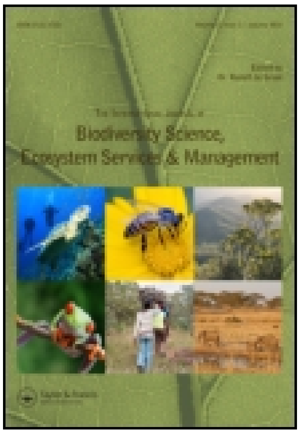

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Conceptualizing the link between marine ecosystem services and human well-being: the case of offshore wind farming

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Conceptualizing the link between marine ecosystem services and human well-being: the case of offshore wind farming

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Although the concept of ecosystem services has drawn a prolific amount of recent research, little work has been done on the links between marine ecosystem services and coastal human well-being at a regional scale. Key questions in this context are that of appropriate categories for assessing human well-being and how to link different determinants of human well-being to specific ecosystem services supplied in adjacent marine areas. This paper presents the results of a case study that links tangible and intangible ecosystem benefits to a range of material and immaterial factors constituting human well-being. Determinants of human well-being were defined and indicators selected to make these linkages traceable. Ecosystem services were assessed for the offshore environment along the west coast of Schleswig-Holstein, Germany, based on the assumption of strong future development of offshore wind farming and considering the environmental and socio-economic impacts of such developments on the coastal region. This paper illustrates some conceptual problems in linking ecosystem benefits to human well-being. Based on an economic analysis and a questionnaire survey, two examples are presented where an evidence-based link could be demonstrated between an ecosystem service impacted by offshore wind farming and change in human well-being. The results presented should be understood as an analytic framework and precondition for gathering empirical data.

Keywords: marine ecosystem services; offshore wind farming; human well-being; quality of life; objective living conditions

Introduction

Ecosystem services have become a highly prominent research field during the recent years (Fisher et al. 2009). Complex ecological processes and structures can be translated into functions and services, which in turn can be linked to individual livelihoods or societal well-being (Haines-Young and Potschin 2010). A considerable body of research addresses the valuation, measurement and depletion of ecosystem services (a good review on the current state-of-the-art is provided by de Groot et al. 2010). However, research on human well-being in the context of ecosystem services, and the impacts of changes in ecosystem services on elements of human well-being, is still underrepresented in current research. One reason may be conceptual in nature, related to the difficulty of establishing a solid link between human well-being and changes in ecosystem services. In order to trace changes in ecosystems all the way through to measurable impacts on human well-being, a proper distinction is thus needed between ecological processes and functions, ecosystem services, the benefits these may yield, and finally, determinants of human well-being, together with appropriate data and evidence for causalities between the respective changes. Boyd and Banzhaf (2007), Fisher and Turner (2008) or Burkhard et al. (2010) illustrated an ongoing conceptual discussion of key ecosystem services terms. This paper clearly distinguishes ecosystem services from the benefits they provide. Whilst the processes and structures of natural systems do provide specific ecosystem services, the benefits that spring from them are demand led, arising from the active utilization of the available services for a human good. Ecosystem services are a necessary precondition for deriving ecosystem benefits, but it is ecosystem benefits which in their unity contribute to human well-being.

While the ecosystem-related elements of the above supply-beneficiary chain are comparatively well researched, the same does not apply to the human well-being side. The Millennium Ecosystem Assessment (MEA) recognizes security, the basic material for a good life, health and social and cultural relations as the main determinants of human well-being, which in turn are influenced by the freedoms and choices available to people (MEA 2005, p. VI). It then argues that the provision of services depends on the state of the ecosystems in question – with human intervention capable of either amplifying or reducing the benefits available to human society. Importantly, the MEA (2005) also argues that the experience of such benefits and therefore human well-being is dependent on context and situation. Although the MEA (2005) does not say so explicitly, it is obvious in all the categories put forward by the MEA that human well-being is never just a structural issue – which is a precondition for realizing certain values – but also a matter of subjective judgment and experience. In tackling the ecosystem services–human well-being

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Figure 1. Conceptual model of ecosystem services in marine areas and human benefits/well-being in coastal areas (own design, Benjamin Burkhard).

relationship, two issues therefore need to be dealt with: First of all, a context-dependent definition needs to be provided for the constituent determinants of human well-being. Secondly, relationships need to be built between determinants of human well-being and the benefits that ecosystem services provide.

Literature provides some approaches for defining and measuring the benefits provided by ecosystem services. This, however, has so far mostly focused on the tangible benefits provided by ecosystems and the material determinants of human well-being. An example is the income or employment generated from utilizing provisioning ecosystem services (Postel and Carpenter 1997). But ecosystem services also produce intangible benefits, which are difficult to measure and contribute to human well-being in a non-material, altogether personal and subjective way. Some links have been established between the benefits arising from cultural ecosystem services and personal satisfaction and pleasure (e.g. Gee and Burkhard 2010; Schaich et al. 2010); in addition, a large independent body of research exists on similar 'intangibles' dealing with the satisfaction derived from experiencing nature, landscapes or wildlife (Xu and Bengston 1997; Lothian 1999; Vining 1999; Dietz et al. 2005; Harshaw and Tindall 2005; Ignatow 2006).

In this paper we argue that full assessment of human well-being must comprise economic, social and personal well-being, and that the material and immaterial determinants of human well-being must be linked back to ecosystem services and related benefits. The significance of ecosystem benefits for human well-being is best demonstrated in situations of change, where a shift takes place in the ecosystem services provided, where the range of available benefits might conceivably alter, and where trade-offs may be required between different benefits and consequently different impacts on human well-being. Our case study is an attempt at establishing links between ecosystem benefits and human well-being, using the advent of offshore wind farming in the German North Sea off the coast of Schleswig-Holstein as a case study example. Specifically, the case study seeks to

(1) identify the impacts of offshore wind farms on (a) ecological structures and processes and (b) the provision of ecosystem services and
(2) identify and conceptualize how and via which channels change in ecosystem benefits affects human well-being.

