Expanding the role of participatory mapping to assess ecosystem service provision in local coastal environments

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Abstract:

There has been increasing international effort to better understand the diversity and quality of marine natural capital, ecosystem services and their associated societal benefits. However, there is an evidence gap as to how these benefits are identified at the local scale, where benefits are provided and to whom, trade-offs in development decisions, and understanding how benefits support well-being. Often the benefits of conservation are poorly understood at the local scale, are not effectively integrated into policy and are rarely included meaningfully in public discourse. This paper addresses this disjuncture and responds to the demand for improving dialogue with local communities and stakeholders. Participatory GIS mapping is used as a direct means of co-producing knowledge with stakeholder and community interests. This paper drives a shift from development of participatory approaches to adaptive applications in real-world case studies of local, national and international policy relevance. The results from four sites along the UK North Sea coast are presented. This paper showcases a robust stakeholder-driven approach that can be used to inform marine planning, conservation management and coastal development. Although the demonstration sites are UK-focused, the methodology presented is of global significance and can be applied across spatial and temporal scales.

Keywords: ecosystem services; societal benefits; co-production of knowledge; participatory mapping; marine protected areas; coastal developments

Research Highlights

- Adaptive stakeholder-driven approach to participatory mapping and engagement.
- Satellite imagery used to engage stakeholders in natural capital discussions.
- Workshop outputs can be used for marine planning and conservation management.
- Contributes to the wider discussion with a focus on socio-cultural value.

1. Introduction

International scientific efforts, such as the Millennium Ecosystem Assessment (MA, 2005), have focused on furthering our understanding of the diversity and quality of ecosystem services provided by the environment and how these can benefit society. The MA (2005) first separated ecosystem services into four distinct categories: provisioning (the products obtained from the ecosystem); regulating (the benefits obtained from the regulation of ecosystem processes); supporting (those that are necessary for the production of all other ecosystem services, but do not yield direct benefits to humans); and cultural (the nonmaterial benefits people obtain from ecosystems) services. Within Europe, The Economics of Ecosystems and Biodiversity (TEEB) project developed an ecosystem services framework (de Groot et al., 2010), which was based upon a conceptual model adapted from Haines-Young and Potschin (2010) and Maltby (2009) and, similarly to the MA, was applied to a range of ecosystems (including marine/open ocean, coastal systems, wetlands, rivers/lakes, forest, deserts and urban areas). Whilst, the Common International Classification of Ecosystem Services (CICES) formed part of the analytical framework for ecosystem service assessments under Action 5 of the EU Biodiversity Strategy (Maes et al., 2014) and was also adapted for application at a local level within Belgium (Turkelboom et al., 2013). More recently, the dialogue around this has evolved to encompass the concept of natural capital, which can be defined as the stock and flow of both renewable and non-renewable natural resources (e.g. water, biodiversity, air) that provide benefits to society (NCC, 2019). Within the UK, a number of studies have attempted to categorise the links between ecosystem services, societal benefits and well-being across a broad spectrum of ecosystems that make up natural capital (e.g. UKNEA, 2011), including more specifically with respect to the marine environment (e.g. Beaumont et al., 2007; UKNEAFO, 2014; Friedrich et al., 2015; Turner et al., 2015; CoastWEB[1]). Further scientific effort has focussed on the identification of indicators to assess state, behaviour and trajectory of marine ecosystem services (Hattam et al., 2015a; Atkins et al., 2015) and how important designated marine habitats and species at a national scale are in delivering individual services and/or benefits (Fletcher et al., 2012; Potts et al., 2014; Saunders et al., 2015; Burdon et al., 2017).

Coastal waters, and the diverse habitats and species they sustain, provide society with food to eat (provisioning service), regulate the climate we live in, break down the waste we produce and protect us from coastal erosion and flooding (regulating services) (MA, 2005; Turner et al., 2015). They provide an inspirational seascape that allows us to play, contemplate and create (cultural services), and are essential for our individual and social well-being. The continued delivery of these ecosystem services, however, is under increasing pressure as a result of both human activities and the ongoing impacts of climate change. In addition, the advancement of Blue Growth (i.e. the long term strategy to support sustainable growth in the marine and maritime sectors as a whole) has led to further opportunities for maritime (and supporting) industries, resulting in increased pressure along the coastal zone, and has more recently led to a shift in activities further offshore (e.g. aquaculture, renewable energy development) (Börger et al., 2014; OECD, 2016).

Although a relatively recent addition to the conversation around ecosystem services and their value, there exists a myriad of recognised methods and approaches to assess socio-cultural values (e.g. Klain & Chan, 2012; Börger et al., 2014; Kenter et al., 2015; Cooper et al., 2016; Kenter et al., 2016) and their inclusion in ongoing conversations around marine natural capital. These range from quantitative, deductive approaches employed through large-scale questionnaires using Likert scale style questions as a method of assessing non-monetary values, through to more inductive, qualitative approaches of data gathering, including interviews, focus groups, workshops and an increasing use of art to elucidate

[1] http://valuing-nature.net/coastweb

values, through methods such as photo elicitation and visual mapping (Andrews et al., 2018). Mapping ecosystem services and the values (both monetary and non-monetary) attributed to them provides decision makers with the ability to design management grounded in a spatial understanding of the ecosystem e.g. mapping can identify spatial variation in ecosystem service supply and value (Martinez-Harms & Balvanera, 2012; Brown & Fagerholm, 2015). Despite a recent growth in research effort around community-based mapping approaches (Raymond et al., 2009), there remains a significant knowledge gap regarding the socio-cultural value associated with natural capital and ecosystem services, as well as the social deliberation that determines trade-offs and exchanges between these services in the determination of societal welfare. As a counterbalance, this paper shifts the spotlight onto methods of socio-cultural valuation, specifically examining the role of participatory mapping as a tool through which socio-cultural values can be elucidated.

Participatory mapping is a direct means of co-producing knowledge with stakeholder and community interests, often in contrast to the simplifications and technocratic approaches of traditional Geographical Information Systems (GIS) that avoid social complexity and political negotiation. Participatory mapping approaches refer to a range of methodologies to capture spatially explicit data in a participatory way (Brown & Fagerholm, 2015), underpinned by effective stakeholder and community engagement processes (Damastuti & de Groot, 2019), producing knowledge and understanding of place and use on a local scale (Brown & Reed, 2012). In the context of ecosystem services valuation and mapping, relevant actors provide local, spatially explicit information about ecosystem service provision, use and value (both monetary and non-monetary, where possible), negating the need to use proxy data derived from literature or modelling (Brown & Fagerholm, 2015). Building on participatory mapping approaches, actively engaging stakeholders and local communities with a Participatory Geographical Information System (PGIS) approach (Elwood, 2006) allows more accurate spatial mapping of ecosystem uses and values on a local scale to be undertaken and can provide a rich data set relating to values (Klain & Chan, 2012). Participatory mapping (GIS) projects have gained status in recent years, particularly with the recognition that social-ecological systems tend to be 'messy' and complex, knowledge is diverse and contested and spatial representations have inherently political elements (Cutts et al., 2011); all of which may be avoided by traditional GIS approaches. Furthermore, participatory mapping results in a more comprehensive understanding of spatial variation in valuation and provides a platform for the consideration of multiple values, as well as providing a potential mechanism for conflict resolution when addressing potential trade-offs between ecosystem services and users (Ruiz-Frau et al., 2011; Brown et al., 2014; Brown & Fagerholm, 2015; Moore et al., 2017).

As with all methods, there are potential limitations of participatory mapping as a way of engaging stakeholders. For the process to be effective and representative, it is necessary to ensure stakeholders with varying levels of influence, interest, knowledge and spatial relationships with the environment are given an opportunity to participate (Elwood, 2006; Brown & Kyttä, 2014; García-Nieto et al., 2015), which can be logistically complex and challenging. Providing this equal opportunity for engagement refers not only to inviting stakeholders to participate, but also to ensuring participants have a clear understanding of the aims and objectives and are contributing to the discussion from a similar knowledge baseline (Elwood, 2006). Further, design of any participatory process must be sensitive to any cultural, political or social tensions within the stakeholder group and the local context (Elwood, 2006). There is, therefore, considerable onus on the design and facilitation of the participatory mapping process to ensure it does not inadvertently exclude, which could potentially lead to bias, impact the validity and integrity of the data collected and undermine the wider stakeholder engagement process.

Despite these potential limitations, participatory approaches are increasingly considered best practice for eliciting meaningful values relating to the natural world. However, valuing the non-tangible and subjective personal-spatial nature of many of these (e.g. sense of place, peacefulness, tranquillity) remains a challenge, resulting in a limited understanding of many socio-cultural values (Klain & Chan, 2012; Brown & Fagerholm, 2015). Our approach seeks to address this by working closely with stakeholders across a series of workshops, actively encouraging participants to include spatially bounded information about how and where they use the coastal and marine environment, in addition to the valuing information. While participatory mapping and GIS approaches are becoming increasingly commonplace, their use in a marine and coastal context remains limited (Moore et al., 2017). This paper builds on existing work examining social-cultural values and the inclusion of community views and local environmental knowledge (see for example Berkes et al., 2007; Klain & Chan, 2012; Chan et al., 2012a,b; Nursery-Bray et al., 2014), and presents a flexible and adaptive methodology that can be applied across a range of coastal contexts, contributing to the growing literature base around the applicability of, and indeed the need for, participatory mapping to support effective and sustainable coastal management.

