Integrating management tools and concepts to develop an estuarine planning support system: A case study of the Humber Estuary, Eastern England

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ABSTRACT
Estuaries are important because of their multiple uses and users which often makes them challenging to manage since management must strike a balance between the needs of users, the estuaries' ecological and economic value and the context of multiple legislative drivers. To facilitate management we have therefore developed an Estuarine Planning Support System (EPSS) framework using the Humber Estuary, Eastern England, as a case study which integrates the current legislation tools and concepts. This integrated EPSS framework is an improvement on previous approaches for assessing cumulative impacts as it takes into account legislative drivers, management tools and other mechanisms for controlling plans/projects specific to the estuary. It therefore enables managers and users to assess and address both the current state and the way in which a new industrial, port or urban development could impact an estuary in an accessible and understandable framework.

1. Introduction

Estuaries are important areas globally for many activities including industry, being hubs for the import and export of goods, tourism, and biodiversity including species and habitats of conservation importance (Elliott and Whitfield, 2011). The increase in the wide range of associated human activities has increased the pressures on coastal resources, causing environmental degradation and societal problems (Borja et al., 2010a, 2010b; Halpern et al., 2008; Berger and Hodge, 1998).

In order to mitigate the risks on these areas and optimise their use for industry, tourism and nature conservation, estuaries are often managed through the use of an estuarine planning or management scheme e.g. the Humber Nature Partnership (Defra, 2014). In the rare cases where one exists, the estuarine planner's role is to sustainably manage an estuary while taking into account the needs of a large number of potentially conflicting users and stakeholders. In order to achieve this, and irrespective of whether the estuarine planning falls to an individual, a committee or a loose arrangement of statutory bodies, an integrated planning system is required to harmonise the policies, management plans, legislation and administration bodies. This paper proposes an Estuarine Planning Support System (EPSS) as a framework to aid sustainable management with a focus on the Humber Estuary but the general approach can be adapted to other estuaries worldwide.

Recent marine and estuarine management worldwide, but especially throughout Europe, has focused on a set of concepts and approaches which are integral to the implementation of several legislative tools but have not been integrated into one planning support system (Counsell and Haughton, 2006; Mee et al., 2008; Hering et al., 2010; Townsend et al., 2011; Whitfield et al., 2012; Borja et al., 2013). The concepts and tools can be summarised as:

- Governance including legislative tools and sectoral management schemes (Apitz et al., 2006; Fujii, 2007; Environment Agency, 2008; Boyes and Elliott, 2014);
- The administrative complexity of marine and coastal management and the need for harmonisation (Boyes and Elliott, 2015);
- Nested–DAPSI(W)R framework (Elliott, 2014, developed from the DPSIR approach in Atkins et al., 2011);
- Risk Analysis and Risk Management approaches linked to infrastructure developments and as a component of Environmental Impact Assessments (Cormier et al., 2013);
- Ecosystem approach (Helsinki and OSPAR, 2003; Elliott et al., 2006; Carpenter et al., 2009; Haines–young and Potschin, 2011; Farmer et al., 2012)
- Ecosystem services and societal benefits (Beaumont et al., 2007; Atkins et al., 2011; Elliott and Whitfield, 2011; Luisetti et al., 2014; Turner and Schaafsma, 2014)
- The 10–tenets for successful and sustainable management (Elliott, 2013; Barnard and Elliott, 2015).

Given this complexity, there is a need by estuarine managers/ planners, statutory bodies and by industry for an EPSS framework to integrate these into a conceptual model and then a working framework, which is a simplification of but also an aid to the decision making process. Here we use the Humber Estuary as a case study, however the proposed EPSS framework can be used for other estuaries worldwide as its approach can be adapted to other countries' legislative requirements. The framework does not simplify the legislation but rather demonstrates how it should be enacted and accommodated (Townsend et al., 2011; Boyes and Elliott, 2014).

For an ecosystem management and strategic assessment to be successful, the relevant management levels must be identified to ensure all objectives can be addressed i.e. international directives, national legislation and regional plans (Apitz et al., 2006; Boyes and Elliott, 2014). The various water and land uses, including functions and values should also be identified and assessed within the different disciplines e.g. socio–economists, natural scientists, and policy and decision makers.

To ensure holistic management of a system an effective EPSS should: take into account the different disciplines and hence be based on the natural and social sciences; show the legislative aspects that need consideration; identify the steps that need to be taken to achieve the legislative requirements and objectives of the project, and encompass all relevant stakeholders' views (Gross, 2003; Barbier et al., 2011; Townsend et al., 2011). It should be noted that an EPSS is a representation of a generalised integrated estuarine management process to aid and support the decision making process. Hence it will aid in decision–making rather than be an automated mechanism for taking the decision.

This paper aims to present the conceptual basis of the EPSS framework using a real case–study and incorporate the following objectives:

- What legislative drivers and management tools are available already for the management of an ecosystem?
- How can these tools be modified and taken forward with legal requirements to produce an overarching and integrated EPSS?
- How does the EPSS aid in decision making?

1.1. Study area and method for developing the EPSS framework

This study uses the Humber Estuary, Eastern England, as a case study area. It begins at the confluence of the River Ouse and River Trent and flows easterly to the city of Kingston–Upon–Hull where it then flows south eastwards, and enters the North Sea between Spurn Point and Donna Nook (Fig. 1). The Humber drains approx. 20% of the land mass of England and is important for both regional and national economic development, acting as a route for ~20% of the UK import trade in 2012 and 10% of the UK export trade (DfT, 2014). It is also of international importance for its nature conservation features and tourism features and its conservation designations. The high level of economic activity in the Humber Estuary and its many uses and users demonstrate the requirement for sustainable and holistic management to ensure that the features of this estuary will be available for future generations while allowing for continuing economic, recreational and environmental development.

In order to provide the necessary context for management the following section reviews the different legislation, management schemes and tools for the Humber Estuary that should be integrated into an EPSS framework.

1.2. Governance

A key problem in managing a large ecosystem such as the Humber Estuary is defining the hierarchy of decisions within the management framework (Apitz and White, 2003; Boyes and Elliott, 2015). It is important to recognise that the management of an ecosystem needs to incorporate the natural cycles, interactions and relationships, and must not focus on just one aspect in one discrete area. For any estuary, the first step is to identify the high–level managers and stakeholders. The

