The 10-tenets of adaptive management and sustainability: An holistic framework for understanding and managing the socio-ecological system

Steve Barnard*, Michael Elliott

Institute of Estuarine and Coastal Studies (IECS), University of Hull, Hull HU6 7RX, UK
* Corresponding author
Tel.: +44 01482 463405
fax: +44 01482 466772
E-mail address: steve.barnard@hull.ac.uk (S. Barnard)

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Abstract

The three basic principles of sustainable development, relating to ecology, economy and society, have long been embedded within national and international strategies. In recent years we have augmented these principles by a further seven considerations giving rise to the so-called 10-tenets of sustainable management. Whilst theoretically appealing, discussion of the tenets to date has been largely generic and qualitative and, until the present paper, there has been no formal and quantitative application of these tenets to an actual example. To promote the concept of successful and sustainable environmental management there is the need to develop a robust and practical framework to accommodate value judgements relating to each of the tenets. Although, as originally presented, the tenets relate specifically to management measures, they may also be applied directly to a specific development or activity. This paper examines the application of the tenets in both of these contexts, and considers their incorporation into an assessment tool to help visualise and quantify issues of sustainability.

Key words

Assessment, Environment, Ethics, Management, Policy, Sustainable development

1. Introduction

1.1. Economic development and sustainability – where does sustainability lie?

Planners need to maximise economic development while achieving environmental sustainability (Elliott, 2011, 2014), satisifying the so-called Brundtland definition of sustainability for 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (WCED, 1987). This presents a conflict between the opposing imperatives of growth and development, on the one hand, and ecological (and perhaps social and economic) sustainability on the other (e.g. Redclift, 2005). Such a conflict requires us to determine options for economic development and the likely associated impacts on sustainability (see Robinson, 2004). Consequently, planners need to determine the development path in a given area so that the local resources are used efficiently, the environment is protected and its economic welfare is promoted in a socially just way (e.g. Briassoulis, 1999; Gasparatos *et al*., 2008).

Successful sustainable development should reflect the three dimensions or pillars of sustainability: economics society and the environment (e.g. Defra, 2012) seen as a 'three-legged stool' (e.g. Young, 1997) where all three dimensions are equally important. An alternative, but allied, paradigm views the three dimensions as three intersecting areas with the overlapping area representing overall sustainability. The underlying concepts for both models assume that each element (society, environment and economy) is equally weighted in determining sustainable action or policy. Irrespective of whether the concept of sustainable development is an oxymoron, Dawe and Ryan (2003) nevertheless suggested that the three-legged stool analogue is intrinsically flawed: the environment is not a leg for the

sustainable development stool, but the floor upon which the stool must stand. They therefore suggest that the three dimensions of sustainability should be considered within a hierarchical model where economy is nested within society, and society nested within the environment (Fig. 1). This emphasises that environment is the single limiting factor that governs what is possible as regards the other two sustainability considerations.

2. Assessing sustainability

2.1. How can we recognise sustainability?

It was earlier suggested (Elliott, 2002) that the human response to anthropogenic changes in the marine system needed to be more successful via three tenets; that actions should be socially desirable, environmentally and/or ecologically sustainable, and economically viable. These three tenets have long been cited in national and international strategies and reflect the three principles or dimensions of sustainability. These, together with a further three tenets – that actions should be technologically feasible, legally permissible and administratively achievable – were suggested as necessary to achieve successful, marine environmental management. In addition, the socially desirable tenet was expanded to include 'socially tolerable'. For example, we may not actively desire our waste to be discharged into the sea but we tolerate it as a cost-effective means of disposal.

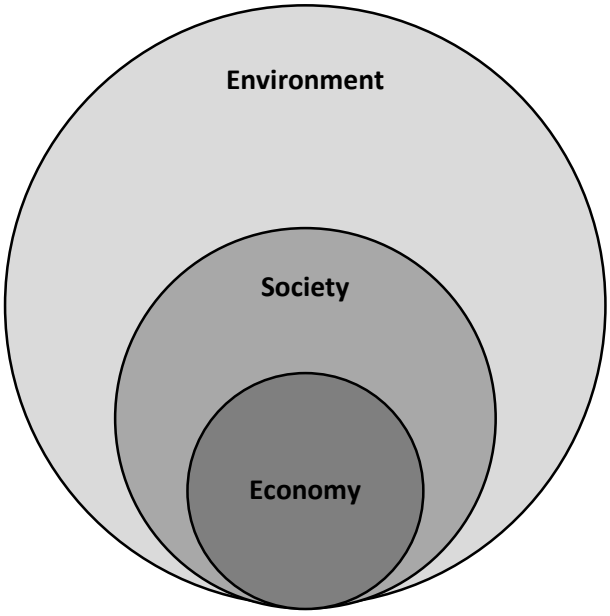


Fig. 1 – The hierarchical relationship of the three principle dimensions of sustainability.

Subsequently, Elliott *et al.* (2006) proposed a seventh tenet (that actions should be politically expedient) reflecting the view that, irrespective of compliance against the first six tenets, without political support management responses may have no realistic chance of implementation.

