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Marine Ecosystem Services and Integrated Management: "*There's a crack, a crack in everything, that's how the light gets in*"!

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Introduction

There have been many recent developments and discussions regarding marine science for policy, governance and management in the pages of *Marine Pollution Bulletin* and elsewhere and especially the movement towards systems analysis to cope with the complexity of marine natural and human systems (for example, Elliott et al., 2017, 2020a, b; Cormier et al., 2022, and references therein). It is emphasised that the marine system has to be viewed through both eco-centric and anthropocentric lenses but both aspects are needed to consider the whole ecosystem. Because of this, it is now especially appropriate to reappraise an integrative model linking the natural and social sciences, governance and management. If such a model can be agreed then it would enable a recipe for assessing and managing human activities in the sea. Such a model would need to merge the natural and social sciences, not least to include concepts regarding the ecosystem services and societal goods and benefits provided by our oceans. Despite this, and perhaps as expected, there continues to be discussion and even argument relating to the meaning, interpretation and use of the relevant terms, especially regarding the concepts relating to ecosystem services. This article attempts to clarify the ecosystem services concept while also proposing such an integrative model.

Ecosystem Services and Societal Goods and Benefits

Increasingly, the links between the human use of the coastal, estuarine and marine systems by human activities and the resulting health and status of the natural environment may be regarded as a socio-ecological system (O'Higgins et al., 2020). This has given rise to a very large body of work on ecosystem services, a concept now developed through an 'alphabet spaghetti' of acronyms – CICES (e.g. Haines-Young and Potschin, 2018), TEEB (de Groot et al., 2002), IPBES (2019), SEEA-EA (System of Environmental Economics and Accounting – Ecosystem Accounting - https://seea.un.org/ecosystem-accounting), etc. However, much of that literature begins 'ecosystem services are the benefits that society obtains from the environment' – arguably a very anthropocentric view but one which increasingly leads to confusion not least that one sentence merges two concepts – that of services and that of goods and benefits. Despite this, and as shown even in the few references mentioned here, marine users and their regulators are now very familiar with the term ecosystem services in that the prevailing legislation under which they operate has these as a central pillar.

Furthermore, all marine regulators are (or should be) emphasising that the marine users and their activities must protect the structure and functioning of the natural system, while enabling ecosystem services and delivering societal goods and benefits as typified by the concept of the Blue Economy. Despite this, there is still confusion in the terminology, the subject of much discussion in recent years. This article aims to indicate some of the inconsistencies and perhaps lead to discussion to avoid that confusion via a set of propositions.

It is not possible in this limited space to present the whole chronology of the ecosystem services concept but illustrations of its genesis can be given. For example, de Groot et al. (2002) in TEEB merges the two terms using the generic phrase of 'goods and services'. Subsequently, the UN 2005 Millennium Ecosystem Assessment (https://www.millenniumassessment.org/en/index.html) set the basis for the system in use today of an assessment framework which comprises four categories of ecosystem services: *Production services* involve products and services obtained from the ecosystem; *Regulating services* are the benefits obtained from the regulation of ecosystem processes; *Cultural services* are the non-material benefits people obtain from ecosystems, and *Supporting services* are those that are necessary for the production of all other ecosystem services, but do not yield direct benefits to humans. In the context of identifying, defining and quantifying goods and services provided by marine biodiversity alone, Beaumont et al. (2007) introduced a further fifth category to those of *Option use values* which are associated with safeguarding the option to use the ecosystem in an uncertain future.

Again, this four- or five-point categorisation results in merging ecosystem services and societal goods and benefits in four of the five types. Beaumont et al. (2007) apparently compound the confusion by referring to ecosystem goods and services as 'the direct and indirect benefits people obtain from ecosystems'; however, despite therefore merging two concepts, they also implicitly view ecosystem goods as distinguished from services in representing the 'materials produced' that are obtained from natural systems for human use.