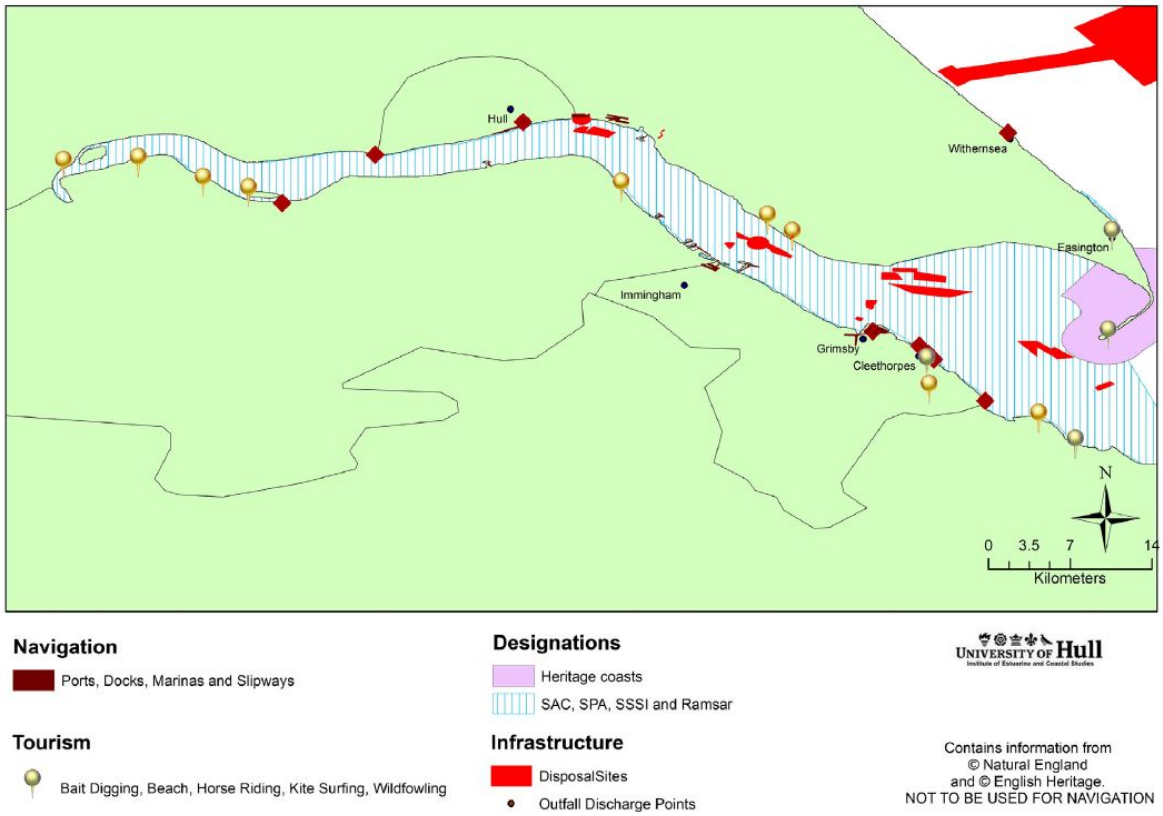

Fig. 1. The Humber Estuary and its uses and users.

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Humber Estuary is monitored and managed by different agencies with specific functions and remits and responsibility (Table 1). As for many estuaries, the Humber has many aspects to be managed, each of which requires a competent authority and that depending on the remit of the authority may be to conserve, manage or implement a legislative requirement (Table 2). Some of these statutory requirements have resulted in named plans being produced and adopted, although the large number of plans/requirements require an integrated system to enable managers to apply the necessary processes in a logical and comprehensive way.

Table 1
Aspects of environmental management on the Humber Estuary: lead authorities and existing management plans.

Generic management aspect	Lead authority	Management plan(s)
Habitats	Statutory nature conservation bodies	Estuary Management Plan; Coastal Habitat Management Plans (CHaMPs)–Habitat Management Plans; European Marine Site Management Plans
Environmental quality	Environmental Protection Agency (EPA)– type organisations	Humber River Basin Management Plan
Water space usage	Port authorities	Port Development Plan
Navigation	Port authorities	Port Development Plan
Infrastructure	Municipalities/federal state	Structure Plan
Energy extraction	Private companies EPA organisations	The local authorities have their own renewable energy plans for their jurisdictions
Biological extractions	Fishery bodies	Fish and Shellfisheries Management
Estuarine water extraction	Private energy companies	River Basin Management Plan
Upstream water abstraction	Water supply companies	River Basin Management Plan
Land space usage	Municipalities/federal state	Structure Plan
Erosion and flooding control	EPA, municipalities, etc.	Shoreline Management Plan; Flood Risk Management Plan
Industry	EPA and private companies Municipalities/federal state	Local Enterprise Plan (LEP)
Recreation and tourism	Local authorities, agencies and organisations	The local authorities have their own recreation plans for their jurisdictions; Humber Nature Partnership Management Action Plan

Table 2
The different agencies and organisations that manage parts or all of the Humber Estuary (— denotes that the group/organisation does not fall under the "type" category).

Area of responsibility	Group/organisation	Advisory	Private utility	Executive non departmental public body	Formal agreements	Forum	Government body	Harbour authority	HGO expertise	Landowner/ manager and NGO pressure	Lobby	Partnership	Land management	Promotion	Statutory	Stakeholder
Water quality	Environment Agency (EA)	—	—	Y	—	—	—	—	—	—	—	—	—	—	Y	—
	Water Companies	—	Y	—	—	—	—	—	—	—	—	—	—	—	—	Y
Nature conservation	Defra	—	—	—	—	—	Y	—	—	—	—	—	—	—	Y	—
	Natural England	—	—	Y	—	—	—	—	—	—	—	—	—	—	Y	—
	EA	—	—	Y	—	—	—	—	—	—	—	—	—	—	Y	—
	Royal Society for the Protection of Birds	—	—	—	—	—	—	—	—	Y	—	—	—	—	—	—
	Lincolnshire Wildlife Trust	—	—	—	—	—	—	—	—	Y	—	—	—	—	—	—
	Yorkshire Wildlife Trust	—	—	—	—	—	—	—	—	Y	—	—	—	—	—	—
	Yorkshire Naturalists Union	—	—	—	—	—	—	—	Y	—	—	—	—	—	—	—
	Spurn Heritage Point	—	—	—	—	—	—	—	—	—	—	Y	—	—	—	—
	Humber Nature Partnership	—	—	—	—	Y	—	—	—	—	—	—	—	—	—	—
Shipping and ports	Marine Management Organisation	—	—	Y	—	—	—	—	—	—	—	—	—	—	Y	—
	ABP Humber Estuary Services	—	—	—	—	—	—	Y	—	—	—	—	—	—	Y	—
	Humber Sea Terminals, APT, Conoco Philips	—	—	—	—	—	—	Y	—	—	—	—	—	—	Y	—
	British Waterways	—	—	—	—	—	—	—	—	—	—	—	—	—	Y	—
Development	Local Planning Authorities	—	—	—	—	—	—	—	—	—	—	—	—	—	Y	—
	Associated British Ports	—	—	Y	—	—	—	—	—	—	—	—	—	—	Y	—
	Environment Agency	—	—	Y	—	—	—	—	—	—	—	—	—	—	Y	—
	Humber Local enterprise Partnership	—	—	—	—	—	—	—	—	—	—	Y	—	—	—	—
Flood protection	Defra	—	—	—	—	—	Y	—	—	—	—	—	—	—	Y	—
	Humber Estuary Coastal Authority Group	Y	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Environment Agency	—	—	Y	—	—	—	—	—	—	—	—	—	—	Y	—
	Local Planning Authorities	—	—	—	—	—	—	—	—	—	—	—	—	—	Y	—
	Internal Drainage Boards	—	—	—	—	—	—	—	—	—	—	—	—	—	Y	—
	Local Landowners	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Y
Tourism	Visit Hull and East Yorkshire, Visit Lincolnshire	—	—	—	—	—	—	—	—	—	—	—	—	Y	—	—
Fishery	North Eastern Inshore Fisheries and Conservation Authority	—	—	—	—	—	—	—	—	—	—	—	—	—	Y	—
	EA	—	—	Y	—	—	—	—	—	—	—	—	—	—	Y	—
	Fishing/Sea Angling Clubs	—	—	—	—	—	—	—	—	—	—	—	Y	—	—	—
	National Federation of Fisherman's Organisations	—	—	—	—	—	—	—	—	—	Y	—	—	—	—	—
Wildfowling/ hunting	Local wildfowling clubs, Upper Humber wildfowling committee, Humber wildfowl refuge committee	—	—	—	—	—	—	—	—	—	Y	—	Y	—	—	—
Agriculture	National Farmers Union (North East Region), Country Landowners Association (Yorkshire)	—	—	—	—	—	—	—	—	—	Y	—	—	—	—	—

The managers for the Humber Estuary (see Table 2) have a responsibility to either enact or at least adhere to the current legislation with the governmental Department of Environment, Food and Rural Affairs (Defra) and Natural England having remits to ensure that the legislation has been fully implemented. The Humber Estuary, as with many other large coastal and estuarine environments, has numerous directives and strategies in place for the management of discrete areas and the ecosystem as a whole. The key legislative tools are considered below starting with national legislative drivers and then international legislative drivers.