Finally, Elliott (2013) suggested that a further three tenets (relating to cultural, ethical and communication issues) should be added for sustainable and successful management measures or responses to anthropogenic change (Table 1). Subsequently, these were explored in relation to risk assessment and risk management (Cormier *et al*., 2013; Elliott *et al*., 2014a). By fulfilling the tenets, the management of an environmental problem will be sustainable, protect the environment and be pragmatic (Elliott and Cutts, 2004), especially where the economic imperative is paramount, and will be societally more acceptable, encouraged and visible.

As presented previously (Elliott, 2013) most of the tenets reflect the importance of society and economy rather than the environment within the concept of sustainability. Moldan *et al.* (2012) suggested that, while sustainability denotes a particular property of the system, sustainable development is ensured by two key ideas. Firstly the Brundtland definition of development (WCED, 1987) and secondly Article 1 of the Rio Declaration (UNCED, 1992) that humans 'are at the centre of concerns for sustainable development [and] are entitled to a healthy and productive life in harmony with nature'. Both of these ideas reflect an anthropocentric view and emphasise the societal aspects of development.

Similarly, in their original order, the first four of the 12 principles of the Ecosystem Approach underpinning the UN Convention on Biological Diversity relate to societal desires, economics and management (Elliott, 2011). It is not until the fifth principle that ecology is mentioned, suggesting that the economic and societal aspects of marine management may have equal or perhaps even greater weight than ecological aspects, especially in financially difficult times. All of this infers that the multiple views of sustainability cannot be reconciled (Robinson, 2004), although George (1999) had earlier suggested that, if sustainable development is to become a practical reality, it should be possible to be tested with a given development. We suggest here that the 10-tenets provide a basis for undertaking such a quantitative test, first considering the main issue of addressing whether human developments or activities, which in many cases are constrained by legislative and administrative frameworks, are overall sustainable. The original narratives relating to the 10-tenets (op cit., Mee et al., 2008) provide a reasonably robust background and show that each tenet fulfils an important role in defining sustainability dimensions. However, applying them, we question whether there a simple pass/fail test for each tenet and whether all of the tenets need to be 'passed' in order for an action to be described as sustainable. This calls into question the meaning of the term 'tenet' – for the terms to be called this requires that they are widely applicable and relevant.

Table 1 The 10-tenets for successful and sustainable environmental management (after Elliott 2013).

Environmental management should be:
Socially desirable/tolerable: environmental management measures are as required or at least are understood and tolerated by society as being required; society regards the measures as necessary.
Ecologically sustainable: measures will ensure that the ecosystem features and functioning and the fundamental and final ecosystem services are safeguarded.
Economically viable: a cost-benefit assessment of the environmental management indicates (economic) viability and sustainability.
Technologically feasible: methods, techniques and equipment for ecosystem and society/infrastructure protection are available.
Legally permissible: there are regional, national or international agreements and/or statutes which will enable and/or force the management measures to be performed.
Administratively achievable: the statutory bodies such as governmental departments, environmental protection and conservation bodies are in place and functioning to enable successful and sustainable management.
Politically expedient: the management approaches and philosophies are consistent with the prevailing political climate and have the support of political leaders.
Culturally inclusive: local customs and practices are protected and respected.
Ethically defensible (morally correct): the wishes and practices of individuals are respected in decision-making.
Effectively communicable: all horizontal links and vertical hierarchies of governance are accommodated and decision-making is inclusive.

A rigid threshold between pass and fail is often unrealistic in practice as two nearly indistinguishable measurements for any given tenet that happen to fall either side of the threshold value will be separated into pass and fail. This effect focuses attention on the threshold values used as a simple pass/fail approach places excessive emphasis on their definition (e.g. Cornelissen *et al*., 2001). The decision on where such thresholds (if used) should lie is one that would require input from a wide range of stakeholder groups and, additionally, the transportability of such thresholds (e.g. within or between countries) is likely to be problematical. The alternative approach, proposed here, is to develop a scale of compliance for each tenet.

The second issue considered here is one of how to integrate across ten separate tenets. Previously we suggested that all of the tenets require compliance to achieve successful management and sustainability (e.g. Elliott, 2013; Elliott *et al*., 2014a) also suggested by, for example, George (1999). In contrast, Moles *et al*. (2008), Kondyli (2010) and Clark and Kozar (2011) consider each indicator of sustainability independently without requiring that all indicators should demonstrate compliance.

2.2. Sustainability and the DAPSI(W)R framework

Economic development (for example activities such as port expansion or redevelopment along an estuary) will invariably increase environmental pressures, which need to be prevented or mitigated through specific management measures. Such relationships between society's adverse effects on the environment, and responses to such effects, can be formalised through the development of a systems-based approach, DAPSI(W)R (Elliott, 2014, modified from the DPSIR approach of Atkins *et al*., 2011) (Fig. 2). Drivers, which are the key demands by society (for example a desire for economic

growth), require societal Activities which can create Pressures (the mechanisms of change, for example via a proposed port development). Such Pressures give rise to State Changes in the natural physico-chemical–biological environment and Impacts on human Welfare (see also Cooper, 2013) which then require a Response by society (e.g. as economic or legal instruments or other management measures).

