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A pilot for using the five capitals approach for marine plan development in the East of England

(MMO1336)

...ambitious for our seas and coasts

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1 Summary

The five capitals model is a concept which assesses and integrates natural, human, social, manufactured, and financial capital, and considers their interactions to inform decision-making. Application to date has largely been confined to the business world but has been extended more recently to planning and the environment sector. Howell Marine Consulting was commissioned by the Marine Management Organisation to explore whether a five capitals approach could provide more robust methods to help marine planners consider the carrying capacity of the east marine plan area, and the consequent trade-offs between competing sectors.

A literature review, workshop, and interviews with experts were used to develop and validate early thinking, which concluded that the five capitals approach has merit and could strengthen the marine planning process but comes with multiple challenges and more questions which will need to be addressed. Relative value determined by stakeholders, rather than assigning monetary value, was identified as being the most suitable method to inform trade-offs.

Carrying capacity and related concepts such as thresholds and cumulative effects were explored in depth, but the team concluded that the academic community is far from understanding ecological carrying capacity for a marine plan area, and when the concept is extended across all five capitals it becomes even more complex. It was recommended that setting targets or limits through a five capitals approach would be more pragmatic and achievable (See Section 4).

An asset register was developed for all five capitals across three sectors – aggregates, offshore renewables, and fisheries – in the east marine plan area. The process identified significant challenges in finding data at an appropriate scale, which was comparable across multiple sectors. A main learning point at this stage was that social capital assets are more relevant at a local community scale.

A conceptual framework to apply a five capitals approach to marine planning was then developed, with examples of how this could work at each stage. An important stage of the framework is understanding and capturing the complexity of interactions between assets. As proof of concept, asset networks were developed for each of the three sectors. Each asset is colour coded to signify which capital the asset represents, and arrows link the assets to indicate a general direction of flow. Common assets across the three sectors are highlighted.

Consideration was given to how the conceptual framework could be scaled-up to cover more sectors and applied to the remaining marine plan areas in England. Each marine plan area has a unique pattern of use which brings different sectors, capitals and interactions into play, which can be understood and considered through applying the conceptual framework. Scale was explored more broadly and highlights the potential to apply the five capitals approach at multiple scales, from informing government policy and strategic assessments, through to marine licensing decisions.

Recommendations were made to help advance thinking further, fill evidence gaps, and trial the conceptual framework.

2 Introduction

2.1 Context and objectives

The Marine Management Organisation (MMO) is responsible for marine planning in England under the Marine and Coastal Access Act (2009). The East Marine Plans were the first to be adopted in 2014 and have been through two review cycles. In 2023 the process to amend these plans will begin, as per the recommendation of the Secretary of State. In doing so, increasing competition for space, driven by the accelerated roll-out of offshore wind in line with the British Energy Security Strategy (BESS) must be considered alongside the need to protect and restore biodiversity and maintain other livelihoods, as is currently being explored through the Defra Marine Spatial Prioritisation Programme.

The MMO commissioned Howell Marine Consulting (HMC) to explore whether a five capitals approach could provide more robust methods to help marine planners consider the carrying capacity of the east marine plan area (EMPA), and the consequent trade-offs between competing sectors to ensure this is not exceeded. The objectives for the project were:

1. Explore and critically appraise the potential benefits and challenges of applying a five capitals approach to:
    I. describe and identify the carrying capacity of the EMPA; and
    II. manage trade-offs for space
2. Develop asset registers for the natural, human, social, manufactured, and financial capitals across fishing, aggregates and offshore renewables sectors within the EMPA
3. Consider how the approach can be scaled up across multiple sectors and remaining marine plan areas with a focus on sustainable use.

2.2 Introduction to a five capitals approach

Capital can be defined as a resource either used or available for use in the production of goods and services (Natural Capital Committee, 2019). The five capitals approach is a concept developed by Jonathan Porritt (Forum for the Future 2011) that allows for multiple types of capitals, and their interactions, to be assessed when making decisions. This approach provides a basis for understanding sustainability in terms of the economic concept of wealth creation or ‘capital’ by considering the following five types of capitals (Forum for the Future, 2023a):

- **Natural capital**: that part of nature which directly or indirectly underpins value to people, including ecosystems, species, freshwater, soils, minerals, the air and oceans, as well as natural processes and functions.

- **Human capital**: people’s health, knowledge, skills and motivation.

- **Social capital**: institutions that help us maintain and develop human capital in partnership with others, for example, families, communities, businesses, trade unions, schools and voluntary organisations.

- **Manufactured capital**: material goods or fixed assets which contribute to the production process rather than being the output itself.

- **Financial capital**: enables the other types of capital to be owned and traded. It has no value itself, but is representative of natural, human, social or manufactured capital.

Recently, the five capitals approach has gathered interest within the environment and planning sectors. To date, its application to marine environmental management has been limited, largely focusing on interactions between two sectors (for example fishing and offshore wind) or the socio-economic impacts of an activity or decision (such as the impact of marine protected areas on the local fishing industry). More detailed information on the five capitals approach and its applications can be found in section 3.1.6.

This report contains overviews of the information gathering approach used (literature review and workshop), the development of asset registers for the five capitals and focal marine sectors (fishing, offshore renewables, and aggregates), and a further exploration into how the five capitals approach could be applied and scaled up to incorporate additional sectors and marine plan areas. Finally, recommendations for application and further research are made.

3 Objective one: explore and critically appraise the potential benefits and challenges of using a five capitals approach to inform carrying capacity and trade-offs

3.1 Literature review

To inform thinking a literature review was conducted, under objective one, setting out current knowledge of the theory, application, and examples of use of the five capitals approach, and, more specifically, providing the basis for an assessment of whether this approach has the potential to inform analysis of carrying capacity and trade-offs in a marine planning context. Wherever possible, evidence from the marine environment was used across a range of information sources, including peer-reviewed academic literature, government reports, and published project reports. Sections 3.1.1 through to 3.1.6 provide an overview of the important findings. The full literature review can be found in Annex A.

3.1.1 Carrying capacity

Where there are multiple demands on resources within a defined space, identifying the maximum amount of resource use that can take place without diminishing its condition is a challenge for marine planning. The concept of carrying capacity is a complex construct, but one which could help decision makers tackle this challenge.

Carrying capacity theory is contextual and has been defined in multiple ways across different disciplines, however, in all its applications, carrying capacity refers to a defined space containing a finite amount of resource. Within the context of the use and management of the natural environment, the carrying capacity of a region is defined as *“the ability to produce desired outputs from a constrained resource base to achieve a higher and more equitable quality of life, while maintaining desired environmental quality, and ecological health”* (Khana et al., 1999). Further definitions, highlighting the breadth of application and interpretation are set out below.

Ecological carrying capacity

- Earth’s capacity to sustain human life: “*the margin of the habitat’s, or environment’s ability to provide the resources necessary to sustain human life*” (Geores, 2001)
- Aquaculture production: *“the amount of production that can be maintained without leading to unsustainable changes to ecological processes, services, species, populations, or communities in the environment.” (*Falconer et al., 2018)
- Conservation: *“the maximum use that the biota or the physical processes of an area can withstand before becoming unacceptably or irreversibly damaged.”* (McLachlan and Defeo, 2018)

Physical carrying capacity

- Aquaculture development: *“the total area of marine farms that can be accommodated in the available physical space.”* (McKindsey et al., 2006)
- Conservation and management: *“a design concept, based on the number of use units (people, cars, boats, and vehicles) that can physically be accommodated in a certain area.*” (McLachlan et al., 2018)

Production carrying capacity

- Aquaculture developments: *“the stocking density of bivalves at which harvests are maximised.”* (Falconer et al., 2018)

Social carrying capacity

- Recreational activities: *“the level of recreational use an area can sustain without an unacceptable degree of deterioration of the character and quality of the resource or of the recreation experience.”* (McLachlan et al., 2018)
- Aquaculture development: “*the level of farm development that causes unacceptable social impacts”.* (Falconer et al., 2018)

Economic carrying capacity

- Global carrying capacity: “*the biophysical properties of a finite earth and the realities of economic transformation determine the economic carrying capacity of our planet. Economic carrying capacity takes the form of maximum global economic welfare derivable from the sustainable throughout flows of the ecosphere.”* (Wetzel and Wetzel, 1995)

- Fisheries management: *"There also has been a distinction made between "ecological carrying capacity, which refers to the limitation of a population due to resources, and a management-oriented, maximum sustainable yield for a population, referred to as an "economic carrying capacity," which is usually lower than ecological carrying capacity.*" (Hartvigsen, 2001)
- Tourism: "*the capability of both tourism destinations and protected areas to accommodate recreational use."* (McCool and Lime, 2001)

Despite this variation, all definitions set out to describe the acceptable parameters within which an activity can take place. These limits can be very clearly defined and informed by empirical data, such as the physical limitations of a site for aquaculture or wind farm development, or they can be more subjective and qualitative, for example the acceptable level of social impact of a development is determined by the community being impacted.