1.2.1. National legislative drivers

Firstly, the UK Marine Policy Statement (MPS) is a framework for preparing marine plans and decisions which may affect the UK Marine Area. This includes any area submerged by seawater at mean high water spring tide (MHWS), aswell as the tidal extent (atMHWS) of rivers, estuaries and creeks, out to the UK Exclusive Economic Zone (the Renewable Energy Zone until the Exclusive Economic Zone is reached) and the UK sector of the continental shelf (HM Government, 2011). The objectives of the MPS need to be incorporated into the EPSS as they emphasise sustainable development and management while encouraging a robust evidence base on which to base policy decisions. As it is a statement rather than a framework, there is no conceptual model for the MPS; the EPSS however will need to be compliant with the MPS.

A key legislative driver of the MPS is the European Water Framework Directive, which covers the catchment, transitional waters (estuaries, lagoons, etc.) and coastal waters out to 1 nautical mile. It aims to protect or result in good ecological status (or potential) of water bodies through the implementation of the River Basin Management Plans (RBMP) by 2020 (Apitz et al., 2006; Borja et al., 2010a, 2010b, 2013). The ecological status is based in turn on the status of the biological, hydromorphological and physico–chemical quality elements within the system (WFD; 2000/60/EC). The EPSS will be required to identify projects that could potentially impact the WFD status of a waterbody and provide guidance on the assessment. TheWFD concept model (Fig. 2) will therefore be incorporated into the EPSS to ensure that the WFD is considered when developing a new project or policy.

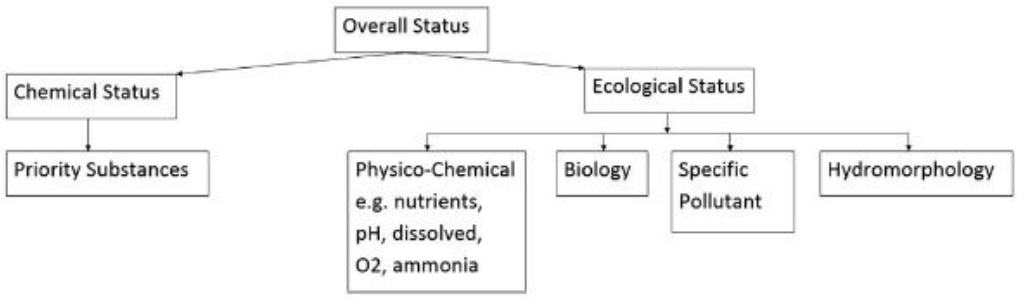

Fig. 2. Conceptual model of the WFD.

Another dominant piece of national legislation is the Marine and Coastal Access Act 2009 which makes all works below MHWS up to the tidal limit licensable or notifiable to the Marine Management Organisation (MMO) (Boyes and Elliott, 2015). Application for a Marine Licence follows a process whereby the applicant identifies whether a Marine Licence is required and if so follows a defined route through the process with the MMO (Fig. 3). The conceptual model (Fig. 3) is incorporated into the EPSS to ensure theMarine and Coastal Access Act is taken into consideration.

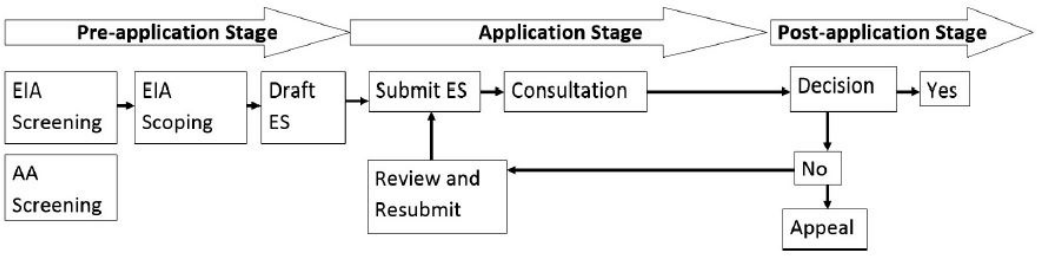

Fig. 3. An overview of the Marine Licensing process of the MMO under the MCAA.

The Marine Works (Environmental Impact Assessment) Regulations (as amended) 2011 requires a project to undergo an Environmental Impact Assessment (EIA) if it falls under Annex I or Annex II of the European EIA Directive (2011/92/EU as amended), and is within English or Welsh territorial waters up the MHWM up to the tidal limits to determine whether it requires a Marine Licence. The process (Fig. 4), involves a significant effort in the consultation stage with the applicant requesting guidance from the Licensing Body and the views of the public prior to submission. The process is iterative with the EIA and final Environmental Statement (ES) being reviewed and amended as required.

The process finishes with an ES, an integrated mitigation package e.g. a Habitats Regulations Assessment (HRA, embodying the UK Regulations required to enact the EU Habitats Directive (see below)), and if necessary, an agreed mitigation and/or compensation package, which can be economic, resource or habitat centred or the development being rejected.

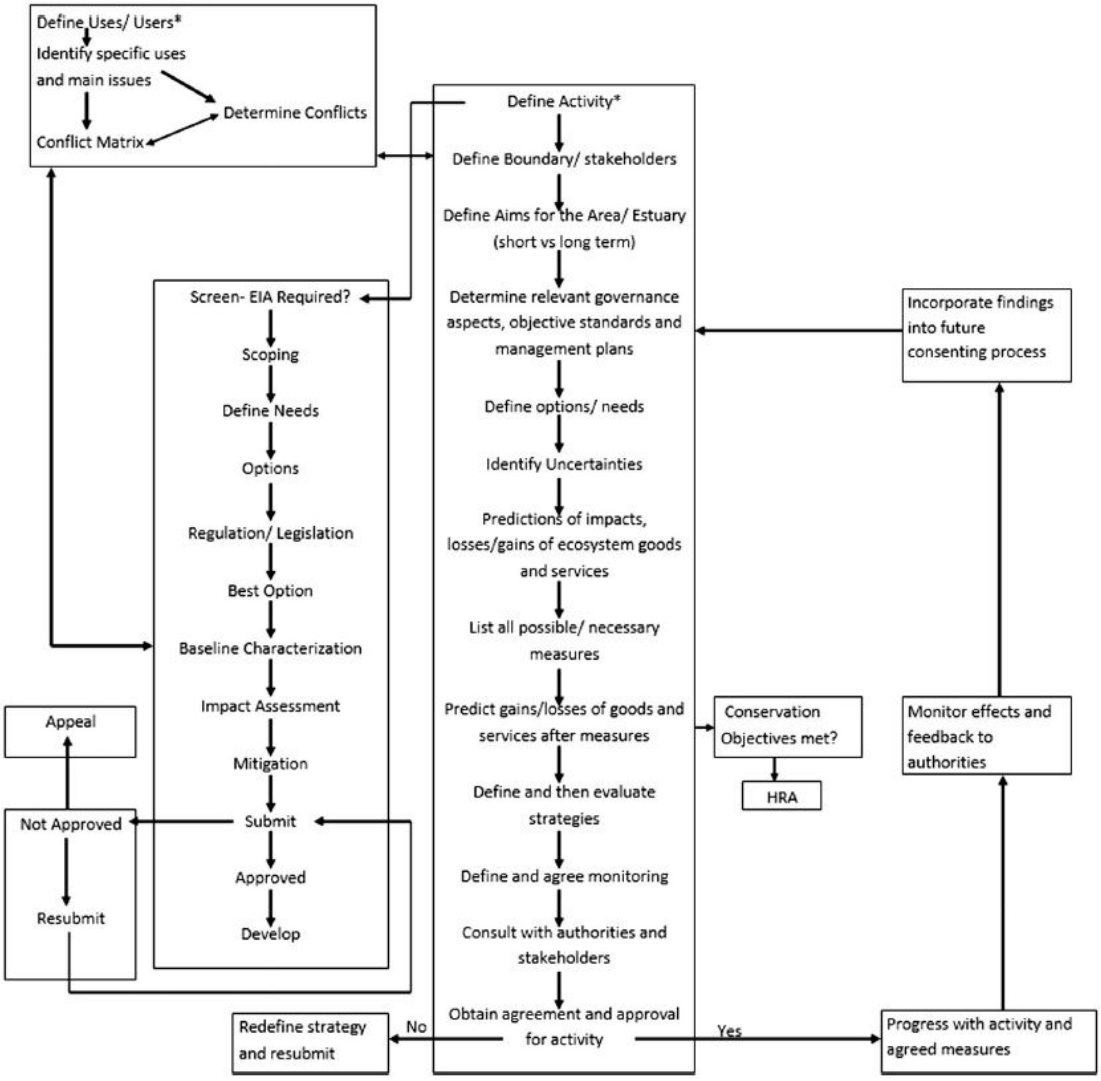

Fig. 4. An overview of the EIA process (*denotes possible starting points).

