A framework linking ecosystem services and human well-being: Saltmarsh as a case study

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A framework linking ecosystem services and human well-being: operationalising the concept in Welsh saltmarsh

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1. Abstract
The ecosystem services approach is based on the interdependencies between nature and human well-being. The ecosystem services aspect of these conceptual classifications is well-developed but the well-being aspect still remains unstructured and vaguely defined. This research advances and exemplifies the linkages between ecosystem services and well-being, with important insights for environmental and health management. An integrated framework was developed by adapting and linking the UKNEA-FO framework with Smith et al.'s (2013) human well-being domains. Besides benefits, the notion of disbenefits was incorporated to recognise the potentially detrimental effects from interacting with nature. Benefits and disbenefits occur at the social-ecological interface so they are classified by the seven domains of well-being they affect. Accounting for disbenefits and benefits specifically increased understanding of the differences in magnitude of their impact on society, spatial scale, and users. The framework is applied to Welsh saltmarshes, where we see that benefits mainly accrue at larger scales with a greater magnitude affecting local to global individuals, while disbenefits tend to occur at a smaller scale and impacting in-situ individuals only. Through trialling our integrated framework on Welsh saltmarshes it is evident that, by including the disbenefits and explicit well-being domains, this approach enables the greater inclusion and understanding of human well-being from the natural environment.

2. Introduction

The ecosystem services (ES) approach is centred on the interdependencies between nature and human well-being (Schleyer et al. 2017; Steger et al. 2018). A wealth of research has addressed the challenge of applying the ES approach empirically (Fisher et al. 2009; Boyd and Banzhaf 2007; Fisher and Turner 2008; Burkhard et al. 2010) and several definitions and classifications have been developed (National Ecosystem Assessment classification 2011; de Groot et al. 2010; Fisher et al. 2009; Beaumont et al. 2007). The ecosystem services aspect of these classifications is well-developed but the well-being aspect is still being developed and the conceptual links between ecosystem services and human well-being remain varied and vaguely defined. There is a need to clarify the links between ecosystem services and human well-being, and to operationalise these linkages in practice.

Human well-being is a multi-dimensional concept, with various interpretations and no universally accepted definition (Dodge et al. 2012) which in part explains the challenges in linking it to ecosystem services. Well-being encompasses positive physical, social and mental conditions, not just the absence of negative circumstances such as disease (Summers et al. 2012; Statham and Chase 2010; WHO 1948). It includes both objective dimensions of well-being, such as level of wealth (economic) and air quality (environmental), and subjective dimensions, such as self-reported life satisfaction (OECD 2011). Within current conceptions of objective well-being, two main approaches have been documented. The first approach is the Basic Needs approach which attempts to classify the minimum needs, health and autonomy, that must be satisfied for long-term well-being (Doyal and Gough 1984, 1991; Neef 1992). The second objective approach is the Capabilities approach (Sen 1992) which recognises the importance of a person's *ability* to do the things they want to do (capabilities), as well as achieving those things (functionings). There are two general approaches to subjective well-being: one that focuses on positive feeling, pleasure or hedonia and one focusing on positive functioning, personal fulfilment or eudaimonia (Longo et al. 2017). Alongside these approaches, many scales, indices and classifications of well-being have been developed, such as The Human Development Index (UNDP 1990), Well-being of Nations (Prescott-Allen 2001), Gross National Happiness (Ura 2008), Flourishing (Huppert and So 2013) and Scales of General Well-being (Longo et al. 2017). Despite these attempts to define human well-being, it remains an elusive or abstract term for some, it is not currently traded as a market commodity (Batavia and Nelson 2017; Garcia Rodrigues et al. 2017; Fish et al. 2016) and quantifying it accurately remains a challenge (Breslow et al. 2016; Fish et al. 2016).

The Millennium Ecosystem Assessment (MA 2005) explicitly linked nature to human well-being through the definition of a set of ecosystem services (see Figure 1). The MA is one of the key drivers for the upsurge in ecosystem service and human health and well-being research and its integration into policy. The MA argued that the experience of human well-being is dependent on context, and that it is never just a material issue, but also of subjective judgment and experience. Recent publications have striven to further illustrate the linkages between ecosystem services and human well-being through different frameworks for specific purposes (e.g. La Notte et al. 2017; Hattam et al. 2017; Breslow et al. 2016; Santos-Martín et al. 2013; Smith et al. 2013). The most widely used ES frameworks globally include United Kingdom's National Ecosystem Assessment Follow-On (UKNEA-FO), The Economics of Ecosystems and Biodiversity (TEEB), the Common International Classification of Ecosystem Services (CICES) of the European Environment Agency and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). Of these, only the UKNEA-FO framework attempts to provide a link between ecosystem services and specific constituents of human well-being, using an additional category of "benefits" to exemplify this link to well-being. The importance of distinguishing between services (means) and benefits (ends) is an addition to the MA (2005) that is now widely accepted (Boyd and Banzhaf, 2007; Fisher et al., 2009; Wallace, 2007), with Fisher et al. (2009) defining benefits as the actual contributions made to human well-being and welfare. *Benefits* ('good things') and *disbenefits* ('bad things') derive from ecosystems which different people value positively or negatively, including non-marketed ones, e.g. outdoor recreation, bleak view (UKNEA 2011; Ostfeld and Keesing 2017). It is benefits and disbenefits specifically that provide a direct link between ecosystem services and human well-being.

Benefits and disbenefits are seen as being a product of the interaction between the ecosystem and five capital inputs to generate positive or negative human well-being (Costanza et al. 2011; Fish et al. 2016; Maack and Davidsdotirr 2015; UKNEA-FO 2014). The five capitals include natural (i.e. ecosystems), social (e.g. trust, social cohesion), human (e.g. knowledge and skills), built (e.g. infrastructures, equipment) and financial (e.g. monetary currency) (Maack and Davidsdotirr 2015; Costanza et al. 2011; Fish et al. 2016). For example, often currency expenditure is needed to visit places and carry out outdoor recreation activities.

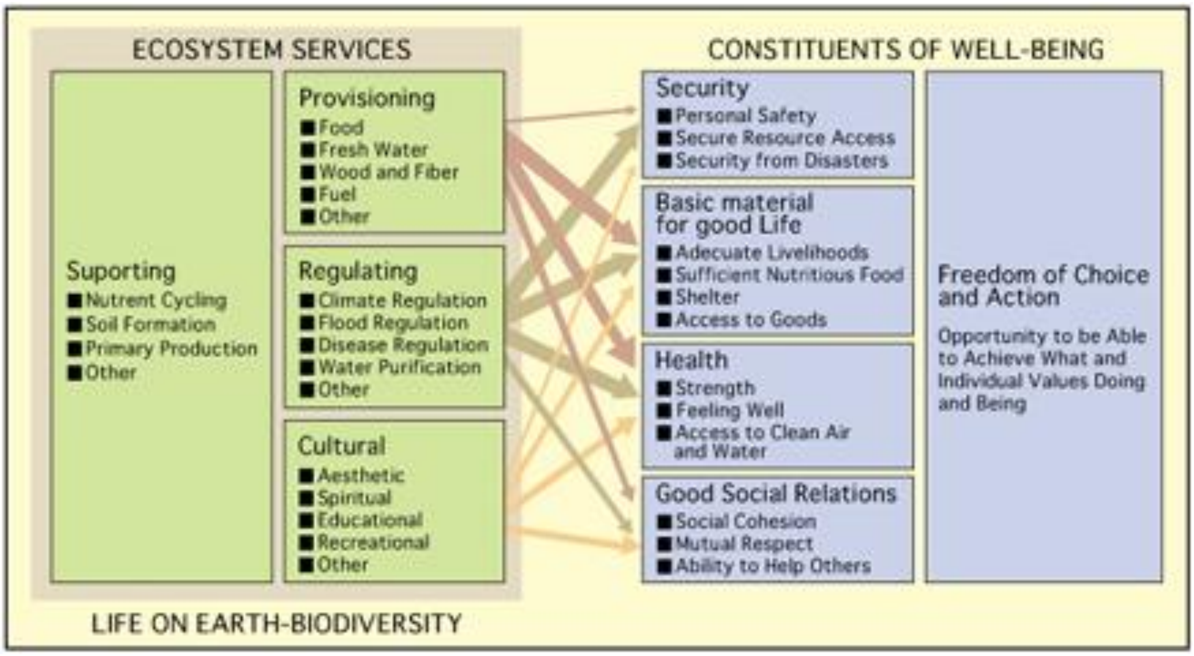

Figure 1. The UKNEA-FO ecosystem services framework (source: Millennium Ecosystem Assessment 2003).