After a brief overview of the expected impacts of offshore wind farming on marine ecosystem services (for a full review see Lange et al. 2010), the remainder of this paper focuses on the question of how changes in the supply of ecosystem services affect human well-being and how such impacts can be traced and measured. Information and results presented in this paper were generated applying a diverse set of methods from social, natural and economic sciences. To avoid a heterogeneous listing and to stress the conceptual nature of this paper, methods are mentioned within the text when they become relevant for understanding the argumentation.

Our approach is framed by a simplified version of the five-step ecosystem service 'cascade' suggested by Haines-Young and Potschin (2010) (Figure 1). Here, the ecological integrity of the North Sea ecosystem (i.e. its functioning as described by present ecosystem structures and processes) serves as a basis for regulating, provisioning and cultural services, which in turn yield benefits to humans and thereby influence human well-being (economic, social and personal well-being). Benefits manifest themselves in the adjacent coastal region through demand and can be based on utilitarian or non-utilitarian values (including intrinsic values). The service 'producing' areas in the sea (after Fisher et al. 2009) in this case are spatially distinct from the coastal areas where the beneficiaries are located.

Since most offshore wind farms in the German North Sea still remain to be built, the results presented in this paper are derived from scenario-based assessments rather than real-time observation or monitoring. The scenario is based on the development plans of the German government aiming at an installed power of more than 25,000 megawatt by 2030 (Federal German Government 2002), which would amount to large-scale roll-out of offshore wind farming in the German North Sea. We begin by setting out the results of ecosystem service assessment and a closer look at human well-being.

Background: impacts of offshore wind farming on marine ecosystem services

Assessment of the ecosystem benefits–human well-being connection in the above sense needs to begin by defining the ecosystem services in question and determining how they respond to change. We refer to a recent extrapolative study which established the potential effects of offshore wind farming on ecosystem services supply in the case study region (Lange et al. 2010). The study adapted ecological integrity and the categories of regulating, provisioning and cultural ecosystem services to the offshore shore wind farm case study to assess potential consequences of strong offshore wind farm development in the years to come. Impacts on the ecosystem and respective service supply were then modelled or extrapolated. This takes into account the innate dynamism and variability of the marine environment, accepting that modelling can only predict short-term impacts of offshore wind farming on the marine ecosystem's integrity (Burkhard et al. 2011) and does not say much on the long-term effects of offshore wind farms (Koch et al. 2009).

This study confirmed that ecological integrity parameters in the North Sea will be affected due to the insertion of hard substrates into the water body (e.g. wind turbine piles, scour protection). Probably, artificial reef-like ecosystems will develop in immediate vicinity of the piles, an effect already observed in Danish offshore wind farms (Dansk Olie og Naturgas Energy 2006). This would cause alterations in underwater ecosystem structures and processes, leading to increasing energy and matter flows and increasing species abundance in the long term (Burkhard et al. 2011). Nevertheless, negative impacts of offshore wind farm development are to be expected underwater on marine mammals and above water on certain migrating and resting seabirds. Ecological integrity indicators and related assessments are elaborated in more detail in Lenhart et al. (2010) and Burkhard et al. (2011).

Regulating ecosystem services are not expected to change significantly, but may show slight and locally restricted reactions to the introduction of offshore wind farms.

In the case of provisioning services results are not clear-cut, as the impacts of offshore wind farm development on, for example, fish provision seems to be species-, region- and season-dependent (Lenhart et al. 2010). What is interesting, however, is the interpretation of this by different interest groups, which is indicative of an interest-driven perception of benefits and a human well-being connection: Whilst the fishery community, harvesting the provisioning ecosystem service 'fish', mainly interprets offshore wind farms as a threat (opinion survey by Michler-Cieluch and Kodeih (2008)) – exclusion from those sites is felt to lead to drops in catch and therefore income – conservationists argue that commercially used fish populations could benefit because wind farms act as a no-catch zone and reserve area (Federal Agency for Nature Conservation 2004). In the long term a fishery ban within offshore wind farms could even increase the catch in the surrounding areas. Moreover, offshore wind farms hold substantial potential for co-use (Michler-Cieluch 2009), where an expansion of mariculture within the wind farms could lead to an increase in the provisioning service of 'food'.

The response of cultural ecosystem services to offshore wind farm development is varied. Visibility from the shore and accessibility were identified as some of the central factors defining the impact potential in this context, although other factors also come into play. Accessibility is related to the potential to make use of offshore wind farms for tourism, by offering excursions by boat or guided tours, for example. Visibility from the shore is an important factor in determining the impact of offshore wind farms on aesthetic seascape values. Irrespective of visibility, offshore wind farming also impacts on the perceived wilderness value of the sea, which was shown to be an important immaterial value (Gee 2010). Whilst offshore wind farming can thus strengthen certain cultural services – such as 'knowledge systems', on account of the influx of new technical knowledge in the region – others, for instance, 'habitat and species value', were shown to be quite negatively impacted (Busch et al. 2010).

When discussing the impacts of offshore wind farming, regulations associated with Environmental Impact Assessment (EIA), a mandatory precondition for the approval of offshore wind farms, should be mentioned. EIA provides methods to identify and quantify ecological impacts, which means it is restricted to the environmental sector. Ecosystem service assessment additionally aims at tracing the consequences of those ecological impacts in the economic and cultural sphere.

The above shows that strong offshore wind farm development does have tangible impacts and that measurable changes will result in a range of ecosystem services. But how does this change impact on human well-being? Some benefits, such as the example of provisioning services, are clearly economic; there is also the option value of offshore wind farms in the context of co-use which might yield a deferred impact on economic well-being at some point in the future. The conservation benefit, on the other hand, is an immaterial, ethical value that would impact on personal held values, for example.

To begin to trace these connections, we identify six ecosystem services, from a pool of services provided by the German North Sea, being directly affected by offshore wind farming. Table 1 gives an overview of these, together with their case study-specific definition, which was drawn up by a standing workshop of interdisciplinary researchers. It should be noted that they refer to different spatial and temporal scales of ecosystem service change and that they are conceptual only at this stage unsupported by any concrete data. Based on these, human well-being can then be investigated more closely to test for any direct response to ecosystem service changes.