1.2.2. International legislative drivers

The primary directives for nature conservation are the EEC Council Directive 92/43/EEC of 21 May 1992 on the Conservation of Natural Habitats and of Wild Fauna and Flora (Habitats Directive) and the Wild Birds Directive (Directive 2009/147/EC), with their overall aims to protect species and habitats. The sites selected for designation under the Birds and Habitats directive together form Natura 2000 sites, which were introduced to conserve natural habitats and species that are rare, vulnerable and endangered within the EU. To determine whether a plan or project will have an adverse impact on the conservation objectives of a designated site and thereby have an impact on the Natura 2000 network, a Habitats Regulations Assessment (HRA) must be undertaken by the Competent Authority (Fig. 5). If

it is found that the plan or project will have a likely significant effect on the Natura 2000 network there are two possible outcomes: either a mitigation and/or compensation package, e.g. habitat creation, will be agreed between the competent authority (an organisation that has the legally delegated or invested authority, capacity, or power to perform a designated function), applicant and Licensing Body, or the project will be rejected.

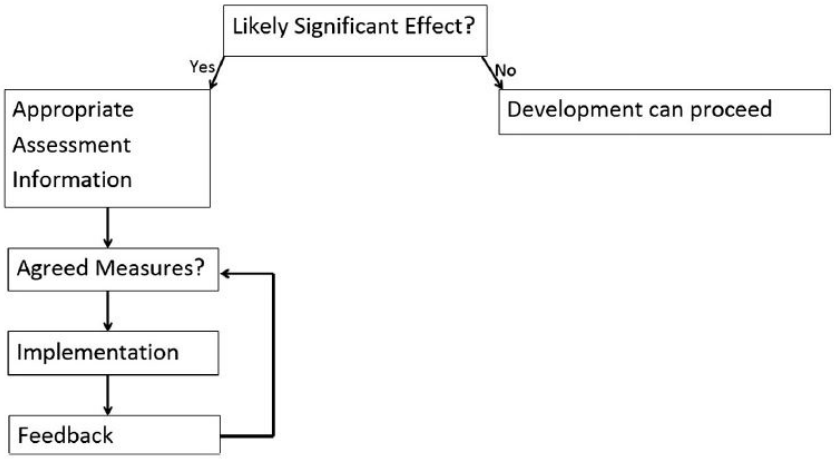

Fig. 5. A simplified overview of the HRA process.

The HRA (Fig. 5) will be incorporated into the EPSS, as it represents the consideration of a key aspect of two principal international directives that plans or projects must address. Early recognition that an HRA may be required means that consultation with Natural England (advisors for the HRA) and the competent authority (the competent authority can change and in some circumstances can be Natural England, the Local Authority or the Harbour Authority depending on the legislative considerations) can be undertaken before the application is formally submitted.

The EU Directive for Maritime Spatial Planning is an International legislative tool (adopted in August 2014 (Boyes and Elliott, 2014)) to establish a framework to help create marine plans and hence promote sustainable growth of maritime and coastal activities and the sustainable use of resources (Diedrich et al., 2010; Mateus and Campuzano, 2008; Varghese et al., 2008). The directive does not define the 'coastal zone', and it is for the Member States to define this. For the purpose of this study, the coastal zone incorporates all tidal waters up to the MHWM and tidal limits of the waterbody as outlined in the UK Marine Policy Statement. The steps in creating a Marine Spatial Plan involves: characterising the baseline; developing a marine plan; monitoring and reviewing to ensure that the management and monitoring programmes are appropriate for the objectives. The EPSS will therefore need to include these steps and be iterative to ensure any management plans are adaptable to include future developments.

The directives and regulations outlined above are designed to ensure that the estuarine environment is managed sustainably but, it should be noted, are not an exhaustive list (for this see Boyes and Elliott, 2014). While some are framework directives (e.g. WFD) where the aim is clear but the methods to reach it differ between the different Member States, whereas others are mandatory, whereby the requirements are clear e.g. the Habitats Directive. The directives and legislative tools are not weighted and therefore there is a need to identify an effective balance and compliance with all of their requirements by the decision makers and managers of an area.

1.2.3. Sectoral management schemes

The various separate directives has led to the development of sectoral management schemes. For example, in the Humber theWFD has led to the development of the Humber River Basin Management Plan in order to improve the status of the water bodies (EA, 2008). The Floods Directive (2007/60/EC) has also led to the development of Flood Risk Management Plans, which all Member States must have in place by December 2015 and must take into account the requirements of the WFD. There is also the requirement to develop and adhere to the Coastal Habitats Management Plans (CHaMPs), in order to manage Natura 2000 sites when developing shoreline management plans or flood and coastal defence

strategies. Their purpose is to predict and record losses and gains to coastal habitats due to natural or anthropogenic changes to the shoreline i.e. such as natural cycles of accretion and erosion along the coastline and coastal squeeze respectively, and secondly to inform the direction for habitat conservation measures to address net losses. Given the obligations to implement and adhere to the legislative tools in the management of the Humber Estuary, including the sectoral management schemes, these need to be included in the EPSS to ensure all commitments are recognised and adhered to during any decision–making process. In particular, there is the need to ensure that as far as reasonably practical, no receptors will be significantly adversely impacted.

1.3. Management tools

In order to satisfy these legislative requirements and to provide guidance, a number of management tools or paradigms have been established but have not been integrated into one overall management framework. These will be discussed below with the aim of integrating into an overarching EPSS framework.

1.3.1. The DAPSI(W)R Approach

The Driver–Activity–Pressure–State change–Impact (on human Welfare)–Response (DAPSI(W)R) framework, developed from the DPSIR approach, is a tool that integrates economic, social and natural system information into a Risk Assessment and RiskManagement framework to determine impacts on the ecosystem (Atkins et al., 2011; Cormier et al., 2013). The components of DAPSI(W)R are defined as:

• Drivers of change which are the economic and social forces that result from changes in government policies, economic markets and activities of industry;

• Activities are the human actions carried out to provide the Drivers;

• Pressures are the mechanisms produced by the Activities and which will lead to changes to the social and natural systems, habitats and species;

• The State change of the natural system is determined by characterising the physical, chemical and biological conditions, against which the pressures can be assessed;

• The Impacts (on human Welfare) are the results of the pressures against the system status, and ultimately their impacts on the human system, the ecosystem services and societal benefits (Atkins et al., 2011);

• The impacts, if adverse, will require a Response, which can be directed towards any other element of the model to achieve a balance between the benefits of development and cost to the ecosystem.

The response can include for example economic and legislative instruments. It should be noted that there are different types of pressures: namely endogenic managed pressures (those causes and consequences arising from within the system that managers can control) and exogenic unmanaged pressures (those pressures arising from outside of the system and for which only the consequences within the system can be managed). The aim of the DAPSI(W)R framework is to help managers identify the ecological and human systems that may impact on or interact with the structure and function of the ecosystem and then apply measures to prevent or control the adverse changes.