Despite a rapidly developing evidence base, there remains an evidence gap as to how ecosystem services are identified at the local scale, what benefits are provided and to whom, how trade-offs between services and benefits are negotiated in planning, and how benefits support positive social well-being. This paper addresses this disjuncture and responds to the demand for improving dialogue, understanding and access to ecosystem services and linking these services to the emerging well-being agenda. Using the observations from four stakeholder workshops, this paper examines the potential for participatory mapping to capture socio-cultural values in a local or regional context and influence coastal decision-making. In so doing, this paper drives a shift from the development of such approaches to real-world application and testing at the local community scale.

2. Background

Ecosystem services have the potential to lead to diverse benefits for society; therefore, it is appropriate to consider their broader value (Atkins et al., 2013). There has been increasing attention given to the valuation of ecosystem service approaches in science, and this has recently been followed by an uptake and use by stakeholders (Tallis et al., 2008; Norgaard, 2010; de Groot et al., 2010; Dempsey & Robertson, 2012; Beery et al., 2016; Willcock et al., 2016). For example, at the EU-level, an assessment of the value of ecosystem services is called for under the EU 2020 Biodiversity Strategy (EU, 2011), which emphasises the need 'to value ecosystem services and to integrate these values into accounting systems as a basis for more sustainable policies'. Additionally, the EU's Water Framework Directive and Marine Strategy Framework Directive both explicitly call for the integration of valuation into the environmental management process (Burdon et al., 2016). Furthermore, at a UK scale, the importance of ecosystem services and natural capital was recently highlighted within the UK Government's 25-Year Plan to Improve the Environment (HM Government, 2018), which recognises the need to take a natural capital approach to understand the full value of the marine environment and incorporate it within decision-making in England. Similar efforts are being taken across the UK's devolved administrations. For example, the Scottish Government is currently developing a draft 'Environment Strategy for Scotland' which incorporates natural capital thinking into the national policy context. It is developing a series of 'knowledge accounts' to guide implementation on safeguarding natural capital (Scottish Government, 2018). The concept of 'full value' is interpreted in these cases to mean not only the economic values of the coastal and marine environment but also the broader social, cultural and ecological values of the system.

There is an increasing emphasis in the marine sciences on the importance of understanding how society interacts with the natural environment (McKinley & Fletcher, 2010, 2012; Fletcher et al., 2012; Jefferson et al., 2015; Potts et al., 2015; Bennett, 2016; Bennett et al., 2017). This is matched by an emerging interest by decision-makers on how social–ecological interactions can be operationalised in a policy, planning and management context. An example is the emphasis in the green economy domain on the integration of natural capital within an inclusive green economy (Lok et al., 2018). Expanding local partnerships with the communities who directly use a range of ecosystem services should deepen the understanding of these benefits and promote local biodiversity conservation. Furthermore, linking social and ecological systems and developing novel models of governance and assessment help to deliver an ecosystem approach under the UN Sustainable Development Goals and the Aichi Targets (Geijzendorffer et al., 2017).

When considering valuation of natural resources 'Total Social Value' is one of many concepts that can be used to incorporate the views of both individuals and society as a whole and their values associated with ecosystem service provision into the decision-making process to support the determination of policy options and management measures (MA, 2003). This holistic approach recognises the importance of considering both ecological value and socio-cultural value, alongside the more traditionally recognised economic values (Figure 1).

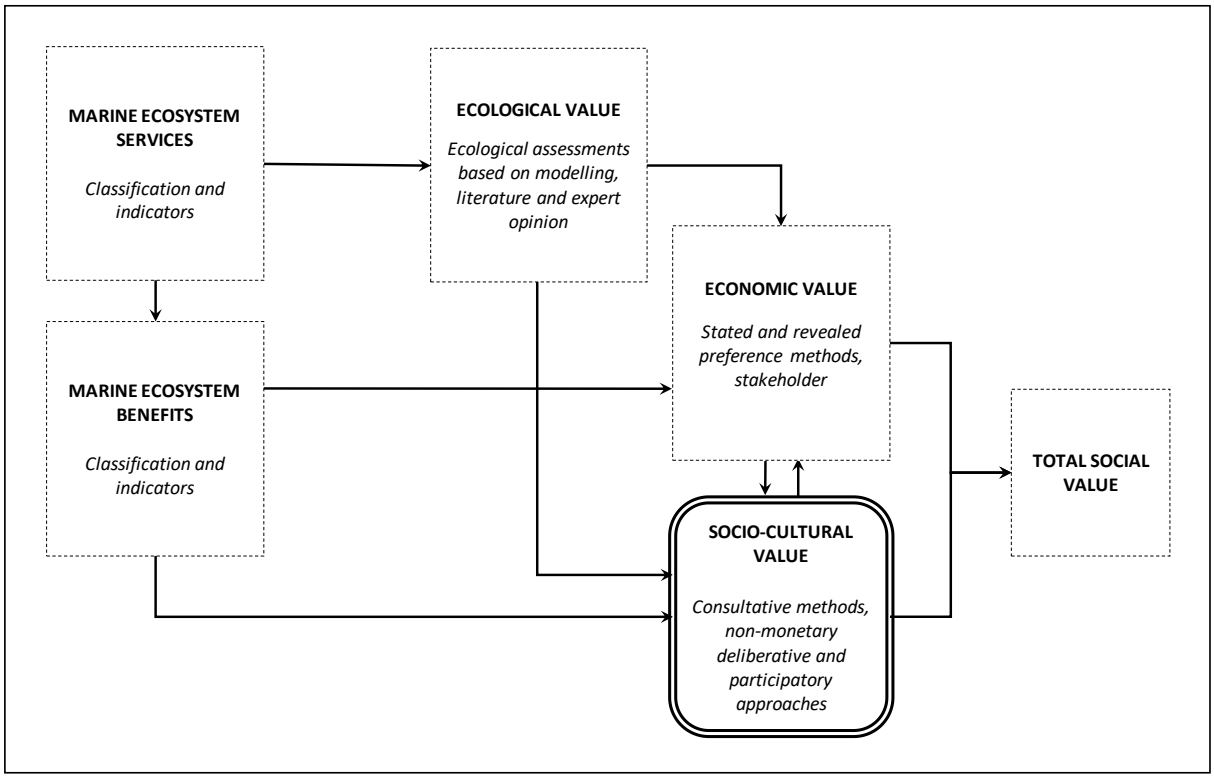

Figure 1: Valuation of marine ecosystem services, including socio-cultural values (adapted from Burdon et al., 2018).

There is a growing evidence base relating to marine ecosystem services which consider these three elements, assessing ecological value (e.g. Derous et al., 2007; Pascual et al., 2011), economic value (e.g. Börger et al., 2014; Jobstvogt et al., 2014a) and socio-cultural value (e.g. Jobstvogt et al., 2014b; Hattam et al., 2015b; Kenter et al., 2015). More recently, the need to ensure valuation takes account of those benefits that are intangible or immaterial has garnered increasing attention from both the research and policy communities (see for example, Chan et al., 2012a; Chan et al., 2012b; Pike et al., 2010), with participatory processes highlighted as being crucial to successfully elucidating these

harder to measure values (Klain & Chan, 2012; Martin et al., 2016). However, at present, the majority of valuation studies focus on a small range of provisioning services (e.g. fisheries - Fonseca, 2009), regulating services (e.g. carbon sequestration and flood defence - Luisetti et al., 2015) and cultural services (e.g. recreation - Bhatia, 2012), with an emphasis on economic valuation using stated and revealed preference methods (see Cooper at al., 2013 for a review of methods applied in the marine environment). This paper contributes to the wider discussion around total value with a focus on the socio-cultural value (as presented in Figure 1).

3. Methods

This paper has developed an adaptive approach to participatory mapping, whereby community and stakeholder activities, perceptions and experiences can be directly captured, digitised and used to inform local coastal and marine planning initiatives that improve the management of biodiversity and the benefits that flow from natural capital. This approach engages local coastal stakeholders to discuss the social benefits derived from local ecosystems, how those benefits are spatially distributed and how they trade-off against other uses of the marine environment.

3.1 Demonstration Sites

Four demonstration sites were selected to reflect a diversity of anthropogenic activities, natural features, and coastal communities along the North Sea east coast in Scotland and England (Figure 2). Workshops were co-designed and co-delivered with the relevant local coastal partnership (Table 1) to ensure that the aims and objectives of the workshop were appropriate at the local scale and that relevant stakeholders were identified and enrolled for participation from an existing network of local stakeholders. The two Scottish workshops focussed on coastal stretches and interactions between human activities and marine protected areas, whereas the two English workshops adopted a case study approach focussing on areas of interest as identified by The Wash and North Norfolk Marine Partnership, and the Humber Nature Partnership as part of their Natural Capital Vision for the Humber (HNP, 2017).