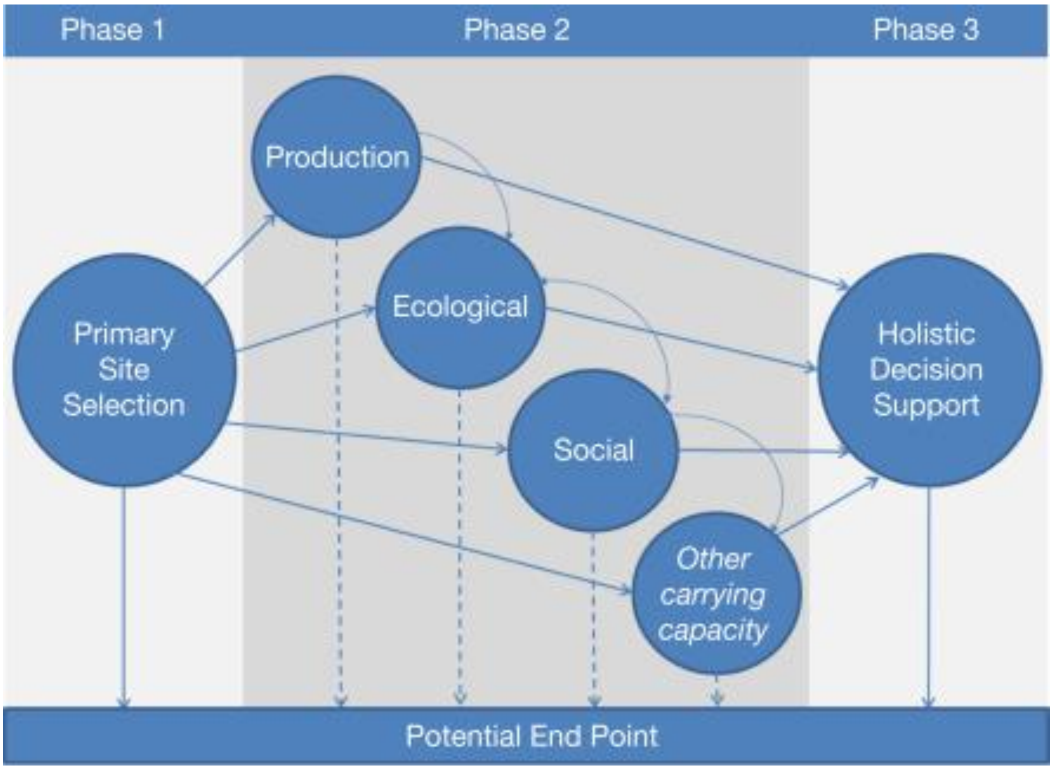
In practice, the application of ecological carrying capacity to inform environmental management decisions is challenging, as it is difficult to quantify, likely to vary over time, and may not be representative of the actual species population size (Rachlow, 2008). Within environmental management, carrying capacity is difficult to define and has largely been used to describe a theoretical ecological limitation. While it is possible to use a theoretical limit to support decision making, it may not provide the level of accuracy required and be open to scrutiny.

The use of carrying capacity has been explored within the academic literature for informing discrete development activities. For example, McKindsey et al. (2006) recommend the use of four types of carrying capacity: physical, production, ecological and social carrying capacities, in a hierarchical approach to identify suitable sites for aquaculture developments:

- **Physical carrying capacity**: the initial site identification that includes area suitability, species to be farmed, and physical characteristics of the environment. This information can provide an indication of the total area potentially available for aquaculture.
- **Production carrying capacity**: the maximum production that can take place in the identified area, which can inform stocking density. This is usually assessed at a farm level.
- **Ecological carrying capacity**: the amount of production that can be maintained without causing unsustainable changes to ecological processes, services, species, populations, or communities in the environment.
- **Social carrying capacity**: the amount of aquaculture development that can take place without unacceptable social impacts, which can include visual impact, traditional fishing rights, and the needs of other marine users. This can often be balanced out by factors such as job creation and income generation.

The hierarchical approach provides a systematic and stepwise approach to determining the limitations of a location within which an aquaculture farm must operate. Falconer et al. (2018) expanded upon the hierarchical approach by integrating linkages between the different carrying capacities and introducing end points within the process to be identified: for example, if the physical carrying capacity assessment identifies the site as unsuitable, the process ends before the next stage begins (Figure 1). The five capitals approach, as well as each of the capitals individually, has the potential to inform each of the stages of the proposed decision-making process.

Figure 1: Phased approach of applying carrying capacity to site identification for aquaculture production (Falconer et al., 2018)



The hierarchical approach allows for specific carrying capacities to be prioritised, determined by the order of which they feature within the process (for example, first being the priority), and for each progressive step in the process to be based on a sound understanding of the preceding stage. The sequence that each of the carrying capacities are placed within the decision-making process can be informed by policy targets and plan objectives, which can link directly to how each of the five capitals are weighted in importance.

3.1.2 Thresholds

Thresholds have been used in a wide range of disciplines and generally denote a point where the measured characteristic begins to experience a notable change. In marine environmental management, ecological thresholds are regularly used to identify the point at which there is *"an abrupt change in an ecosystem quality, property or phenomenon, or where small changes in an environmental driver produce large responses in the ecosystem"* (Groffman et al., 2006).

Groffman et al. (2006) identified three ways threshold concepts have been applied in ecology, which align with a five capitals approach as both concepts require an understanding of socioecological interactions within a system. The foundational role of natural capital places additional importance on ecosystem thresholds, but thresholds for social, human, manufactured and financial capital can have important implications for decision making, for example, acceptable levels of tourists visiting a beach, available skilled labour, infrastructure capacity and financial investment, respectively. A five capitals approach could enable thresholds to be defined and applied to the decision-making process.

3.1.3 Cumulative effects assessment

Cumulative effects assessments (CEAs) are a form of environmental assessment aimed at identifying how the combined effects of human activities contribute towards environmental change. An effective CEA identifies, measures, mitigates and manages the effects of multiple human activities on the environment. Wilsteed (2019) identified multiple considerations that need to be applied when conducting CEAs, which emphasises the complexity of assessing environmental impacts from multiple stressors, and the need for further understanding of interactions, the temporal and spatial scales at which effects occur, and the need to consider external effects.

Judd et al. (2015) recommend that a four-step framework, based around the principles of environmental risk assessment, is applied to cumulative effects assessment. This framework could provide a useful starting point for framing the purpose of a five capitals approach, identifying, and assessing linkages between capitals and activities, and how to act on the resulting findings.

Wilsteed (2019) and Judd et al. (2015) both highlight the importance of identifying the purpose of carrying out a cumulative effects assessment, as this will influence the approach taken, the receptors included and, therefore, the output. This is also an important consideration for applying the five capitals approach. Given the broad, complex, and comprehensive nature of the five capitals approach, clarifying its intended purpose will be critical for ensuring it functions efficiently and works towards achieving the desired outcomes.

3.1.4 Trade-offs

When used in its original economic context, a trade-off is required when the "*basic economic fact that limitation of the total resources capable of producing different commodities necessitates a choice between relatively scarce commodities*" (Samuelson, 1970). The core elements of this definition, which can be applied more broadly are:

- there is a finite amount of human and natural resources available
- humans need to make choices about how to use resources
- choices involve a 'sacrifice' represented by the foregone production of goods and services each choice entails (Turkelbloom et al., 2018).

To ensure effective and equitable marine resource use trade-off decisions are made, an understanding of available natural capital, the ecosystem services they provide, the interactions between natural capital and marine users, and the interactions between marine users, is required.

Trade-offs must be made when the needs or wishes of multiple stakeholders, within a shared space or system, are incompatible, and the achievement of one desired outcome is detrimental to another. National targets and priorities are important drivers in trade-off assessments, particularly for spatial prioritisation. The most direct need for trade-offs in marine planning occurs when the desired resources of multiple stakeholders exist within the same space, requiring either consideration of co-existence or the prioritisation of access to one sector.

The loss of benefit to competing stakeholders can result in value trade-offs, which define how much must be gained in the achievement of one objective to compensate for a lesser achievement on a different objective. Value trade-offs that adequately express a decision maker's values are essential both for good decision making in multiple-objective contexts and for insightful analyses of multiple-objective decisions (Keeny, 2002).