Human well-being in the context of quality of life

Having established the link between offshore wind farming and its impacts on ecosystem services, the next step is to develop an approach for investigating the human well-being side of the equation.

Human well-being is a construct that has been paraphrased as 'complex, controversial, and continually evolving' (Butler and Oluoch-Kosura 2006, p. 1). It is a broad and elusive term that so far lacks a universal

Table 1. Specific ecosystem services provided by the German North Sea (own design).

Ecosystem service	Definition specific to the case study	Potential indicator(s)
Global climate regulation (regulating service)	OWFs provide renewable energy and help mitigating greenhouse gas emissions.	CO_2 reduction potential
Provision of food (provisioning service)	Fish catches are impacted by OWFs by (a) fishery restrictions within OWF areas (which can lead to recovery of depleted stocks) (b) OWFs potentially provide new fish nursery grounds and food sources (c) co-use potential for mariculture.	Tons of fish or maricultural goods (mussels, algae) harvest per temporal unit
Provision of wind energy for electricity generation (provisioning service)	OWFs use wind energy to generate electricity.	Megawatt electricity generated per temporal and/or spatial unit
Aesthetics/beauty of landscape (cultural service)	OWFs affect the visual perception of the coastal land/seascape, for example, the perception of the sea as wide empty expanse (open horizon).	Level of OWFs' acceptance by coastal residents and/or visitors
Image of the region/recreation (cultural service)	OWFs can have (a) positive effects: helping the region to develop a more up-to-date image (modernization) and offering new recreational activities (trips to OWFs) or (b) negative effects: detracting the region from essential traditional qualities.	Regional advertisement topics; recreational activities offered
Species and habitat value (intrinsic value of nature as cultural service)	OWFs fundamentally change the natural habitat and implement artificial structures. Evaluation and trade-off assessments may take place on an individual level.	Number of species and individuals affected by OWFs; number/extension of habitats affected by OWFs

Note: Selection based on (a) impact of offshore wind farm (OWF) development and (b) direct linkages to determinants of human well-being.

definition, with interpretations ranging from quality of life (QoL), prosperity, welfare or empowerment to happiness (McGillivray and Clarke 2006). As a result interrelations between human well-being and ecosystem services are equally diverse and often linkages are poorly understood and controversial (Howarth and Faber 2002; Müller and Burkhard 2007; Fisher et al. 2009). A major difficulty is that all ecosystem services, whether as abstract as nutrient cycling or as obvious as food provision, somehow can be conceived to contribute to human well-being, be it directly or due to indirect linkages.

The most common and best established (key) indicator for human well-being is economic welfare, offering ready links to a range of ecosystem services (e.g. Heal 2000; Turner et al. 2003; Plummer 2009). At the same time a sectoral, exclusively economic perspective on human well-being is incomplete as it excludes the potential of environmental quality, interpersonal relations or the subjectivity of appreciation as important features contributing to human well-being.

QoL is a concept that allows a broad conceptual approach to human well-being. The concept is characterized by combining objective societal and subjective individual dimensions to describe the state of well-being. Both dimensions offer different access points to ecosystem service–human well-being relationship.

Definitions of QoL

QoL as a social political concept arose in the 1960s as an alternative to the concept of welfare. Moving away from the view that 'more' necessarily equalled 'better', QoL reflects the recognition that growth may have limits, as well as changes within society towards more differentiated, post-modern patterns of living and working (Noll 2000). Early definitions of QoL are disparate, including a focus on the state or quality of society at large, although it has become clear that measuring 'good life' is mostly to be done at the level of the individual and not for society as a whole. QoL has since become an essential element in development strategies and is measured in various indices, for example, the UNDP Human Development Index (United Nations Development Programme 2010).

Nevertheless, some fundamental problems associated with determining and measuring human well-being persist. Development indices focus on the more fundamental human needs such as food, water, shelter, freedom, access to education, healthcare and employment, but although they can measure the extent to which these can be met (Costanza et al. 2008), they often miss out on the collective and other non-material elements of well-being such as solidarity, the opportunity to live a self-determined life or identity. Allardt (1993), for example, defined QoL based on three categories: 'having', which includes all material dimensions of living, such as economic resources, work, health, housing, education; 'loving', which includes all social needs such as the need to belong, social networks, friendship and family; and 'being', which includes all optional aspects such as participation, self-actualization, political activities and leisure time.

Empirical approaches to measuring QoL mirror this duality. The more objective 'level of living' approach essentially is a resource-based concept. The view is that the individual's condition is governed by the combination of resources (controlled by the individual) and external determinants (outside the control of the individual), and that this condition, in combination with the individual's aspiration level, governs his/her well-being (Erikson 1974, p. 275). Another concept is primarily concerned with 'the experience of life rather than with the conditions of life' (Campbell et al. 1976 quoted in Noll (2000, p. 10)). QoL is seen to be subjective, determined largely by immaterial components, which means that it needs to be measured at the level of subjective well-being using indicators such as happiness or satisfaction (Campbell and Converse 1972; Inglehardt 1989, e.g. happiness index).

Operationalizing QoL and human well-being

Human well-being thus results from the coming together of good conditions of life – in other words, the meeting of fundamental human needs – and a positive sense of subjective well-being, which is the perceived satisfaction with how these needs are met. Glatzer and Zapf (1984) called this *objective conditions of life*, which are tangible, observable factors such as income, housing, work conditions, family relationships, social contacts, health and social and political participation and *subjective well-being*, which is how individuals rate their specific conditions of life and life in general. Apart from a general sense of contentedness, this individual rating also includes cognitive and emotional aspects such as hopes and fears, happiness and loneliness, expectations and demands (Glatzer and Zapf 1984, p. 23). Importantly, this is no static relationship, in that personal satisfaction is affected by a multitude of variables and the relative weight given to different human needs by society may alter over time (Costanza et al. 2008). Offshore wind farming is an example of an agent that may trigger a shift in the relative importance assigned to factors contributing to QoL.