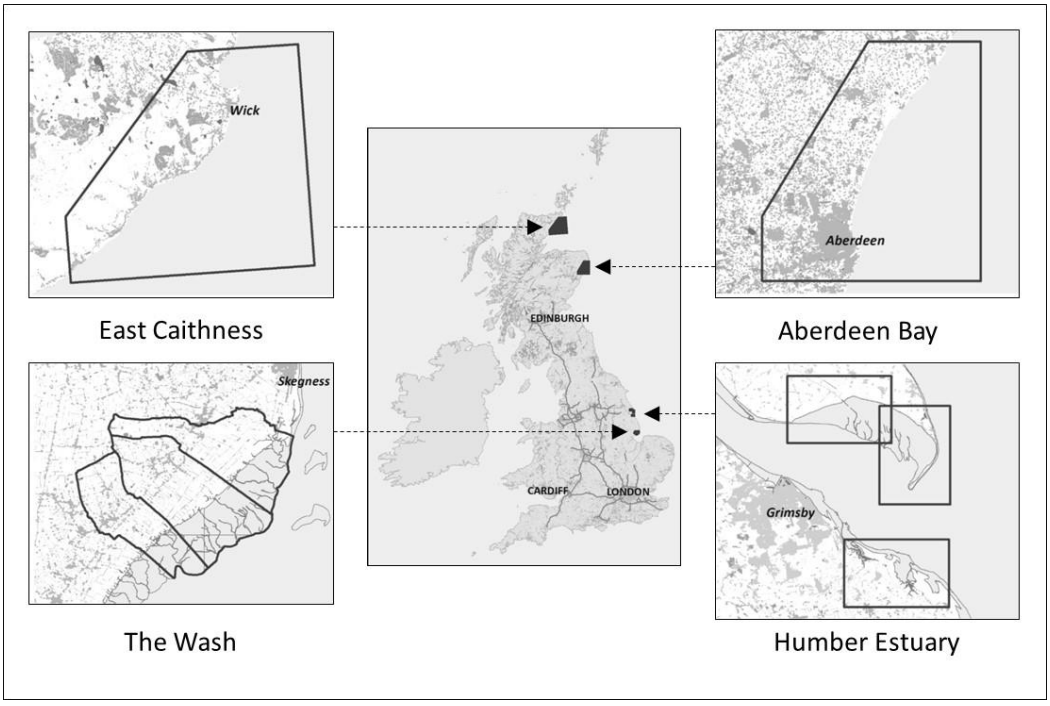

Figure 2: Locations of the four demonstration sites.

Table 1: Summary of demonstration sites.

Features	East Caithness	Aberdeen Bay	Humber Estuary	The Wash
Nearest Cities/Towns	Wick	Aberdeen, Peterhead	Hull, Goole, Cleethorpes, Grimsby,	King's Lynn, Hunstanton, Boston, Skegness, Spalding, Wisbech
Main tributaries	River Wick	Dee, Don and Ythan	Aire, Derwent, Don, Hull, Ouse, Trent and Wharf	The Great Ouse, Nene, Welland, Witham
Activities	Industry, Fishing, Shipping, Renewables, Infrastructure & Ports, Tourism, Recreation	Industry, Oil & Gas, Renewables, Shipping, Recreation; Infrastructure & Ports	Shipping, Industry, Renewables, Tourism, Recreation, Infrastructure & Ports	Agriculture, Fishing, Infrastructure & Ports, Mariculture, Tourism, Recreation
Marine Protected Areas (MPAs)	East Caithness Cliffs Nature Conservation MPA, East Caithness Cliffs SPA and Noss Head Nature Conservation MPA.	Forvie NNR, Foveran Links SSSI, Ythan Estuary and Meikle Loch Ramsar site, Ythan Estuary, Sands of Forvie and Meikle Loch SPA, Buchan Ness to Collieston Coast SPA, Bullers of Buchan Coast SSSI, Collieston to Whinniefold SSSI, and Sands of Forvie and Ythan Estuary SSSI	Humber Estuary SAC, SPA, EMS, Ramsar, SSSI	The Wash and Gibraltar Point SPA, The Wash and North Norfolk coast SAC, Ramsar, SSSI, NNR
Local Coastal Partnership	Moray Firth Coastal Partnership	East Grampian Coastal Partnership	Humber Nature Partnership	The Wash and North Norfolk Marine Partnership
Workshop Coverage	Wick in the north to Lybster in the south	Peterhead in the north to Aberdeen in the south	3 case study sites – Welwick, Spurn and South Bank (Cleethorpes to Donna Nook)	3 case study sites – Wainfleet, Friskney & Wrangle coastal parishes

NOTE: MPA=Marine Protected Area; SSSI=Site of Special Scientific Interest; SAC=Special Area of Conservation; SPA=Special Protection Area; NNR=National Nature Reserve; EMS=European Marine Site.

3.2 Workshop Aims and Objectives

After collaborative discussions with the relevant local coastal partnerships, the two workshops in the north east of Scotland focussed on human activities within East Caithness and Aberdeen Bay. The workshops identified and mapped the multiple sectoral activities which occurred within these sites and how protected marine features (i.e. habitats and species) could support activities via the provision of ecosystem services and 'benefits'. The facilitators did not define the term 'benefits' as the workshops aimed to capture the full range of perceived benefits from the marine environment from the stakeholders perspective.

Designed similarly, following discussions with the relevant local nature/marine partnerships, the two workshops on the English east coast focussed on:

- Identifying and mapping natural features of interest within the Humber Estuary (focussing on all intertidal features) and The Wash (focussing on saltmarsh);
- Identifying and mapping the benefits provided by these features; and
- Discussing the use of both satellite imagery and participatory mapping in the future management of these designated sites.

3.3 Stakeholder Engagement

The range of organisations represented at each workshop reflected the aims and objectives of the workshop (Table 2). Each workshop consisted of three groups of 4-5 stakeholders plus a facilitator (except for East Caithness where a lower turnout resulted in only one group on the day) to ensure an even balance between the representation of organisations, and that each stakeholder had an opportunity to participate in the discussions and mapping exercises. Through discussions with the local project teams, stakeholders were identified and contacted by the local coastal partnership to ensure that the full range of local voices were represented at each workshop.

Table 2: Summary of organisations represented at each workshop.

	Aberdeen Bay	**East Caithness**	**The Humber**	**The Wash**
Date	6 July 2017	7 September 2017	22 May 2018	20 February 2018
Location	Forvie National Nature Reserve Visitor Centre, Collieston	The Pulteny Community Centre, Wick	Water's Edge Visitors Centre, Barton Upon Humber	Lincolnshire Wildlife Trust's Coastguard Centre, Gibraltar Point, Skegness
Local Partnership	East Grampian Coastal Partnership	Moray Firth Coastal Partnership	Humber Nature Partnership	The Wash and North Norfolk Marine Partnership
Stakeholders	Aberdeen City Council; Scottish Natural Heritage; Royal Society for the Protection of Birds; University of Aberdeen; Vattenfall Windfarms Ltd.	Caithness Seacoast Ltd.; Independent participant; The Environmental Research Institute (the University of the Highlands and Islands); The Highland Council; The Wick Society	University of Hull; Yorkshire Wildlife Trust; East Riding Council; North East Inshore Fisheries and Conservation Authority; Natural England; Environment Agency; Lincolnshire Wildlife Trust; North East Lincolnshire Council; Royal Society for the Protection of Birds; Marine Management Organisation	Natural England, Eastern Inshore Fisheries and Conservation Authority; Environment Agency; Wildfowlers; Lincolnshire Wildlife Trust; Graziers and land owners
Total attendees	12	7	15	14

3.4 Workshop Activities

While all four case study sites (Figure 1) have broadly similar features and the methodology has common activities, an adaptive approach was adopted throughout the workshops. This enabled the research team to test different approaches, obtain feedback from the stakeholders, review and adapt the methodology in response to the needs and interests of stakeholders at each case study site. All four workshops were designed with a consistent structure, comprising a series of introductory presentations at the start of the day, a series of interactive identification and mapping sessions throughout the day, and ending the day with a plenary discussion and stakeholder feedback.

The workshops were all stand-alone exercises, which complemented existing work undertaken by the respective local coastal partnerships. The specific activities undertaken and discussion topics covered were co-developed by the local coastal partnership and the project team in order to reflect the specific aims and objectives of each workshop (Table 3). In the case of the East Caithness and Aberdeen Bay, workshop design centred on identifying coastal and marine activities and how activities can be influenced by the ecosystem services that are provided by marine protected areas. In the Humber Estuary these discussions focussed around the Natural Capital Vision for the Humber (HNP, 2017) whereas the discussion in The Wash workshop centred around findings from the Common Ground Project (MCS, 2017). In order to ensure consistency in the workshops, the lead author of this paper facilitated all four workshops, with the second author facilitating three out of the four workshops.