The concepts were then further modified (e.g. by Fisher et al., 2009) to indicate that a fully functioning ecosystem maintains a set of ecosystem services and that these can be separated into fundamental (also termed intermediate) services or characteristics (encompassing the physico-chemical environment) and final services (the biological elements and processes resulting from the fundamental services which will lead to the benefits for society). The concepts were then modified, for example by Turner and Schaafsma (2015) and Potschin et al. (2015) and through the increasingly adopted CICES framework (Haines-Young and Potschin, 2018), to suggest that the fundamental structure (the natural capital and the ecosystem structure and functioning) and final ecosystem services then produce societal benefits.

It is now emphasised that these require to be obtained through the introduction of human capital and complementary assets. At its simplest, human capital can be regarded as inputting energy, time, skills, knowledge and money or the ability for humans to be sentient beings, thereby allowing them to appreciate aesthetic values and to enjoy nature. However, this scheme, or so-called cascade in CICES, then produces overlaps between ecological structure and functioning and intermediate services, between intermediate services and final services, and between final services and societal goods and benefits – thereby adding yet more confusion which needs to be resolved.

To give an example of this current thinking, the natural system can maintain the hydrographic processes which create the conditions for invertebrates as food for fishes and then harvesting the fishes requires boats, harbours, and the skills to process, use and enjoy those fish. As another example, the natural processes can deliver marine sands and gravels but these become marine aggregates for construction only when the vessels and infrastructure are created to exploit them. As a further example, the natural system can produce a blue whale but human capital is required for society to confer a greater value to that animal than just if it was yet another animal. Indeed, it can be argued that nature itself would not confer a greater value on the whale than it would a polychaete worm!

Hence, human activities occur within the socio-ecological system in which physico-chemical functioning delivers ecological structure and functioning (see Figure 10 in Elliott et al., 2017) which then produce ecosystem services (the central part of the continuum). With the addition of human capital and complementary assets, the ecosystem services then enable societal goods and benefits to be gathered (Elliott et al., 2017). The latter can then be valued both as TEV (Total Economic Value) and TSV (Total System Value) in which TSV can include components for which it may be difficult to derive a monetary value. This constitutes use/non-use, tangible/non-tangible, material/non-material and 'feel-good' values.

The above comments have led to here proposing a unified iteration of the model for ecosystem services and societal goods and benefits (Figure 1). It is recommended that the term ecosystem services should only refer to the central part of the model and should always be distinguished from societal goods and benefits. Secondly, it is concluded that supporting services are no different from usual ecosystem structure and functioning, and that cultural services are a misnomer in that the natural environment does not recognise 'culture' which only appears after the addition of human capital. Finally, the model further indicates that ecosystem services is merely an intermediate step giving flows from ecosystem structure and functioning (natural capital) to societal goods and benefits. However, logically, this then leads to the question of whether the term ecosystem services is even needed, hence the merging of natural capital and ecosystem services in Figure 1.

[Figure 1 here]

Figure 1 The proposed unified ecosystem services and societal goods and benefits model

This reinforces the point that ecosystem management now centres around ensuring that the natural system can maintain its natural health which has internal processes (services) from which society can obtain goods and benefits. Hence there is the need to be clear regarding the use for, and definition of, the separate terms. In order to achieve this, all of the above comments and extensive discussion with colleagues have led to a set of propositions for further evaluation within the ecosystem services and associated concepts (Table 1).

Table 1 Propositions for the Revision of the Ecosystem Services Concept
Proposition #1 – along the 'ecosystem services cascade' (or continuum) from ecosystem structure to ecosystem functioning to intermediate ecosystem services to final ecosystem services to goods and benefits to valuation, the term 'intermediate ES' is redundant (cf. Potschin-Young et al., 2017) as this is just ecosystem functioning and hence the 'final' part of the term for ecosystem services is also not needed.
Proposition #2 – ecosystem services should be separated from societal goods and benefits as to be obtained the latter requires an input of human capital, hence it is illogical to group