Objective conditions of life can be described by a range of indicators. Infrastructure is a valuable indirect proxy for QoL as it is a necessary prerequisite for achieving a certain standard of living (Ruppert and Schaffer 1969; Fürntrapp-Klopp 1995). In the spatial planning literature, the prerequisites for a good life are also termed 'determinants of QoL', which commonly refer to demography (e.g. age structure, migration), and basic infrastructure (housing, education, leisure, health and public transport). Added to these is the economic status of a region, measured for instance by income levels and employment (BBR 2005; Licht-Eggert et al. 2007). The assessment of objective

Table 2. Human well-being described by the concept of quality of life (own design).

Objective conditions of life	Subjective well-being
Measured at the level of society	Measured at the individual level
Based on economic and structural indicators (economic indicators, state of the public sector, etc.)	Based on personal perception and experiences Includes immaterial values
Statistical data and infrastructure as a proxy measure	Based on empirical data (e.g. surveys)

living conditions can draw on regional data sets on the economic performance of an area and information on infrastructural facilities administered and updated by public statistical offices.

Subjective well-being is the subjective rating of objective living conditions and societal standards (Majer 1984). It is a time- and context-specific construct mediated by personal perception, experiences, personal value systems, life priorities and goals. In contrast to objective living conditions the assessment of subjective well-being is more difficult as it requires the gathering of empirical data via individual interviews or questionnaires (Table 2).

Linking ecosystem services and QoL on the North Sea coast of Schleswig-Holstein

The North Sea coast of Schleswig-Holstein is a structurally weak region and subject to population decline (Licht-Eggert et al. 2007). It is also characterized by a historically close relationship of residents with sea (Ratter et al. 2009), high nature conservation values (Wadden Sea National Park) and tourism as a mainstay of the local economy (Common Waddensea Sea Secretariat and World Heritage Nomination Project Group 2008). Both material and immaterial factors are therefore likely to play an important role in shaping subjective estimates of QoL in this region.

The first step in establishing links between ecosystem service change and QoL was thus to select suitable contributors to human well-being. Twelve determinants of human well-being were selected, which allowed for a differentiated perspective and for which a direct causal relationship could be constructed between specific ecosystem services and objective or subjective determinants of human well-being (Figure 2). Particular reference was made to the objective determinants of QoL used by the German Federal Statistical Office (2008) and the Federal Spatial Development Report (BBR 2005), with focus on economic and social well-being. Reference to personal well-being is based on the results of a questionnaire survey of local residents presented later in the text. If possible, the consideration of personal well-being should be increased in similar studies in future.

To assess and rate the strength of an ecosystem service–determinant of human well-being linkage,

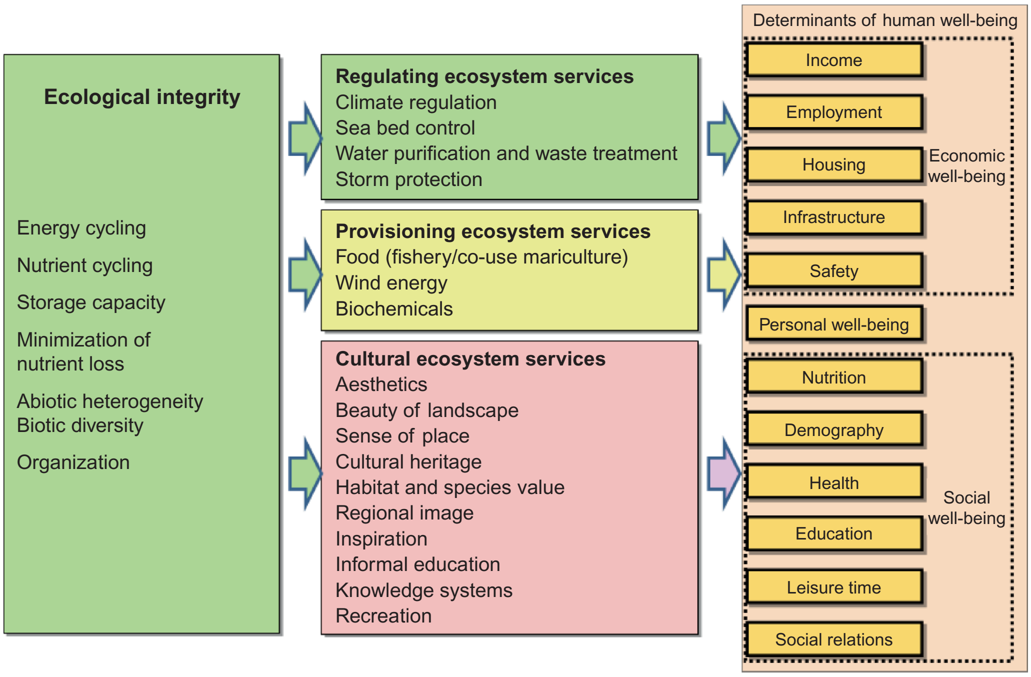

Figure 2. Marine ecosystem services potentially impacted by offshore wind farm development (direct or indirect) in the German North Sea and related determinants of human well-being.
Source: Adapted from Busch et al. (2010).

potential indicators were identified. This was done based on a review of existing indicator sets (e.g. McMahon 2002; Gehrlein 2004; BBR 2005; Licht-Eggert et al. 2007; Müller and Burkhard 2007). The result is an indicator set specific to the case study area and sensitive to aspects of offshore wind energy. Table 3 gives a description of the various determinants and examples for potential indicators.

In the next step, a standing interdisciplinary workshop was organized to discuss conceivable links between the potential changes in the six ecosystem services identified previously as especially relevant (Table 1) and the impacts of that change on the 12 determinants of well-being. This was done in a qualitative way, assuming strong development of offshore wind farming in the German North Sea Exclusive Economic Zone. Obvious and direct connections were specified and their impact potential discussed. More discussion was held on the weaker and more indirect connections, and connections discarded where no consensus could be reached.