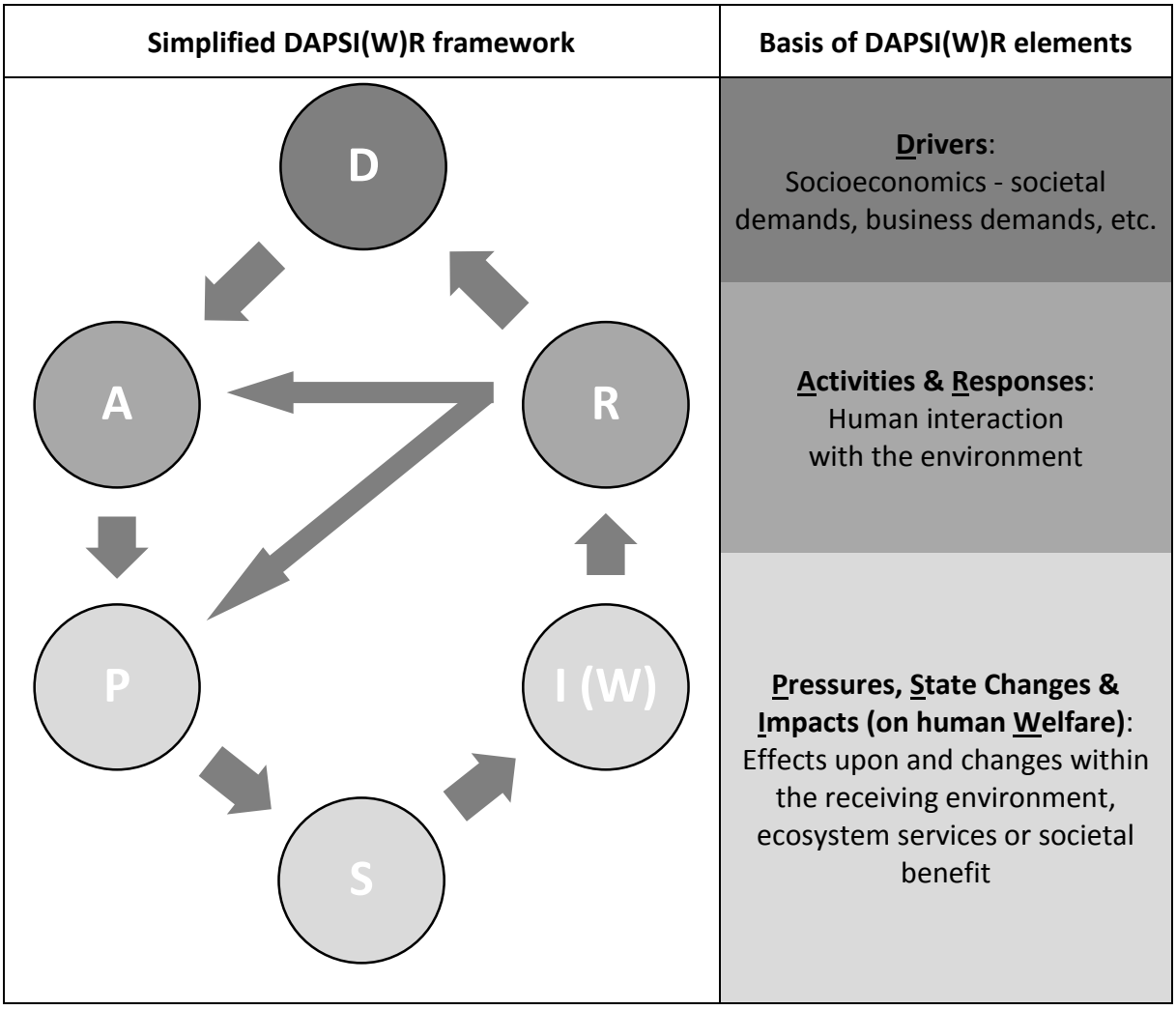


Fig. 2 – Basis of DAPSI(W)R elements.

The DAPSI(W)R framework relies on defined system boundaries, the demarcation of which depends on the particular issue that is of interest and how that issue has been conceptualised (e.g. Svarstad *et al*., 2008). In terms of their relationships, the Pressures, State Changes and Impacts that are linked to any one single Driver and Activity, such as the need for food from wild fisheries, may be related to the Pressures, State Changes and Impacts linked to other Drivers and Activities, for example aquaculture which uses fish meal produced by the wild fisheries. Even if we restrict our analysis to consideration of just the P, S and I(W) relationships, it is probable that, for anything but the simplest of systems, we are nevertheless in a position where we are likely to be considering overlapping State Changes, Impacts and Responses (cf. Atkins *et al*., 2011).

The complexity of the DAPSI(W)R framework is increased significantly both due to time (such as different Drivers operating at different times but where there may be a time-lag in the system) and across wider spatial scales (for example a set of Drivers in an estuary will have to be related to Drivers both in the catchment and at sea). Therefore, the assessment is constantly evolving and has to accommodate moving baselines (such as caused by climate change, Elliott *et al*., 2014b) and 'unbounded boundaries' such as events at oceanic scales (Elliott, 2013). In addition, the proactive or reactive development of Responses may lag behind the introduction of Pressures and the range of Activities and Pressures operating within a given system may themselves be introduced at different times.