everything as the term ecosystem services (i.e. the system can provide something but it requires human capital in order to take advantage of this).
Proposition #3 - there is the need for ecological valuation for one part of the system, relating to the natural domain (Derous et al., 2007; Pascual et al., 2012), but socio-economic valuation for the remainder in the human domain; this allows an analysis to be both eco-centric and anthropocentric even if both use different units and currency.
Proposition #4 – the term 'supporting services' is both a misnomer and unnecessary as these purely relate to ecosystem structure and functioning (and as such the term is no longer used); provisioning and regulating of ecosystem structure and functioning are usual ecological aspects and even provisioning 'needs' regulating (by internal or external mechanisms); indeed all supporting, regulating and provisioning processes merely indicate the ecosystem is working normally before society extracts quantities and qualities from it.
Proposition #5 – 'cultural services' is also a misnomer as 'cultural' only refers to what is possible with human intervention, i.e. after human capital has been inserted as the natural ecosystem does not recognize culture and so term should be dropped; for example, a landscape has been created (i.e. provisioned) by the natural system but it only becomes a 'nice landscape' when we do something to regard it as such; a 'cultural service' such as landscape/seascape is provided by the natural environment in the same way as a fish, a blue whale or a red alga; in nature these components are treated equally, i.e. a nice seascape or an iconic species is only what humans call them after inputting human capital (cf. CICES v5 in Haines and Potschin (2018) acknowledges they are 'enabled' by humans).
Proposition #6 - provisions are the societal goods and benefits as the outcome from provisioning ecosystem services and as such can be material/non-material, monetary/non-monetary, tangible or non-tangible, from extraction or by interaction – all of these societal goods and benefits require an injection of human capital (money, time, energy, skills, knowledge or as sentient beings), and even non-material provisions such as enjoyment/well-being/satisfaction can be monetarized. The main distinction here then requires 'provisioning' services to result in 'provisions' which will need regulating or to be regulated.
Proposition #7 – provisions can either be extracted or even just interacted-with but both therefore need human capital input for that interaction and extraction (both words containing 'action'); e.g. removing an ornament or a fish is no different from taking a photograph or retaining a memory or pleasant experience; hence the provisions should fulfil all basic human needs as indicated by Maslow's hierarchy (Elliott et al., 2017).

Proposition #8 – in relation to the term provisioning ecosystem services, the previous inclusion of the provision of ornaments and aquaria materials as terms is again unnecessary – they only become ornaments or an aquarium species after human capital is put in, otherwise they are just natural materials (biotic or non-biotic).
Proposition #9 – the term 'regulating and maintenance services' is often used but this appears to be tautological as maintaining a quantity involves regulation and so only the term 'regulating' is needed; the comments here leave only two types of ecosystem services: regulating and provisioning and even those provisioning ones will need regulating by the natural environment.
Proposition #10 – it is also necessary to consider natural <u>dis-benefits</u> from the environment although the natural system cannot provide a dis-service to humans but only dis-benefits when human actions degrade the system; e.g. natural organic enrichment will produce natural levels of hydrogen sulphide or methane by bacterial action but once humans inhabit an area (thereby inputting human capital) then there is a dis-benefit.
Proposition #11 – given the above, creating pressures and impacts from human activities equates to creating eventual dis-benefits in monetary/aesthetic terms, i.e. an ecologically-poor structure and dis-functioning will eventually lead to dis-benefits as long as human capital in inputted, such as by inhabiting an area.
Proposition #12– the concept of ecosystem service flows is also a misnomer as there are only flows of ecological materials through ecological processes until humans get involved and then it should more accurately be termed the flow of goods and benefits to society.
Proposition #13 – by removing the concept of cultural services as a category of ecosystem services, it is suggested that societal goods and benefits can be grouped into three types: extracted provisions (where society takes materials and energy), environmental regulation (including hazard and risk reduction and protection of human safety), and interaction provisions (cultural, aesthetic and health benefits).
Proposition #14 – despite the creation of several ecosystem services schemes, there needs to be a way of producing a unified and harmonised theory and model which will satisfy all cases where ecosystem services and societal goods and benefits are discussed otherwise the underlying theory must be flawed.
And finally, as a fundamental central question:

Proposition #15 – it is necessary to question whether the term ecosystem services is any different from the usual ecosystem structure and functioning characteristics and hence the anthropocentric discussion should predominantly focus on societal goods and benefits.