However, a value trade-off does not necessarily need to be valued in a single currency (for example, pounds sterling). It is possible to compare decisions based on changes in sectoral values (in absolute or percentage terms), which would allow for distinctly different ecosystem services to be compared, including those that rely on non-market values, such as aesthetics or conservation (White et al., 2012).

The draft MMO1274 East Marine Plan Spatial Assessment, a spatial analysis of the EMPA to understand suitability of specific locations to support different sectors, states that "*Policy interventions will be focused on marine plan policies, but where there is interrelation with wider government policies, these will be outlined at a high-level. They are likely to include or relate to:*

- *policies that encourage co-location between certain sectors*
- *spatial policies giving priority to certain sectors in certain areas*
- *policies that insist on collaboration for environment protection and enhancement.*" (MMO1274 Report).

The inclusion of co-location (seen as a sub-set of co-existence) and prioritisation to certain sectors highlights the importance of trade-offs within the spatial management of the EMPA. Ensuring these spatial, sectoral trade-offs are well-informed, evidence-based, incorporate trade-offs between the five capitals, and align with the Plan objectives will be critical for delivering sustainable use of the marine area.

In their paper on assessing trade-offs in large marine protected areas, Davies et al. (2018) identified four mechanisms that may give rise to trade-offs:

- management priorities – management decisions prioritise certain objectives and invest in associated activities
- everyday resource use decisions – trade-offs between extraction and short-term well-being and resource condition and long-term sustainability
- externality of resource use – the exploitation of one resource has impacts on other resources
- biophysical relationships – conditions of one environmental good or service are dependent on the conditions of other environmental goods and services.

While they focus on natural capital benefits linked to MPAs, these four mechanisms can be applied to all five capitals, independently and collectively, and assist with developing multiple scenarios to inform trade-offs.

Management of priorities to inform trade-offs will be an important component of the five capitals approach, as these will reflect policy objectives and provide a basis for weighting each of the capitals in decision making. Similarly, a five capitals approach could provide the foundations for assessing the externality (direct and indirect impacts) of resource use, providing a more comprehensive understanding of implications of management decisions.

3.1.5 Interactions

A critical component of developing trade-off scenarios is the identification and understanding of interactions, both direct and indirect, between assets, ecosystem services, human activity, and human well-being. A greater understanding of these interactions will provide the foundations required to identify immediate and broad impacts associated with an activity or decision, mitigation opportunities, and opportunities for multiple benefits.

Davies et al. (2018) identified three types of trade-offs while assessing the impacts of large marine protected areas:

- between different ecological resources (supply trade-offs)
- between ecological resources and the well-being of resource user (supply-demand trade-offs)
- between well-being outcomes of different users (demand trade-offs).

While these trade-offs focus on the interactions between natural capital assets and the asset users, the categorisation of supply and demand, or provider and beneficiary, can be applied across all five types of capital asset.

While Davies et al. (2018) focused on asset-user interactions, Nilsson et al. (2016) focused on the interactions between policy objectives, namely the delivery of Sustainable Development Goals, and how the pursuit of one goal influences the achievement of another. For example, the pursuit of converting land use from agriculture to bioenergy production (SDG 7 – Affordable Clean Energy) might counteract food security (SDG 2 – Zero hunger) and poverty reduction (SDG 1 – No Poverty). Understanding these interactions can help guide the development of new policies and strategies and optimise efforts towards achieving SDGs.

To support decision makers, Nilsson et al. (2016) developed a seven-category scale of how SDGs could influence each other, both positively and negatively (Figure 2). Where interactions between SDGs fall within the three negative categories, trade-offs will be required.

Figure 2: Scale of influence the delivery of Sustainable Development Goals have on each other (Nilsson et al., 2016).

GOALS SCORING
The influence of one Sustainable Development Goal or target on another can be summarized with this simple scale.

Interaction	Name	Explanation	Example
+3	Indivisible	Inextricably linked to the achievement of another goal.	Ending all forms of discrimination against women and girls is indivisible from ensuring women's full and effective participation and equal opportunities for leadership.
+2	Reinforcing	Aids the achievement of another goal.	Providing access to electricity reinforces water-pumping and irrigation systems. Strengthening the capacity to adapt to climate-related hazards reduces losses caused by disasters.
+1	Enabling	Creates conditions that further another goal.	Providing electricity access in rural homes enables education, because it makes it possible to do homework at night with electric lighting.
0	Consistent	No significant positive or negative interactions.	Ensuring education for all does not interact significantly with infrastructure development or conservation of ocean ecosystems.
–1	Constraining	Limits options on another goal.	Improved water efficiency can constrain agricultural irrigation. Reducing climate change can constrain the options for energy access.
–2	Counteracting	Clashes with another goal.	Boosting consumption for growth can counteract waste reduction and climate mitigation.
–3	Cancelling	Makes it impossible to reach another goal.	Fully ensuring public transparency and democratic accountability cannot be combined with national-security goals. Full protection of natural reserves excludes public access for recreation.

Reviewing how the delivery of the East Marine Plan objectives interact and influence one another, informed by the five capitals approach and using a similar approach to Nilsson et al.'s seven-category scale, could help identify and improve conflicting policies, and highlight synergies. This can also be broadened out to consider how the Marine Policy Statement's High Level Marine Objectives interact and can inform Strategic Assessments.

3.1.6 Five capitals approach

Capital can be defined as a resource either used or available for use in the production of goods and services. There are several forms of capital described within the literature, but the five most referred to are natural, social, human, manufactured and financial. Appendices A through to E in the literature review provide a more detailed description of these capitals.

The concept of capital was first applied in an environmental context as humanity realised that increasing demand for economic growth was severely impacting the earth’s natural resources. By better understanding the flow of natural capital assets, the services they provide, and their benefits to society and the economy (which includes human, social, manufactured, and financial capital), a holistic approach can be developed that places the environment at the core of decision making (Goodwin, 2003).

Natural capital approaches initially focused on the economic valuation of resources, often accompanied by a cost-benefit analysis of investment versus output. While this approach can support decision-making, if all costs are not known and integrated into the evaluation, the chance of poorly informed decisions increases. Identifying all associated costs has proven to be particularly challenging when making decisions on environmental use. More recent thinking involves taking an integrated approach that considers the interconnectivity between capitals within the context of human well-being (Stebbings et al., 2021).

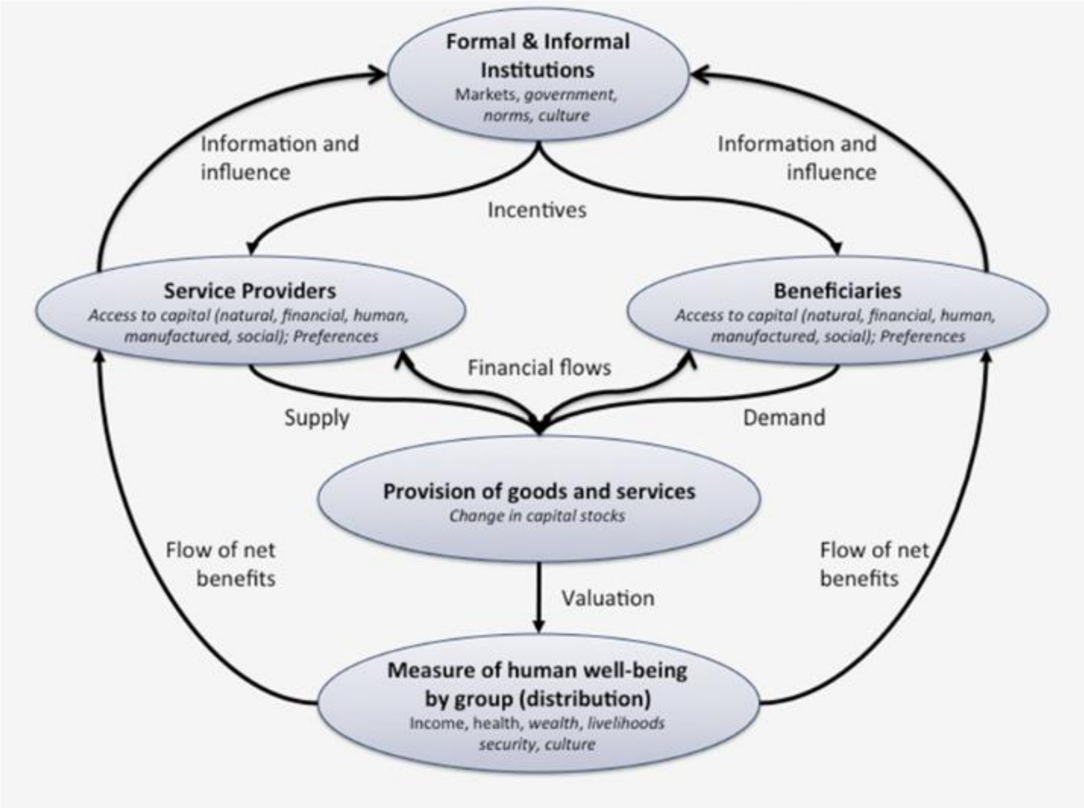
The five capitals approach has to date been largely confined to the academic and business communities. It incorporates the interconnectivity of all five capitals, rather than assessing each in isolation (Edwards-Jones et al., 2022), and provides a framework which could help assess the wider extent of policy decisions, which includes the environment, communities, economic sectors, and industries. Through this approach, the sustainability of decisions and overall policy implementation could be assessed (Forum for the Future, 2023b).