Despite the addition of the ‘benefits’ category and the presence of well-being in the ecosystem service frameworks and classifications, well-being often remains only superficially defined, with the majority of the emphasis being placed on the ecological functions and ecosystem services. In the practical application of the frameworks the issue is exacerbated due to minimal exploration and quantification of the well-being component in the models. There are five key reasons why the human well-being component remains poorly understood in the context of ecosystem services: a) there are complex conceptual frameworks that do not mention human well-being; b) human well-being is included in some frameworks, but implicitly, without breaking it down into its different components (Vaz et al. 2017); c) the classification of benefits and disbenefits has been disparate and varied with poor recognition of the role of both benefits and disbenefits resulting from the interaction of humans and nature; d) frameworks have not been applied in practice to test their feasibility; and e) the well-being concept is not clearly defined in the literature making its application more complex. As a result, the linkages between ES and human well-being remain poorly understood (Daw et al. 2016; Seymour 2016; Yang et al. 2015). Elucidating these linkages has become urgent as policy (and legislation) is increasingly emphasising nature’s role in human well-being, with examples including the “Health 2020” European health policy framework, The UK’s Well-being and Health Policy Report 2014, and The Well-being of Future Generations (Wales) Act 2015.

This paper addresses four of the five reasons for the failure of the incorporation into frameworks and empirical application of human well-being. An improved framework is developed, adapting the UKNEA-FO approach with three key additions to account for i) the presence of disbenefits in addition to benefits; ii) the inclusion and classification of benefits and disbenefits based on their effect on human well-being as distinct levels in the framework; and iii) the different components or domains of human well-being. These additions are based on the premise that nature provides ecosystem services which in turn result in benefits or disbenefits after the interaction with different capitals; they recognise the need to better incorporate benefits and human well-being within conceptual frameworks. The framework proposed is then validated through its application to a case study that seeks to identify the ecosystem services, benefits and disbenefits provided by Welsh salt marshes, and to identify and conceptualize how and via which channels ecosystem benefits and disbenefits affect human well-being.

3. A framework linking ecosystems and human health and well-being

To better link nature, ecosystem services and human well-being we propose an adapted UKNEA-FO framework that introduces the concept of disbenefits, links the classification of benefits and disbenefits to their effect on seven human well-being domains and details these domains (adapted from Smith et al. 2013) (Figure 2).

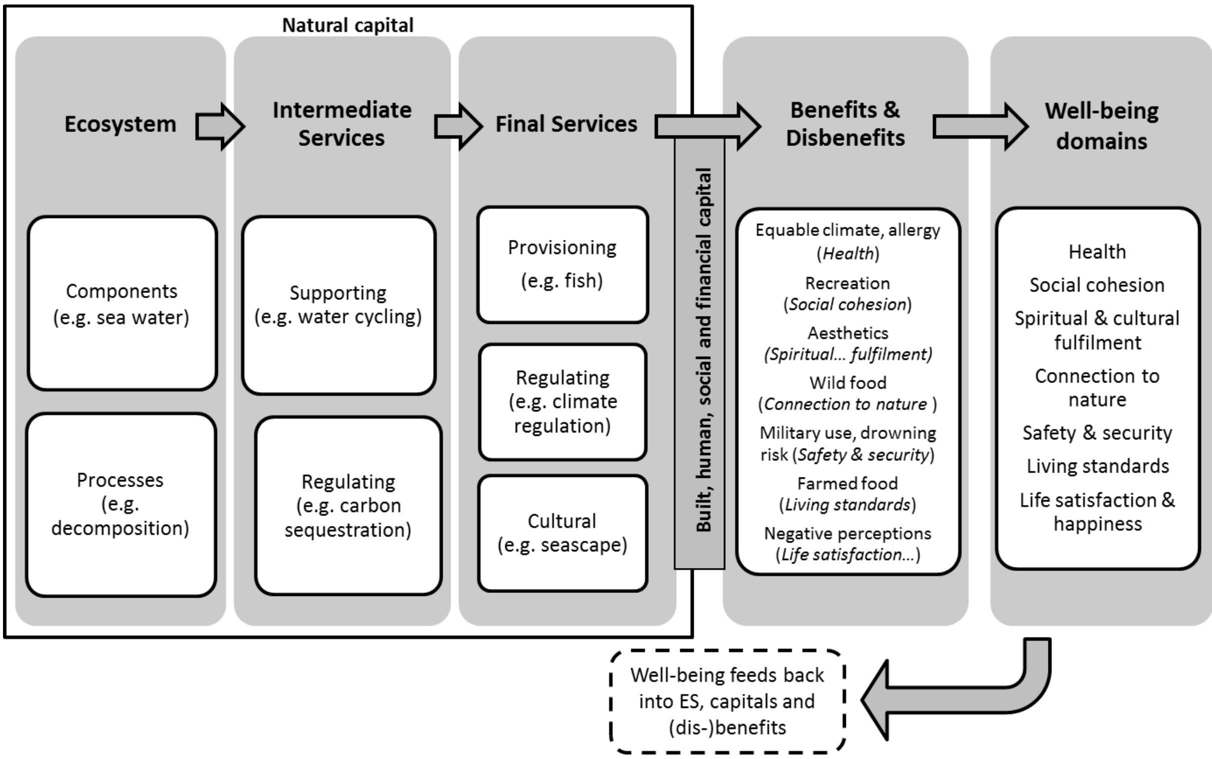

Figure 2. Conceptual framework of the links between ecosystems and human health and well-being, adapted from the UKNEA-FO framework and Smith et al. 2013.

We add disbenefits (also known as disservices or bads) to the framework as when the focus of a study is to link nature to well-being objectively, it is necessary to recognise the potentially detrimental effects from interacting with nature. Compared to the growing surge of publications on ecosystem services, disbenefits, particularly in natural ecosystems, have scarcely garnered attention despite their potential to undermine well-being (Lyytimäki et al. 2015; Shackleton et al. 2016). Disbenefits are perceived or actual unpleasant, unwanted or economically damaging effects that humans may experience from ecosystems (Ostfeld and Keesing 2017; Lyytimäki 2014), e.g. risk of drowning, bee stings. Humans can perceive or experience a disbenefit from actively or passively interacting with the environment. Like benefits, disbenefits can vary in intensity and scale, and they can ensue differently to various individuals or communities (Shackleton et al. 2016; Agbenyega et al., 2009) depending on factors such as acquired knowledge, personal values and agenda, and the overall political, economic and social settings at different scales and times (Busch et al. 2011; Shackleton et al. 2016). For instance, one person's aesthetically-pleasing, biodiverse saltmarsh (providing benefits) is another person's source of allergy, mud and bleak views (providing disbenefits). Often disbenefits are a downside of a benefit or ecosystem service (Shackleton et al. 2016), e.g. an ecosystem can store and process waste and pollutants, and at the same time transfer these pollutants up the food chain.

Disbenefits have no universal typology and have been classified based on their origin (Lyytimäki and Sipila 2009), their consequences (Shackleton et al. 2016; Escobedo et al. 2011), the well-being dimensions impacted (Vaz et al. 2017) and other broader reasons (Lyytimäki 2014). However, the above classifications do not allow for an explicit comparison to benefits. Further, benefits have generally been classified in line with the ecosystem services classification, which only takes account of the ecological aspects and is inappropriate with the disbenefits. Benefits and disbenefits occur at the social-ecological interface (i.e. with the input of other capitals); therefore, they are classified based on their effect or impact on human well-being (von Döhren and Haase 2015), i.e. benefits and disbenefits are classified by the domains of well-being they affect. This distinction between ecosystem services and disbenefits and benefits classifications is important as a key step towards elucidating pathways between nature and human well-being.