An Integrated model

By incorporating the above thinking, and that in the references mentioned here and elsewhere, current concepts and principles in marine ecological functioning, governance and management can be placed within an overall, integrated model (Figure 2); in the figure the arrows with narrative linking the boxes serve to create the storylines which can be traced to give the means of addressing the use and abuse of the seas. As a starting point, the marine ecosystem and its use by society has a central horizontal continuum (spine) going from the left of the figure in which a suitable physico-chemical structure and functioning produces environmental fundamental niches occupied by the biota, the ecological structure and biodiversity, and functioning depending on the tolerances of individual species. These aspects then link through ecosystem services which, after society inputs human assets and complementary capital, to produce provisions such as societal goods and benefits. That human capital is the ability to input time, money, energy, skills, and knowledge as well as the ability of being sentient, thereby obtaining goods and benefits. This continuum, the central spine in the Figure 1, is a modified version of the ecosystem services cascade promoted by the CICES approach.

Managing the marine environment then requires a cause-consequence-response framework, such as the increasingly-used DAPSI(W)R(M) (pronounced *dap-see-worm*) concept of **D**rivers, **A**ctivities, **P**ressures, **S**tate changes (on the natural system), **I**mpact (on human **W**elfare) and **R**esponses (using management **M**easures) (Elliott et al., 2017). These are embedded in the model (Figure 1) in which the upper right-hand corner of the model indicates a cycle in which Drivers of basic human needs, such as the need for food, energy, shelter, satisfaction and employment, require to be produced by societal activities, again the inputting of human capital (which by definition includes social and build capital). Creating societal goods and benefits then satisfies those basic human needs.

[Figure 2 here, give as landscape on full page]

Figure 2 The socio-ecological system aiming to unify the DAPSI(W)R(M) framework, the means of degrading the natural system and recovery management measures, and the ecological structure and functioning to ecosystem services and societal goods and benefits continuum.

However, our marine activities often (or perhaps usually) create pressures, defined as the mechanisms of change, as adverse environmental effects which can degrade both natural and human domains. Those pressures can be created inside a designated management area (i.e. termed endogenic pressures) or externally (i.e. the exogenic pressures created perhaps elsewhere in a catchment or even globally). Those pressures lead to adverse environmental consequences such as the deterioration of the natural system and loss of biodiversity (the State change, S) or even as a reduction in the quality of human welfare (I(W)); the operation of those pressures is thus in the upper half of the diagram. The degradation of the human and natural environment is then denoted by the central spine being grey.

In turn, those activities, pressures and effects on natural and human domains can be regarded as having spatial and temporal footprints which all need quantifying (Elliott et al., 2020b). The management actions (responses) also have a spatial and temporal dimension, the so-called management response-footprint pyramid from the local to the global (Cormier et al., 2022).

Such adverse environmental consequences then need to be prevented, addressed, mitigated and/or compensated, and reversed using responses by both the users and their regulators, using management measures. This forms the so-called Programmes of Measures (PoM) indicated in various legal instruments such as European Union Directives and so forming the basis of Ecosystem-based Management. Those PoM should aim to ensure and regulate the provisions for society in the light of natural and anthropogenic hazards and risks (e.g. Elliott et al., 2019).

Of course, preventing environmental degradation in the first place is the most desirable but if this is not possible or successful then passive or active recovery and/or restoration techniques are required. Passive responses may involve merely removing the cause of the pressures and allowing the degraded ecological system to recover. However, if this is not successful then active recovery and restoration will be required, by geo-engineering or ecoengineering, the latter now commonly termed Nature-Based Solutions (as shown in the lower part of the diagram). In turn, that ecoengineering may be of two types – type A in which the suitable habitat is created which then allows recruiting organisms to regain their population, or, if Type A is not successful, then Type B ecoengineering in which organisms are artificially introduced through restocking, replanting or reseeding (Elliott et al., 2016).

In turn, to have a successful and sustainable management then management measures and solutions implemented by the users and their regulators must encompass governance (the policies, politics, administration and legislation under which the regulators operate) and economic and technological instruments and approaches available to the users and/or their regulators; for the measures to be sustainable they need to be acceptable (or at least tolerable) to society, culturally, ethically/morally – together constituting the so-called 10-tenets of successful and sustainable environmental management (Elliott et al., 2017). To achieve this, marine users and their regulators will then be required to employ adaptive management.