Table 3: Summary of activities, materials and outputs from each workshop

Activities	**East Caithness**	**Aberdeen Bay**	**Humber Estuary**	**The Wash**
Introduction to the workshop	✓	✓	✓	✓
Introduction to the local nature/coastal partnership	✓	✓	✓	✓
Introduction to participatory mapping	✓	✓	✓	✓
Introduction to natural capital / ecosystem services	✓	✓	✓	✓
Introduction to satellite imagery			✓	✓
Identifying and mapping maritime activities	✓	✓		
Identifying and mapping features			✓	✓
Identifying and mapping benefits	✓	✓	✓	✓
Local application of the matrix approach	✓	✓		
Plenary discussions	✓	✓	✓	✓
Stakeholder feedback	✓	✓	✓	✓
Materials	**East Caithness**	**Aberdeen Bay**	**Humber Estuary**	**The Wash**
Flipcharts	✓	✓	✓	✓
Industry maps	✓	✓		
Tourism/recreation maps	✓	✓		
Site designation maps	✓	✓		
Bathymetry maps	✓	✓		
Local ecosystem service matrices	✓	✓		
Aerial images (Sentinel-2)			✓	✓
Outputs	**East Caithness**	**Aberdeen Bay**	**Humber Estuary**	**The Wash**

Workshop report (including stakeholder feedback)	✓	✓	✓	✓
Online interactive maps	✓	✓		
Interactive pdf files			✓	✓

3.5 Workshop Materials

Given the focus of the East Caithness and Aberdeen Bay workshops on anthropogenic activities and protected sites, the stakeholders were provided with three A0 scale maps which presented (1) the recreational activities which occur within the case study site; (2) the extent of maritime industries in the case study site (e.g. fishing, pipelines, renewable energy); and (3) the designated features within each case study site (e.g. EU Special Areas of Conservation, Scottish Nature Conservation MPAs). The three maps were composites of relevant spatial data sets from the Marine Scotland National Marine Plan Interactive (NMPi) (Marine Scotland, 2018). Each map included broad scale habitats derived from NMPi and Scottish Natural Heritage SiteLink (SNH, 2018) and included bathymetry. For the participatory mapping exercises, stakeholders on each table could choose which of the three A0 maps they wished to annotate, providing information for inclusion in the final GIS output which would contain individual layers for each of the three maps as well as the stakeholder input. At the East Caithness workshop only one annotated map was produced as a result of the smaller group size and representation of stakeholders. At the Aberdeen Bay workshop, duplicates of each of the three A0 maps were provided on each of three tables, with each table producing its own independent annotated map. The annotated maps from the three tables were integrated post-workshop producing a single output in GIS.

After the mapping exercises, the stakeholders at the East Caithness and Aberdeen Bay workshops were provided with edited versions of the ecosystem service matrices, developed by Potts et al. (2014) for UK habitats and species and by Burdon et al. (2017) for UK seabirds. The Matrix Approach recognises the relative importance of protected UK marine features in delivering ecosystem services and societal benefits (as defined by the UKNEAFO, 2014), highlights the confidence in the relationship between a particular feature and the ecosystem services they deliver, and thus provides a valuable visual tool for stakeholder engagement. An example of the Matrix for Aberdeen Bay designated habitats is provided in Figure 3. The matrix activity formed part of the discussion at the two Scottish workshops as a means to compare local observations against the broader (UK) assessments within the matrix.

Feature Type†	EUNIS code	Feature	Intermediate services											Goods/Benefits															
			Supporting services							Regulating				from Provisioning					from Regulating				from Cultural services						
			Primary production	Larval and gamete supply	Nutrient cycling	Water cycling	Formation of species habitat	Formation of physical barriers	Formation of seascape	Biological control	Natural hazard regulation	Waste breakdown and detoxification	Carbon sequestration	Food (wild, farmed)	Fish feed (wild, farmed, bait)	Fertiliser and biofuels	Ornaments and aquaria	Medicines and blue biotechnology	Healthy climate	Prevention of coastal erosion	Sea defence	Waste burial / removal / neutralisation	Tourism and nature watching	Spiritual and cultural well-being	Aesthetic benefits	Education and Research	Physical health benefits	Psychological health benefits
Existing Habitats protected under EU legislation																													
E	A2.5	Coastal saltmarshes and saline reedbeds	2	3	3	1	3	3	3		3	3	3	3	1	3			3	3	3	3	3	1	3	1	1	1
E,W	A2.2	Intertidal sand and muddy sand	3	3	3	1	3	1	3		3	1	2	1	2	1			2	3	3	1	1	1	3	1	3	3
E,W	A2.3	Intertidal mud	3	3	3	1	1	1	1		3	3	3	3	3	1			3	3	3	3	1	1	1	1	1	1
E,EU	A2.4	Intertidal mixed sediments	3	3	3	1	3	1	1		3	1	2	1	2	1			2	3	3	1	1	1	1	1		

Scale of ecosystem service supplied relative to other features

- # Significant contribution
- # Moderate contribution
- # Low contribution
- # No or negligible ESP
- Not assessed

Confidence in evidence

- 3 UK-related, peer-reviewed literature
- 2 Grey or overseas literature
- 1 Expert opinion or Obvious
- Not assessed

Feature type†

- S Scottish MPA search feature
- E English MCZ feature
- W Welsh HP MCZ feature
- EU EU Habitats Directive Annex 1 feature or sub-feature

Figure 3: The Matrix Approach for protected habitats in Aberdeen Bay (after Potts et al., 2014).

Given the focus of the Humber Estuary and The Wash workshops on mapping features, satellite imagery was used to generate maps for each demonstration site. True-colour composite images from bands 2 (blue), 3 (green) and 4 (red) of cloud-free Sentinel-2 satellite images at 10 m pixel resolution were projected into British National Grid coordinates and printed on A1 scale paper, which required less meeting room space than the A0 maps used in the Scottish workshops. For the Humber Estuary, three coastal sites (Welwick, Spurn, Cleethorpes to Donna Nook) were selected based on sites previously identified within the Humber Nature Partnership's natural capital vision for the Humber (HNP, 2017). The image for the Humber was taken on 17 January 2018 from Sentinel-2. For The Wash, three adjacent coastal parishes (Wrangle, Friskney and Wainfleet) were selected based on the extent of saltmarsh habitat present and particular management interests associated with the saltmarsh. The image for The Wash was taken on 9 April 2017 from Sentinel-2. At the Humber Estuary workshop, each table focused on a different geographical case study from the mouth of the Humber Estuary (three in total), whilst at The Wash workshop the stakeholders focussed on one of three adjacent coastal parishes per table. At both workshops stakeholders were provided with the opportunity to move around tables and thus sense-check the mapping undertaken by others at the workshop.

In addition to the maps, each workshop used a range of flip-charts, pens, post-it notes, and sticky dot based activities to capture the information from the stakeholders. To support data collection, each workshop facilitator took their own notes of discussions, which were verified by the participants after the workshop.

3.6 Analysis and Reporting

The annotated maps were photographed at the end of each workshop, and then digitised using GIS software ARC GIS. In the East Caithness and Aberdeen Bay workshops, the activities data was hand drawn over the top of the formal spatial data. This approach allowed for sense checking of local perspectives against the national data sets. Hand drawn data were discussed by the stakeholders and were digitised into vector layers using the Android mapping application GIS Pro. The layers were then imported to ARC GIS for scaling and clean-up before being imported as layers onto ESRI Web Apps (ARC GIS online) which was made publicly available via a web link. The maps from the Humber Estuary and The Wash workshops were digitised using ARC GIS software and were then converted into interactive Pdfs which were circulated to the stakeholders for sense-checking and feedback. The advantages of an interactive Pdf are that stakeholders do not require GIS software, GIS expertise or internet access to interrogate the data layers making them more accessible and user-friendly.

3.7 Stakeholder Feedback

In order to facilitate a co-productive and adaptive approach, stakeholders who attended the workshops were asked to complete a short workshop evaluation questionnaire. The questionnaire consisted of five questions, using a mix of both open (qualitative data) and closed (quantitative data) questions. These aimed to collect stakeholder feedback on: (i) the usefulness of the workshop overall, (ii) the usefulness of each of the workshop activities (e.g. mapping exercises as described above), (iii) the quality of the materials used in the workshop exercises, (iv) the quality of the venue and catering, and; (v) an opportunity for stakeholders to provide suggestions as to how the workshops and/or the process could be improved. In total, 36 responses were received across the four workshops, with the stakeholder comments collated, analysed and used to review and adapt the final workshop process presented in this paper. For the closed, quantitative questions, descriptive statistical analysis was used to examine overall trends in the responses obtained. This gave the research team an indication of stakeholder views across all four workshops, and allowed any differences between cases to be identified. Open, qualitative questions were analysed using a manual thematic coding approach

whereby the responses to open questions were reviewed by the research team to identify emergent themes. The data were reviewed numerous times to ensure confidence in the final thematic codes assigned. Where appropriate, italicised quotes taken from the stakeholder feedback are used to support the presentation of results.

4. Results

The workshops results are presented below with respect to the mapping of activities, features and benefits, workshop outputs and stakeholder feedback.

4.1 Activities Mapping

Stakeholders at the East Caithness workshop identified a range of recreational and commercial activities and designations, including several not mapped onto, or in contrasting intensity to those on national marine database layers (Figure 4). Stakeholders were enthusiastic to discuss and map activities, requesting more detailed maps at a finer scale. The low intensity of activities in East Caithness reflects the low population in the area, although a diverse range of activities were identified. Activities of cultural importance including historic sites, castles and wrecks were discussed, reflecting the regions strong connection to their cultural heritage. Inconsistencies and inaccuracies of existing data in East Caithness were highlighted including the spatial distribution of wrecks and dive sites.