For objective living conditions, for example, causal chains were constructed using the BBR's determinants of QoL (BBR 2005) as a guide. A simple example apart from offshore wind farming is the direct link that can be established between provisioning services (e.g. mussels from the sea) and local employment, in this case the number of jobs available in mussel fishery. Investment in mussel farming, and thereby increasing the exploitation of this provisioning service, can lead to additional employment, which could attract more people to the region. This in turn would increase the demand for housing, education or public transport, the provision of which would have positive impacts on objective living conditions. Similarly, the loss of a provisioning service (e.g. fish) could lead to a loss of income on the coast, with consequences for employment, demography (people may need to move away) and infrastructure (housing, schools, health care, etc., would no longer be needed, leading to a decline in availability). For subjective estimates of well-being, the results of a qualitative survey were used that addressed attitudes to offshore wind farming by local residents (Gee 2010). From this survey, changes in subjective well-being in response to the arrival of offshore wind farming were identified.

It should be pointed out that the aim of this approach was to conceptualize potential impacts in principle, thus setting the scene for the later monitoring of offshore wind farm-induced changes in human well-being in the case study region. For this reason this study does not include distinct economic scenarios for the region with and without offshore wind farms (e.g. considering the incomes and taxes generated in offshore wind farming and related economic sectors). The results presented here should be understood as an analytical framework and precondition for gathering empirical data, which would need to take place in parallel to the realization of commercial offshore wind farms. While findings support the relevance of several identified linkages (see Lange et al. 2010), further in-depth analysis will be required once the planned offshore wind farms enter the construction and operation phase.

Examples of verified linkages

An example for a verified connection is the one between the provisioning ecosystem service 'energy' (electricity being generated by offshore wind turbines) and employment

Table 3. Determinants of human well-being in the case study area and potential indicators (own design).

Determinants of human well-being	Definition specific to the case study	Potential indicators
Economic well-being		
Income	Disposable income, that is, the income available to individuals for meeting their respective needs. The material basis available to each individual for participating in social life	• Average annual income per level of education • Disposable household income • Share of persons claiming benefits • Per capita gross domestic product (GDP), by region/country
Employment	Diversity and security of available jobs within the region, linked to the overall regional employment/unemployment ratio. Employment is an important factor for maintaining social stability in the region	• Regional employment rate • Regional unemployment rate • Share of the total workforce per sector
Housing	Availability of a range of different housing options (singles/families/retired persons/holiday homes), reflecting the need to plan new developments sensitively and sustainably (in keeping with local style) and with sea level rise in mind (vulnerability/security)	• Regional demand for housing • Living area per inhabitant • Rent index per m^2 • Annual new land use
Infrastructure	As in other industrial countries basic infrastructure in the region is considered a public good. Here it means basic service infrastructure such as energy supply, transport and telecommunication	• Public transport network, • km of roads • Share of renewable energies in energy consumption (private households and industry/ business)
Security	Security from sea-borne threats. Extreme events such as storm surges are included here as well as threats resulting from human uses, such as shipping accidents or accidents on oil platforms	• Overall length and elevation of dykes • Number of shipping accidents • Annual public spending on sea defences
Personal well-being		
Personal well-being	Subjective determinants of quality of life	• Personal satisfaction and happiness
Social well-being		
Nutrition	Defined here as the availability and quality of regional marine food such as fish and mussels	• Suppliers of local produce in the region • Price index of local produce
Demography	Defined here as the dynamic changes of social structures and the overall social composition	• Immigration/emigration • Population structure • Birth and death rates • Share of foreign inhabitants
Health	Defined as access to health infrastructure and the overall status of health infrastructure within the case study area	• General practitioners per inhabitant • Accessibility of hospitals (distance/time travelled) • Hospital beds per inhabitant • Average number of sick days per person per year
Education	All forms of education and training. Formal education (e.g. in a schools context, formal vocational training) is set apart from informal education (voluntary participation in adult further education programmes, environmental interpretation, field, visits, etc.)	• Pupil/class ratio • Day care places per 100 children • Number of trainees/apprentices per 1000 employees • Number of adult further education classes
Leisure	Individual leisure activities (indoor and outdoor) and the provision of the infrastructure required to engage in these.	• Cultural and leisure (sport) facilities/programmes/courses
Social relations	Social stability resulting from social networking and interchange. The degree of self-organization within society is considered an indicator of society's potential to regulate social conflicts	• Number of citizen's initiatives • Number of non-profit organizations and associations • Volunteers/population • Membership in associations

as an objective determinant of human well-being. An input–output analysis performed by Hohmeyer (2006) for the case study region modelled the potential of offshore wind energy to create new employment opportunities.

Three different scenarios were calculated for different strengths of offshore wind farm development (little, modest and high). Analysis assumed a maximum regional share of the wind energy value chain, leading to new employment through (a) direct investment into offshore wind energy (foundation of new companies and growth of existing ones, new jobs in construction sector), (b) operation and maintenance of offshore wind farms (new jobs in offshore service sector) and (c) an expected multiplier effect in terms of additional consumption as a result of new jobs within the region (Figure 3).

The *y*-axis represents the respective additional person years of employment generated. Negative impacts on employment, for example, due to the replacement of jobs in the conventional energy sector, are not expected because of the absence of large conventional power plants in the region. This explains the high net effect on employment shown in the diagram (the respective third bar of each scenario in Figure 3). Under the 'high implementation' scenario of offshore wind farming, up to 125,000 potential person years of employment were calculated as achievable. The results show the potential of offshore wind farming as a major economic driver for employment in the region. This would impact on the indicators for employment (regional employment rate and regional unemployment rate, see Table 3). Economic well-being would therefore respond to this scenario. It should be stressed, however, that the realization of this potential depends on a multitude of external factors. Supportive policies providing the necessary infrastructure (offshore wind service harbours, etc.), for example, are a precondition for attracting investors to the region.