This framework, together with its concepts and terms, will enable marine users to cope with the plethora of environmental management aspects and the demands of environmental regulators. This is required in order to achieve a sustainable and successful activities but within a healthy, productive, diverse, clean and sustainable marine environment – thereby constituting the adopted vision for our seas.

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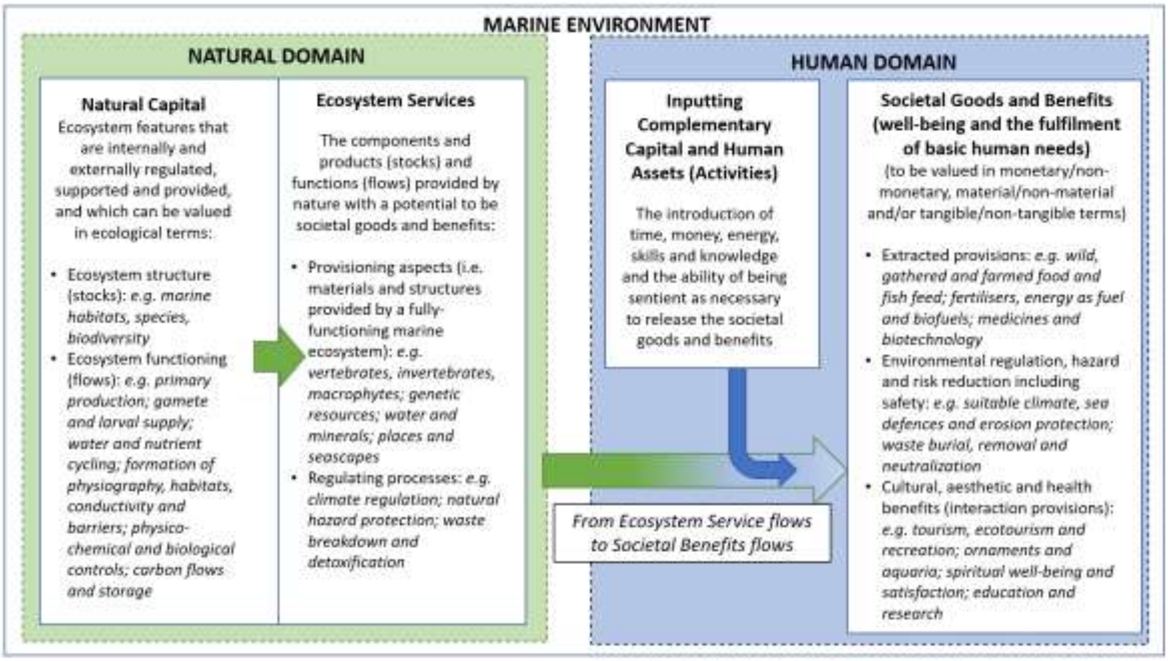

Figure 1 The proposed unified ecosystem services and societal goods and benefits model