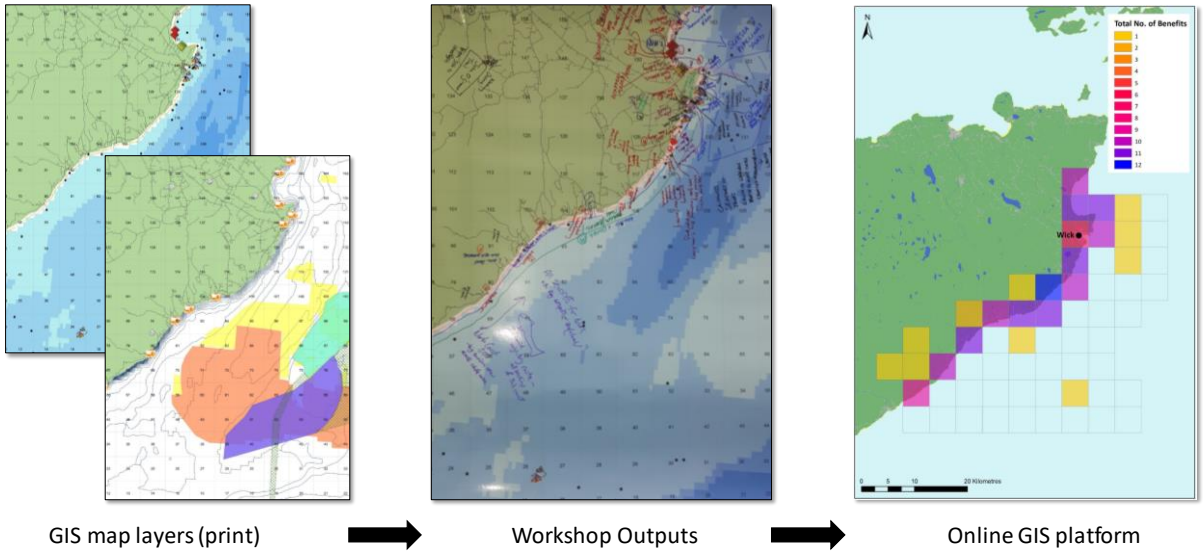

Figure 4: Mapping process and outputs from the East Caithness workshop.

Activities mapping (Figure 5) in Aberdeen Bay revealed many small-scale low impact activities, particularly in the tourism and recreation sector, were not captured at a local scale or were not present in the national marine database. Recreational activities including board sports (surfing, windsurfing, paddle boarding), walking, recreational fishing, horse riding and wildlife watching, despite local importance, were not represented in the formal layers and amended by participants. The mapping recognised the importance of a range of activities around wildlife watching, photography, and education that reinforce cultural benefits associated with sense of place, well-being and health. Recreational activities were distributed along the open beach systems of Aberdeen city beach and Balmedie beach but rely on public access points such as car parks and roads. A range of recreational activities were identified, from easily accessible beach walks in an urban environment to more remote 'wilderness' experiences on Balmedie Beach and Black Dog. The wildlife watching sector was clustered around access points and ecological features, in particular at the points where the river systems meet

the coast. This in itself ranges from highly modified habitats and harbours (the Dee mouth), locally noted for Bottlenose Dolphins to estuarine systems such as Donmouth and the Ythan Estuary with its mudflats and saltmarsh habitat attracting wildlife including waders and seals. Multiple overlapping activities were identified and mapped, particularly across recreation and tourism. While overlapping activities contribute to multiple benefits (e.g. sense of place and physical and mental health) stakeholders highlighted examples where activities have impacted local sites. In Aberdeen, overlapping activities such as salmon netting, wildlife watching, coastal walks and boating have interacted with protected sites for seals; popular areas for 'consumption' of ecosystem services have a lack of infrastructure to support higher visitor numbers; and golf course development has undermined the integrity of dune systems and impacted cultural services such as sense of place.

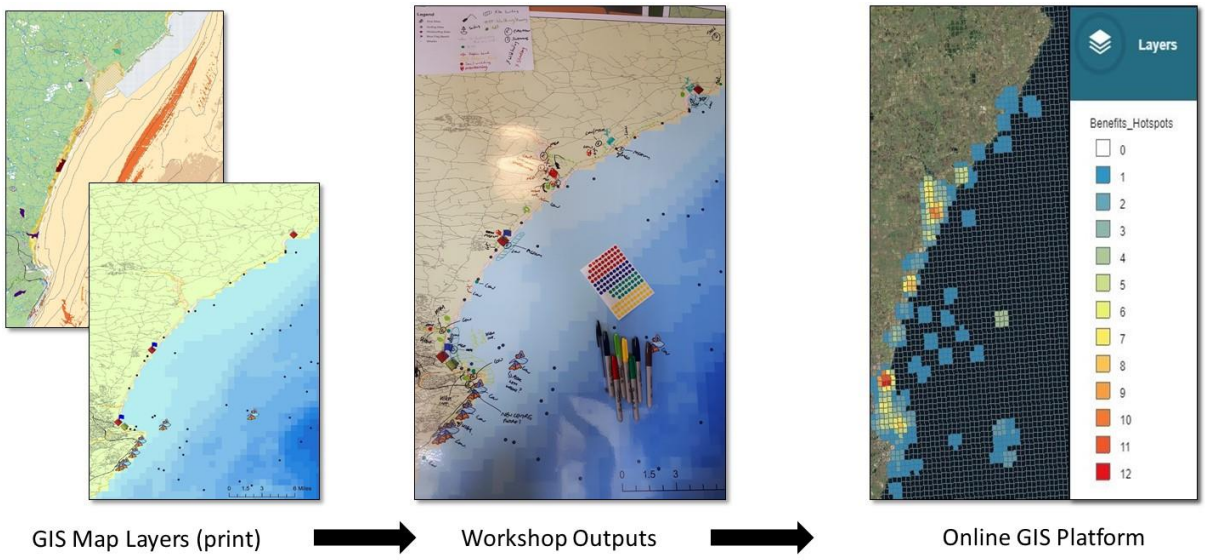

Figure 5: Mapping process and outputs from the Aberdeen Bay workshop.

Stakeholders commented that it was useful to learn about activities, with one stakeholder commenting that it was useful to "[understand] the extent of what is available on our local coasts and sea". A view from an industry representative noted "*[the approach] is very useful for providing information on the local area and the services and goods provided by the local ecosystems. Important for industry to consider these wider services so as to prevent knock-on effects*". Local government noted that "*the discussion with local stakeholders take ideas [on ecosystem services] into a wider field"* and "*allows for good overview of the services provided and their importance within a specific area*". The activity mapping highlighted the diversity of local coastal use, but importantly indicated that overlapping activities can place pressures on natural capital and that both activities and benefits can be socially contested.

4.2 Features Mapping

Features were mapped in the Humber Estuary, focussing on three case study areas (Welwick, Spurn and Cleethorpes to Donna Nook). The activity started with the stakeholders identifying the types of features that can be identified from the satellite image of their case study site. The number of features identified varied between sites (e.g. Welwick n=19; Spurn n=23; and Cleethorpes to Donna Nook n=12) and included a range of both natural features such as broad scale habitats (mudflats, sandflats and saltmarsh) to man-made structures (managed realignment sites, flood banks and pipelines). Once a list was produced, the stakeholders drew the features on to the A1 scale paper map produced using a satellite image, and generated their own colour-coded key for each feature. This exercise required

local knowledge to accurately map and sense-check the features which were visible from the satellite image and also enhanced the level of stakeholder buy-in to the process given that the stakeholders were responsible for all lines drawn on the map. An example of the map generated for the Welwick site is shown in Figure 6. After the workshop the lines drawn by the stakeholders were digitised, with the colour coding and feature types being standardised across the three Humber Estuary sites, resulting in a digital image of features (Figure 6).

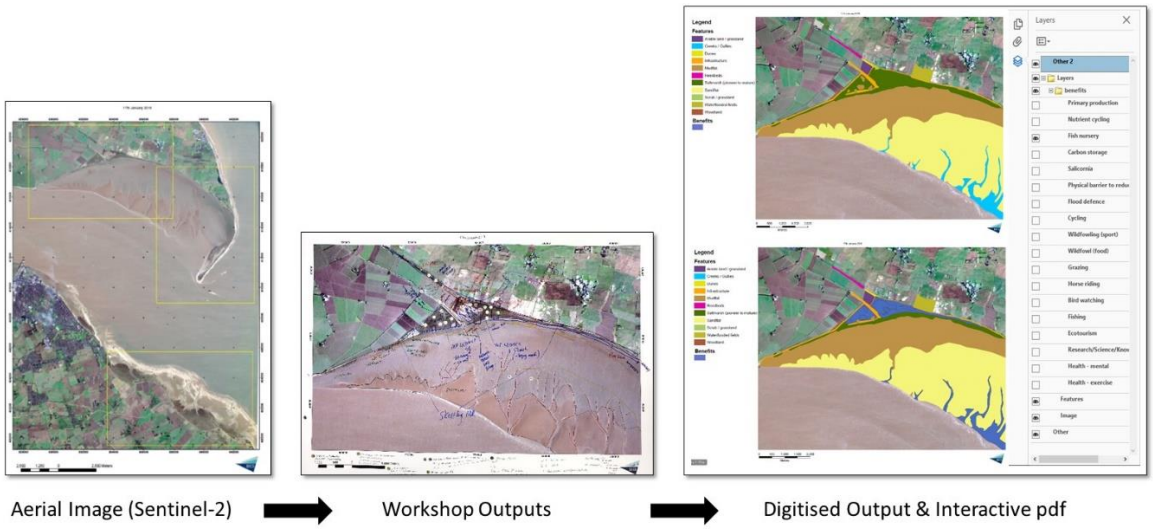

Figure 6: Mapping process and outputs from the Humber Estuary workshop. Example shown is for the Welwick case study site.