We further adapt the framework through the employment of an adapted version of Smith et al.'s (2013) comprehensive human well-being framework (Table 1) to tackle the challenge of linking ecosystem services and benefits to human well-being (Figure 2). The framework includes subjective, economic and environmental well-being elements alongside basic human needs. Smith et al.'s framework allows for the effect of changes in (objective and subjective) well-being as a result of changes in ecosystem services. It is important to note that not all well-being measures include physical health directly (e.g. Longo et al. 2017), so we ensured this was included as a well-being dimension. To create the index, Smith et al. did an extensive review of published indices of well-being and quality of life; they identified 157 well-being domains and from these developed a core set of nine domains. The domains include health, connection to nature, education, leisure time, life satisfaction and happiness, living standards, safety and security, social cohesion, and spiritual and cultural fulfilment. We have adapted the framework to seven domains by excluding leisure time and education as indicators of well-being, as these two are already accounted for in our framework as benefits contributing to human well-being. Table 1 presents examples and measures of human well-being for each of the seven domains. In Figure 2 examples of how the benefits and disbenefits are linked to the domains are demonstrated.

Table 1. Objective and subjective example measures of human well-being included in the seven domains selected, adapted from Smith et al. (2013), Longo et al. (2017), Dolan and White (2007), Leisher et al. (2013).

	HUMAN WELL-BEING DIMENSIONS						
	Health	**Social Cohesion**	**Spiritual and cultural fulfilment**	**Connection to nature**	**Safety and security**	**Living standards**	**Life satisfaction and happiness**
EXAMPLES OF EACH DIMENSION	Physical/ physiological (e.g. nutrition, water, exercise, balance)	Community relationships/ bonds	Cultural identity (language, customs)	Biophilia (emotional affiliation of humans to nature)	Personal physical security	Income level, employment	Work-life balance (leisure time)
	Mental/ psychological (mood, happiness)	Pro-social behaviour (participation, volunteering)	Heritage values (e.g. song, artefact)	Sense of place in nature	National physical security	Public and household infrastructure	Sense of purpose
	Behaviour development	Trust, reciprocity	Attendance at spiritual services	Visits to zoos, outdoor activities	Financial security	Energy	Friendships
	Access to clean environment (water, air)	Sense of community	Visits to historical sites	Time spent in natural environments	Crime rates	Parental/elder care	Self-esteem
	Cognitive abilities	Divorce rates	Cultural diversity and resilience	Investment in nature access	Accident-related injuries and deaths	Household assets	Personal development
	Life expectancy, mortality	Migration patterns	Investment in houses of worship or museums	Inspiration	Exposure to risks	Economic diversity and sustainability	Choice, freedom, respect

4. Applying the framework to Welsh saltmarshes

We propose the development of a framework to incorporate disbenefits as well as benefits, a classification for the disbenefits and benefits, and explicit well-being domains to advance our understanding of the linkages between nature and well-being. This framework is tested using the case study example of Welsh saltmarshes (or “Morfa heli” in Welsh).

The saltmarsh environment is an upper inter-tidal habitat taking place in low energy, tide-dominated coastal settings that is characterised by the existence of salt-adapted vegetation (French, 2003; Fagherazzi et al., 2012; Beaumont et al. 2013). Saltmarshes colonise soft-sediment, low-wave disturbance shorelines in bays, estuaries and lagoons; they are a global habitat, but flourish particularly in the temperate regions of the world (Silliman 2014; Adam 1993). Although in the past these habitats were seen as wastelands, they are now widely recognised for providing valuable services to humans (Silliman 2014). The natural productivity and the abundance of organisms in saltmarshes is equivalent to, and often surpass, those in other highly productive ecosystems, including coral reefs and tropical rain forests (Silliman 2014). Saltmarshes are essential for sustaining healthy fisheries, coastlines, and communities; they are an essential part of our economy and culture. Saltmarsh has a value as coastal defence, for its carbon sequestration capacity, as well as a role in filtering and diminishing pollution, and in supporting water quality, fisheries, agriculture, recreation and tourism (Adnitt et al. 2007; Barbier et al. 2011; NOAA 2017). Despite the valuable services provided by saltmarshes, they are highly threatened by human disturbances, including: invasive species, eutrophication, land use change, pollutants including oil spills, altered hydrologic patterns, and climate change effects, including sea-level rise and extreme weather events (Kirwan et al. 2016; Silliman 2014; Deegan et al. 2012). Saltmarshes are thus an ideal habitat for applying this framework, as they provide an array of ecosystem services from local to global scales, particularly protecting against flooding and erosion.

Saltmarshes are found in all the major estuaries and bays of the Welsh coast (Boorman 2003); they cover 7,345 ha (JNCC 2016), which represents 48% of the Welsh intertidal habitat (out of 15,232 ha listed in EU habitats directive). Although no specific information exists for saltmarshes, we know that the Welsh coastal and marine environment is a vital natural asset, contributing £6.8 billion to the national economy and supporting over 92,000 jobs. Furthermore, over 60% of the population of Wales live and work in the Welsh coast, including all major cities and many important towns (WWF Cymru 2012). Coastal erosion is occurring along 23% of the Welsh coastline (UKMMAS 2010a) with 208,000 residential properties at risk from riverine or coastal flooding (Auditor General for Wales 2016). Farm land, businesses, national infrastructure including transport and utilities, and sites of cultural or environmental importance are also at risk of coastal flooding and erosion. One popular coastal management policy is to use nature-based solutions which allow for realigning shoreline habitats like saltmarsh to reduce erosion and the impact of flooding (Auditor General for Wales 2016). Furthermore, the pioneering Well-being of Future Generations Act (2015) highlights the importance of building resilient coastal governance and management systems for people’s welfare. Likewise, the recent Welsh State of Natural Resources Report (SoNaRR; 2016) emphasises the importance of ecosystem resilience and the need for further research on transitional coastal ecosystems between land and sea (McKinley et al. 2018). Wales is thus a fitting location for applying the proposed framework, due to the local economic importance of saltmarshes, their potential to reduce flooding and erosion impacts and their prospective role in the implementation of recent legislation linked to well-being.

Welsh saltmarshes support basic ecosystem processes (e.g. geological processes, decomposition, ecological interactions and evolutionary processes), which underpin the intermediate ecosystem services (e.g. primary production, nutrient and water cycling, natural hazard regulation, waste breakdown, carbon sequestration) and final ecosystem services (e.g. species, ornamental materials, natural hazard protection, climate regulation, water supply, genetic resources, landscape) provided (McKinley et al. 2017 under review). These ecosystem services, with input from the four capitals (built, human, social and financial), generate benefits (based on McKinley et al 2017 under review) and disbenefits (based on a search of the literature and expert opinion; see below) for humans. Here we apply the framework developed (Figure 2) to standardise the well-being contributions made by saltmarshes. For each of the benefits and disbenefits we describe the current situation in Welsh saltmarshes, and, using the framework in Figure 2, we then link these to human well-being.

4.1 Saltmarsh benefits and health and well-being

This section describes the relevant ecosystem services underpinning each specific benefit that Welsh saltmarshes can provide, it outlines each of the benefits and then the well-being domains they affect. There is more information and understanding available for some benefits over others, highlighting areas for future academic research.

Equable and favorable climate

Saltmarshes are globally significant in terms of their capacity to sequester and store carbon at rapid rates (Chmura et al. 2003; Jones et al. 2008; Alongi 2012). Through high primary productivity and flow attenuation, saltmarsh plants sequester and store atmospheric carbon which derives in rapid soil development or sediment accumulation which results in deposition of waterborne organic carbon in deep peat layers (Artigas et al. 2015; Coverdale et al. 2014; Duarte et al. 2013; Shepherd et al. 2007). Moreover, given saltmarshes are flooded frequently, their soils are typically waterlogged and hypoxic (if not anoxic), which reduces the rate of carbon oxidation (Trevathan-Tackett et al. 2017). Sequestration rates in Welsh saltmarsh are estimated to range from 64 to 219 gC/m2/yr (Cannell et al. 1999; Chmura et al. 2003; Adams et al. 2012), equal to 2.35 - 8.04 tonnes CO^2/ha/yr. In addition to the sequestration of carbon Welsh saltmarshes hold considerable carbon stocks, estimated to be in the region of 660 tonnes (Beaumont et al. 2014).

