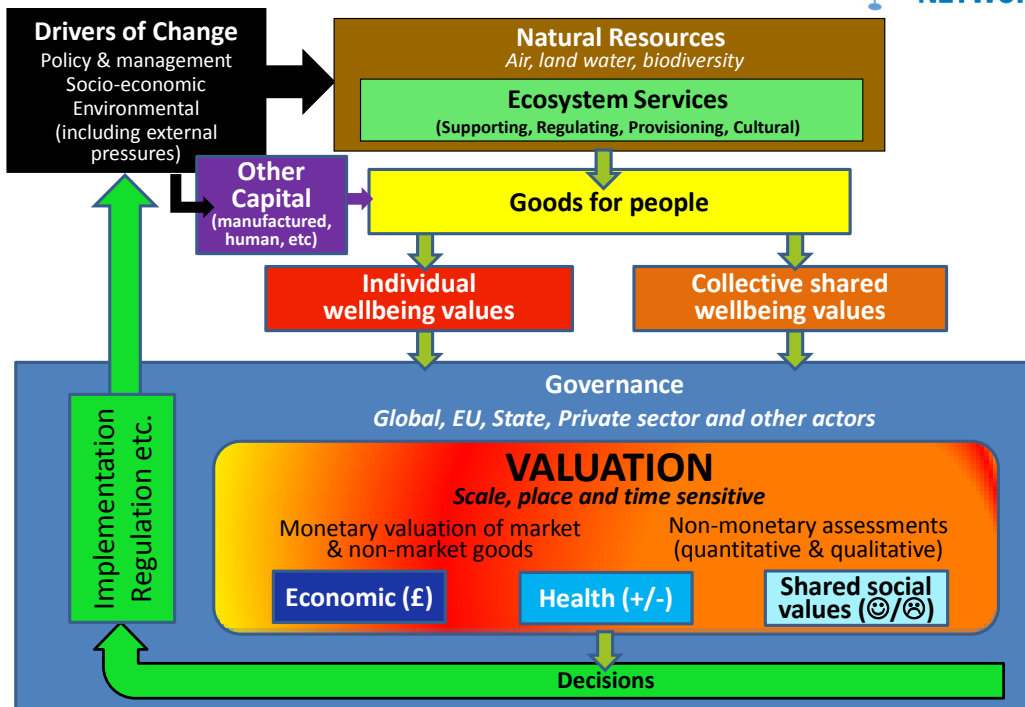


Fig. 6. Conceptual Framework of the Valuing Nature Network (<http://www.valuing-nature.net>)

The ecosystem service concept is being positively assessed by the UK government as a useful approach for policy appraisal recognising that it changes the focus of HIA and EIA approaches from a focus on valuing environmental damage (e.g. air pollution impacts etc.) to one that stresses the value of services provided by the natural environment. The importance of assessing implications for whole systems is also emphasized, rather than addressing a few focal services in isolation, often to the detriment of overlooked services (DEFRA, 2007). DEFRA (2007) provided a practical guide to the key steps to be undertaken in valuing ecosystem services in a policy appraisal context. In summary they are: (i) establish the environmental baseline; (ii) identify and provide qualitative assessment of the potential impacts of policy options on ecosystem services; (iii) quantify the impacts of policy options on specific ecosystem services; (iv) assess the effects on human welfare; and (v) value marginal changes in ecosystem services.

The various ecosystem service frameworks and the DPSIR and mDPSEEA frameworks have a variety of uses including: a) as conceptual frameworks for problem framing and elicitation; b) as scientific tools to understand and possibly predict complex human-environment and ecosystem interactions; c) as tools to guide management and policy decision making and responses; and d) as communication tools for interaction with stakeholders.