Features were mapped at The Wash workshop, focussing on three coastal parishes (Wainfleet, Friskney and Wrangle). Given the focus of The Wash workshop on saltmarsh, the features identified were all sub-features of saltmarsh. A total of 7 sub-features of saltmarsh were identified, which included pioneer low, pioneer middle, middle marsh, upper marsh, high upper marsh and grazed marsh. In addition, infrastructure were also identified which included sea walls and a managed realignment site. The stakeholders identified these sub-features on A1 scale paper copies of the satellite images by drawing around the extent of each sub-feature (Figure 7). Following the workshop, the extent of each sub-feature was digitised using GIS software and converted into an interactive pdf which allows the different sub-features to be turned on and off by the user (Figure 7).

Figure 7: Mapping process and outputs from The Wash workshop. Example shown is for the Wrangle coastal parish.

4.3 Benefits Mapping

All stakeholders were asked to identify the benefits they receive from the marine and coastal environment. No definition of benefits was provided in order to capture the full range of benefits that the stakeholders identify being gained from the marine environment. The full range of benefits identified by each workshop is presented in Table 4.

Table 4: Benefit categories as identified by the stakeholders at each of the four workshop

Cumulative List of Benefits	East Caithness	Aberdeen Bay	Humber Estuary	The Wash
Primary production		1	1	1
Nutrient cycling	1	1	1	1
Pollination				1
Formation of species habitats		1	1	1
Formation of physical barriers			1	1
Formation of seascape / soundscape	1	1	1	
Biological control		1		
Carbon sequestration		1	1	
Food for human consumption	1	1	1	1
Food for fish/birds	1		1	
Fertiliser and biofuel			1	
Climate regulation	1	1	1	
Prevention of coastal erosion		1	1	
Sea defence		1	1	1
Waste burial			1	1
Waste breakdown	1	1	1	1
Tourism and nature watching	1	1	1	1
Spiritual & cultural wellbeing	1	1	1	1
Aesthetic benefits			1	
Education and research	1	1	1	1

Physical health	1	1	1	
Mental health	1	1	1	
Renewable energy	1	1	1	
Sediment transport		1		1
Shipping		1	1	
Historical culture	1	1	1	
Improved farming / grazing			1	1
Employment	1	1		
Improved local economy	1	1	1	
Emergency services			1	
MOD training		1		
Interactions between sectors	1			
Natural systems		1		
Community cohesion (social)	1	1		
Biodiversity	1			1
Personal safety	1			
Art and photography				1
Semi-precious stones				1
Total Number of Benefits	**19**	**25**	**26**	**17**

Once identified by the stakeholders, the benefits were each assigned a reference number and were then mapped onto the activity maps (Figures 4 & 5) or the feature maps (Figures 5 & 6) using sticky dots on which the reference number is written. Following the East Caithness and Aberdeen Bay workshops, the benefits were digitised, with outputs being presented either using an online platform to illustrate where benefits are produced. This can be displayed as heat maps of benefits (Figures 4 & 5) or be converted into an interactive pdf file (Figures 6 & 7) in which benefits can be selected in relation to the feature which provides that particular benefit. For example, Figure 6 shows the importance of creeks and managed realignment in providing fish nursery (supporting ecosystem service), whereas Figure 7 shows the importance of the pioneer low and middle saltmarsh for wildfowling (cultural benefit). In addition to the digitised outputs, a brief workshop report was produced following each workshop which was circulated to all the stakeholders who attended the workshops.

Following the workshops, the benefits identified by the stakeholders (Table 4) were categorised using the marine ecosystem service categories developed in the framework for the UK coasts (Turner et al., 2015) i.e. identifying the proportion of supporting, regulating, provisioning and cultural benefits identified (Figure 8). For mapping purposes, some of these services were further sub-divided. For example, tourism and nature watching was broken down by the stakeholders into sub-categories such as bird watching, cetacean watching, dog walking, kayaking, and surfing. Benefits from all four Millennium Ecosystem Assessment categories (MA, 2005) were identified at each workshop, thus recognising the importance of coastal systems in delivering supporting, regulating, provisioning and cultural benefits. Although outside the scope of the MA (2005), economic activities were also noted, including those related to employment (e.g. employment income or job creation) or abiotic benefits (e.g. shipping, renewable energy generation).

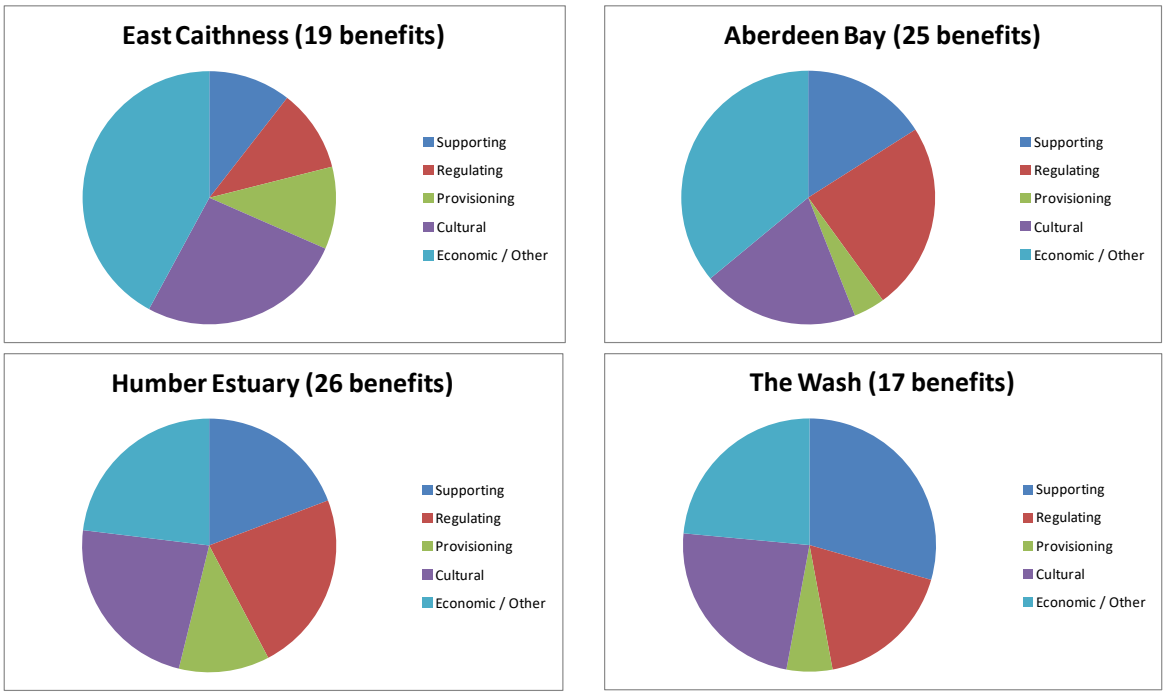

Figure 8: Summary of benefit categories identified by stakeholders at all four workshops.

4.4 Stakeholder feedback

Qualitative analysis was carried out on the text-based responses collected through open-ended questions included in the evaluation forms at each workshop to provide a more in-depth understanding of stakeholder perceptions towards the workshops and their activities. Analysis found that bringing together a range of stakeholders and providing an opportunity to hear from '*other interested parties'* and to '*see other people's views…'* were commonly mentioned by stakeholders as being one of the primary benefits of this workshop approach. This was further emphasised by one workshop attendee (The Wash) who stated that the process and *'the benefits mapping [activity] really opened my eyes to the natural resources and the benefits of saltmarsh'*. The location specific, multi-modular approach of having multiple workshop sessions was identified as an advantage of the process, with one stakeholder stating that it was *'good to have the opportunity to develop discussions and themes, [in a way that was not] unduly rushed'*, highlighting the potential value of this approach as an effective stakeholder engagement tool. Furthermore, as the concepts of ecosystem services and natural capital continue to dominate the conversation around natural resource management, the workshops were seen as a valuable introduction to the application of the natural capital concept and approach at a local scale.

Stakeholders at the Scottish workshops believed that the ecosystem service matrices (adapted from Potts et al., 2014) would be a useful tool in MPA designation and management, particularly the latter, and for use in stakeholder engagement. Feedback suggests that stakeholders saw the matrices as a good visual tool to condense large volumes of data into an accessible format, but that the ability to see the data sources behind the scoring would strengthen the validity of the approach. Stakeholders felt that more time would be required to fully understand and then apply the matrix approach at the local scale; however, they saw value in local adaptations of the matrices to interrogate changes in ecosystem service provision resulting from different management scenarios.

The feedback received from the stakeholders was used by the authors to refine the methodology for subsequent workshops (Table 5). This resulted in the development of a co-produced adaptive, modular structure for marine stakeholder participatory mapping workshops (Figure 9).