The benefit of this carbon sequestration and storage service is the regulation of a stable and equable climate, from local to global scales (Nellemen et al., 2009; Irving et al., 2011; Pendleton et al., 2012). To facilitate trade-offs between different ecosystem services (and beneficiaries) this benefit can be valued monetarily using a proxy such as a carbon price. Beaumont et al. (2014) valued the ecosystem service of saltmarsh carbon sequestration by combining the previously calculated sequestration rates with the mid DECC (2011) CO2 price, calculating 2009 values of £34.56 – 118.26 per ha per year. If we assume an area of Welsh saltmarsh of 6950 ha in 2010 (Beaumont et al. 2014) this equates to a benefit value of £240,192 - 821,907 per year.

In terms of well-being, the benefit of equable and favourable climate is mainly linked to the *health* domain at a global scale through preventing the increase of the earth's surface temperature which has potential to change patterns water and food insecurity, disease, vulnerable human settlements, extreme climatic events, and migration (Hajat et al. 2014; McMichael 2013; Thomas et al. 2014). Without the maintenance of an equable climate vector-borne diseases could magnify their reach and death rates, more heatwaves are likely to occur, the burden from malnutrition, diarrhoea, and cardiorespiratory and infectious diseases might increase, as well as morbidity and mortality from a likely increased intensity, frequency and duration of extreme weather events such as heavy rainfall, flooding, storms and droughts (Singh 2010; Costello et al. 2009). *Social cohesion* may also be impacted if migration patterns are forced to change.

Reduced hazard risk

Saltmarshes have the potential to mitigate flooding in coastal areas by reducing erosion, wave and tidal energy, as well as storing flood waters (Möller 2006; Möller et al. 2014). Wave energy dissipation may be achieved by wave breaking, removal of plant and soil material from the marsh, and by drag from the vegetation canopy and topographic features associated with the marsh surface and margin (Möller and Spencer 2002). The efficiency with which the energy of moving water is absorbed (attenuation) varies with marsh continuity (Loder et al. 2009), vegetation community structure and with the density of vegetation canopy (Bouma et al., 2005). Marsh vegetation also has a shoreline stabilizing effect with respect to resistance of the marsh surface to erosion by waves (Möller et al. 2014; Ford et al. 2016). Several authors have found that the lessening in flow energy encourages sedimentation and allows a majority of saltmarshes to keep up with sea level rise (Morris et al., 2002; Kirwan and Temmerman, 2009; Goodman et al. 2007). These results suggest that large marshes with dense and productive vegetation will decrease wave energy and stabilise shores more effectively than deteriorated or severely altered marshes (Möller 2006).

Reduced hazard risk is arguably the most important location-specific benefit provided by saltmarshes. In Shepard et al.'s (2011) meta-analysis they found that wave attenuation is greater across marsh vegetation than intertidal mudflat. Although it was initially thought that, under storm conditions, water depth thresholds exist that may lessen the efficiency with which vegetation decreases wave energy (Möller et al. 1999), a large-scale flume experiment showed that, even under 2 meter water depths and storm waves, saltmarsh surfaces reduce wave heights by 15-20 % over a distance of only 40 meters. Up to 60% of this observed wave reduction is ascribed to the vegetation cover alone, with topographic roughness and bed friction at the sediment interface likely accounting for the remainder (Möller et al. 2014). The most important saltmarsh attributes for wave attenuation are thus vegetation density, height, and stiffness, marsh surface topographic variability and marsh width (Möller 2006).

Reduced hazard risk can be linked to five health and well-being dimensions: *health, social cohesion, safety and security, living standards,* and *life satisfaction and happiness*. Saltmarshes help mitigate the likelihood and/or severity of coastal flooding and in turn reduce the subsequent health impacts that might arise before, during and after a flood event; from potential risk to life, injury and physical health effects (e.g. asthma, gastrointestinal illness etc.), through to mental health impacts (e.g. sense of powerlessness, post-traumatic stress disorder, anxiety; Mason et al. 2010; Fewtrell and Kay 2008; Tapsell 2000) and loss of ontological security, i.e. stable mental state (Walker-Springett et al. 2017; Whittle et al., 2010; Tapsell and Tunstall, 2001, 2008). Flooding can also result in a number of adverse experiences, such as hindered or delayed travel, disturbed sleep patterns, relationship break-down, displacement and loss of place attachment to name a few, which have been shown to undermine life satisfaction and happiness amongst flood-affected individuals and communities (Walker-Springett et al. 2017; PHE 2017). In addition, people who experience flooding can lose confidence in the authorities responsible for responding to flood events (Tapsell 2000) reducing social cohesion. Living standards are also affected as flooding can cause the short- or long-term loss of public and private infrastructure (e.g. houses, bridges), utility assets (e.g. water systems, power stations), and livelihoods (Fenn et al. 2016; Almeida et al. 2016).

Military and industrial use

The relative inaccessibility and uncompromising terrain of saltmarshes make them ideal areas for military activities such as training areas, small arms fire or bombing ranges (Radley 1994; Jones et al. 2011). In Wales, several coastal military areas are used for practice in air-to-air combat manoeuvres, bombing and firing tests. These include, among others, the Air Defence Range at Manorbier Head on the Pembrokeshire coast, the Pembrey Sands Air Weapons Range, the Castlemartin firing range in Pembrokeshire (Ministry of Defence 2012) and firing and bombing range at Pendine in Carmarthenshire (National Trust 2003). Cardigan Bay is also a military practice area and there are some relatively small munitions dumping grounds off the coast of Pembrokeshire (UKMMAS 2010a; OGL 2015). Oil and gas facilities and pipeline construction, as well as electricity transmission and their landfall occur on saltmarsh (Jones et al. 2011), mainly the South Wales networks with terminals at Dragon and Milford Haven, Pembrokeshire (Morrell 2006).

Regarding well-being, this benefit is mainly linked to safety and security, in particular to physical national security; as well as for living standards, as these industries create employment locally and energy nationally. There may also be potential negative impacts arising from changes to place identity and loss of access.

Farmed food

Soil quality, underpinning livestock grazing, relates to the ability of soils to perform multiple functions as a component of a healthy ecosystem. In saltmarshes these functions include soils' capacity for plant productivity, water infiltration and retention, carbon sequestration, waste remediation, and erosion resistance. Soil organic matter (SOM) content has been related to many of these functions and is considered a key indicator of soil quality. In saltmarshes, SOM is sensitive to the length of time vegetation has been established (Pagès, unpublished data) and the species composition of vegetation (Ford, unpublished data, saltmarsh app.). It is also affected by the composition of sediment deposited by tides (deBattiste, unpublished data). Similarly, vegetation influences soil structure and microclimate, and introduces necromass which affect soil respiration (Raich and Tufekcioglu, 2000 in Duarte et al. 2013). Thus, both physical and biological factors combine to regulate soil quality. Soil quality can have important implications for the ability of saltmarshes to keep up with sea level rise, and the ability to provide fertile pasture for grazing livestock (Jones et al. 2011).

Pollination and disease and pest regulation are also important ecosystem services related to farmed food. It is estimated that insect pollination in the UK contributes £430 million to crop market value (Smith et al. 2011) and there is proof that wild pollinators are more important for this service than managed bees (Garibaldi et al. 2011, 2013). Pollination services increase with proximity to natural areas (Garibaldi et al 2011) and British saltmarshes support an extensive range of natural pollinators (e.g. Agassiz 2000; Ford et al. 2016; Ford unpublished data; Stenhouse 2005) which are likely to have local importance in providing pollination to neighbouring farm land. Saltmarsh can also provide habitat for predators offering natural pest control within the saltmarsh and for adjacent land and properties. However, as for pollination, the extent of these services in Wales is unknown (Jones et al. 2011).

Agricultural production of domesticated livestock on saltmarshes includes sheep and cattle for meat (Jones et al. 2011). There is evidence that livestock has been grazed on saltmarshes in the UK since neolithic and Bronze age (Barr and Bell 2016). Researchers estimate that 80% of Welsh saltmarsh is grazed (discussions by RESILCOAST and CoastWEB project partners, August 2017). Grazing occurs mainly on the upper saltmarsh grasslands where the soils are suitably developed to support richer vegetation. The sheep graze on plants such as saltmarsh grasses (e.g. common saltmarsh grass *Puccinellia maritima*, red fescue *Festuca rubra*) samphire (*Salicornia* sp.), sea lavender (*Limonium* spp.) and thrift (*Armeria maritima*) (http://www.foodadventure.co.uk/partner/ gower-salt-marsh-lamb/). In Wales the production of beef and lamb is worth £596.6m per annum (Statistics for Wales 2016); with 8.8 million sheep, three times the number of people (BBC 2013). Saltmarsh grazing produces meat products with a unique taste which are sold on average at 100% more than other meat (Jones et al. 2011), such as from the Gower. Sales of saltmarsh lamb are reported to be increasing, as TV chefs have promoted the product for its quality and flavour (http://www.itv.com/news/wales/2015-07-03/tv-chefs-boost-sales-of-welsh-trademark-salt-marsh-lamb/).