The application of a five capitals approach to decision making must take into account:

- political priorities
- risk and capital thresholds
- the spatial, temporal, and quantitative limitations and boundaries within the study area
- the different scales capitals operate at, and the units used to express them
- the relationships and interdependencies between capitals
- trade-offs within a single capital as well as those between different multiple capitals.

Several theoretical frameworks have been developed to integrate multiple capitals in decision-making (such as Grafton et al, 2005; Pearce et al., 2012; Da Silva et al., 2020; Stebbings et al., 2021, Harris et al., 2022). For example, the integrated approach proposed by Guerry et al. (2015) is shown in Figure 3.

Figure 3: The integration of a natural capital approach in decision-making (Guerry et al., 2015)



Commonalities between theoretical applications of a five capital approach include:

- defining a (spatial) scale and period at which the assessment is carried out
- defining specific objectives and considering prioritisation of certain capitals
- taking stock of all capitals involved to understand the status quo, interactions, goods and service flows, and other conditions (for example, asset registers, natural capital accounts, etc.)
- valuing and weighting of assets
- creating scenarios to include, for example, trade-off decisions and potential consequences on, typically, the environment.

Crucially, successful application of a five capitals approach requires interdisciplinary and inter-institutional cooperation and coordination (for example, Causon et al., 2022; Bateman & Mace, 2020; Stebbings et al., 2021).

3.2 Workshop

The application of a five capitals approach to the environmental sector is new, and it was important to gather a range of perspectives across academia, industry, and policy makers to inform this study. The workshop was used to test HMC's early thinking on five capitals approaches, our understanding of carrying capacity and trade-offs, and potential frameworks for application to marine planning.

3.2.1 Structure and questions

The workshop consisted of a short presentation highlighting the concept of five capitals and findings from the literature review (Annex A), followed by two break-out sessions of three groups to explore specific questions emerging from the scoping phase of the project. A Miro board, including reference materials and an early framework for application of a five capitals approach, was used to facilitate discussions (Figure 4). Feedback was provided by facilitators at the end of each break-out session.

The first break-out session focused on interactions and dependencies between capitals, answering two questions:

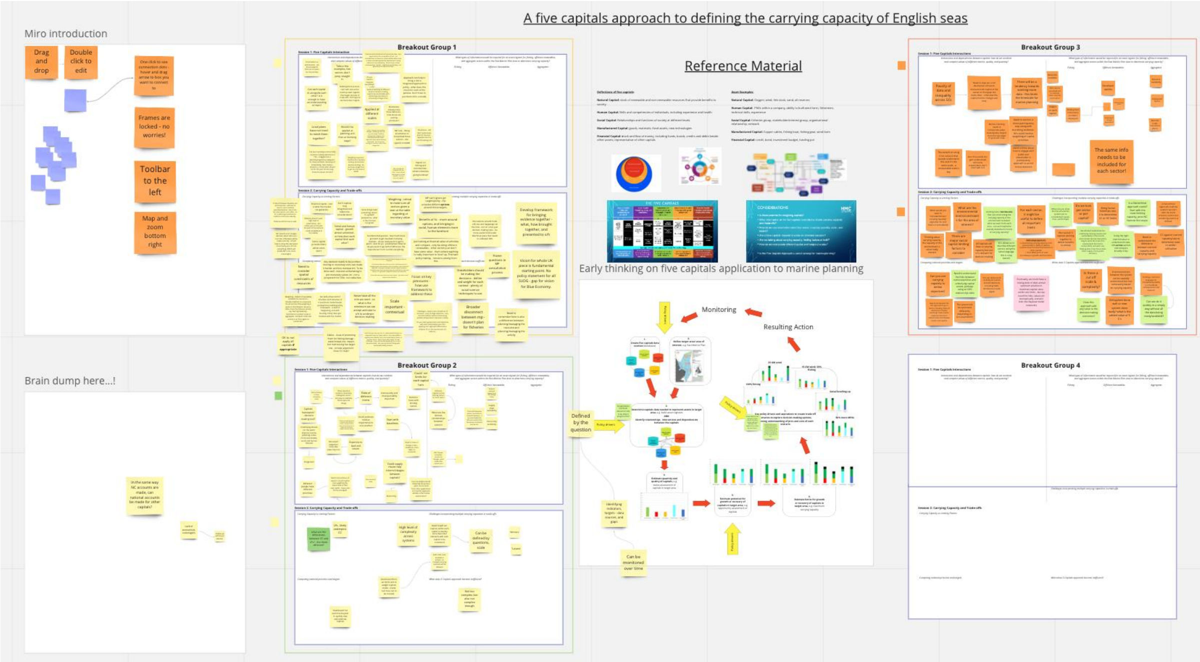
- How do we combine and compare value of different metrics, quality, and quantity?
- What types of information would be required for an asset register for fishing, offshore renewables, and aggregate sectors within the EMPA to determine carrying capacity?

The second, longer, break-out session focused on carrying capacity and trade-offs and covered four further questions:

- What, if any, is the difference between carrying capacity and limiting factors?
- What are the challenges incorporating multiple carrying capacities in trade-offs?
- How do we deal with competing national priorities and targets?
- When does a five capitals approach become inefficient?

Participants were given the opportunity to add to the Miro board during the sessions, and for 24 hours after the workshop finished. Each group answered the questions differently, from systematic to freestyle, so all contributions were clustered under common themes to enable analysis (Figure 4).

Figure 4: Completed Miro board showing reference materials and high level of interaction.



Please see the separate version of figure 4 to view it in full.

3.2.2 Main messages

Value of a five capitals approach

Questions were raised over whether the five capitals approach improves upon and adds value to existing approaches. Considering the complexity of the five capitals approach, and the amount of data required, it might not be worth applying a new system if it can't be done well. Further, the point of application was raised, suggesting that the approach may be more effectively applied to a marine plan Sustainability Appraisal.

The underlying drivers to develop this approach were considered to include improving the marine planning process, increasing sustainability, improving integration of separate systems, and making decision-making more focused on social and human elements of society. Most agreed that it could be a valuable way to better integrate decision making, and understand carrying capacity, especially by giving more consideration to human and social capital.

A major benefit of a five capitals approach is that it allows us to describe different sectors using the same language and compare the same metrics when making trade-off decisions. However, there is a need to balance the complexity when considering multiple capitals and sectors; too complex and the approach becomes unworkable, too simple and it becomes meaningless.

Carrying capacity and trade-offs

The main message emerging was that we need to better understand carrying capacity. There was agreement that the natural environment or ecological carrying capacity should always be the priority, but we still don't understand how to determine it. We have targets in place and work ongoing to understand the link between environmental state and delivery of ecosystem services.

It was felt that limiting factors might be constraining the carrying capacity of the environment to deliver what we want from it, but careful thought needs to be given to whether each capital can usefully be described in terms of carrying capacity. It might be useful to start with the most limiting capacity, possibly natural capital, to narrow the scope of the complexity, which will be essential in making any framework manageable.

National priorities could be used to create 'red lines' not to be crossed when considering decision options. Creating decision-tree frameworks across the five capitals with limiting factors set on assets and capitals in the right places, and informed by science and stakeholders, could be useful. Understanding supply chains, resource availability and flows around assets around the five capitals could be useful in considering how carrying capacity is estimated.

Asset data types and needs

A need was identified to map out a full end to end description of how to measure each capital at the outset, so that gaps are made clear from the beginning and the metrics don't end up evolving over time leading to ineffective monitoring. The same information needs to be captured for each sector, to allow things to be compared and trade-offs explored in a consistent way.

Data inequality across the capitals will be a big barrier at the outset, whilst quality and interoperability are important and must be understood across the five capitals before thinking about combining them in a decision-making process. There will be a tendency to want more data before action is taken, but it must be recognised that data is likely to always be incomplete so agreement must be made on the minimum that is acceptable which will need to be worked out with stakeholders in a participatory approach.