Table 5: Summary of stakeholder feedback and how it refined the workshop methodology.

Stakeholder Feedback	Workshop(s)	Refined Methodology
The provision of pre-reading in the form of contextual information and background for the specific locations, as well as workshop activities, would be more efficient and lead to more effective engagement from workshop attendees.	Aberdeen Bay & Humber Estuary	A more detailed background document to be circulated prior to each workshop to outline the workshop aims and objectives, but also to state which case studies will be covered within the workshop (Figure 9).
The scale of the maps used at the workshops was not sufficiently detailed to capture activities at a local scale.	East Caithness	Move to using maps derived from Satellite imagery for both the Humber Estuary (Figure 5) and The Wash (Figure 6) and which resulted in habitats being mapped down to a 10m scale.
To ensure representation from as many relevant stakeholders at workshops as possible, it was suggested that extending the invitation out more widely would be beneficial.	Aberdeen Bay, East Caithness	For future workshops, invitations will be sent to key stakeholders as early in the process as possible. However, it must be recognised that participation in these workshops is voluntary and it may not always be possible to have representation from every stakeholder organisation or group.
Stakeholders made recommendations regarding the materials used during the workshops, including the provision of multiple maps to support high volumes of data and avoid confusion ('maps became messy/confusing due to volume of information') or providing maps for both summer and winter to allow for seasonal comparisons to be made.	Aberdeen Bay, Humber Estuary, The Wash	Incorporating satellite imagery into the stakeholder-driven methodology allows for comparison between maps over time. This allows seasonal or historic comparisons to be made if that is of interest to the stakeholders at the local scale. For example, The Wash workshop used images from different seasons.
It would be useful to try and plot where humans go around the estuary. Data can be obtained for activities such as cycling (e.g. using the STRAVA app.) but we could also build on the access and activity mapping undertaken under other projects.	Humber Estuary	A mapping activity (Task 7, Figure 9) is included within the proposed methodology to capture the activities as well as the features and benefits. Such mapping activities have recently been applied on behalf of the MMO (Project 1136[2]) for non-licensable activities.
Stakeholders suggested that an iterative process of 3-4 workshops would be valuable.	East Caithness	A series of 3 workshops is proposed which can be tailored to meet the needs of particular local groups (Figure 9)
Stakeholders expressed a desire to know more about the outputs of the workshop and how these might be used in the future to support decision making and coastal management in their local areas.	Humber Estuary, The Wash	It is proposed that a series of workshops would be developed so that the second workshop would start with the output of the first, and so forth. For example, a second workshop could start to use the interactive pdfs developed in Workshop 1 (Figure 9).
The ecosystem service matrix approach was seen as a valuable tool which could be used to assess trade-offs under different scenarios; however more time was needed to understand the approach.	Aberdeen Bay, East Caithness	The ecosystem service matrix approach was omitted from subsequent workshops (Humber Estuary, The Wash) due to time constraints but it is was seen as a valuable approach for understanding trade-offs (Task 11, Figure 9).

3.5 Adaptive methodology for future workshops

This paper has applied a locally-focused stakeholder-based participatory methodology which integrates different kinds of knowledge into a more nuanced local understanding of ecosystem services. Its application can assist coastal communities in understanding what natural capital features are present in their localities and how these features produce a diverse range of services and benefits

[2] The intensity and impacts of non-licensable activity on MPAs (MMO Evidence Project 1136) https://www.gov.uk/government/publications/evidence-and-the-marine-management-organisation-mmo/evidence-projects-register

and how these benefits interact to shape human engagement in coastal environments. Future application of the methodology has the potential to influence how coastal communities engage in planning with local authorities and how communities respond to increasing policy interest in developing natural capital strategies under the UK 25 Environment Plan and the draft 'Environment Strategy for Scotland'. As the UK and all devolved administrations progress marine spatial planning under their respective national marine strategies, there will be increasing demand for improved local data on ecosystem services and how they are used and contested in coastal communities, particularly when trade-offs will need to be made across overlapping or competing activities. It is also applicable to other UK and international coastal contexts where natural capital assessments are becoming more commonplace and demonstrating the multiple benefits of healthy ecosystems and marine protected areas is becoming a key part of marine planning.

Feedback from the stakeholders on each activity has resulted in refinement of the methodology employed at subsequent workshops, with the overall feedback and testing of the activities at multiple sites resulting in the development of a co-produced adaptive methodology (Figure 9). This methodology has a flexible structure, providing opportunity for bespoke workshops to be co-developed with local marine stakeholders. Working in collaboration with local coastal partnerships was a major strength in the approach. Depending on the issues of interest at the local scale, a series of workshops can be co-designed to ensure local specificity and application (if required). For example, where a local coastal partnership is interested in only identifying features (Task 2), mapping benefits (Task 3) and having a general discussion around management issues (Task 4), then a one-day workshop would be sufficient for their needs. Where stakeholder groups wish to develop and apply the tools further (i.e. interactive pdfs, ecosystem service matrices, etc.) then a bespoke series of workshops can be tailored to meet their needs. As a further example, where site features have already been identified and mapped, then a shorter (half-day) workshop could be co-developed which jumps straight from Task 1 to Task 3, where the focus would be on the identification and mapping of the benefits provided by the features which have previously been mapped. Likewise, where activities have already been mapped (i.e. Task 7) then this stage would not need to be repeated but could be included within the interactive pdfs after workshop 1. Finally, where management options exist for an area, Task 8 can be skipped and the final workshop can focus on trade-offs associated with the different management options.

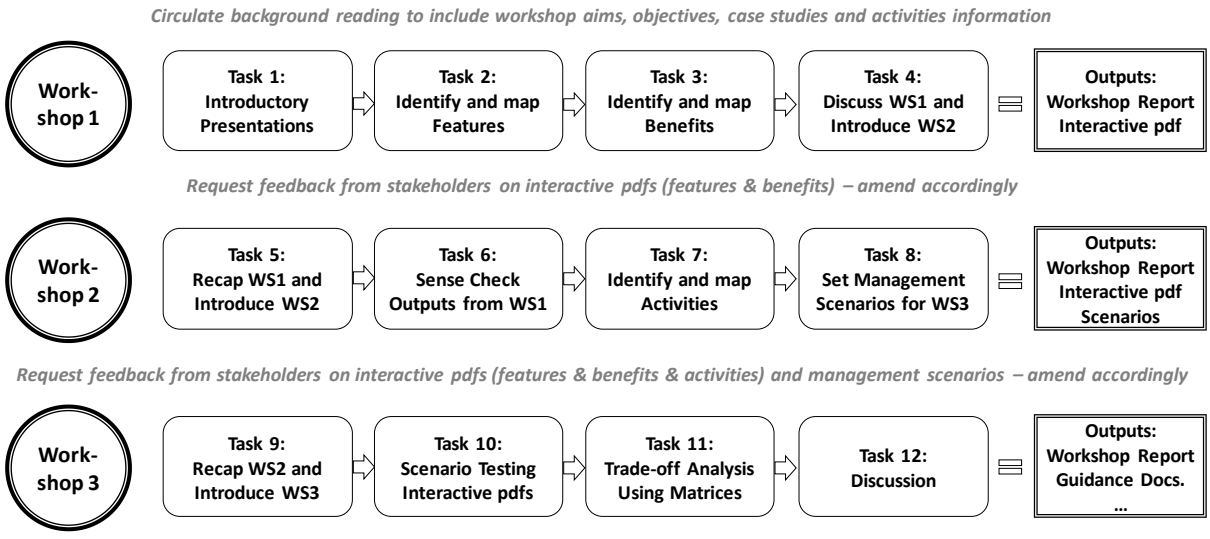

Figure 9: Flexible, modular structure for marine stakeholder participatory mapping workshops.

4. Discussion

In the UK, the implementation of a natural capital and ecosystem services approach is gaining traction at the national scale and has yet to filter down to the practical realities of implementation in use in coastal communities. This is also reflected in the domain of policy, where implementation of the Sustainable Development Goals (UN-DESA, 2019), the UN Aichi Targets for Biodiversity (CBD, 2019) and an inclusive green economy (Altenburg & Assmann, 2017) refer to natural capital and ecosystem services as a strategic influence in macro-economic and sector wide reform. Recent efforts to incorporate natural capital into mainstream policy practice include the construction of national natural capital accounting systems and asset registers. For example, the UK Office of National Statistics has developed a system of natural capital reports specifying the economic contribution of ecosystem services (ONS, 2017), while Scottish Natural Heritage (the nature conservation agency in Scotland) has developed a Natural Capital Index that focuses on the contribution of terrestrial ecosystems to social wellbeing (SNH, 2017). Similar approaches to understanding ecosystem services across a range of Welsh environments have been applied in the recent Welsh State of Natural Resources Report (NRW, 2016), while the link between the natural environmental and societal well-being is more explicitly supported through the recent Well-being of Future Generations (Wales) Act (2015). While we note the utility of these recent advances, approaches at the international and national policy scale should be supplemented by implementation at the local scale (as set out in this paper) where identification and understanding of the extent and quality of local ecosystem services can support policy delivery and community aspirations for local environmental planning and quality.