The original DPSIR had shortcomings as a communication tool between researchers, stakeholders and policy makers due to varying definitions of its components (Berger and Hodge, 1998; Barnes and McFadden, 2008; Mateus and Campuzano, 2008; Svarstad et al., 2008) and because it did not allowmultiple drivers or stressors to be incorporated into a single model to demonstrate the complex interdependencies of the ecosystem (Maxim et al., 2009; Ness et al., 2010).

However it has been extended to incorporate different Drivers, Activities and Pressures and interactions between these, to provide a nested framework to prioritise and manage a system (Atkins et al., 2011; Elliott, 2014).

The DAPSI(W)R framework is a Risk Assessment and Risk Management framework: by identifying all of the potential drivers, activities, pressures, state changes and impacts on societal welfare, environmental managers can assess the relative importance of each component. This will aid in prioritising where management and mitigation and/or compensation measures (i.e. responses) are

required. These mitigation measures are termed risk management, as the responses will manage and control the drivers and pressures exerting the state changes and impacts.

The DAPSI(W)R framework is incorporated into the proposed EPSS as it demonstrates the relationships throughout the cycle and identifies at which points managers can respond to pressures, state changes and impacts i.e. the response affects the drivers, activities, pressures and state changes. The framework also emphasises the requirement for an iterative process whereby the environment and response strategies are monitored, assessed and modified, where necessary to meet the requirements of the legislative and administrative tools, i.e. the laws to be followed and the competent authorities responsible for implementing them.

1.3.2. The ecosystem approach

As indicated above, there is a history of sectoral management in estuaries, i.e. for particular threats, uses and/or users. Many factors must however be taken into consideration to ensure that all relevant potential relationships and interactions are addressed when managing an estuary such as: the carrying capacity, the connectivity to catchment and marine areas, and the impacts of ecological influences e.g. climate (Low et al., 1999; Aubry and Elliott, 2005; Rosenberg and McLeod, 2005; Atkins et al., 2010). While 'carrying capacity' was originally used only in an ecological sense, more recently it can also refer to socio–economic aspects, i.e. not only the number of wading birds supported by estuarine feeding grounds but also the capacity of the estuary to support navigation or industry (Elliott et al., 2007).

The ecosystem approach is a holistic approach to both protect and maintain the natural features while at the same time allow for an area to produce ecosystem services and deliver societal benefits (Elliott, 2011). It is designed to account for the entire estuary including the natural, physical, chemical, geographic and climatic factors, and to integrate its activities to identify the relationships and interactions that may be present. The UN Environmental Programme (UNEP) defines five core elements and the Convention for Biological Diversity defines 12 guiding principles of ecosystem–based management, which have been incorporated into the EPSS framework (Table 3) (Elliott, 2011; Cormier et al., 2013).

The ecosystem approach is now being incorporated into European Directives in order to view the system as a whole and not as a series of independent component parts. No specific framework is identified within the directives on how to incorporate the Ecosystem Approach into management strategies and hence there is the potential for different models to be developed and therefore this will be built on for the EPSS framework (Farmer et al., 2012; Maltby, 2000).

Table 3
The five core elements of ecosystem based management as defined by the United Nations Environmental Programme and how these will be incorporated into the EPSS.

Need (in line with the 5 core elements)	Incorporation into the EPSS
Recognising connections between marine, coastal and terrestrial systems, as well as between ecosystems and human societies	By ensuring the process is iterative with feedback mechanisms.
Using an ecosystem service perspective, where ecosystems are valued for the basic goods that they generate, e.g. for food, as well as for important services, e.g. denitrification	Identification of stakeholders and producing a conflict matrix during the baseline surveys of characterising the environment for an impact assessment
Addressing cumulative impacts of various activities affecting an ecosystem	This is addressed through the EIA process and is highlighted as a separate step given its importance
Manage and balance multiple and sometimes conflicting objectives that are related to different benefits and ecosystem services	Identification of the ecosystem goods and services that the ecosystem provides and the extractions of the goods and services and assessing as part of the impact assessment
Embracing change, learning from experience and adapting policies throughout management process	Identification of stakeholders and producing a conflict matrix during the baseline surveys of characterising the environment for an impact assessment

1.3.3. Ecosystem goods and services

Ecosystem goods and services are those resulting from the natural structure and functioning of the system, that enable societal benefits including recreational use and educational purposes, to be obtained, whether directly or indirectly (Atkins et al., 2014). Although the Humber Estuary provides many ecosystem goods and services for society there are many differing definitions regarding what constitutes ecosystem goods and services and how they should be classed (Binghamet al., 1995; de Groot et al., 2002; Eftec, 2005; Brander et al., 2006; Beaumont et al., 2007; Barbier et al., 2011; Townsend et al., 2011; Fothergill et al., 2012). Here the ecosystem goods and services have been classified in Table 4 (Brauman et al., 2007; Fisher and Turner, 2008). In essence, ecosystem services are provided by the functioning of the natural system and then, through the addition of human capital and complementary assets of time, energy, money and skills, can be used to deliver societal benefits (Atkins et al., 2014).

Table 4
The classifications of the ecosystem goods and services.

Value	Service group	Examples
Direct	Provisioning	Production of food
		Production of timber
		Production of water
		Navigation
	Cultural	Recreation
		Tourism
		Landscape use
Indirect	Cultural	Education
		Research
	Regulating	Water/soil/air purification
		Climate regulation
		Carbon sequestration

Ecosystem services and societal benefits are regarded here as the currency leading to system valuation which can improve the understanding of the problems and trade–offs to be used in the decision making process (Chee, 2004). In order to value ecosystem goods and services, there is a requirement to have an understanding of the ecological processes, components and functions that generate services and an understanding in the way in which services translate into specific benefits is required (Atkins et al., 2014; Turner and Schaafsma, 2014).

Furthermore it is important to identify the links between the ecosystem functions and human support systems in order to understand how the relationships are connected and how even small changes could influence the estuary (Fig. 6). This step should be taken when characterising the area for development (Fig. 7) and so it should be integrated into the EIA process and thus the EPSS. Due to the large scale of the Humber Estuary, determining the total ecosystem goods and society benefits have not yet been determined for the entire area. Instead themultiple benefits arising from the different habitats and their connectivity for the entire site have been identified from the literature (e.g. Swift et al., 2004; Barbier et al., 2011;Townsend et al., 2011).

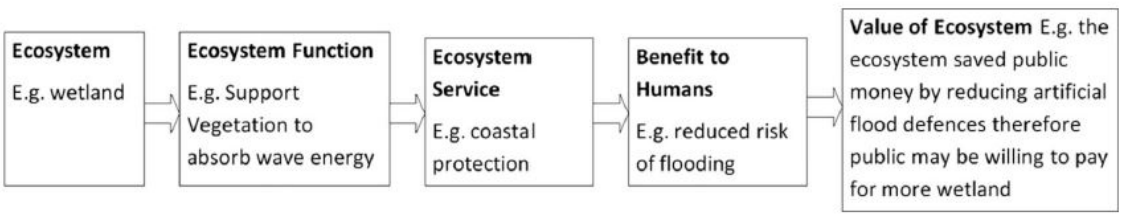

Fig. 6. A conceptual model showing how ecosystem functions link to human support systems. Modified from Fothergill et al. (2012).