Pressures (mechanisms that cause marine State Change) can be separated into two types: endogenic managed pressures and exogenic unmanaged pressures (Elliott, 2011). Endogenic managed pressures arise where the causes of potential adverse effects come from within the system and management at the local, regional and/or international scale can respond to both the causes and consequences of the pressures (e.g. shoreline development and coastal squeeze). In contrast, exogenic unmanaged pressures represent change arising from outside of the system and which cannot be managed, limiting the human Response solely to addressing the consequences of the pressure (e.g. changes in relative sea level due to isostatic rebound, Elliott *et al*., 2014a).

Estuarine functioning is dependent on connectivity between an estuary and both its catchment and the adjacent marine area (Elliott and Whitfield, 2011). Consequently, when aiming for sustainable developments within estuaries, we have to address not only those developments but also the interactions between them and those both at sea and within the catchment. Responses to the causes of problems may therefore need to be directed not only at the estuary, but also at the sea and the catchment.

As originally presented (op. cit.) the 10-tenets relate to actions or management measures. That is, human Responses include a set of tools available to society for managing systems and so may be regarded as having to meet the tenets for environmental management (Atkins *et al*., 2011); this allows us to achieve the central aim in environmental management to protect and enhance ecological structure and functioning while ensuring ecosystem services and delivering societal benefits including ecological and socio-economic connectivity (Elliott, 2011, 2013). Under such a framework, the development-related Activity and resultant Pressures that require management are themselves not directly considered in the assessment of sustainability addressed through consideration of the 10- tenets. In previous discussions it has been assumed that the proposed measures (the management Responses) would, if they were applied completely, ensure the prevention of, or provide adequate compensation or mitigation for, the State Changes and impacts of the development or activity; hence by definition if the management measures can be judged to be successful and sustainable then the development and activity will be successful and sustainable.

However, the DAPSI(W)R approach (Fig. 2) suggests that, while State Changes and Impacts (on societal Welfare) together represent the changes to the natural and human receiving environment, the causes from direct human interaction with the environment are clearly represented not just by Responses (via the linked sequence of Drivers, Activities and Pressures) but by Activities themselves. Hence, not only management (i.e. the Responses) should be considered when assessing sustainability through the application of the 10-tenets but also those Activities (for example estuarine port developments) responsible for producing the Pressures. In this context it is axiomatic that environmental management is not really managing the environment but rather managing human behaviour.

2.3. Application of the 10-tenets

2.3.1. Initial considerations

The 10-tenets, having been originally conceived as a check-list for measures developed to address State Change and Impacts, can also be used to address Activities (e.g. infrastructure development) arising from socio-economic Drivers. Whilst not significantly changing their fundamental intent, consideration of the 10-tenets in this way (i.e. in relation to both the ‘Pressure’ and the ‘Response’) requires that the tenets be reworded slightly from their initial form and applied separately at two points in the DAPSI(W)R model – the Activities and the management Responses (Table 2).

Applying the tenets independently in this way emphasises the DAPSI(W)R framework more closely and gives a more holistic view, allowing the likely sustainability of a proposed development activity to be assessed as a whole. For example, the management regime includes prevention, mitigation and/or compensation or the need to convince society to accommodate change. It also has the distinct advantage in that it permits an initial assessment of the sustainability of a proposed activity without the need for information on specific Response measures (which may be very highly site-specific and not fully known until much of the detailed planning for a proposed activity has been undertaken). In considering the measures that may be required in response to a proposed activity or project it is important to recognise that there may be a spatial disconnect; activity-specific measures (e.g. compensation or mitigation schemes) may not necessarily be taking place at the site of the activity.

Table 2 – Interpretation and application of the 10-tenets both to Activities and Pressures and to management measures (Responses).

Tenet:	Tenet applied to:	
	Activities and/or development Pressures (pre-development decisions)	**Management measures (Responses) (during and post- development actions)**
Ecologically sustainable	Should not impact on ecosystem features and functioning, and both fundamental processes and ecosystem services should be preserved; preventative measures should be in place prior to the activity	Where needed, management measures should ensure that ecosystem features and functioning, and both fundamental and final ecosystem services, are safeguarded; the habitat and/or resource compensation will have the desired effect
Technologically feasible	The methods to create the development are achievable and permitted within technological and engineering constraints	Methods, techniques and equipment for ecosystem and society/infrastructure protection and the ecohydrological and eco-engineering methods are available
Economically viable	Economic imperatives allow the development to occur and it is a viable proposition	A cost-benefit assessment of the management measures indicates (economic) viability and sustainability; habitat and resource compensation and user compensation are affordable
Socially desirable/tolerable	Society regards the development or activity as necessary, the underlying drivers are at least understood, and the adverse effects of the development are tolerated by society	Society regards the environmental management measures (including mitigation and/or compensation) as necessary or they are at least understood and tolerated by society
Ethically defensible (morally correct)	The wishes and practices of individuals have been covered in the EIA and they are respected in decision-making	The wishes and practices of individuals are respected in decision-making
Culturally inclusive	Local customs and accepted practices are protected and respected at all stages but especially in the planning stage	Local customs and accepted practices are protected and respected
Legally permissible	A legal (regulatory) impact assessment has been performed to allow the development to take place; Horizontal links and vertical hierarchies of governance are accommodated and decision-making is inclusive	There are regional, national or international agreements and/or statutes which will enable and/or force the management measures to be performed
Administratively achievable	Horizontal links and vertical hierarchies of governance are accommodated and decision-making is inclusive	Statutory bodies (such as governmental departments, environmental protection and conservation bodies) are in place and functioning to enable successful and sustainable management
Effectively communicable	Horizontal links and vertical hierarchies between stakeholders are accommodated and decision-making is inclusive via EIA consultation	Horizontal links and vertical hierarchies of governance are accommodated and decision-making is inclusive
Politically expedient	The development or activity is consistent with the prevailing political climate and has the support of political leaders	Management approaches and philosophies are consistent with the prevailing political climate and have the support of political leaders