Another proven link is that between the cultural ecosystem service 'aesthetics' and personal well-being, which reflects the subjective and personal dimension of human well-being. A postal questionnaire survey assessed local residents' views on the local landscape and the impacts of offshore wind farming, enabling better understanding of the relationship between these two components. The survey points to the significance of immaterial sea values in the perception of the sea and by extension cultural ecosystem services. Key points are the perception of the sea as a seascape (the wide, open horizon), as wilderness (an untamed place) and as a place for which we have a particular responsibility (protecting marine fauna, the sea as a last refuge) (Gee and Burkhard 2010). Table 4 indicates the importance of these values to the residents in the coastal region in comparison to other values. The survey then goes on to assess people's view of the likely impact of offshore wind farming and the reasons they give for either supporting or rejecting this new technology. Fears concerning the above values rank top as a reason for opposing offshore wind farming, and some of the responses are rather emotional, indicating strong attachment to certain essential qualities of the sea ('offshore wind farming would mean a loss of everything that is important to me' (quoted from survey)). The opposite view was also encountered, with residents arguing offshore wind farming would constitute a viable, less intrusive alternative to wind farming on land.

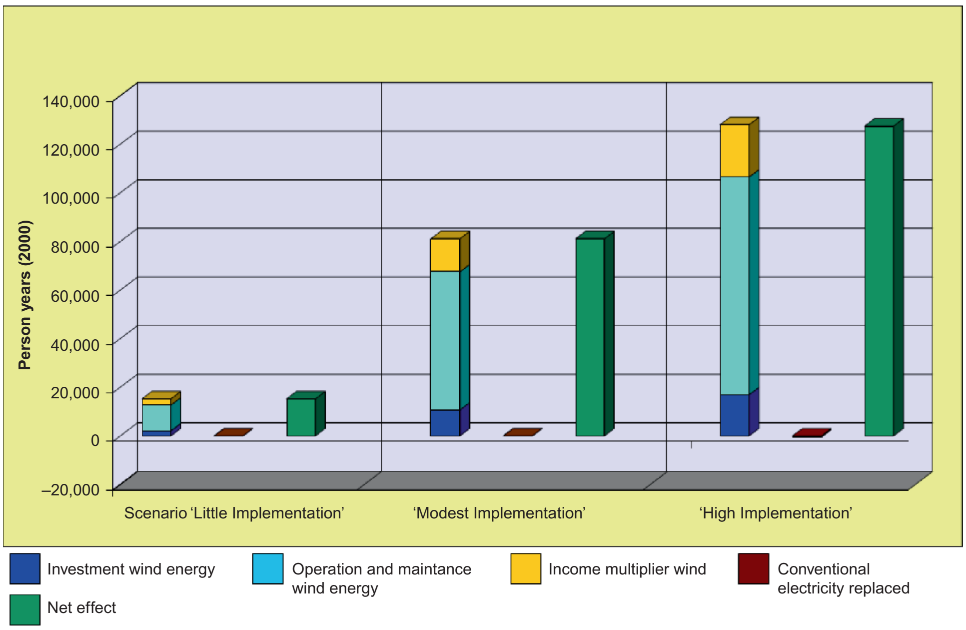

Figure 3. Cumulated effects on gross value added along the North Sea coast of Schleswig-Holstein due to the development of offshore wind energy in the German part of the North Sea until 2030 (taking into account investments until 2030 and operation until 2050).
Source: Adapted from Hohmeyer et al. (2010).

Table 4. Survey results demonstrating the importance of material and immaterial values for individually experienced quality of life at the North Sea coast of Schleswig-Holstein.

'How important is. . . for your life at the west coast of Schleswig-Holstein?'

	Very important	Important	Neither nor	Not very important	Not important	No answer
(a) Clean water, air, beach and tidal flat (%)	87	12	0	0	0	1
(b) Healthy and diverse plant and animal communities (%)	72	26	1	0	0	1
(c) Attractive landscape (%)	58	32	6	2	0	2
(d) Wide open horizon (%)	57	29	8	4	0	2
(e) Untouched nature (%)	40	40	16	1	1	2
(f) Spending leisure time by the sea (%)	38	50	8	3	0	1
(g) Challenging employment (%)	32	44	16	5	1	2
(h) Economic growth (%)	22	53	16	5	2	2
(i) New industries and technology (%)	17	37	18	17	9	2
(j) Attraction of profitable companies and industries	13	33	19	22	11	2

Note: $n = 387$, figures rounded to the nearest whole number.
Source: Adapted from Bruns and Gee (2010).

The survey results show that offshore wind farming is not a neutral agent, but one that impacts on all the values shown in Table 4. The top of the table indicates the high relevance of natural and landscape qualities for local residents within the case study region. Immaterial values (categories a–e) are rated as of central importance for QoL along the North Sea coast of Schleswig-Holstein, in particular (a) clean environment and (b) healthy flora and fauna, followed by specific landscape qualities (c and d). Simultaneously, new industries like offshore wind farming (i) and attracting such industries to the region (j) are less important in this survey (Gee 2010). As offshore wind farming will change the seascape, and also impact on the ecosystem or elements of it, immaterial values such as the open horizon (d) or untouched nature (e) will be particularly affected. This shows the direct linkage between the cultural ecosystem service 'aesthetics', which is influenced by offshore wind farming, and the personal sense of well-being felt by residents on the coast.

Overview and critique of the linkages identified

Apart from the proven linkages, a multitude of further potential interrelations were detected. While a majority of these represent indirect, loose connections implying causal chains with several argumentative steps, others are known direct interdependencies between ecosystem services changes and determinants of human well-being in the case study region.