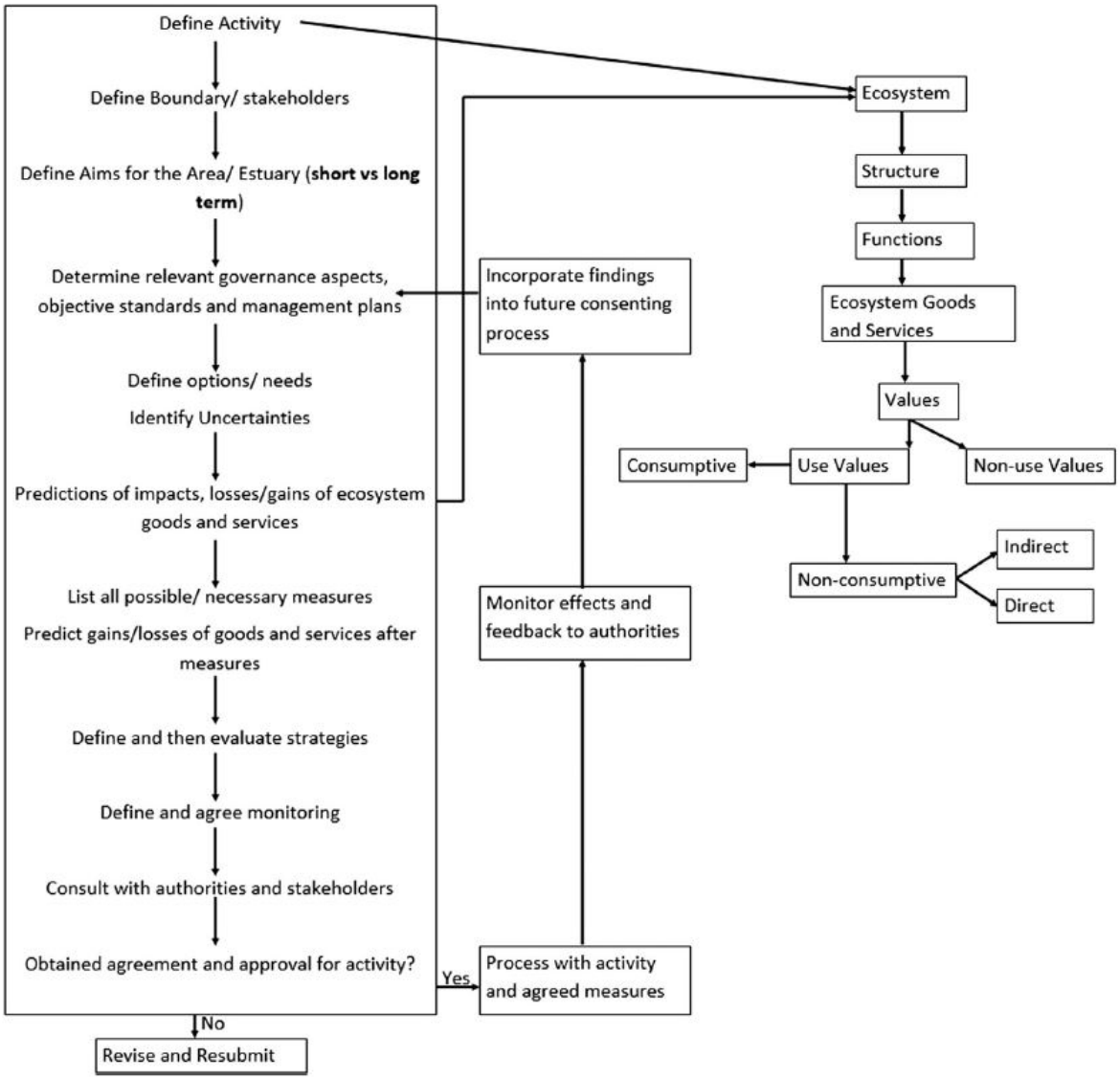

Fig. 7. Overview of identifying the ecosystem goods and services of an ecosystem.

These ecosystem goods and services arising from the Humber Estuary are interlinked and have complex interactions (Table 5). If one ecosystem function or service is altered this will not only impact the ecosystem goods and services that can be provided for human well–being but also on the biodiversity that they support. With many users and uses, it is expected that conflicts occur between industry and nature, tourists and private landowners (Table 2). When considering any type of impact assessment, stakeholder views should be considered to prevent or exacerbate a conflict between these groups. Taking a holistic view is needed to identify the potential conflicts between a development/policy change on the ecosystem goods and services that a system provides. Hence the EPSS should clearly define the steps that identify and define the boundaries between the relevant stakeholders.

Given the increasing importance placed on identifying and assessing the ecosystem goods and services that a system provides in relation to environmental status and the uses and users, e.g. as shown by implementing the MSP and WFD Directives, the EPSS will be developed to accommodate this need. The EPSS will demonstrate when the ecosystem goods, services, conflicts and indicators should be identified and indicate the potential next steps in protecting the essential estuarine natural and socio–economic features.

To identify conflicts, a conflicts matrix should be used to identify where ecosystem goods and services and uses are conflicting, beneficial or neutral (Table 2 and Fig. 8 show when a conflict matrix should be produced). This allows for the determination of the potential impacts and may also help in identifying their likely magnitude (spatial extent, duration or intensity). It will also inform any mitigation and/or

compensation package dependent on the impact and those stakeholders that may be affected by possible changes. The process of determining a conflict matrix (Fig. 8) is incorporated into the EPSS, as it is integral to the EIA process.

Table 5
The ecosystem goods and services provided by different areas within the Humber Estuary.

Service group	Final ecosystem service	Estuary — water body	Estuary — mudflats	Estuary — sand dunes	Managed realignment sites[a]	Conservation designations[b]	Agriculture[c]
Provisioning	Crops	N/A	N/A	N/A	N/A	N/A	Food
	Livestock	N/A	N/A	N/A	N/A	N/A	Food
	Fish	Food and for recreation	For recreation	N/A	Food and for recreation	For recreation	N/A
	Trees/vegetation	N/A	N/A	Prevention of erosion, for recreation and healthy climate	Prevention of erosion, for recreation and healthy climate	Prevention of erosion, for recreation and healthy climate	N/A
	Water supply	Drinking water	N/A	N/A	N/A	N/A	Irrigation
	Navigation	Import/export of goods	N/A	N/A	N/A	N/A	N/A
Regulating	Climate regulation	Healthy climate	Healthy climate	Healthy climate	Healthy climate	Healthy climate	N/A
	Carbon sequestration	Healthy climate	Healthy climate	Healthy climate	Healthy climate	Healthy climate	Healthy climate
	Disease and pests	N/A	N/A	N/A	N/A	N/A	N/A[d]
	Pollination	N/A	N/A	N/A	N/A	N/A	Food
	Noise	N/A	N/A	N/A	N/A	N/A	N/A
	Water purification	Drinking water	Drinking water	Drinking water	Drinking water, fish for food and recreation	Drinking water	Irrigation
	Soil purification	N/A	N/A	N/A	N/A	N/A	N/A
	Air purification	Healthy climate	Healthy climate	Healthy climate	Healthy climate	Healthy climate	Healthy climate
	Maintain biodiversity	For recreation, visual amenity, education, research	For recreation, visual amenity, education, research	For recreation, visual amenity, education, research	For recreation, visual amenity, education, research	For recreation, visual amenity, education, research	N/A
	Nutrient cycling	Healthy climate	Healthy climate	Healthy climate	Healthy climate	Healthy climate	Healthy climate
	Sediment formation and stability	N/A	Prevention of coastal erosion/sea defence	Prevention of coastal erosion/sea defence	Prevention of coastal erosion/sea defence	Prevention of coastal erosion/sea defence	Prevention of coastal erosion/sea defence
	Shoreline protection	N/A	Prevention of coastal erosion/ sea defence	Prevention of coastal erosion/sea defence	Prevention of coastal erosion/sea defence	Prevention of coastal erosion/sea defence	N/A
Cultural	Places and Seascapes	Recreation, future uses, visual amenity, tourism, education, research and landscape use					Future uses, education, research and landscape use

[a] Managed realignment sites can be salt marsh or mudflats or a combination of both so that ecosystem goods and services provided are dependent on the reason for creation and the site specific details.
[b] The ecosystem goods and services provided by conservation designations depend on the reasons for designation and the features of conservation interest.
[c] The ecosystem goods and services provided by agriculture depend on the type of farming and therefore are site specific.
[d] Agriculture is affected by disease and pests and there are certain diseases/pests that can be used in controlling the environment but these are very site specific.