Application of the five capitals approach

Rather than "jumping straight in" when applying five capitals to marine planning, it was felt that the process should start by considering all five capitals within the system. It was also considered ok not to analyse all of them at the start as much of the information may be contextual. A multi-stage approach should be explored that determines the carrying capacity of the natural capital and what benefits it can deliver, followed by identifying the bottlenecks across other capitals which impact the delivery of benefits and how natural capital is limiting growth of other capitals.

A baseline using current data will be essential; all change must be measured against this baseline and will ideally be tracked over time. Each time five capital stocks are evaluated provides an opportunity to recalibrate stocks against the baseline, which would create a rolling system of re-evaluation over time, underpinned by stock monitoring systems that could benefit from development of indicators, targets and methods.

Any five capitals framework should be driven by policy questions, and we need to understand the links between national policies and underlying capital assets, perhaps using a Sustainable Development Goal-style relationship table (Figure 2). This will help determine the scale of application and data requirements.

The natural capital academic community evaluate the flows of ecosystem services from natural capital assets as a means of understanding how these assets relate to wider society. We need to investigate whether similar systems exist for the other four capitals and if these are suitable to be used in the same fashion. Daryl Burdon's matrix approach (Burdon et al. 2017) may indicate some useful elements to explore further.

Valuation

Opinion on whether all capital assets should be assigned a monetary value was split. Some argued that this was a robust methodology to provide an equal standing for different capital assets, whilst others thought that this would create inequity for those values which are difficult to monetise – as well as being very labour and cost intensive. As the data that underpin these systems differ it is difficult to combine them under one valuation system common to them all, and perhaps it would also be inappropriate to do so as well. It may be more appropriate to estimate their value relative to one another instead, making sure they are all accounted for in the decision-making process. There appeared to be universal agreement that a sensible and transparent weighting of values and/or indicators is going to be important.

Stakeholder participation

Stakeholder participation will be essential. A combination of expert and non-expert input into a five capitals application will be needed. Experts are needed to lead and inform the process, and non-expert judgement and public views are essential to inform valuations and weightings of capitals. Caution with expert groups needs to be taken to ensure that expertise in any one capital type does not over-weigh its importance relative to the others, to enable balanced decision-making across all five capitals. Establishing decision-making priorities is therefore important as it will help ensure objective weighting.

It is essential that during stakeholder participation examples are provided to illustrate application of the five capitals approach, as these will help build an understanding of how it will look in practice. Tools – for example, dashboards and traffic lights systems - will be a valuable way to communicate carrying capacity and trade-offs across capitals and sectors.

An overview of the main topics discussed during the workshops is shown in Figure 5.

Figure 5: Clustering of common themes from the workshop

Please see the separate version of figure 5 for viewing in full.

3.3 Discussions with subject experts

Follow-up discussions with four subject experts[1] were organised after the workshop to gain further insight into the application of different capitals, with a focus on the use of social capital. These discussions evolved around the main aspects of the scale or level of application, relevant assets and available data sources, ongoing initiatives that could inform a five-capital approach, and the involvement and relevance of stakeholders.

[1] Jasper Kenter (Aberystwyth Business School, Ecologos Research Ltd), Tara Hooper (Natural England), Gurpreet Padda (MMO), Mark Atkinson (Defra)

There was consensus among social scientists consulted that social capital should be applied at a community level. Social capital assets that could be assessed at such level include community structures, local groups and organisations, as well as social characteristics, such as community resilience, multiple indices of deprivation, and access to financial and well-being support structures. At this level, social capital could help describe how communities and organisations operate in terms of independent and collaborative relationships, level of trust and bonds, member and volunteer participation, communication tools, and existing norms and rules. An example of the latter would be 'gentleman's agreement' within the fishing community, where fishermen agree to limit their activities to areas their families have fished for generations.

From this local scale, social capital could be extended, but decision-making at plan level should consider impacts on communities, including imminent restrictions (negative impact) and long-term benefits, which makes time an important consideration in the five-capital approach. At a higher level, principles of good governance and related governance structures could be considered assets for social capital. Insights and information on aspects of social capital could be collected from existing data sources, including the 'People in Nature' surveys, indices of multiple deprivation, public attitude surveys, and 'understanding society' surveys.
Other ongoing sources of information that could support a five-capital approach include research by the University of Exeter on trade-offs in social capital, Seafish data on fishing community structures, and – in relation to natural capital - a joint project by the MMO and Natural England (NE) on marine plan sustainability appraisals.

The latter was further discussed with the lead author, providing valuable insight in how this project and the sustainability appraisal process can complement each other and further efforts for increased transparency in decision-making. While the joint MMO and NE project aims to create an evidence base providing guidance on existing natural capital stocks, services, limitations and 'red flags' for development, as well as associated risks in the context of policy objectives, this project will add to the thinking of integrating other capitals, which remains limited in the current decision-making processes.

In summary, experts agreed that there is no 'magic solution' to valuing interactions and assets, and that monetised values are not useful or even possible. Any form of weighting of asset values should be done in consultation with stakeholders, which validates the outcomes of this project. Furthermore, experts agreed that prioritisation of capital assets would depend on policy objectives and the context/scale at which decisions are made.

3.4 Initial thoughts on the benefits and challenges of applying a five capitals approach to marine planning, carrying capacity and trade-offs

Informed by the literature review, workshop, and follow-up interviews, it is felt that a five capitals approach has great potential to build on current approaches of assessing trade-offs in the marine environment, but there are still uncertainties of its use in determining carrying capacity. Further thinking and discussion confirmed our views on carrying capacity, and these are set out in section 4. Our initial thoughts on the benefits and challenges of applying a five capitals approach to marine planning are set out below.

Benefits

- Provides a more comprehensive scope to inform trade-offs by including the assets and interactions of social, human, manufactured, and financial capital. This broader assessment can assist with identifying direct and indirect interactions, multiple-benefit outcomes, and opportunities for mitigation.
- The development of asset registers for the five capitals can inform assessments of the current state of capital assets and highlight risks and thresholds that can inform trade-offs and carrying capacity assessments.
- The five capitals approach can be applied to the planning process in a variety of ways, from the development of policy targets and objectives to managing direct conflicts for marine space.
- There are opportunities to apply the five capitals approach in a structured, stepwise way that allows for the capitals to be prioritised to reflect policy targets and marine plan objectives.
- The five capitals align well with, and can support the delivery of, the UN Sustainable Development Goals as well as the delivery of Good Environmental Status.

Challenges

The five capitals approach has the potential to provide multiple benefits to marine planning, but there are a number of challenges that need to be addressed to ensure the five capitals approach is efficient and informative:

- Some assets are potentially shared across multiple capitals, particularly some cultural ecosystem services such as human wellbeing which could also be considered under human and social capitals. This will need further consideration.
- The five capitals approach is not a one-size-fits-all solution and will need to be developed on a case-by-case basis depending on the location, activities covered, and the purpose for its use.
- Data availability, in particular ecological data, is critical to inform the five capital asset registers, which form the basis of the approach.
- Determining which data are required, and at which scale, is essential for ensuring the five capitals approach functions efficiently and towards the desired outcomes.
- Valuing and weighting indicators to measure different capitals is an essential step to determining trade-offs and making information useable and accessible to decision makers. However, as this step determines and prioritises importance of different assets it is one that requires comprehensive consideration and further investigation.
- Incorporation and comparison of different types of value – monetary and non-monetary - becomes increasingly complex as more capitals are considered.

- The five capitals approach requires an understanding of a range of different aspects, namely: the functionality of services, interactions between assets for different capitals, outside impacts (for example, climate change), and interchangeability/substitutability.
- Despite being the most studied, the application of ecological carrying capacity is the most complex, yet from a five capitals perspective, is the most important given its foundational role in supporting the other capitals. However, there is potential for linking ecological carrying capacity with the descriptors for GES.
- Addressing temporal scale is a challenge for trade-off assessments and cumulative effects assessments, in particular the cumulative effects of small, but constant, impacts over a long period of time. Incorporating multiple systems that operate over different timescales will be a challenge for the five capitals approach.
- The ability of environmental thresholds (and carrying capacity) to support decision-making and deliver successful environmental management has been questioned, as they are an *"appealing conceptual way of looking at ecosystems"* but with *"no real potential for practical application".* (Groffman et al., 2006) It is unclear whether the five capitals approach has the potential to address these concerns.

4 Conclusions on carrying capacity

One aim of this project was to assess if a five capitals approach has the potential to increase our understanding of the carrying capacity of a marine plan area and consequently inform trade-offs and decision making.