Farmed food has a direct effect on the health, via the provision of food high in protein; as well as on living standards through income generation for saltmarsh farmers who can sell lamb and beef at a premium.

Wild food

Saltmarshes are key environments for estuarine biodiversity, with high primary production, supporting many habitats for shelter,feeding, mating, nurseries, reproduction and migration bases (Williams et al. 1994; Doyle and Otte, 1997; Vinagre et al., 2008; Cacador et al., 2009). In the UK, they provide nursery grounds or migratory routes for high importance commercial marine fisheries, including European seabass (*Dicentrarchus labrax*), sea trout (*Salmo trutta*), Atlantic salmon (*Salmo salar*), European flounder (*Platichthys flesus*), grey mullet (*Chelon labrosus*), among others (Colclough et al. 2004; Jones et al. 2011).

This benefit includes three main wild food groups coming from saltmarshes: plants, fish, and game. Although there is not much information on the fish benefits, a study on Essex saltmarshes found that commercially important species, such as Atlantic herring (*Clupea harengus*) and European bass (*Dicentrarchus labrax*), comprised 45.5% of fourteen species caught (Green et al. 2009 in Jones et al. 2011). Wildfowling is a popular sport in Wales (for meat: Marchington 1980, or sport) with a long history of hunting associated with saltmarshes which play an important part in the life cycle of many species of wildfowl. The wildfowling seasons are 1st September – 31st January above the mean high water mark and 1st September – 20th February below the mean high water mark. The quarry species in Wales include ducks (gadwall goldeneye, mallard, northern pintail, common pochard, northern shoveler, Eurasian teal, tufted duck, and Eurasian wigeon), geese (Canada, greylag, pink-footed and white-fronted), waders (common snipe, Eurasian golden plover, Eurasian woodcock), and others (Eurasian coot, common moorhen). The British Association for Shooting and Conservation (BASC) encompasses wildfowling clubs all over the UK including 19 in Wales, such as the Wentloog Wildfowlers (http://wentloogwildfowlers.co.uk/about-us-2/), the Dyfi, Mawddach and Dysynni Wildfowlers' Association (http://www.dyfimawddachwildfowlers.org.uk/), and The Dee Wildfowlers and Wetlands Management Club (http://www.deewildfowlers.co.uk/).

A varied range of plants are gathered informally for use as foraged wild food throughout the UK, such as Samphire (*Salicornia spp.*), Sea Aster (*Aster tripolium*), Sea purslane (*Atriplex portulacoides*). Commercially, samphire is sold as a luxury item at £3.50/kg (Jones et al. 2011) and there is also a small-scale, recreational harvesting of common samphire by individuals and groups. Saltmarsh foraging happens in many places in Wales, such as near Portmeirion village North Wales and Pembrokeshire estuaries (accessed 31.07.17): www.goforaging.co.uk/; www.countryfile.com/explore-countryside/food-and-farming/what-forage-wales; www.wildaboutpembrokeshire.co.uk/walks/; https://tastethewildblog.co.uk/2012/09/14/filming-on-the-gower-mangalitsa-pork-and-salt-marsh-vegetables/). Beyond food, saltmarshes can potentially provide ornamentals, pharmaceuticals, or genetic resources. However, if any, these are still poorly understood but are worth exploring and conserving for future medical and industrial use (Picard 2017).

The benefit of wild foods contributes to well-being in five domains: health, connection to nature, social cohesion, spiritual and cultural fulfilment, and living standards. The *health* domain is affected through the provision of organic food. Wild foods also contribute to *connection with nature* and *social cohesion* as they are often done by groups of people with a common mind-set of living in a closer relationship with nature. Wildfowling and fishing clubs can also be linked to *spiritual and cultural fulfilment* as they are often family or societal traditions. When obtained for commercial purposes, fish and game can contribute to *living standards* by income provision.

Recreation

Most, if not all, ecosystem services from saltmarshes underpin the benefit of recreation, particularly wild species diversity, which refers to high diversity, or rare/unique plants, animals, and insects. Saltmarshes are notable for hosting wild species found exclusively in these unique coastal habitats. UK saltmarshes host around 40 species of higher plants, which are largely restricted to this habitat and occur within 28 distinctive saltmarsh plant communities (Rodwell 2000). Greater diversity is found among the invertebrate fauna of saltmarshes which comprises around 290 resident species, almost 150 of which are restricted to saltmarshes (Doody, 1992). There are significant populations of eyebright (*Euphrasia heslop-harrisonii*), ground beetles *Amara strenua* and *Anisodactylus poeciloides*, natterjack toad, narrowmouth whorl snail (*Vertigo angustior*) and endemic sea-lavenders (2 *Limonium* species) (Jones et al. 2011), all UK BAP priority species, on saltmarsh. The UK's estuaries are internationally important for the huge numbers of overwintering waterbirds (Cayford & Waters 1996; Rehfisch et al. 2003). Some meadowland bird species also make intensive use of saltmarsh habitats; such as Eurasian oystercatchers, northern lapwing (Allport et al. 1986), common redshank (Green et al. 1984) and twite (Davies, 1987). Guette et al. (2016) highlight the importance of preserving the oldest and the least deteriorated saltmarsh areas to conserve their associated biodiversity.

Recreation on or overlooking saltmarshes includes opportunities for exercise, dog-walking, hunting, cycling, horse-riding, fishing, wildlife/ bird-watching, boating and picnicing (Jones et al. 2011), among others; as well as wildfowling, fishing and foraging (mentioned above). There is a strong tradition of coastal tourism in Wales, particularly seaside tourism in North and South West Wales that supports half of all tourism (Welsh Assembly Government 2008a; OGL 2015). In a 2012 Welsh survey (WWF Cymru 2012) three out of four people (75%) agreed that the Welsh coast is an important part of their life. The most popular reason for visiting the coast is to walk along it (61%) and the 3rd most important is wildlife spotting (20%). Saltmarshes are the most valued habitat by birdwatchers (Jones et al. 2011). These findings are probably linked to the creation of more coastal paths as part of the Wales Coast Path (opened in 2012) which passes over or close to many saltmarshes around the country (see map on http://www.walescoastpath.gov.uk/plan-your-trip/wales-coast-path-maps/?lang=en; WWF Cymru 2012). In Wales, there are many saltmarshes designated as Sites of Special Scientific Interest (SSSI), Special Areas of Conservation (SAC), Special Protection Area (SPA) or Ramsar sites (Jones et al. 2011), such as the Carmarthen Bay and Estuaries SAC and the Dyfi Estuary. Visitors are often interested in natural history and have a tendency to stay by the landward edges of saltmarshes (Manly 2004; Jones et al. 2011). A national study in Wales (Henke and Petropoulos 2013) found that Gwynedd, Denbighshire and Merthy Tydfil had the largest recreational areas. The Ruiz-Frau et al. (2013) recreation study estimated the total expenditure obtained from seabird watching in Wales was £3.7million per annum. Three areas were highlighted as the most popular for recreation activities: around the Isle of Anglesey, the Llŷn Peninsula and the Pembrokeshire coast.

Recreation refers to hands on activities in situ at the saltmarsh, thus influencing five well-being domains: health, social cohesion, spiritual and cultural fulfilment, connection to nature and life satisfaction and happiness. Recreation can improve physical and mental health which in turn increases life satisfaction and happiness; in group or family settings it can contribute to social cohesion; traditional activites enhance cultural fulfilment; and often a connection to nature is forged.

Aesthetics

The saltmarsh landscape is underpinned by specific bio-physical characteristics (supporting and regulating ecosystem services) that determine its potential aesthetics on it. For instance, saltmarshes are dynamic ecosystems which experience changes in extent, elevation, internal morphology and vegetative cover over time. In the past, the main value ascribed to saltmarshes was for restricted agricultural use or as key wildlife areas, mainly of interest to bird watchers or wildfowlers (EA 2007). Although still challenging to measure, the aesthetic benefits from saltmarshes are likely to be substantial.