2.3.2. Scoring against the 10-tenets

As discussed above, consideration of the 10-tenets within the DAPSI(W)R framework effectively allows a two-stage assessment of sustainability. Initially the sustainability of a proposed development may be assessed by considering how well the tenets are addressed by the Activities associated with the proposed development. Subsequently, proposed management measures (Responses) can be assessed against the tenets.

At its simplest, moving from a purely conceptual and qualitative position (e.g. Elliott *et al*., 2014a) to a more objective and practical application of the 10-tenets requires the development of a quantitative scoring system for recording value judgements of compliance against each tenet. It is then possible to combine these objective judgements, to provide a composite assessment of the overall level of sustainability associated with a given development.

A quantitative scoring system is proposed here for standardising the implementation of each tenet on a common scale from minimal to full compliance. This has the benefit of removing the potential problem of mixed metrics or different scales adversely influencing, or skewing, any subsequent assessment. Furthermore, defining minimum and full compliance in 'absolute' terms for each tenet irrespective of any specific location, allows for subsequent comparisons to be made, not only between different activities in any one area but also between activities in different areas. This requires us to propose and define fixed points, describing minimal and full compliance with each tenet (Table 3).

The adoption of definitions for minimal and full compliance allows, by interpolation, the allocation of scores against each tenet for a given development or activity. In practice, however, it will be beneficial to develop further guidance on intermediate values, lending a greater level of consistency and repeatability in the (interpolative) scoring process.

2.3.3. Illustrative examples of tenet scoring

To illustrate the proposed method we use the hypothetical but likely scenario of a development proposal for a new port (Development A) within an ecologically important and environmentally sensitive estuary. An Environmental Impact Assessment suggests that the development is likely to have significant adverse impacts on the environment and that a number of measures are required to mitigate for this (McLusky and Elliott, 2004, for example, give the potential effects of ports in estuaries). In addition, the development does not have a great deal of public support although it does fit with government policy and has been promoted through local media. The management measures that are proposed to address the impacts due to the development have been tried and tested on similar projects and environments elsewhere and are known to be effective and economically viable (e.g. Environmental Management Systems for the operation of the port and a habitat compensation scheme for areas lost under the development). In contrast to the development itself, there is a general acceptance and understanding that the measures (which are well supported by local government policies) are needed and local stakeholder groups have been closely involved in their development. Current legislation relevant to the measures is well developed, and the administrative framework provided by conservation and environmental protection bodies in the area is well established and should support their implementation.

An alternative development (Development B) for the same area, the construction and operation of a new marina, is likely to have a lesser impact on the environment. Although being promoted less strongly by government, it has more support from local stakeholders and the general public and is seen as being ethical and inclusive. For Development A, the management measures that are proposed (e.g. replacing lost environment with compensation habitat) have been well demonstrated elsewhere, although in this instance there is some degree of uncertainty around their economic viability. Furthermore, the planned compensation measures are located at a site that is relatively remote from the development itself and, as a consequence, it cannot be ensured that the ecosystem features and functioning will be safeguarded at the development site and or at the local scale. In addition, the political support and the legal and administrative frameworks in the area where the measures are proposed for Development B have a lower emphasis than for the compensation site for Development A. Example scores for these two scenarios, A and B, are summarised as Table 4 using Table 3 for the proposed development and management measures. It is axiomatic that, while the assessment of any environmental damage relates to the Pressures, the actions to control this relate to the Activity.

Table 3 Proposed scaling for tenets: normative definitions of minimal & full compliance