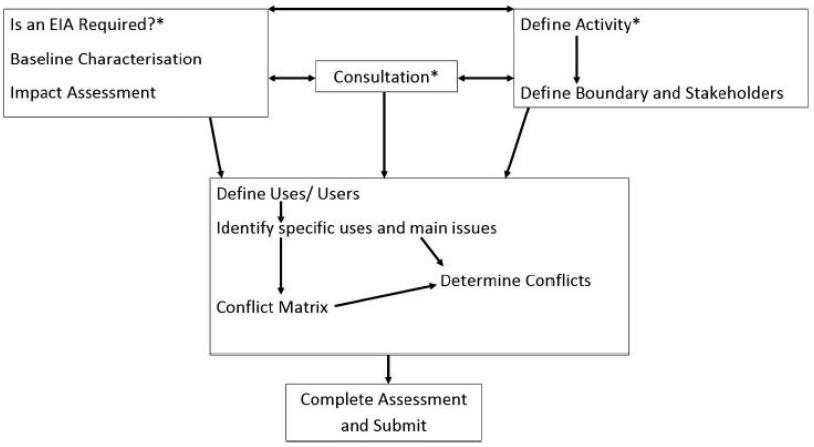

Fig. 8. An overview of determining the conflicting uses and users of a system for an impact assessment (*denotes possible starting points) and its use in the wider assessment process.

1.3.4. Ten tenets of sustainable development & management

Sustainable development not only refers to the environment but also to society and the economy. There are varying views on the relative importance and hence weighting of the three 'pillars of sustainability' environment, society and economy (Barnard and Elliott, 2015). However, as a more comprehensive view of all aspects, the management responses should be in line with the '10 tenets' of sustainable

development as defined by Elliott (2013) and expanded by Barnard and Elliott (2015). Again this holistic approach needs to be incorporated into the EPSS (Table 6).

These tenets re–emphasise the need for a multidisciplinary approach to environmental management by ensuring that all aspects are considered and that the development proposals are sustainable in all aspects. This requires the natural, socio–economic and political scientists to have agreed definitions and terminology to allow for the effective communication to decision makers and society. In order to ensure that the management measures are informed, the future scenarios and the management of shifting baselines should be linked to monitoring and modelling.

Table 6
The ten tenets of sustainable development, their definitions and examples of their use on the Humber Estuary.

Tenet	Definition	Example
Administratively achievable	The organisations responsible for the consenting, implementation and regulation of the activities already exist and have the capability to do so. This is especially important when determining new policies or implementing directives.	The Green Port Hull project required permission from the MMO, EA, Hull City Council and required advice from Natural England. It is important that the developer receives clear advice from the different organisations and licensing bodies while ensuring that all the legal instruments are abided by.
Ecologically sustainable	Maintaining the natural system and carrying capacity as well as protecting ecosystem services, structure and function for future generations.	Chowder Ness Managed Realignment Site, as part of the Immingham Outer Harbour project, was constructed to compensate for the direct habitat loss (22 ha) and indirect habitat losses (5 ha) of designated habitat. The site ensured the function of the designated sites and overall the *Natura 2000* network.
Economically viable	Ensuring that any management measures such as monitoring, mitigation, compensation, recovery, restoration or other which requires funds to maintain it are not so onerous that it would make the scheme unviable. An example in the Humber Estuary is the dredging and disposal activities whereby the applicant has to consider alternative, beneficial uses for the dredged material (as in other EU estuaries and coastal ports).	Sediment removed during maintenance dredging is generally formed from fine, mobile material that has recently been deposited from the tributaries, from within the estuary and from coastal erosion. There are limited uses for this material without costly dewatering and treatment. The disposal of this dredge material is justified since removal to designated disposal sites within the estuary keeps the sediment within the sediment budget. It is also economically unviable to require the applicant to wait until an alternative use for the material has been investigated and confirmed before dredging can commence since dredging is essential for port operation.
Technologically feasible	Ensuring that any management measures are feasible and sustainable and to consider the methods and technology which would be required to carry out or maintain the measures are available.	As technology such as modelling tools has advanced, applicants can use more realistic scenarios in calibrated and validated models to inform the EIA. The Competent Authority may require the applicant to create compensation land. Given these sophisticated models, scenarios can be used to determine if the site will develop as required by the Habitats Regulations.
Socially desirable and tolerable	Management measures need to be tolerable to the public and stakeholders.	In determining which flood defences to refurbish and when, the Environment Agency consults stakeholders and the public to ensure that all possible aspects and impacts have been considered (Environment Agency, 2008).
Legally permissible	Any management measure must abide by the various laws, regulations, directives and international agreements and treaties.	Developers generally identify the regulations and management strategies must be abided by and in the Environmental Statements. This allows the planning authorities to ensure that relevant legislative tools and management strategies have been identified and that the Environmental Statement adheres to these legislative tools.
Politically expedient	Political leaders need to support any management measure and therefore need to fully understand the scientific and socio–economic arguments for any management measure.	The Deregulation Bill, which is currently still in draft form and in UK Parliament, will require decision makers to identify the desirability of economic growth of applications to support UK's economic growth. This means that although environmental aspects will still be taken into consideration, their importance will be weighted less than economic viability in the decision making process.
Ethically defensible (or morally correct)	Understanding that any management measures must be considered in terms of their ethics and morals.	Morals relate to right and wrong behaviour and ethics relates to a set of moral principles. An example in an estuary where it would be morally wrong or unethical would be to allow a development to go ahead e.g. a hard flood defence scheme such as a concrete sea wall if the predictions in the impact assessment had identified that other landowners or users would be negatively affected e.g. due to changing sedimentary regimes affecting a sailing club, with no mitigation or compensation being agreed on or adopted.
Culturally inclusive	Having an increased stakeholder consultation allows public and stakeholders to be involved in the decision making process and to ensure any decisions are accepted (or at least tolerated) by society.	This tenet specifically refers to taking into account people's culture. In the Humber Estuary there are three broad cultures in terms of their residence being urban, country and agricultural. Each culture will have different preferences for the land and estuary. Those in the urban cities will generally prioritise the economic wealth and prosperity of the city. Farmers with agricultural land will prioritise the use of the land and any implications that developments may have. Those who reside in the country may prioritise the natural environment and the recreational activities. All of these cultures, and any others present should be taken into consideration when assessing and determining a plan or project.
Effectively communicated	There is a need to communicate effectively between scientists, decision makers, stakeholders and the public including the agreement of definitions of the terminology.	The requirement to consult is now engrained in legislation e.g. Planning Act 2008. The EIA process relies on public participation to ensure that the EIA assesses all potential impacts. The way in which a developer shows that they have communicated effectively i.e. consulted all of the stakeholders is to submit a Statement of Community Involvement which summarises all of the consultations.

2. The Estuarine Planning Support System and its use in decision–making

The above approaches have been combined to produce the EPSS giving the overarching management options, showing the high level steps required and providing further guidance on how to fulfil the relevant obligations (Fig. 9). This combines all of the legislation and planning tools available into one overarching

conceptual model. As there are differences between the requirements in the decision–making process for projects and for policy, the EPSS has two main parts to accommodate these. This includes links between the different processes and planning tools by identifying the processes that are important when developing or decision–making and will facilitate the communication of complex interactions and connections.

The EPSS focuses on adaptive management according to the starting point of identifying the type of project to be developed i.e. is it an infrastructure development (project) or a response/policy development. It then provides guidance on which steps to follow depending on the requirements of the project and legislation. The EPSS (Fig. 9) shows the relationship of the different steps in relation to the ten tenets of sustainable development (these are in italics and have been abbreviated) and with the DAPSI(W)R approach (these are underlined and are represented by the acronym) for completeness. The EPSS developed here aims to balance between needs of users, the ecological and economic value while considering the multiple legislative drivers.