Aesthetics refer to sense of place, memories, peace, solitude, emotional healing, folklore, natural and cultural heritage, archaeology, religious/cultural sites, World Heritage Sites, and inspiration for art (e.g. books, photography) (Jones et al. 2011). A 2000 Ipsos MORI study for English Heritage and later work for Historic England (2016) evidenced that most every aspect of the environment has value for someone through personal memories and attachments. It is likely that similar findings apply to Wales also (NPW 2013). Swetnam et al. (2017) studied the visual aesthetics of landscape quality in Wales, focusing on assets of cultural, emotional and physical importance to both locals and visitors (Kara 2013). High Visual Quality Index (VQI) values were high in Snowdonia National Park (NP), the coast of Llŷn Peninsula and Anglesey; which have long-term protection as national parks. Contrastingly, Pembrokeshire Coast National Park and the south coast of Wales as a whole are apt to to report low VQI values. These areas are more densely populated, including the cities of Swansea, Cardiff and Port Talbot, as well as areas with a long history of heavy industry (e.g. coal mining, steel-making). Here, the coast is often aesthetically pleasing but includes human features (e.g. infrastructure, road networks) which lower the VQI index. It is important to note though that aesthetic quality changes with time, context and onlookers (Gobster et al. 2007).

Saltmarshes are natural habitats with astounding landscapes that have been captured in art and literature for a long time (McInnes and Benstead 2013). Saltmarshes are usually linked with wild geese and ducks and hunting of these birds (e.g.work by Sir Peter Scott, The Snow Goose book by Paul Gallico; Jones et al. 2011). In Wales, examples include the filming of parts of the 'Taste the Wild' DVD on the Gower Peninsula featuring the saltmarsh (accessed 31.07.17; https://tastethewildblog.co.uk/2012/09/14/ filming-on-the-gower-mangalitsa-pork-and-salt-marsh-vegetables/); the Laugharne Heritage Walk with many historical associations and Dylan Thomas' (writer and poet) Birthday Walk (accessed 01.12.17; http://laugharnetownship-wcc.gov.uk/heritage-trail/); and Prehistoric human and animal footprints fossilized on what used to be a saltmarsh at Borth in Ceredigion (http://heritageof walesnews.blogspot.co.uk/2012/03/prehistoric-landscape-uncovered-at.html).

This benefit has the potential to contribute to four well-being domains: (mental) health by increasing feelings of peace and sense of place; spiritual and cultural fulfilment through the presence and experience of places with cultural and spiritual significance; connection to nature; and life satisfaction and happiness by, for instance, instances of emotional healing.

Education

Saltmarshes are extremely productive ecosystems (Adam 1993), transferring huge amounts of available carbon and energy into the water column and so form the foundation of a rich estuarine ecosystem. Saltmarshes have a varied and abundant fauna composed of marine, freshwater and terrestrial species which have adapted to a salty, tidal environment. They are also a very important habitat for birds which use them for a variety of purposes, including feeding and breeding. Saltmarshes are important ecosystems for humans due to their processes involving interactions of all their soil, water, flora and fauna elements (Stuip et al., 2002; EA 2007). These processes are valued as a resource for general education, scientific and historic discovery and environmental monitoring (English Nature 2002).

This benefit includes formal and informal learning on saltmarshes (Jones et al. 2011), from foraging courses to school and university fieldtrips. Although there is no national level summary of this benefit for Wales, there are many cases that can be mentioned for teaching about saltmarsh ecology, birds, geomorphology, wildlife, among others. For example, The Dale Fort Field Studies Council (FSC) in Pembrokeshire teaches school groups at the Gann saltmarsh (K. Davidson, personal communication; http://www.field-studies-council.org/centres/dale-fort.aspx). The Orielton FSC Field Centre in Pembrokeshire for teaching saltmarsh succession at Bentlass saltmarsh. Regarding formal education, several universities teach on saltmarshes, such as Aberystwyth University, The School of

Ocean Sciences of Bangor University, University of Swansea, and the School of Earth and Ocean Sciences of Cardiff University (The latter two use the Laugharne and the Welsh Severn Estuary saltmarshes for undergraduate fieldtrips). The University of Liverpool also teaches in Welsh saltmarshes (Dr R. Ballinger and Dr John Griffin, personal communication).

Education can have indirect links to three well-being domains: health, through the development of cognitive abilities; connection to nature, through field trips; and living standards, through potential increased employment options from learning experiences.

4.2 Saltmarsh disbenefits and health and well-being

This section describes the relevant ecosystem services underpinning each identified disbenefit that Welsh saltmarshes can provide, it outlines each of the disbenefits and then the well-being domains they affect. There is little information and understanding available for disbenefits, compared to benefits, highlighting areas for future academic research. As shown in Figure 3, it is important to keep in mind that most disbenefits accrue at the local level by individuals actually in a saltmarsh, unlike the benefits that have a wider area of impact and can be perceived ex situ.

Pollutant transmission

Saltmarshes are key areas for biogeochemical cycling and sediment deposition which encourage water filtration by waste breakdown (or detoxification) and immobilisation (Andrews et al. 2006; Andrews et al. 2008; Boorman 2003; Mitsch and Gosselink, 2007). They also retain or remove nutrients from all incoming water sources (Jones et al. 2011), particularly near urban, agricultural and industrial areas (Hwang 2006; Jones et al. 2011). Saltmarsh vegetation is crucial to these roles, as it captures particles by increasing settling or by providing a place for particle adhesion (e.g., Stumpf, 1983; Leonard et al., 1995; Huang et al., 2008; Saiers et al., 2003; Kadlec and Wallace, 2008; Elliott, 2000). Gravitational settling is the main driver for capturing medium to large particles under representative flow situations (e.g., Leonard et al., 1995; Mudd et al., 2010), and adhesion to plant stems drives the trapping of fine particles (e.g., Huang et al., 2008; Fauria et al 2015). Plant roots and microrganisms are also important for processes like nitrification, denitrification (Sousa et al., 2012; Rauch and Denis, 2008; Duarte et al. 2013), iron and sulphide oxidation, and phosphorous cycling (Zak et al. 2008). Different saltmarsh plant species can display different behavior in remediation applications (Carvalho et al. 2011).

Although waste breakdown is a service provided by saltmarshes, it can also result in the disbenefit of waste or pollutant transmission through food chains with still understudied effects on wildlife and humans. According to OSPAR’s criteria, metal concentrations in Welsh coastal sediments tend to be elevated, particularly in heavily industrialised estuaries such as the Severn and Dee, with high concentrations reported for mercury, lead, zinc, arsenic and nickel (Environment Agency 2013). A range of chlorobiphenyls are present in sediments in the Severn and Dee estuaries and high concentrations of Polycyclic aromatic hydrocarbons (PAH) have been reported for the Bristol Channel (Marine Environment Monitoring Group (MEMG) 2004). Measurements of chlorobiphenyls in mussel tissue (*Mytilus edulis*) and fish liver (plaice, dab, whiting and flounder) were assessed against OSPAR criteria, suggesting exceedances within the Severn Estuary and northeast Wales (i.e. Dee Estuary). In addition, concentrations of one particular chlorobiphenyl (CB118) in fish liver were reported above the criteria in Cardigan Bay. The highest UK concentrations for most brominated diphenyl ether congeners in fish were reported in the Irish Sea, amongst other UK regions (UKMMAS 2010b).

Although still understudied, there are potential negative health effects of stored pollutants that are transferred to humans via saltmarsh food items (Jones et al. 2011).

Irritation from animals

A total of 34 different mosquito species have been recorded in the UK, including two which have been recognised recently (Medlock & Vaux 2010). These include six species in the sub-family Anophelinae, all in the genus Anopheles, and 28 in the sub-family Culicinae in seven genera: *Aedes* (3), *Coquillettidia* (1), *Culex* (4), *Culiseta* (7), *Dahliana* (1), *Ochlerotatus* (11) and *Orthopodomyia* (1). The aquatic breeding areas used by mosquitoes vary substantially, including saline pools in saltmarshes (Medlock et al. 2012). Mosquitoes are very responsive to variations in temperature and rainfall; as well as water availability that impacts the survival and abundance of young mosquitoes. The (non-)permanence of water bodies also impacts on mosquito competitors and predators. Thus, any climatic or human changes to water habitats will impact mosquito diversity and density (Medlock and Snow 2008; Medlock and Vaux 2011, 2015).