There is a direct link between the ecosystem service 'global climate regulation' and safety at the local scale, defined in the case study area as security from sea-borne threats (see Table 3). Renewable energy generation, and by extension offshore wind farming, has the potential to mitigate climate change, which can be perceived to reduce the vulnerability of the coastal region to threats such as sea level rise or the increase in extreme weather events. Although the people on the coast still do place faith in existing sea defences, the survey referred to above (Gee 2010) does show a general feeling of support for renewables along the lines of responsibility for future generations and generally protecting the world from climate-related threats, not only at home. By extension, lower vulnerability could have quite tangible impacts on economic well-being, for instance in terms of siting regional infrastructure. Naturally, global climate change will at best be slightly influenced by offshore wind farm development on the German North Sea coast. Nevertheless, the link between changes to an ecosystem at the regional scale and a global ecosystem service is a tangible one, even in the minds of local residents who underscore it with the moral argument of responsibility towards other humans and the natural world.

For the ecosystem service 'provision of food' direct linkages can be established to employment and income since fish and mussels constitute an important economic good. First experiences indicate that offshore constructions have the potential to increase the abundance of fish species due to the emergence of artificial reef structures (Langhamer and Wilhelmsson 2009). In combination with a ban on fishing due to shipping safety, offshore wind farm areas could effectively act as marine protected areas (Lenhart et al. 2010). This would allow commercially used fish species to recover, leading to benefiting effects on fisheries in the surrounding areas of offshore wind farms (Diembeck 2008). Moreover, planned co-uses of offshore wind farms as aquaculture sites for mussels and algae would strengthen the link between 'provision of food' and local employment and income even further. For a detailed review on the social and economic feasibility of wind farm–mariculture integration, see Michler-Cieluch (2009).

Figure 4 shows an overview of the results. The linkages identified are visualized as arrows connecting each ecosystem service with specific determinants of human well-being. The more obvious and direct the linkage, the thicker the arrow. Thin arrows describe a more tenuous and possibly indirect link, although indirect linkages do not necessarily imply the connection is unimportant.

Discussion

The case study example shown in this paper demonstrates that strong direct causal chains can be constructed linking offshore wind farming to changes in marine ecosystem services and on to determinants of human well-being. This paper also showed that some of these relationships could be verified based on survey data or economic scenario analysis. However, the verification, valuation and significance of linkages remain a problem. This particularly applies to indirect linkages, many of which were found in the case study example. Here the universal nature of ecological functions and integrity is such that arbitrariness may result, meaning that indirect relationships can be constructed to every aspect of human well-being set out above. An example is the causal chain between increases in habitat heterogeneity (on account of the introduction of hard substrates), which leads to increased biodiversity, and food web complexity (due to the expected artificial reef effect), which in combination with a fishery ban in offshore wind farms could lead to increases in fish stocks. After a certain time, fisheries might benefit in terms of increased catch due to spillover. The effect would potentially show as additional employment, which would become measureable by showing direct impact on an objective determinant of economic well-being, indicated by changes of the regional unemployment rate (see indicators in Table 3). At the same time it is important to mention that at first a loss of employment in the fishery sector, due to displacement from offshore wind farm sites, is assumed.

Many other similar causal chains are conceivable based on the ecosystem services and potential benefits set out above. All would need to be verified and rated in their comparative significance by means of appropriate indicators.

Some linkages though are supported from experiences and considerations from abroad. In Dutch waters possibilities for shared use of offshore wind farm sites by sustainable fishery are investigated (Dutch Central Government 2009) while in Denmark the co-use of offshore wind farms for mussel and algae cultivation already exists.

The introduction of offshore wind farms and associated developments obviously triggers societal change in the respective regions. The influx of new knowledge and employment opportunities has the potential to induce migration, shape the self-image of a region and initiate transformation and reorganization of other/traditional sectors.

Indicators for those changes are another problem since they will need to be capable of filtering out the offshore wind farm-specific signals from a broad range of wider ecological or socio-economic signals. Whilst this might be achievable for ecological or economic impacts, it is more difficult in terms of human well-being because the available indicators are so far rather general. For the determinants of social and personal well-being, for example, any visible changes will be difficult to relate back to the specific effect of offshore wind farming as a host of other factors could mask or amplify this effect. An ongoing monitoring programme of socio-economic trends is therefore needed as a baseline if offshore-specific signals of change are to be filtered out at all by means of retrospective and cumulative analysis.

Assuming that appropriate indicators are available that show up changes in causal relationships, another problem is the rating of any verified effects. This is a question of where QoL is positioned – is it personal or societal QoL that is to be assessed? – and of the relative importance accorded to different contributors.

It should also be noted that the evaluation of impact chains, or the rating of impacts as positive or negative, is open to manipulation simply by what indicators are chosen to assess changes in ecosystem service provision and human well-being. A proven interrelation exists between the introduction of hard substrates into the water column and increases in (underwater) biodiversity, but this does not automatically mean a positive effect is taking place. If the indicator 'ecosystem nativeness' were to be applied instead of biodiversity, the insertion of hard substrates into the existing ecosystem would count as undesired change to an ecosystem that lacks hard substrates in its natural state. It follows that the choice of indicators has to be reviewed and discussed on a regular basis. Likewise the rating of interrelations between ecosystem services and human well-being has to be revised regularly. While, for example, additional employment certainly is to be rated as a positive effect, it can induce negative changes further down the line (e.g. influx-related shortage of available spots in kindergartens). Also, just because employment is generated on account of offshore wind farming, this is not necessarily an effect that is desired by every stakeholder on the coast (Table 4). Here the question of trade-offs between ecosystem services comes into play, which is ultimately a trade-off between different ecosystem benefits (e.g. employment versus aesthetic qualities of the seascape) and different aspects of human well-being such as economic well-being versus personal well-being. Analysing changes in ecosystem service supply could support trade-off decisions, with science acting to provide information in support of transparent decisions taken by politically legitimized decision-makers.