	Tenet applied to:	
Tenet:	**Activities and/or development Pressures**	**Management measures (Responses)**
Ecologically sustainable	*Minimal compliance* - the development or activity is certain to cause significant disruption to valuable ecosystem features and functioning, and/or to fundamental and final ecosystem services *Full compliance* - there is confidence from good evidence that the development or activity will not impact on ecosystem features and functioning, and fundamental and final ecosystem services will remain unaffected (i.e. the natural ecology is maintained where possible) at a local (site) scale	*Minimal compliance* – the required measures are absent or will not ensure safeguarding ecosystem features and functioning, or fundamental and final ecosystem services *Full compliance* - there is confidence that the measures will ensure ecosystem features and functioning, and fundamental and final ecosystem services, will be completely safeguarded (i.e. the natural ecology is maintained where possible) at a local (site) scale; the measures associated with the activity/project will protect the site potentially impacted by the proposed development or activity
Technologically feasible	*Minimal compliance* - the development or activity cannot be undertaken with existing technologies or techniques *Full compliance* - there is a good technical background that will ensure the development is completed	*Minimal compliance* - there is no technology or practice currently available to support the proposed measures *Full compliance* - methods, techniques and equipment for ecosystem and society/infrastructure protection are available and have been demonstrated on similar projects, at a similar scale and under similar environmental circumstances
Economically viable	*Minimal compliance* - the development or activity is prohibitively expensive and unlikely to be sanctioned by shareholders *Full compliance* – funding is ensured to allow completion	*Minimal compliance* - the measure is not economically viable, even in the short-term *Full compliance* - cost-benefit assessment of the environmental management measures indicates, with a high degree of certainty, both full (economic) viability and subsequent long-term sustainability
Socially desirable/tolerable	*Minimal compliance* - society at large actively rejects any suggestion that the development or activity is needed; if implemented, the development or activity would not be tolerated *Full compliance* - society at large views the development or activity as an imperative; it is tolerated and regarded as necessary	*Minimal compliance* - society at large actively rejects any suggestion that the management measures are needed; if implemented, measures would not be tolerated *Full compliance* - society at large views the management measures as an imperative; they are regarded as necessary
Ethically defensible (morally correct)	*Minimal compliance* - although there may be an understanding, or even acceptance, of the underlying societal need for the development or activity, there is nevertheless the general view that the specifics of the proposal render it ethically or morally indefensible *Full compliance* - the wishes and practices of individuals who are potentially affected by the project/activity have been fully respected in decision-making with no single sector or group being unduly favoured; there is general view that the development or activity is acceptable on moral or ethical grounds	*Minimal compliance* - although there may be an understanding, or even acceptance, of the underlying need for the measures, there is nevertheless the general view that the specifics of the proposal render it ethically or morally indefensible *Full compliance* - the wishes and practices of individuals who are potentially affected by the project/activity have been fully respected in decision-making with no single sector or group being unduly favoured; there is general view that the measures including the future costs are acceptable on moral or ethical grounds