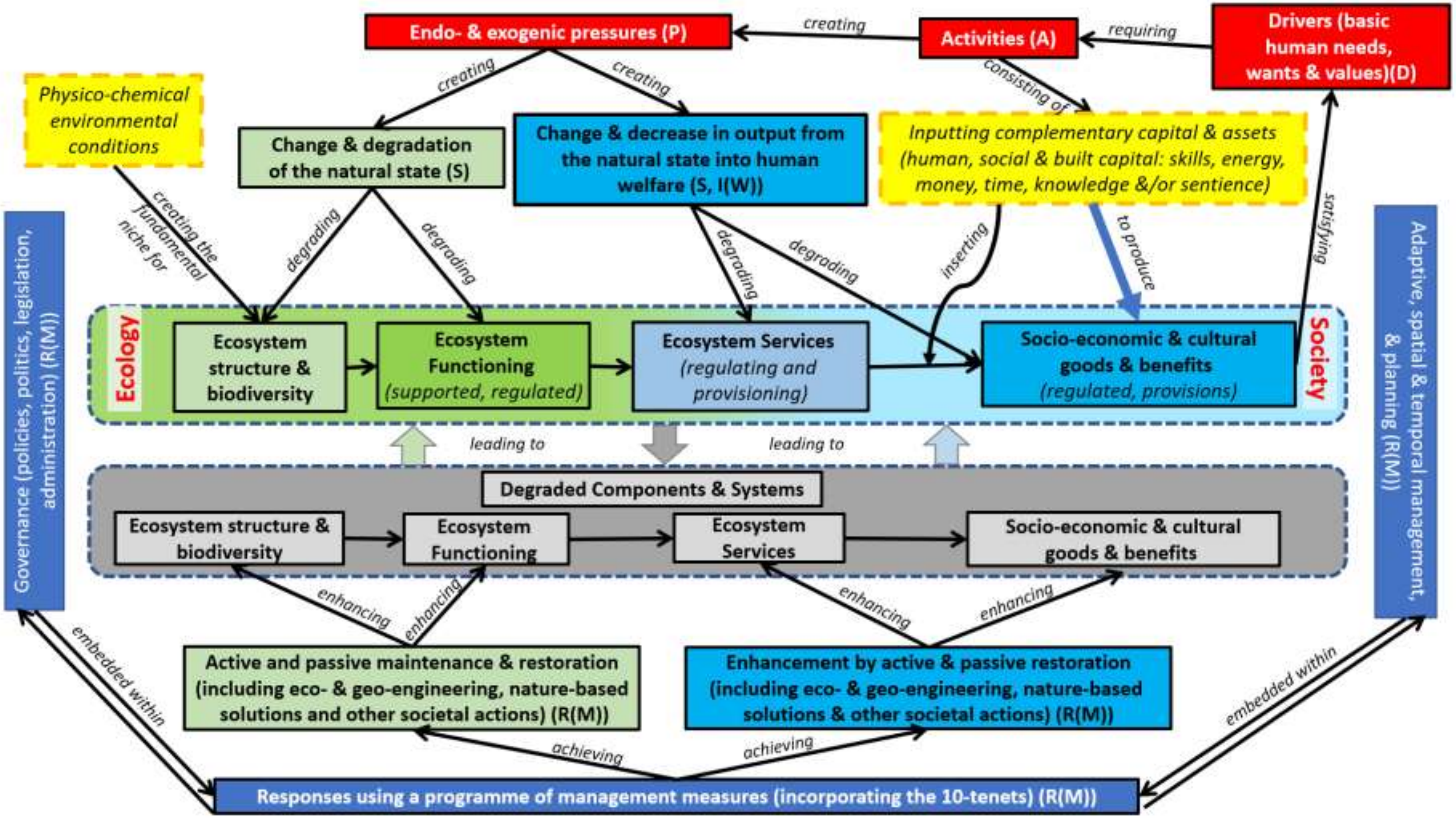
Endo- & exogenic pressures (P)
creating
Activities (A)
requiring
Drivers (basic human needs, wants & values)(D)
Physico-chemical environmental conditions
creating
creating
consisting of
Change & degradation of the natural state (S)
Change & decrease in output from the natural state into human welfare (S, I(W))
Inputting complementary capital & assets (human, social & built capital: skills, energy, money, time, knowledge &/or sentience)
creating the fundamental niche for
degrading
degrading
degrading
degrading
inserting
to produce
satisfying
Governance (policies, politics, legislation, administration) (R(M))
Ecology
Ecosystem structure & biodiversity
Ecosystem Functioning (supported, regulated)
Ecosystem Services (regulating and provisioning)
Socio-economic & cultural goods & benefits (regulated, provisions)
Society
Adaptive, spatial & temporal management, & planning (R(M))
leading to
leading to
Degraded Components & Systems
Ecosystem structure & biodiversity
Ecosystem Functioning
Ecosystem Services
Socio-economic & cultural goods & benefits
enhancing
enhancing
enhancing
enhancing
embedded within
Active and passive maintenance & restoration (including eco- & geo-engineering, nature-based solutions and other societal actions) (R(M))
Enhancement by active & passive restoration (including eco- & geo-engineering, nature-based solutions & other societal actions) (R(M))
embedded within
achieving
achieving
Responses using a programme of management measures (incorporating the 10-tenets) (R(M))

Figure 2 The socio-ecological system aiming to unify the DAPSI(W)R(M) framework, the means of degrading the natural system and recovery management measures, and the ecological structure and functioning to ecosystem services and societal goods and benefits continuum.