A main shortcoming of saltmarshes is their potential role as habitat for nuisance biting insects (Ramsdale and Gunn 2005; see Welsh example at http://www.walesonline.co.uk/news/wales-news/change-climate-sets-scene-mosquitoes-2232740, accessed December 7th, 2017). The main nuisance insects linked to salty habitats such as saltmarsh are: *Ochlerotatus detritus* (Service 1968) and to a lesser extent *Anopheles atroparvus* (part of the *Anopheles maculipennis* complex) and *Oc. caspius*. *Oc. detritus* has been recently linked to nuisance incidences at certain places in the UK (e.g. Dee estuary on the Wirral). Out of nine Welsh local authorities surveyed in 2009, only Wrexham reported nuisance biting by mosquitoes in the previous ten years by *Oc. cantans*, *Cx. pipiens s.l.*, *Cs. annulata*, *Anopheles sp.* (Medlock et al. 2012). Sometimes nuisance biting mosquitoes have affected the local community and decreased tourist numbers, e.g. at Merseyside residents had to seek medical help for excessive, infected bites (ECHO 2014). As above, not only natural saltmarshes, but also managed realignment schemes and flood risk management should plan for dealing with nuisance species (Medlock and Vaux 2015). The interdisciplinary WetlandLIFE project (http://wetlandlife.org/) aims to understand how best to manage mosquitoes and the socio-ecological value of wetlands in England for well-being.

As discussed above, insects such as mosquitoes can be quite a nuisance resulting in negative effects on people's connection to nature (e.g. by discouraging visits to nature) and life satisfaction (especially if at place of residence). Likewise, when the problem of mosquitoes grows in magnitude it can also have implications for physical health generating infections or allergic reactions.

Refuge for vector diseases

Since the late 90s there has been a lot of concern in Europe on the role of native and non-native mosquitoes in the transmission of illnesses to humans (ECDC 2013). Recently, the West Nile virus has been transmitted to humans across large expanses of the Eastern and Central Mediterranean. Mosquitoes in Europe transmit two arboviruses cyclically: Sindbis virus in Scandinavia (Ahlm et al. 2014) and Tahyna virus in the Dyje and Danube river areas (Hubalek et al. 2010). They also have transmitted *Plasmodium vivax* malaria in Greece (ECDC 2011), African flaviviruses such Usutu virus in central Europe (Stiasny et al. 2013), and now the prospect of European transmission of Rift Valley fever virus is a serious concern (Chevalier et al. 2010). The arrival of non-native invasive mosquitoes (e.g. *Aedes albopictus, Aedes aegypti, Aedes japonicus*) and their part in European transmission of dengue and chikungunya viruses is also a reason for public health concern (Schaffner et al. 2013).

So although not reported in recent decades in the UK, there is concern for the potential for mosquito-borne disease transmission in the UK (Medlock and Vaux 2015; Golding et al. 2012) and saltmarshes could provide the habitat. Out of the 34 mosquito species in the UK (Medlock & Vaux 2010, 2015), seven are associated with coastal habitats where they lay their larvae in brackish and saline water. There are three marshland mosquito species have the vectorial capacity to transmit viral pathogens to humans and livestock (Medlock and Vaux 2015; Blagrove et al. 2016; Mackenzie et al. 2015). Thus, natural saltmarsh and managed realignment schemes and flood risk management should plan for dealing with this potential public health risk (Medlock and Vaux 2013, 2015).

Besides the obvious potential health impacts, this disbenefit could also affect the life satisfaction and happiness of coastal residents and visitors that contract a disease.

Danger to human and animal life

Saltmarshes are dynamic habitats characterised by constant changes through time in most if not all aspects, including size, elevation, internal morphology and vegetative cover. Saltmarsh changes occur at varied temporal and spatial scales, both due to the dynamic nature of its processes and external influences, e.g. tidal range, climate, and human activities. It is only when saltmarshes are over 100 years old that they are considered quite stable in relation to the local tide and average sea level. Young saltmarshes however are still in flux which will eventually lead to stability (EA 2007). The above characteristics, among others, create a landscape that presents people and animals (specially livestock, but also pets) with risks of getting stuck, falling, drowning or being caught by high tide. Although these risks are minor, it has been found that for most people saltmarshes are considered unsafe and unwelcoming (EA 2007).

The potential impacts on well-being from these risks, include death (safety and security and health domains), a loss of connection to nature, reduced life satisfaction and happiness, and loss of livesotck (impacting living standards).

Allergy from pollen

Saltmarshes are notable for hosting wild species found exclusively in these unique coastal habitats. UK saltmarshes host around 40 species of higher plants, which are largely restricted to this habitat and occur within 28 distinctive saltmarsh plant communities (Rodwell 2000). Examples include mud flat plants: eelgrass (*Zostra* spp.) and Spartina species, lower saltmarsh species such as sea aster (*Aster tripolium*), samphire (*Inula crithmoides*) and sea blite (*Suaeda maritima*), middle marsh species such as common sea-lavender (*Limonium vulgare*) and sea plantain, and more common species found above high tide level such as sea rush and *Phragmites* (http://www.field-studies-council.org/publications/ pubs/saltmarsh-plants-identification-chart.aspx; Adam 1993).

Allergenic pollen is generated throughout the UK by many trees, grasses and weeds. Many Welsh saltmarshes harbour high concentrations of wind-pollinated plants such as saltmarsh rush (*Juncus gerardii*) which release clouds of lightweight pollen, triggering an allergic reaction in hay fever sufferers (K. Davidson, pers. comm). Pollen can travel long distances (D'Amato et al. 2007) so this can affect the health of coastal residents and visitors. More information is needed to assess the magnitude of this disbenefit.

Allergy from pollen is a common disbenefit from nature that impacts on health (allergic rhinitis or hay fever, exacerbation of asthma in susceptible individuals, and atopic dermatitis; Cecchi 2012; McInnes et al. 2017), connection to nature (i.e. people might opt to stay indoors), and life satisfaction and happiness (e.g. annoying and persistent symptoms).

Limited or lack of use and limited access

Saltmarshes are relatively inaccessible with uncompromising terrain (Radley 1994), normally constituted of mud or fine sand that can be firm or sludgy and unstable. They are dynamic ecosystems that constantly experience changes at different time scales due to tidal ranges all the way to climatic events. Saltmarshes consist of unconnected networks of tidal creeks that are flooded by the tide, with an upward vegetated platform (EA 2007). In order to make saltmarshes accesible, there has been a history of land reclamation in the UK (i.e. embanking saltmarsh for agricultural and industrial uses), which began in several areas in Roman times (EA 2007).

The use of the saltmarsh is often perceived as limited, for example recreation and access, can be viewed as two competing factors (Myatt-Bell et al. 2002). Furthermore, studies have found that in planned cases of saltmarsh extension (managed realingment) there is a pervading concern for retaining public access by the local community and other interest groups (Ledoux et al. 2005), such as at Brancaster West Marsh in North Norfolk (Myatt-Bell et al. 2002) and Cwym Ivy on north Gower (https://naturalresources.wales/about-us/our-projects/cwm-ivy-marsh-habitat-creation-project/?la ng =en).

This disbenefit may impact peoples' connection to nature and living standards (e.g. if unable to use saltmarsh for productive use).

Negative perceptions
People can have negative perceptions towards saltmarsh characteristics underpinned by an array of ecosystem services. For instance, the muddy substrate, the tidal range, lack of trees, flatness, network of creeks, among others.

This disbenefit can include an array of issues, mainly the perception of saltmarsh as an unpleasant or boring landscapes (e.g. wasteland, bleak, murky), having unpleasant smells, generating fear of the possibility of drowning or getting stuck. Although no written records of these negative perceptions were found for Wales, they do occur elsewhere (for example see "In the Salt Marshes, Beware" article in the New York Times, accessed 13th December 2017 http://www.nytimes.com/1990/08/26/ nyregion/l-in-the-salt-marshes-beware-795790.html).

People with negative perceptions towards saltmarsh may feel affected in their connection to nature and life satisfaction and happiness.