3 Discussion

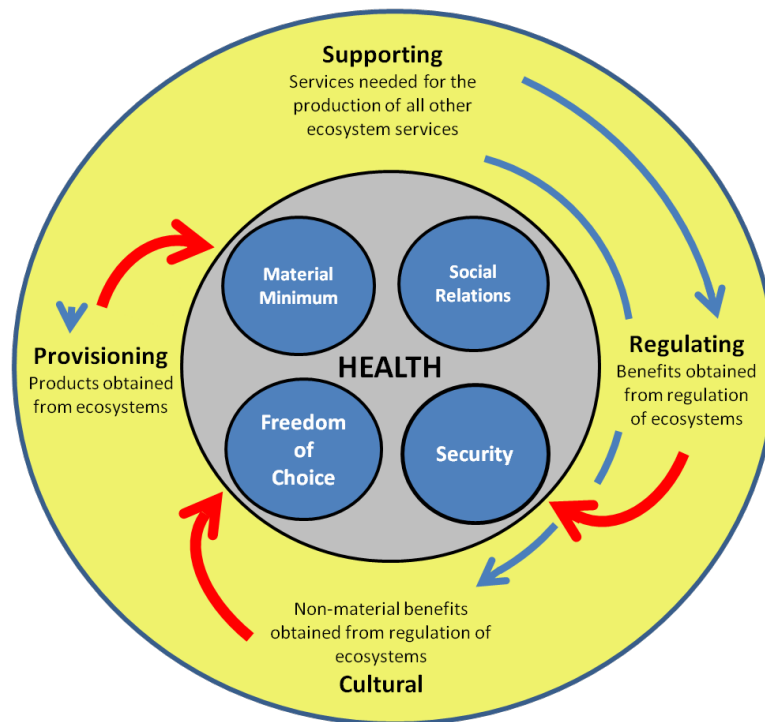


Fig. 7. Relationships between ecosystem services and human health and well-being (adapted from: WHO, 2005)

In recent literature, the application of DPSIR (Tscherning *et al.*, 2012) and moving the ecosystem services concept into practical application (e.g. Nahlik *et al.*, 2012) have been widely discussed. A major challenge for the development and application of any conceptual framework is to account for the complexity with regard to feedback loops across the whole system, or individual components of it. This complexity results in the many different frameworks that have emerged over time.

Conceptually, the frameworks presented in this paper have been developed with different foci; for instance, those dealing more with remedial/removal of adverse effects (e.g. classical *pollution-damage-to-health* relationships) and those taking a more proactive approach (e.g. the provisioning of beneficial effects on human health and well-being). Another aspect that we have not elaborated on is that - in the same way as human influence can adversely affect ecosystems - negative or dis-services of ecosystems (such as transmitting vector-borne diseases or flooding) should be accounted for in a comprehensive impact assessment framework. The resulting frameworks, including dynamic feedbacks, may be considered “a bridge too far”, until a consolidated view has been established in the research and policy communities.

We identify a convergence between the emerging field of *Ecological Public Health* (with its calls for an acknowledgement in policy and action of the integration of social and natural ecology) and the concept of ecosystem services. We suggest that there are close relationships between ecosystem services and four specific aspects of human health and well-being, as depicted conceptually in Fig. 7 which expresses the connectivity of ecosystems and human health/wellbeing.

Based on the experience in using mDPSEEA, and applying the ecosystem service frameworks we believe that there is a need to integrate socio-ecological perspectives within both environmental and public health policy in order to frame complex issues in a policy-relevant way and to support

stakeholder engagement. This implies that a new conceptual framework is required that can provide an underpinning theoretical model, and also help communicate and operationalize *Ecological Public Health*. The integration of the process simplifications represented by Fig. 3 (mDPSEEA) and Fig. 7 (ecosystem services to human health and well-being) provides the basis for such a model.

Here, we propose the integration of ecosystem services aspects into the mDPSEEA framework, extending its remit to account for a more detailed representation of *State* that reflects the different pathways from pressures via services to *Exposure*. This framework, termed *enriched* or eDPSEEA, can provide a platform for a cross-disciplinary integration of approaches to jointly assess impacts of environmental pressures both on human health and well-being, and on ecosystem health and the resulting ecosystem services provided.