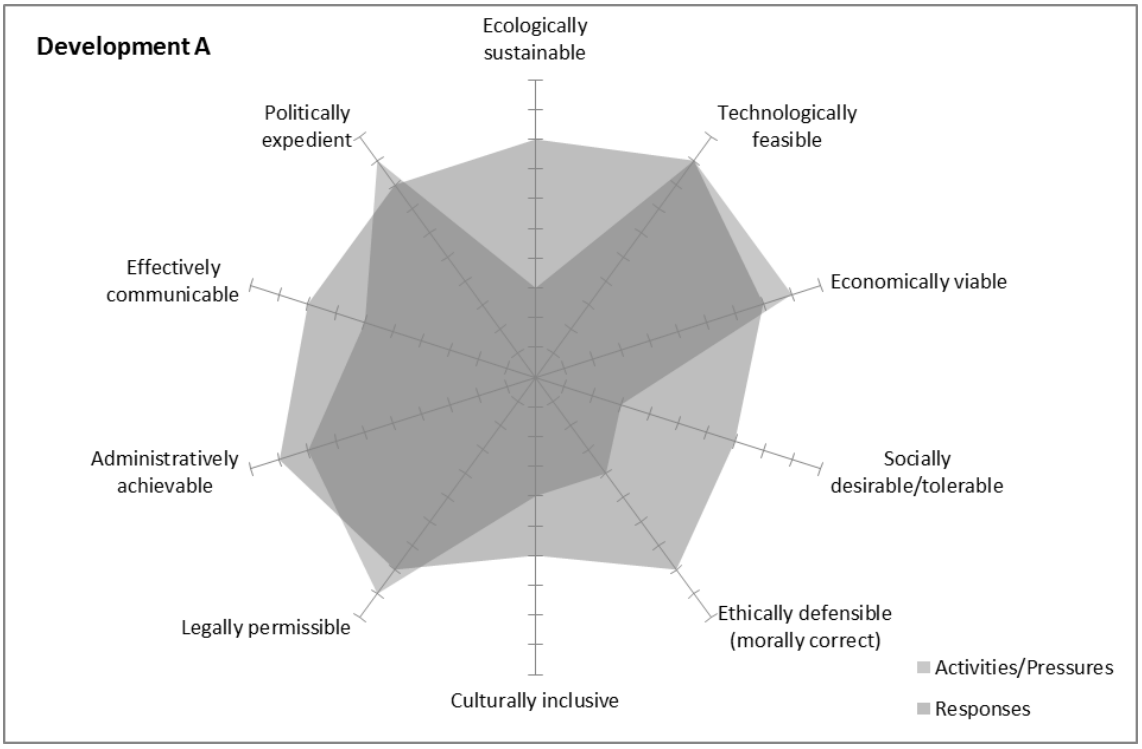
	Tenet applied to:	
Tenet:	**Activities and/or development Pressures**	**Management measures (Responses)**
Culturally inclusive	*Minimal compliance* - the development or activity takes no consideration whatsoever of local customs and practices and these are considered secondary to other considerations *Full compliance* - local customs and practices are fully considered with local needs embedded within the proposals – the proposed development or activity ensures the customs and practices of local communities are not adversely affected; where applicable, aboriginal/first-nation rights are defended	*Minimal compliance* - the measures take no consideration whatsoever of local customs and practices *Full compliance* - local customs and practices are fully considered with local needs embedded within the proposals – the proposed measures ensure the customs and practices of local communities are not adversely affected; where applicable, aboriginal/first-nation rights are defended
Legally permissible	*Minimal compliance* - the development or activity cannot be allowed under current legislation and regulatory environment *Full compliance* – there are no legal impediments to the development being completed	*Minimal compliance* - regional, national or international agreements and/or statutes relating to the implementation of the likely required measures are absent *Full compliance* - there are regional, national and/or international agreements and/or statutes currently in place which will enable and force the likely required measures to be implemented to a full and adequate degree
Administratively achievable	*Minimal compliance* - the statutory bodies will not allow the development to proceed *Full compliance* – the statutory bodies have agreed to the development and similar ones have been sanctioned elsewhere	*Minimal compliance* - statutory (administrative) bodies (e.g. governmental departments, environmental protection and conservation bodies) required to implement (and subsequently operate) the measures are not in place *Full compliance* - the requisite statutory (administrative) bodies (e.g. governmental departments, environmental protection and conservation bodies) are in place and are capable of fully enabling successful and sustainable management (critically, they have a demonstrable 'track record' in enabling such management)
Effectively communicable	*Minimal compliance* - irrespective of the degree of public understanding of the issues surrounding the proposed development or activity, full and open communication is absent or problematic (e.g. full disclosure of the underlying evidence base may not be possible due to military or commercial sensitivity) *Full compliance* - irrespective of their views, the consequences of confirmation or rejection of the proposed development or activity are readily appreciated by the public; where appropriate, media campaigns and other consultations have been successfully implemented across all sectors of stakeholders (for example through newsletters, press articles or roadshows) and have opened communication across horizontal links and vertical hierarchies of governance and decision-making	*Minimal compliance* - irrespective of the degree of public understanding of the issues surrounding the proposed measures, full and open communication is absent or problematic (e.g. full disclosure of the underlying evidence base may not be possible due to military or commercial sensitivity) *Full compliance* - irrespective of their views, the consequences of adoption or rejection of the proposed measures are readily appreciated by the public; relevant stakeholder sectors are aware of the proposed measures (for example through newsletters, press articles or roadshows) and communication has been opened across horizontal links and vertical hierarchies of governance and decision-making
Politically expedient	*Minimal compliance* - underlying requirements for developments are inconsistent with the prevailing political climate; the proposed development or activity is at odds with prevailing policy or strategy statements *Full compliance* - underlying requirements for developments are fully consistent with the prevailing (national) political climate and have the explicit support of political leaders; supporting drivers for the development or activity are documented (for example within policy statements at the national or international level)	*Minimal compliance* - underlying management approaches and philosophies are non-consistent with the prevailing political climate; the measures are at odds with prevailing policy or strategy statements *Full compliance* - underlying management approaches and philosophies are fully consistent with the prevailing (national) political climate and have the explicit support of political leaders; supporting drivers for the measures are documented (for example within policy statements at the national or international level)

There is then the need to communicate to stakeholders the two alternative scenarios, Development A and Development B, in terms of their sustainability. Once an assessment of both the development and the likely management measures have been completed and agreed by stakeholders, a graphic representation of the degree of sustainability associated with the development or activity can be produced by plotting the data on radar (spiderweb) plots with axes representing the 10- tenets (Fig. 3). A similar graphical approach has been used elsewhere (e.g. Gareau *et al*., 2010; Alvarez *et al*., 2013), and in a sustainable development context by Atkisson (2001) in his 'Compass Index of Sustainability' (presenting four composite indicators of sustainability: Nature, Society, Economy and Well-being) and more specifically for assessments of sustainable development across several dimensions (e.g. Moles *et al*., 2008; Kondyli, 2010).

By overlaying the scores for the causes of the effects emanating from the development (the Activity) over those for management measures (the Responses), the approach illustrates the relative sustainability associated with the Activity itself and the associated Response (the legal, economic and management measures to address any resultant Stage Change and consequent Impacts on Welfare). This simple graphical representation of compliance provides an immediate impression of the balance across the 10-tenets. For example, this indicates whether the development meets all of the tenets more or less equally or, while addressing most of them to a reasonable extent, clearly fails to address one or more tenet. The approach also indicates the degree to which the 10-tenets are met overall as shown by the overall size of the graphic, hence a development that gives rise to a plot covering only a small area clearly addresses the 10-tenets less well than a development that results in a larger plot area.