As highlighted in the literature review, carrying capacity is a construct which can be interpreted in multiple ways, and is difficult to determine. It has both spatial and temporal dimensions, meaning that long-term visions or objectives based on any type of carrying capacity could quickly become dated and inappropriate within the intended lifespan of a marine plan.

It was not clear from the initial project question how carrying capacity should be interpreted. For example, spatial carrying capacity is relatively simple to determine and has been applied within marine planning including, most recently, in the draft MMO1274 East Marine Plan Spatial Assessment. Whereas, ecological carrying capacity is dynamic and changes with pressure (for example, climate change), and is not yet well enough understood to inform sustainable use of natural capital.

Below provides definitions and examples for different terms that have been used to describe environmental, or other, limits.

Definitions

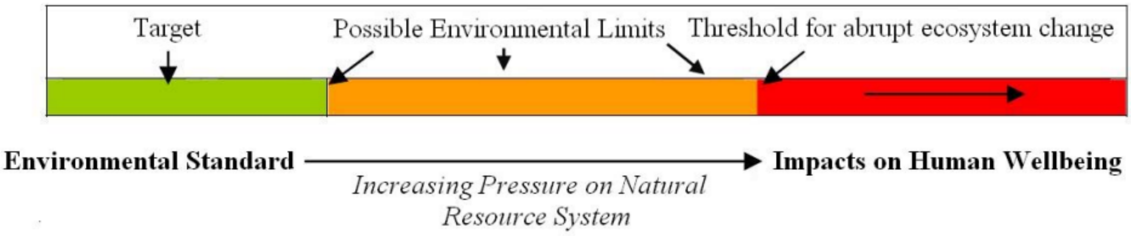
Targets: identified measurable outcomes that are used to monitor against when assessing actions.
For example, the 'good ecological status' requirement set under the EU Water Framework Directive.

Limit: a human-defined point above which there is an anticipated sudden and often catastrophic change – generally applied to the environment where the limit is set to stop decline.
For example, Copenhagen Accord to limit temperature rise due to climate change to 2C above pre-industrial levels.

Thresholds: tipping points that represent abrupt non-linear shifts in state, often used with regard to ecosystems where fundamental changes in species composition and ecosystem function occur.
For example, fish stock collapses caused by unsustainable fishing levels.

Limitations: factors that restrict growth.
For example:

- natural capital – prey abundance
- human capital – lack of training facilities
- social capital – lack of funds for organisations
- manufactured capital – lack of raw materials
- financial capital – lack of cash flow.



(Wentworth, 2011)

Our initial approach was to consider the carrying capacities associated with each of the five capitals and assess whether they could collectively inform a broader understanding of carrying capacity for the area. It quickly became evident, however, that the five capitals all operate at different scales, both spatially and temporally, and behave differently within a system:

- Limits are set to prevent natural capital assets, such as fish stocks or seabed habitats, from exceeding thresholds, beyond which their functioning will be impacted. This will be dependent on other components of the system and will be dynamic, changing with natural and human-induced pressures. Reducing such pressures can enable recovery of natural assets towards targets, and an increase in their ability to deliver services and benefits to society, but this does not depend on the identification of carrying capacity. Whilst ecological carrying capacity is a valid term in theory, it would be very difficult to apply in a simple and meaningful way in this context.

- Limits are not generally set for human capital, as targets are usually set to grow human capital, and is influenced by limitations, such as population size or the number of places available within higher education courses. In many cases, limitations can be reduced through investment, i.e., increasing child benefits for parents or funding the construction of more schools.
- Limits to social capital are generally not set, although these may exist for communities living within a dictatorship, and is usually influenced by limitations, some of which are linked to other capitals. For example, increases in human and manufactured capital can result in more active and valuable social networks. Unlike the other capitals, the more social capital is used, the more valuable it becomes.
- Limits can be set for manufactured capital (for example, a government cap on the number wind farms that can be built within a marine plan area) along with the influence of limitations (for example, the amount and type of human capital available for building wind turbines). In some cases, limitations can be reduced through investment (for example, financial capital to build a new harbour), whereas others are fixed (for example, a finite resource of a raw material, such as copper).
- Financial capital can have limitations (for example, the amount of money available), but this can be variable depending on the level of interest and available resources from investors. However, as financial capital is representative of the other capitals it has no value in or of itself but increases or decreases relative to other capitals.

We, therefore, questioned whether it was possible to use the five capitals to inform a carrying capacity, and whether it was a requirement for making trade-off decisions. Our discussions have led us to the conclusion that carrying capacity is not yet well-enough defined to inform decisions, and that setting targets or limits for each capital may be a better approach.

5 Objective 2. Develop asset registers

5.1 Asset register

An asset register is a structured stock-take of a capital's assets (goods, services, resources) in quantity and/or quality at a defined point in time, at a defined scale. More advanced asset registers can incorporate additional information on the assets' condition, functionality, assigned units and values, flows, and potential interchangeability with other capitals (for example, trade-offs). Flows can be evaluated over a certain period to inform and monitor changes in capital assets.

Objective two of this project involved the construction of an asset register covering the five capitals for all three focal sectors (fishing, offshore renewables, and aggregates). Given the time constraints of this project, the aim was to create a functional template for an asset register and provide example assets to demonstrate the kind of information that could be captured across the three relevant sectors and the five capitals. Learning was captured as the asset register was developed, and the final output was an asset register that enabled the filtering (by sector and capital) of a selection of representative assets (Figure 6). The full asset register can be found here.

Figure 6: Extract from the five capitals asset register for the fishing, offshore renewables, and aggregates sectors in the east marine plan area. Assets can be filtered by sector (columns 1-3) and capital (columns 4-8).

Sector			Capital					Asset (high level)	Assets (detailed)	Stock
Fishing	Renewables	Aggregates	Natural	Human	Social	Manufactured	Financial			
	X		Renewable resource					Provision service	Wind	
X			Renewable resource					Marine space and resources	*Fish- Nursery/ Spawning areas (by species)*	*Placeholder as asset e*
X			Renewable resource						*Fish- Feeding grounds (by species)*	
		X	Non-renewable resource						Dredged area	
X			Renewable resource					Fisheries landings (stock information)	Total commercial fishery landings	85,144
		X	Non-renewable resource					Aggregate landings	Sand and Gravel (marine) landings	9.7
X						Infrastructure		Ports and wharfs	Commercial ports	3
X						Infrastructure			Commercial ports	2
X	X					Infrastructure			Commercial ports	2
X						Infrastructure			Commercial ports	1
X						Infrastructure			Commercial ports	1
X						Infrastructure			Commercial ports	1
X	X					Infrastructure			Commercial ports	2
		X				Infrastructure			Number marine wharfs	22
X						Equipment		Vessels	Fishing vessel over 10m	89
X						Equipment			Fishing vessel 10m and under	172
		X				Equipment			Aggregate Dredger	13
	X					Equipment			*Specialist vessels for OFW installation and operation*	*Placeholder as asset e*

5.2 Methodology

Developing the five capitals, multi-sector, register involved the following steps:

1) A basic asset register template was developed, informed by the literature review.
2) The East Marine Plan was reviewed for general information on important assets relating to fisheries, offshore renewables, and aggregates.
3) Examples and information gathered within the literature review were used to shortlist assets at an appropriate scale that could be applied to one or more of the sectors across the EMPA.
4) Publicly available online data sources were used to identify accessible, up to date, datasets that met the requirements identified in steps 2 and 3.
5) Available data were collated and suitably formatted.
6) Assets were categorised based on available information, comparability between capitals and sectors, and usefulness for decision-making.
7) Different formats were trialled, and the asset register template was updated to allow information to be filtered by capital and sector.
8) The final asset register was populated with all available data and gaps highlighted.
9) A separate register containing metadata and additional available data that could be used to further expand the register was developed.

5.3 Data considerations

In many cases, data required to complete the asset register were not available, either they did not exist, were not publicly accessible or were only available in an aggregated format. These gaps are highlighted in the asset register.

The asset register contains information on the types of data available for each asset, which include count, spatial or aggregated. The scale of data is also listed as:

- international (applicable beyond the UK)
- national (UK-wide)
- regional (particular region, for example, east of England, but not restricted to the marine plan area *per se*)
- marine plan area (plan area-specific)
- local (specific areas within the marine plan area).

5.4 Lessons learned developing the asset register

The first challenge with developing an asset register for the EPMA was determining which assets were most appropriate for inclusion. One of the principle aims of the asset register was to enable assets to be compared across sectors to facilitate trade-offs. Some of the assets included were relevant to all sectors (for example, employment) and allowed for direct comparisons. However other assets, such as fish stocks, were vital for one sector (in this case fishing) but not relevant to other sectors (offshore renewables or aggregates). Given the fundamental importance of fish stocks to the fishing sector, it was important to include it in the asset register.