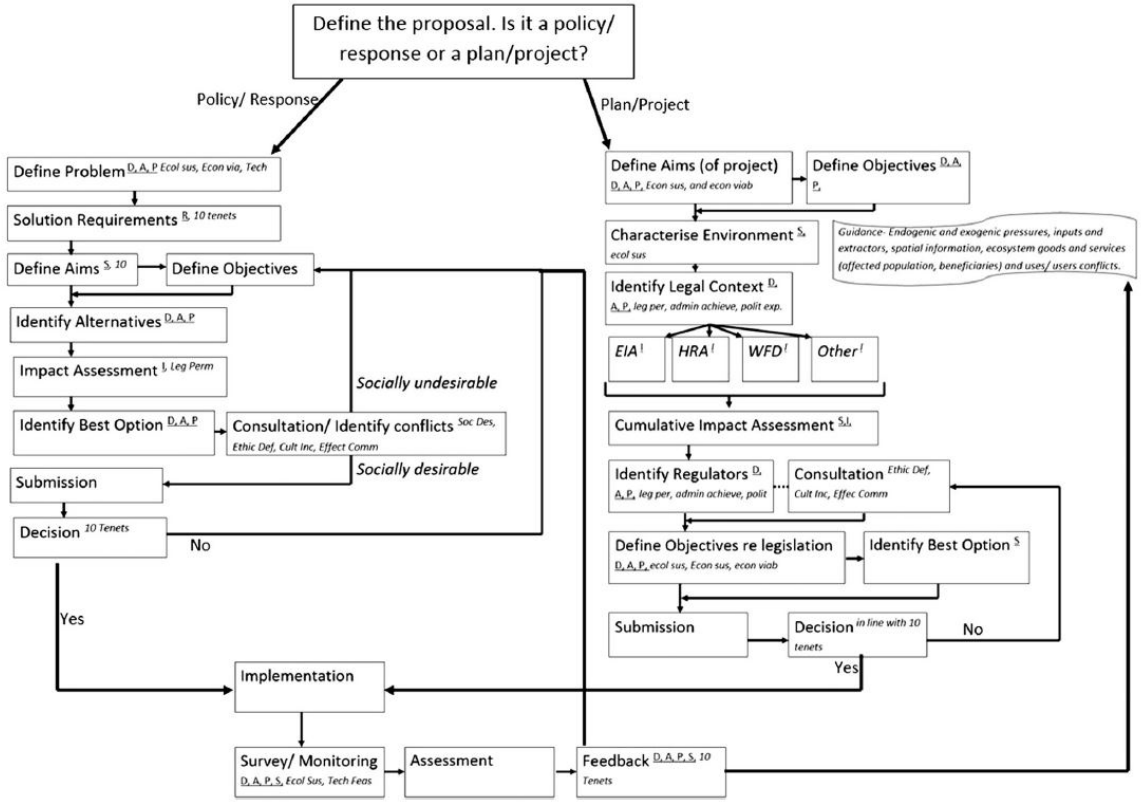

Fig. 9. EPSS for the decision making process of a plan/project or a policy/response.

The EPSS leads the user through the relevant legislation and the pathway through the process and the implementation of the legislation. The EPSS has been divided into two main tools, one for policies and responses, and one for plans or projects. In each case, the EPSS demonstrates that the primary step in any project development or decision making process is to define the problem or aims and objectives to be able to focus the assessment and where necessary the surveys. By defining the aims and objectives of the plan, it allows for the developer/manager to start identifying the legislation that is applicable.

The EPSS shows a step in the process where the legal context needs to be identified and although examples are given, these are not comprehensive and the EPSS can be modified depending on the plan or indeed the location. When identifying the legal context, regional local plans such as the RBMPs should also be taken into account. In order to adhere to the legislation, management tools are used to facilitate decisions and have been used to ensure that the EPSS is a facilitating framework for both planners and decision makers.

The EPSS as already identified, conforms to the DAPSI(W)R approach, as it requires the identification of drivers and activities (users and uses) and then to assess any potential impacts on these as well as

their impact on the natural and human system. This includes identifying both the benefits and conflicts to determine any mitigation and/or compensation measures by identifying the best available option. In order to accomplish this, consultation and communication should start early to agree on terminology and process. Feedback loops identified within the EPSS allows for any mitigation and/or compensation that has been agreed on to be monitored to ensure that it is appropriate or whether further modification is required. The feedback loops also allows for the management to be adaptive to achieve long–term goals and to ensure that transboundary effects are predicted and managed for partial or whole fulfilment of the Ecosystem Approach.

The EPSS identifies which steps accommodate the different stages in the DAPSI(W)R framework and the ten tenets to demonstrate that the EPSS is compliant with these specific management tools. With regard to the ecosystem goods and services, these should be identified when characterising the baseline and be assessed in the impact assessment given their importance in sustaining and improving human well–being. Guidance on how to do this is provided in Fig. 7.

The EPSS developed here relates to the legislation and management tools that are specific to the Humber Estuary but the approach is considered to be generic. As the EPSS has been developed based on specific European legislation, the steps within the processes are common across several of the legislative and management tools and the approach can be applied to other European estuaries. In addition, given that many other countries have similar legislation (such as the Nonindigenous Aquatic Nuisance Prevention and Control, National Environmental Policy, Clean Water and Oceans Acts in the US) then the principles and philosophies described here will apply elsewhere. The EPSS framework is designed to aid decision makers through the process to ensure that all legislative drivers, management schemes and receptors have been taken into consideration. It does not apply weighting to those aspects with perceived greater importance i.e. economic or environment, rather it provides the basis on which the decision makers can develop their assessment.

3. Conclusions

The EPSS has been developed to be flexible in its approach to allow for it to be used elsewhere internationally but also to allow for it to be adaptable for future changes and as science develops. The EPSS identifies some of the legislation that would be applicable to the Humber Estuary but these can be replaced with legislation that is relevant to other sites and where steps are not applicable can be modified or, if redundant, removed.

This study has used the Humber Estuary as a case study as it is a data rich area but the EPSS or the approach to developing an EPSS does not require a data rich site for it to be effective. The EPSS informs the user of the steps to take in order to identify what data are required, when they should be obtained and how to progress though to submission and/or the decision.

The EPSS can be used by various specialists, e.g. planning, hydroecologists, socio–economist, as it has been developed to incorporate all of these fields and rather than specifying steps specific to any area of expertise, it provides guidance on the process which can be adapted to any of the disciplines. The focus of a plan or project i.e. policy, scientific or economic, will vary depending on its aims and objectives and it is important that the EPSS can accommodate these without prejudice.

This kind of adaptable approach to developing an EPSS is useful in the context of the marine and estuarine environment given its susceptibility to changes such as climate change (Barnard and Elliott, 2015), sea level rise (Harley et al., 2006) as well as areas of high population density and development issues (Small and Nicholls, 2003). A flexible and adaptive EPSS will be needed to manage these changing coastlines to ensure that all legislative requirements and management tools are adhered to before a decision on the plan, project or policy has been made.

The EPSS represents the various legislative tools, receptors and stakeholders as discussed above but the EPSS needs to be supported by an in depth assessment of the baseline and potential impacts of a development or policy change. It will also encourage users to research the relevant legislative tools. It is a tool to assist sustainable management of an ecosystem by identifying those aspects relevant to a particular study, impact assessment or to assess a policy response on an ecosystem. As such it does specify how to define the ‘baseline’ from which to assess developments or the objectives of directives such as the WFD.

The EPSS will be modified as it is used at new sites and with different legislative tools, but the model provided in Fig. 9 is structured to allow for this to happen. It can be modified to allow site–specific requirements and legislation to be incorporated into the process. Given the changing future, adaptable and easy to use management plans are needed to manage our pressured coastlines. The EPSS in its current form allows for this by giving a structured process but sufficient flexibility to allow for regional priorities and project specific information.

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