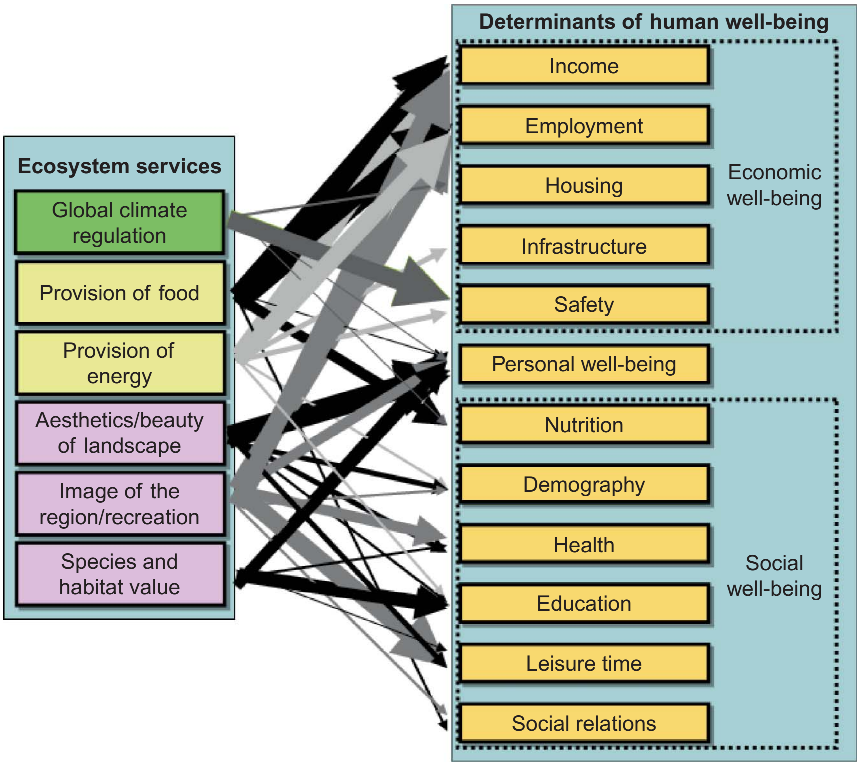

Figure 4. Identified potential linkages between ecosystem services impacted by offshore wind farming and determinants of human well-being.
Source: Adapted from Busch et al. (2010).

The above demonstrates that causal links can be established between the advent of offshore wind farming and human well-being. The links themselves can be shown to be valid and verifiable, as demonstrated by the two examples given. At the same time, the links per se only ever establish causality, in the sense that offshore wind farming indeed impacts on ecosystem services, benefits and ultimately human well-being. The crux, however, is still the act of rating this change as either desirable or undesirable. This depends on individual factors such as personal values, on the societal context at different scales and times, and also the agenda and context of the person or institution responsible for the rating.

Conclusions

The concept of ecosystem services appears to be a valuable tool for analysing and conceptualizing the expected impacts of offshore wind farming on human well-being in the case study area. Despite the difficulties discussed above, the concept allows a multitude of links to be detected between offshore wind farming as an emerging marine use and human well-being on the coast. For six ecosystem services found in the German North Sea, direct links could be established to determinants of human well-being at a conceptual level, albeit of varying strength. Qualitative descriptions of these interrelations were provided, with two of them verified by more detailed investigation. The assessment also demonstrates that the impacts of offshore wind farming on ecosystem services have the potential to affect human well-being through a multitude of indirect routes. The linkages discussed above illustrate effects on both objective and subjective dimensions of human well-being. None of the changes in ecosystem service provision, however, will impact on fundamental human needs such as food, shelter or health in our case study region.

Concerning the impacts of offshore wind farm installation on ecological structures and processes (integrity) and the provision of the ecosystem services, a clear influence can be stated. Ecological impacts appear to be controversial. While the mentioned artificial reef effect is assumed to increase ecosystem functionality under water (e.g. nutrient cycling, storage capacity), negative impacts are expected to occur above water (e.g. habitat loss of seabirds) (Lenhart et al. 2010). Similar circumstances are expected for the provision of ecosystem services. While the provision of renewable energy and maricultural products, assuming co-use of offshore wind farm sites, would increase, offshore wind farm sites would no longer provide fish because of the likely ban on shipping. In the medium term, fish stocks could go up on account of the nursery area effect. To rate and trade-off these impacts constitutes a major challenge because the magnitude of impact strongly differs in accordance to the spatial scale under consideration.

The main question raised by this paper is how changes in ecosystem service supply affect human well-being.

Potential effects were identified and traced based on a definition of determinants of human well-being.

An issue requiring further research is the problem of indicator sensitivity, and of pinpointing cause and effect in the various factors that shape human well-being. Although the determinants of human well-being were adapted to the specific case of offshore wind farming, it is just one factor among many that have a bearing on these determinants. How to assess the proportional contribution of offshore wind energy to any change in the determinants selected within a wider context of change? Factors like demographic change or the global economy are likely to have much stronger impacts on the chosen determinants of human well-being than the development of offshore wind farms. The conceptual approach presented in this paper does not solve this question, but it shows trends and provides a methodology allowing qualitative judgements concerning the impacts of prospective offshore developments on human well-being.

The above leads to the question whether an objective estimate of human well-being at any particular point in time is feasible at all. The discussion of the concepts of human well-being and QoL in Sections 3 and 4 implies that a degree of subjectivity may well be an inherent feature of all assessment of human well-being. Individual differences in the subjective rating of objective living conditions are unavoidable since the components that contribute to personal well-being (e.g. personal value systems or past experience) will differ individually anyway. Nevertheless, changes of defined objective determinants of human well-being alone might be a valuable proxy measure, independent of whether they are rated slightly different on an individual level.

Moreover, it is important to mention that the results of human well-being assessments are strongly influenced by the scale chosen for assessment and the scenario used as a baseline. Changes in the marine environment result in impacts at considerable distance, because system components not originally connected to the site of impact are affected as they make use of relevant ecosystem services. The link between marine ecosystem services impacted by offshore wind farms situated 30–60 km off the shore, but having the potential to shape aspects of human well-being onshore, could be proved on a conceptual basis, providing a valuable example for the relevance and presence of land–ocean interactions.

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