The level of information available varied considerably depending on the sector and the capital. To create an asset register that allowed for comparisons between sectors, a high-level approach was taken that involved identifying assets that were relevant to most, if not all, of the three sectors. The more assets listed per capital, the more variance there will be, and comparisons will become more complex.

To ensure the data sets identified were the most suitable and appropriate, cross-validation of the same or similar information across multiple data sets was required. This also involved checking how often data sets are updated, as differences were identified in the frequency and regularity in data collection.

In some cases, the information considered for the asset register was not available at the required level of detail. For example, employment by sector at a marine plan area level would require a disaggregation of the data that is currently available through Office for National Statistics (ONS). While it was possible to disaggregate and refine some data to a marine plan level (for example, fishing ports), some data were only available at national or regional level, such as dredging vessels for aggregates. In other cases, the required data were not directly available online, such as information on storage facilities, manufacturing, service or maintenance vessels, and maintenance costs. The information could probably be found through extensive online investigation, accessing Companies House data and/or contacting companies directly, but this was outside the scope of this project.

While multiple examples of asset registers for natural and manufactured capitals were found within the literature review, there was limited information on asset registers for human and social capital. Identifying social capital assets that were measurable (and measured) and were suitable at a regional scale was aided and informed by peer-reviewed literature on human and social capital. However, the amount of information available at marine plan level was limited. Some potential sources, such as the People and Nature Survey, were reviewed but they only provided information at national level and not considered suitable for the asset register.

This work demonstrates the complexity of social capital and how it can be measured at different scales and within different contexts, depending on the decisions to be made and questions to be answered. Based on this review, indicator selection for the current asset register focused on three aspects of social capital, namely groups and networks, institutional linkages (governance structures), and social characteristics. The latter was also based on previous studies conducted by the MMO and could further be expanded by measures of national wellbeing (at national scale) from data published by the ONS.

While the asset register provides an inventory of capital stocks, there is potential to integrate linkages between assets and valuations/weightings for each asset and linkages. This level of detail would, however, build in a level of complexity that may render the register unwieldy and less user-friendly. The integration of asset weightings and interactions into the five capitals approach is discussed further in Section 6.

5.5 Expanding the asset register

Whilst developing the asset register, we discussed the different scales and level of detail it should, or could include for example, subdividing fishing vessels by gear-type and fish landings by species, or providing further details on windfarms, such as the number of turbines or cable length. Other aspects relevant to human capital could include physical and mental health status of people employed in different sectors, or level of training and experience.

Discussions with social science experts on social capital provided insights in how to expand and apply social capital at community level, which could include the following considerations: social support structures (for example, access to health care), working relationship-structures, stakeholder engagement level (involvement in decision-making and planning process), trust in government/regulators, access to resources within and between groups/organisations. However, identifying or building data sets that provide the required information would involve extensive research and investment, as such data is currently not available.

The asset register currently includes assets that are directly linked to the three focal sectors, however there is also potential to extend the register to include market and supply chains for each sector. This could include, for example, processing facilities (for example, seafood), restaurants, end-uses of aggregates, and household supply of energy generated by windfarms in the area. The inclusion of these extra layers of detail could provide additional insights to inform trade-offs and scenario development. However, it is important to recognise that expanding the asset registers in this way would increase the level of complexity of the asset register. The initial purpose for developing the asset register will determine whether these additional levels of complexity are required.

6 Objective three; scaling up a five capitals approach across multiple sectors and marine plan areas

Our initial thinking set out in section 3.4 has developed significantly, aided by the development of the asset register and multiple rapid sprint brainstorming sessions. In this section we set out a conceptual framework for applying the five capitals approach, and consider the relationships between assets, registers, and sectors. We discuss major considerations for scaling up the approach and conclude with recommendations for further work.

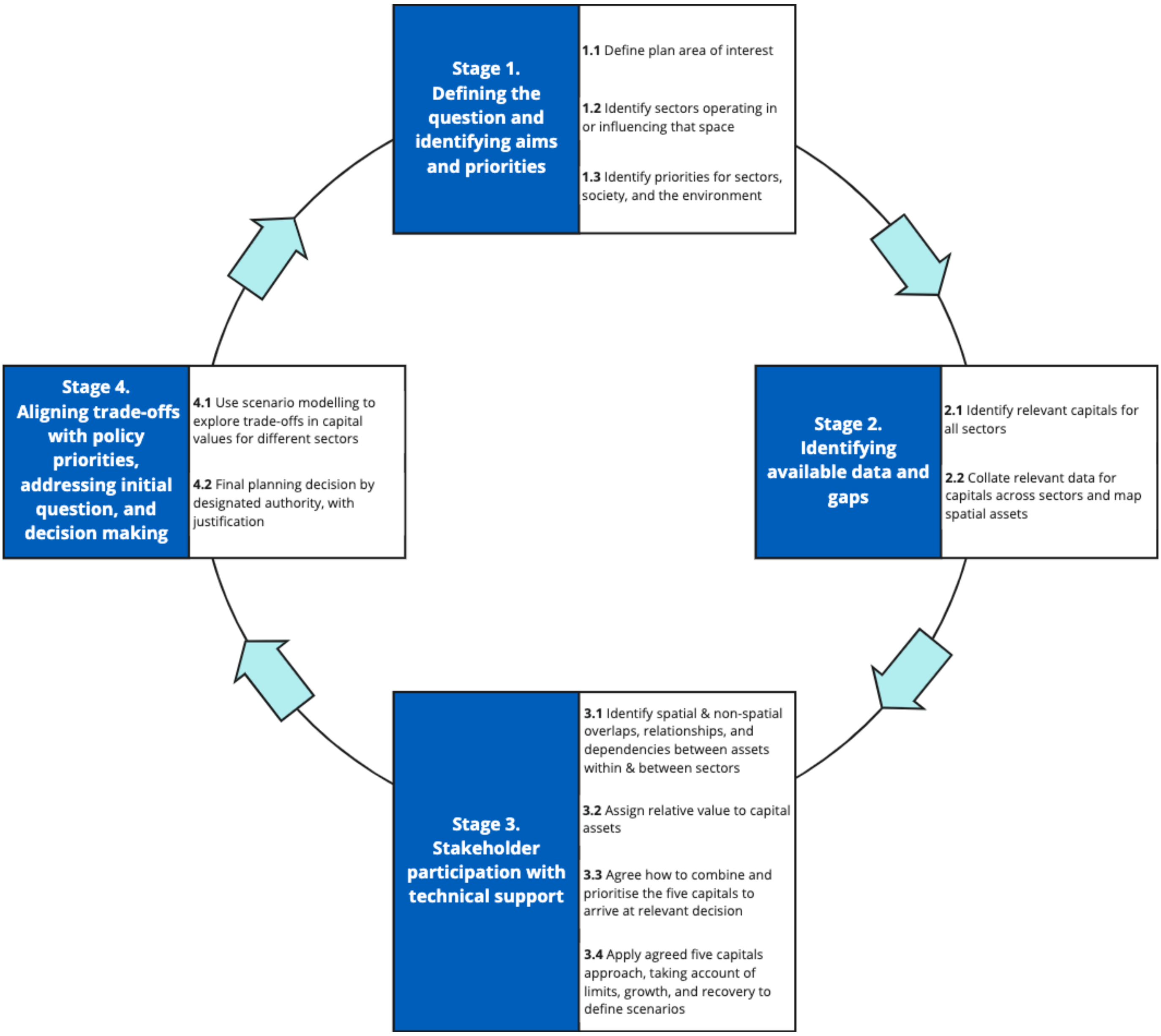
6.1 A conceptual framework for applying the five capitals approach to marine planning

The application of a five capitals approach could support decision making in marine planning, aligning itself well with the aims of current practice under sustainability appraisals, by providing an effective means of evaluating the three pillars of sustainability across environmental, economic and social considerations. It could offer particular advantages over existing assessments owing to the high-level of understanding of the capital assets related to marine planning questions, represented as asset registers.

Further understanding around how the assets relate to one another across the five capitals, such as the inter-dependencies between fish stocks (natural), fishing vessels (manufactured), employment (human), disposable income (financial) and the fishing community (social), (see Figure 8 – fishing asset network), as well as an understanding of any limitations (natural or policy-imposed) on the assets, or 'red lines' not to be crossed, can underpin a truly holistic, balanced trade-off analysis that considers all aspects of a marine planning question. Furthermore, the five capitals approach keeps stakeholders engaged during phases of a decision-making process where their inputs are most effective. An added benefit is that stakeholders may feel more included and 'buy-in' may be higher.