Table 4 Illustrative example of tenet scores

	Development A		**Development B**	
Tenet:	**Activities and development Pressures**	**Management measures (Responses)**	**Activities and development Pressures**	**Management measures (Responses)**
Ecologically sustainable	3	8	7	6
Technologically feasible	9	9	10	8
Economically viable	9	8	9	6
Socially desirable/tolerable	3	7	8	7
Ethically defensible (morally correct)	4	8	7	8
Culturally inclusive	4	6	7	5
Legally permissible	9	8	9	6
Administratively achievable	8	9	8	5
Effectively communicable	6	8	7	7
Politically expedient	9	8	8	7



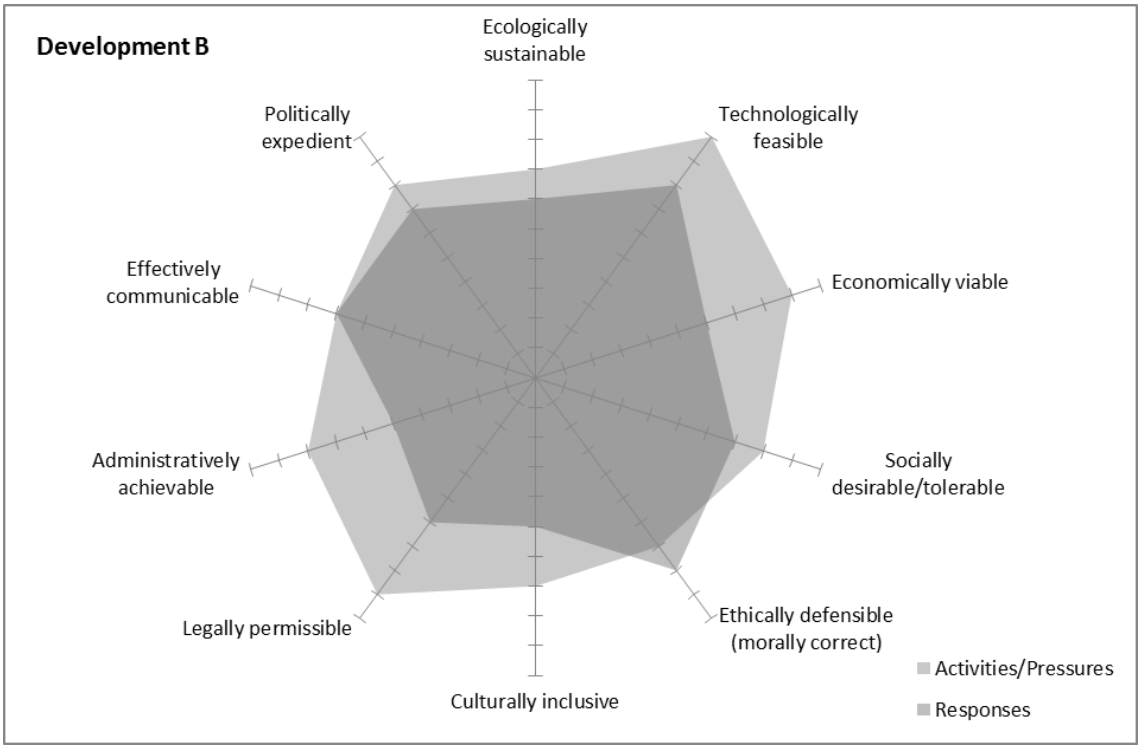


Figure 3 Example sustainability plots

3. Concluding remarks

This paper further develops the practical application of the 10-tenets for successful and sustainable environmental management, as postulated by Elliott (2013). It provides an objective basis for an assessment tool to help examine and visualise issues of sustainability. Whilst the literature gives many examples of indicators being developed to assess sustainability for specific systems or for specific audiences, it is proposed here that the use of the 10-tenets represents a means by which all three dimensions of sustainability (environmental, social and economic) can be considered, and can be transported between sites and to different business sectors. In addition, the approach recognises the relationships between anthropogenic pressures and societal responses and identifies that both need to be considered in successful applications of sustainable development.

As with all sustainability considerations, scale is of central importance. Whilst the DAPSI(W)R framework requires defining the scale of the system under consideration (e.g. in terms of the boundary of the specific issue of interest), it is emphasised that certain management measures (e.g. habitat compensation schemes) may be introduced at locations that are remote from the source of an endogenic managed pressure. Also, where responses are proposed to address environmental perturbations due to exogenic unmanaged pressures these will, by definition, be at a different scale to the local activity and its pressures; for example, while the consequences of climate change need to be addressed locally, the causers require global action (Elliott *et al*., 2014b). This is a feature of current planned or proposed systems and it should be accommodated by all environmental regulatory assessment systems.

The normative definitions for describing minimal and maximal compliance with each of the tenets will be refined with use. It may be possible to make some of the tenet-scales more quantitative For example where a development has to comply with many pieces of legislation and be agreeable to many competent authorities (Boyes and Elliott, 2014, 2015) certain of the scales might represent the number of statutory agencies or pieces of legislation. Despite this, the terminology presented attempts to reconcile the need for clarity (to remove ambiguity and allow for consistency) and flexibility (allowing application to different business sectors and geographic areas). Hence, the development of standard criteria for intermediate scores will be of value.

Further work is required to develop single (composite indicator) scores for both the intensity of the development and the likely management measures. This could integrate the information presented by each of the individual tenets, and the consideration of guidance to help users to identify possible (Response) management measures for specific development types (Activities). In addition, the method proposed here has to be extended to accommodate the fact that most environments have many competing and conflicting developments, across which in-combination and cumulative impacts have to be addressed (e.g. Aubry and Elliott, 2006). It is thus acknowledged that achieving some tenets for one development will differ from achieving others for another development in the same area.

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