This research has highlighted how the perceptions of the benefits provided by the coastal environment can differ between the national and local scale, between official policy documents such as marine evidence databases and the 'on the water' reality for coastal communities. It is this scale mismatch that hides the often overlapping, entwined, contested and complex reality of services at the local scale. With mapping activities, stakeholders commented that it was useful to learn about anthropogenic activities, with one stakeholder commenting that it was useful to "[*understand] the extent of what is available on our local coasts and sea*". A common interpretation by participants was that the larger scale data sets did not represent local realities, particularly in sectors such as recreation. An example from the Scottish case illustrates this point. It is evident from the National Marine Plan for Scotland that there is consensus for increasing recreation and tourism activity in the coastal zone. While national databases specify, in broad terms, where activities occur, we discovered that at the local scale many activities were missing (e.g. horse-riding, small boating activity, board sports) or were considered inaccurate (e.g. dive sites or paths that were not used). Stakeholders at the East Caithness workshop indicated a preference for more fine scale and detailed maps to allow mapping of activities that were locally significant, given that the national databases did not reflect the situation at the local level and supporting local culture was integral to economic development. It is through a participatory mapping process that the fine-scale and locally relevant activities and overlaps are documented, supporting future planning and assessments. While it was beyond the scope of this research to develop policy pathways, a number of options for using participatory mapping data were highlighted during discussions with coastal stakeholders including supporting project and policy assessment (EIA and SEA), community wellbeing planning indicators, local environmental strategies (e.g. recreational and parks strategies; catchment and river plans) and civic strategies for improving natural capital e.g. the Humber Nature Forum Natural Capital Strategy (HNP, 2017). Benefits mapping activities in each workshop followed the same methodology. All four demonstration sites identified a range of benefits they get from the marine environment, covering all four MA (2005) categories (regulating, supporting, provisioning and cultural), in addition, to a range of economic / other categories of benefits. It was interesting to note that the two Scottish workshops, which focussed on mapping anthropogenic

activities, identified a much larger proportion of abiotic benefits within this category. In Aberdeen Bay, benefits 'hotspots' were evident where there was appropriate coastal access, focussing around the City of Aberdeen in the south, accessible beaches and nature reserves present around the Ythan Estuary in the north. Discussion over the 'constellations' of benefits in this case increased the recognition amongst stakeholders that coastal systems are integral for supporting the wellbeing of residents in the North East of Scotland and that this should be included in future planning initiatives and the management of coastal protected sites. The benefits identified by East Caithness stakeholders represented cultural and economic benefits gained from the environment and including the built / cultural environment including historical sites and visitor centres. Although some of the identified benefits such as 'community cohesion (social)', 'employment' and 'improved local economy' do not correspond with the MA (2005) ecosystem service framework, this reflects the values of the region in maintaining the local economy and population and the importance of community cohesion in a relatively sparsely populated and economically vulnerable area. It underlies the importance of cultural heritage, both tangible and intangible, in creating lived seascapes that support community wellbeing. The historical human culture in East Caithness combined with the modern maritime industrial context, represent a strong link between people and the sea, and the importance of benefits from both the 'ecosystem' and abiotic factors such as wind, space and infrastructure.

In contrast, the two English workshops focussed more on the benefits relating to the biotic features of the system, possibly reflecting the focus of the workshop on identifying features from high-definition satellite images. It is also of note that there were fewer benefits identified in The Wash (n=17) than in the Humber Estuary (n=26). However, this likely reflects the focus of the workshop on multiple features in the Humber Estuary, whereas The Wash workshop focussed solely on saltmarsh. Focus on different aspects of the wider ecosystem illustrates an attempt to assign value to all components of the ecosystem, including those included in the supporting services category. This has commonly been attributed the lowest level of social value, and as stated by Klain and Chan (2012), participatory mapping approaches have often omitted this level of detail.

The strength of this research is the co-production of ecosystem services data and awareness within coastal partnerships and networks of stakeholders. By co-producing the research aims and objectives, methodologies and workshops with established networks of individuals or organisations, it ensures that the outputs and outcomes of the research are fit-for-purpose and improve legitimacy with stakeholders (Hattam et al., 2015b*;* Burdon et al., 2018). Each of the four workshops held space for an open discussion regarding workshop activities, the direction of subsequent workshops and to identify and openly discuss potential management issues currently faced by coastal communities. A positive example of this came out of The Wash workshop, where issues regarding public access to the foreshore were raised and discussed relating to a recent increase in fly-tipping, vehicle access and disturbance. Following these discussions, a local working group was created, including representatives from the Ministry of Defence, Natural England, Witham Forth Drainage Board, farmers/landowners, Lincolnshire Wildlife Trust and The Wash and North Norfolk Marine Partnership, which has now actioned the installation of gates and concrete blocks to restrict vehicle access, but still ensure that pedestrians still have public right of way. In Aberdeen, discussions on the social wellbeing benefits of the coast have influenced new developments around establishing marine wildlife watching facilities and cemented concerns about the expansion of golf courses that undermine services from sand dune systems. Engaging a range of marine stakeholders in a workshop setting has not only resulted in the expansion of the role of participatory mapping for natural capital but has also enhanced discussion for management of the coastal and marine environment.

By taking a stakeholder-driven approach, where the outputs of the research are generated by the stakeholders themselves, it ensures buy-in from the start and provides a product legacy for use by the stakeholders at the end of the research. Our approach has focused on the development and application of a methodology, and with future iterations, will be applied in different coastal localities and incorporating additions such as trade-off analysis and future scenarios. For example, the method is currently been applied within a series of stakeholder workshops for the Suffolk Marine Pioneer project (Burdon et al., in preparation). Our focus on using coastal partnerships enabled researchers to identify and connect with those stakeholders who directly benefit ecosystem services and to those who manage, protect and educate about the marine environment and are at the forefront of policy change. A clear signal from all four workshops is that current coastal planning and policy mechanisms at the local scale are poorly equipped to deal with the policy challenge of natural capital and ecosystem services. We recommend a state change in effort and focus from the national scale (e.g. Natural Capital registers) to the community scale accommodating multiple stakeholders, interests and viewpoints around coastal system benefits. Our view is that a range of direct and indirect benefits are produced and consumed at the local scale and that this pattern of spatial heterogeneity across coastal regions should be reflected in UK, national and local policy. The UK is fortunate to have a national network of coastal partnerships, which are a highly valuable, but often under-used resource, to learn more about and implement the natural capital agenda (CPN, 2019). A review of the different management structures of UK coastal partnerships has recently been undertaken, providing a valuable resource for identifying how to determine governance requirements and structures for MPAs (Bennet & Morris, 2017). Future research can build on and facilitate new reforms to deliver the natural capital agenda at the local scale co-produced with community interests and expertise.

Participatory mapping offers a route for engagement in the process of knowledge production linking national initiatives and data with local knowledge, a critical component of an ecosystem approach to management. This research has demonstrated through the production of locally evaluated service / benefits maps that there is a disconnect between the findings of national evaluations and the social reality of diverse, contested and contextual ecosystem services. The outputs indicate that services in the domains of regulatory, provisioning and cultural, are consumed or experienced at the local scale (e.g. shoreline protection, sense of place, recreation and food gathering). The distribution, access to and beneficiaries of these services are subject to social deliberation and negotiation, particularly at times of change when development or bio-physical changes in the local environment drive shifts in the patterns of access or changes in benefits. During the four workshops, participants were engaged in the identification, spatial mapping and discussion of local activities, natural and modified features and the full range of ecosystem service benefits. The project took a strong approach to refinement and adaptation, improving the methodology in response to feedback and incorporating innovative new designs such as the use of satellite imagery to derive feature / benefit relationships. One of the insights of this demonstration work is that attempts to value natural capital and ecosystem services may have been premature, particularly in the context of local understanding and policy. What we have explored in these cases is that the local distribution and understanding of ecosystem services is complex, variable and subject to interpretation. While valuation is a necessary and important tool, this should be preceded by rigorous and detailed understanding of the services that exist in the local context before any valuations are undertaken.

5. Conclusions and Future Work

Although there has been a recent rapid development in our understanding of the values (qualitative and quantitative) of marine ecosystem services, socio-cultural values are often overlooked. This paper has demonstrated the value of incorporating participatory GIS in the co-production of knowledge

about ecosystem services in marine and coastal environments. Positive feedback from all four workshops has shown support for engagement of stakeholders in the local level discussion of natural capital and ecosystem services. Looking to the future, this paper has proposed an innovative, stakeholder-driven, adaptive approach, which has been piloted throughout the workshops, and other associated projects (e.g. MMO1136), aiming to deliver co-developed tools for use in marine planning, conservation management and coastal development strategies at a local, national and international scale. The flexibility in approach enables a bespoke series of workshops to be co-developed with stakeholders, ensuring that both the outputs and outcomes of the process are fit-for-purpose by the end-users in the sustainable management of our coasts and seas. Further research should aim to implement and evaluate the application of the framework to support local decision making at additional sites within the UK, including application within the UK overseas territories, and to test the methodology more widely across the globe. As the call for improved and meaningful stakeholder engagement in marine and coastal decision making continues to grow, this paper demonstrates the successful application of this co-developed, participatory approach within a UK context. Given the flexibility in the approach, the framework has the potential to be adapted for broad-scale use outside the UK, as well as for the management of other ecosystems types (e.g. terrestrial and freshwater catchments).

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