5. *Starting to understand disbenefits and benefits of Welsh saltmarshes*

Understanding the biophysical, social, economic and political settings where disbenefits can be effectively reduced through ecosystem management is crucial for enhancing human well-being (see Figure 4 for summary of links between disbenefits and benefits and well-being). Up till now, this challenge has not been properly considered and is a clear gap in our understanding of the links between ecosystems and human well-being (Ninan and Inoue 2013; (Shackleton et al. 2016). Consequently, disbenefits are expected to entail diverse policies and actions to both natural and social threats (Shackleton et al. 2016).

Table 2 lists the benefits and disbenefits generated by Welsh saltmarshes, and through the application of the framework (Figure 2) associates these benefits with the well-being domain(s) they impact.

Table 2. Benefits and disbenefits, and their associated human well-being domains, identified for Welsh saltmarshes.

Benefits	Disbenefits	Wellbeing domain
▪ Equable climate ▪ Farmed food ▪ Wild food ▪ Recreation	▪ Pollutant transmission ▪ Allergy from pollen ▪ Irritation from animals ▪ Refuge for vector diseases	**Health**

▪ Aesthetics	▪ Danger to human and animal life	
▪ Aesthetics ▪ Recreation ▪ Education		**Social cohesion**
▪ Education ▪ Recreation ▪ Aesthetics	▪ Irritation from animals ▪ Danger to human and animal life	**Spiritual and cultural fulfilment**
▪ Wild food ▪ Education ▪ Aesthetics ▪ Recreation	▪ Irritation from animals ▪ Allergy from pollen ▪ Negative perceptions ▪ Limited or lack of use/access	**Connection to nature**
▪ Military and industrial use ▪ Reduced hazard risk	▪ Danger to human and animal life ▪ Limited or lack of use/access ▪ Negative perceptions	**Safety and security**
▪ Farmed food ▪ Industrial use	▪ Danger to human and animal life ▪ Limited or lack of use/access	**Living standards**
▪ Reduced hazard risk ▪ Wild food ▪ Aesthetics ▪ Recreation ▪ Education	▪ Negative perceptions	**Life satisfaction and happiness**

It is important to note that not all benefits and disbenefits accrue homogeneously to all users at the same magnitude of (positive or negative) impact on society and in the same spatial scale. They are heterogeneous in space and evolve through time (Fisher et al. 2009), and as a result the accompanying well-being influences will also vary. Figure 3 provides a conceptual matrix of saltmarsh benefits and disbenefits that classifies them by user, magnitude and spatial scale of impact. For example, farmed foods are considered to be a benefit to residents, visitors and further afield up to the national level with a mid-range magnitude. The figure also provides three examples of potential temporal shifts due to climate change or management efforts. For instance, there is currently no report of vectors for diseases on saltmarsh but current studies expect this to change with increased marsh creation to mitigate climate change (Medlock and Vaux 2015).

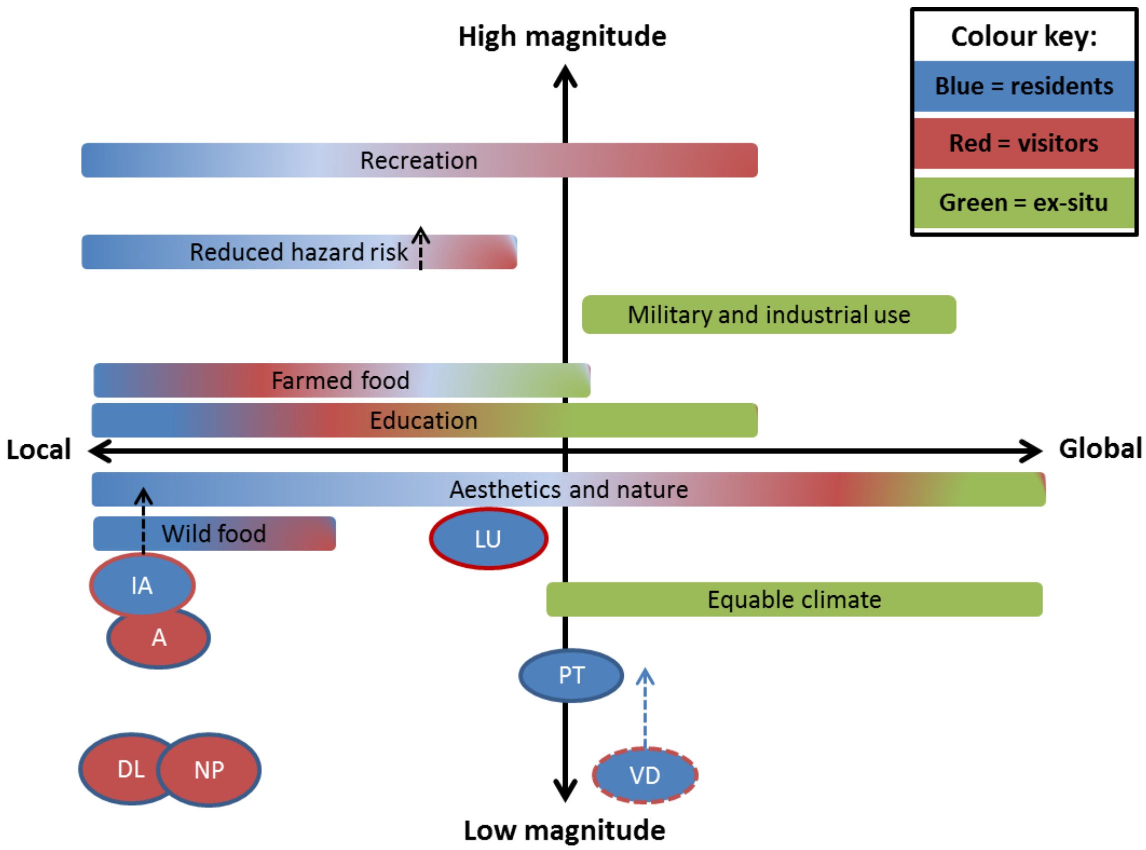

Figure 3. Matrix of benefits (rectangles) and disbenefits (circles) from saltmarshes per user-type (colour) over magnitude and spatial scale; intermittent lines/arrows= potential temporal change; A=allergy, DL= danger to human and animal life, IA= irritation from animals, LU= Limited or lack of use/access, NP= negative perceptions, PT=pollutant transmission, VD= refuge for vector diseases.

6. Conclusions

This research advances and exemplifies the linkages between ecosystem services and human well-being, with important insights for environmental and health policy. An integrated framework was developed by adapting and linking the UKNEA-FO framework with Smith et al.'s (2013) comprehensive human well-being domains. The notion of disbenefits was incorporated into the framework as it is necessary to recognise the potentially detrimental effects from interacting with nature. Disbenefits have no universal typology and have not allowed for an explicit comparison to benefits. Benefits and disbenefits occur at the social-ecological interface so we classify them by the domains of well-being they affect. We further employ seven domains of well-being from Smith et al. (2013): health, connection to nature, life satisfaction and happiness, living standards, safety and security, social cohesion, and spiritual and cultural fulfilment. The selected domains do not conflict with ecosystem benefits but are the result of these.

Accounting for disbenefits and benefits specifically increased understanding in the differences in magnitude of their impact on society, spatial scale, and users (depending on factors such as a person's knowledge, personal values and agenda). Saltmarsh benefits mainly accrue at larger scales with a greater magnitude (e.g. reduced hazard risk) affecting local to global individuals, while disbenefits tend to occur at a smaller scale and magnitude affecting in-situ individuals only. Through trialling our integrated framework on Welsh saltmarshes it is evident that, by including the disbenefits and explicit well-being domains, this approach enables the greater inclusion and understanding of the well-being from the natural environment, in this case saltmarsh. Previous literature has struggled to account for the well-being attributes of saltmarshes in a structured and objective fashion, and this approach overcomes this barrier, resulting in the first comprehensive assessment of the well-being associated with saltmarshes.

Future areas of research can include the translation of the proposed framework into a decision support tool to help public agencies deliver well-being objectives. In Wales specifically, such tools could facilitate the implementation of the Well-being of Future Generations (Wales) Act 2015 and the production of local well-being assessments. More widely, we recommend the application and verification of the proposed framework in different socio-cultural settings worldwide. Whilst further research is required, this framework represents an important stepping stone for advancing holistic assessments of well-being in future ecosystem services research.

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