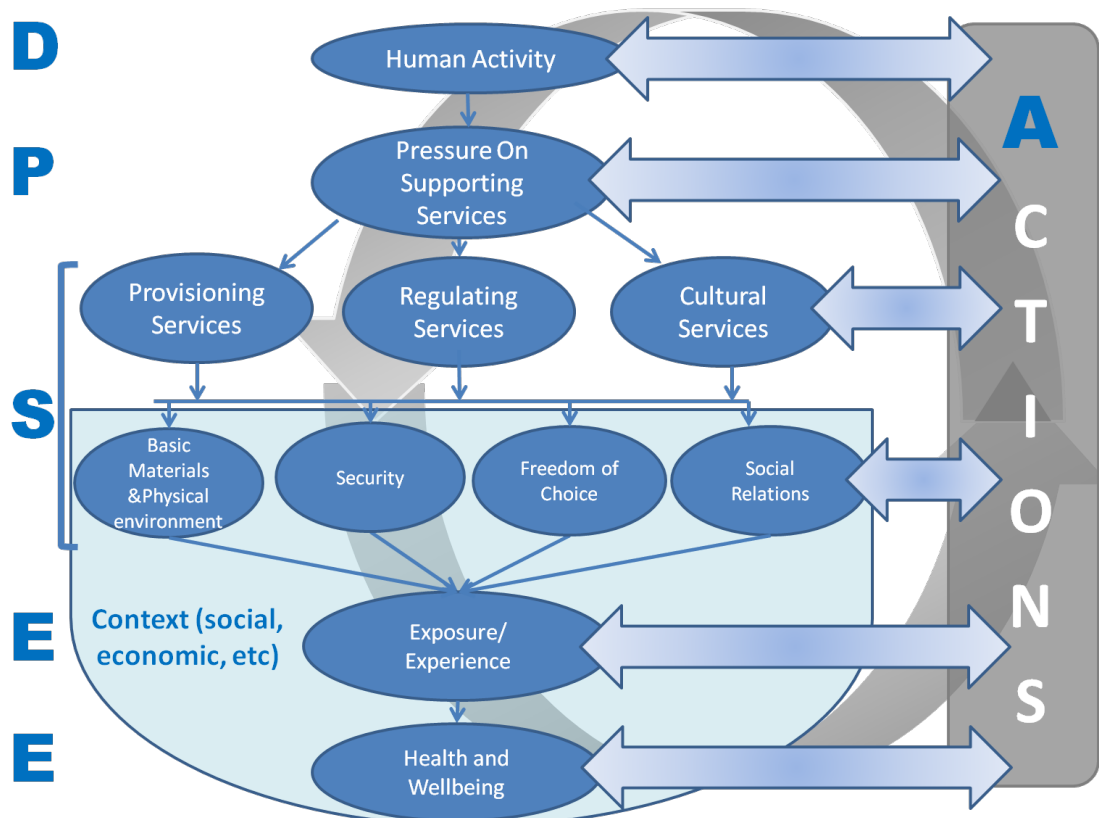


Fig. 8. Enriched DPSEEA (eDPSEEA) - a conceptual framework for an integrated assessment of human and ecosystem health and ecosystem service provision.

The eDPSEEA framework explicitly acknowledges that the actions of humans can operate at several points in the system which have “knock-on” effects (blue arrows and grey arrow in background). This combines the reality represented in both the mDPSEEA framework and the ES frameworks which tend to assume a single unidirectional flow of influence. In reality, some interactions between ES and human health and well-being may not be as clear-cut as Fig. 9. suggests; and ES aspects directly affect humans through *Exposure/Experience* and *Effect* through a more subjective experience of well-being and environment (Dolan and White, 2007). Further to that, as ecosystem services are themselves context dependent, the original contextual approach of mDPSEEA needs to be expanded to incorporate environmental aspects. These issues will, however, require a more detailed discussion than is possible here, and will be addressed in a forthcoming paper.

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