Here we outline how a five capitals approach could be applied to a marine planning question, describing steps along a process that could be taken to address that question (Figure 7). This approach is purely hypothetical and intended to demonstrate the broad steps that could carry out a five capitals-based assessment; it is outside of the scope of this project to fully explore the precise details required to carry this approach out or to carry out a full test demonstration. Such a trial is recommended for further work in future.

Figure 7: Five capitals assessment framework for decision making in marine planning.



Stage 1: Defining the question and identifying aims, and priorities

The process begins by defining the question or the issue to be addressed using a five capitals approach. Correctly articulating this is fundamental as it will underpin the evidence required, stakeholders to engage with and how to 'trade-off' management options to make a decision. Special attention should be paid to any aims or targets that relate to the question being asked, as well as any policy-related priorities, as these will drive scenario modelling to explore trade-offs (see step 4.1). The following three steps lead on once the question is adequately defined:

1.1 Define plan area of interest

The spatial area of interest in which the question/decision, and its outcome is most relevant, should be selected to define the boundaries of the decision-making process and limit the scope. For example, this may be a marine plan area, highly protected marine area, windfarm leasing zone, or fishing grounds, each depending on the nature and scale of the question.

1.2 Identify sectors operating in or influencing area of interest

Once the area of interest has been defined, all sectors and interests that operate within that area that are relevant to the question should be identified.

1.3 Identify priorities for sectors, society, or environment

A review of the priorities for the relevant sectors in the area of interest, as well priorities for society or the environment, will start to build an understanding of potential targets to reach and/or limits not to be exceeded when making the decision. Useful priorities to review include plan policy objectives (if relevant), sector plans, and national and regional policy priorities.

'What if' examples

Question:
How many gigawatts of wind energy can be sustainably created in the east marine plan area without serious detriment to the fishing and aggregates industries?

Plan area of interest:
England's east marine plan area (EMPA)

Relevant sectors:
Offshore wind energy sector, commercial fishing sector, marine aggregates sector

Priorities:

- Maximise opportunities for offshore wind capture in EMPA;
- Limit reduction in fishing output to x;
- Limit reduction in aggregates output to y;
- Limit impacts to marine protected areas, highly protected marine areas and GES status of EMPA.

Stage 2: Identify available data and gaps

The second stage involves identifying and collating the data needed to address the question and preparing it for application of a five capitals approach. As current databases were not established to store either environmental, social, human, manufactured or financial capital data explicitly, the relevant information will have to be sourced and aggregated under these five capital headings. Gaps encountered in the information required should be noted and, if considered a priority, targeted for future evidence gathering.

2.1 Identify relevant capital assets for all sectors under consideration

An assessment should be carried out to identify the relevant capital assets from each of the five capitals that represent the sectors and interests operating within the defined area of interest. It is also important to agree at the outset how each capital will be defined, quantified, and measured so that change over time can be reliably monitored.

2.2 Collate relevant data for capitals across sectors and map any spatial assets

Once the relevant capital assets have been identified for each sector, a search for data and information to represent those assets should be conducted. Relevant information should be categorised, collated, and used to populate an asset register. The asset register should provide details on the asset quantity, quality, sector-relevance, and capital-relevance – as covered in Section 4 of this report. It is also important to consider the relevance of assets to the priorities noted in Step 1.3 above.

Alongside the asset registers a standard method of measuring each capital should be identified and agreed across all sectors. This will likely employ a 'relative' means of asset and capital quantification to account for differences in how capital assets are measured (for example biodiversity, economic and social metrics of measurement are all different across the capitals). Where possible, spatial data collected as part of the asset register development should be mapped to provide a visual representation of sector activity and their associated assets.

'What if' examples

Relevant capital assets

Lists of assets for each of the five capitals to represent the:

- Offshore wind energy sector;
- Commercial fishing sector;
- Marine aggregates sector.

Asset registers:

Asset registers/lists detailing the name and category of each asset (of the five capitals), the quantity, quality (condition), sector-relevance, capital-relevance and priority-relevance are created for the:

- Offshore wind energy sector;
- Commercial fishing sector;
- Marine aggregates sector.

Maps of spatial assets:

- Offshore wind energy sector licensed areas and ports;
- Fish landings data, fish nursery areas, fish spawning areas, ports and harbours;
- Marine aggregates sector licensed areas and ports.

Stage 3: Stakeholder participation with technical support

In this critical stage of the process a technical team prepares relevant information via readily accessible outputs and tools. These are validated by a group of stakeholders, who help shape the evidence into trade-off options for decision-makers to consider. As stakeholder time is precious, their engagement time must be carefully planned to maximise their input, aiming to harness and channel their expertise to better tackle the question under investigation.

3.1 Identify spatial and non-spatial overlaps, relationships, and dependencies between assets within and between sectors

Using the information gathered for the asset registers, asset networks are created to highlight the main assets for each sector, shared assets used by multiple sectors, and the relationships/linkages between the capital assets (see Section 6.2). Stakeholders can verify and modify asset network maps to better reflect reality.

3.2 Assign relative value/importance to capital assets

To prepare trade-off options for decision-makers to consider, a means of understanding the relative importance or value of one asset over another, or of one capital over another, must first be known. This may be accomplished by asking stakeholders with expertise in the issue under investigation to estimate the relative importance of capital assets in asset relationship maps, assigning a relative value where possible (recognising this will be challenging and will require a robust stakeholder participation process). These values should represent or be informed by the asset registers of each capital type in the first instance, thus providing a link to 'real' world accounts of these capital assets. In addition, the stakeholder group should also account for benefits and services provided by each asset when estimating its relative value in this decision-making process, whilst ensuring that double-counting of values is avoided.

'What if' examples

Stakeholder groups established

Groups with representatives from Non-Government Organisations, commercial operations in wind and aggregates, local community groups, fisheries associations, port authorities, markets, Crown Estate.

Asset networks

Asset network diagrams created for offshore wind energy sector, commercial fishing sector, marine aggregates sector (see latter example below) validated by stakeholders (See Section 6.2 for further detail).

Relative values of capital assets:

Stakeholders agreed in workshop to estimate relative asset values on a 10-point scale of importance, allowing for easier working across asset and capitals despite their conceptual differences.

3.3 Agree how to combine and prioritise the five capitals to arrive at relevant decision

Further stakeholder discussion will inform how assets (that now are valued relative to one another) and their relationships across the capitals in each sector, may be combined and prioritised ahead of any decision-making. There are numerous ways to do this, each depending on the relative importance of each asset in each capital, whether any sectors, capitals or assets should have priority over any others, and the nature of any inter-dependencies or common assets shared by each sector (for example, ports). Some options to consider are:

1) All capitals/sectors given equal importance?
2) Should natural capital be given priority, in hierarchical model?
3) Should one capital/sector be given priority due to policy, in hierarchical model?

3.4 Apply five capitals approach in the ***chosen way,*** *taking account of limits, growth, and recovery to define scenarios*

The limitations and, if applicable, upper and lower limits for each capital should be identified and set, respectively. These will inform the potential for growth and set the lower limit for possible erosion of a capital as a result of decision making. These are the boundaries in which the trade-offs will operate.

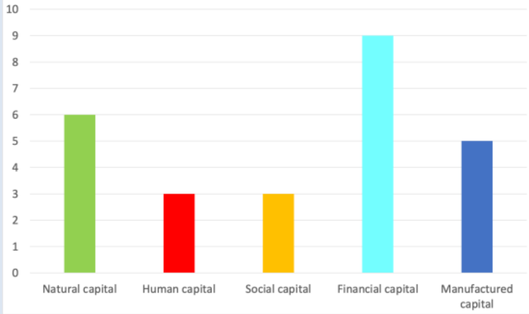
The final inputs from the stakeholder group will set out a range of scenarios in which the question being explored could be realistically manifested. They will outline the various chosen ways in which this could happen, considering any potential mitigation and compensation measures that may be relevant to the decision-makers. It should be noted that at this stage, government scenarios (for example offshore wind expansion) may take priority.

'What if' examples

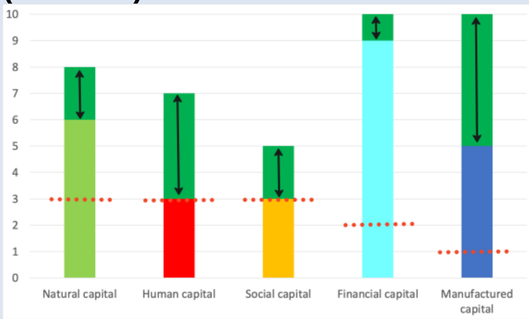
Priority of capitals decided by stakeholders

For this question, the technical team and stakeholders agreed the capitals should be considered in a hierarchy, in this order of priority: natural capital (highest), human, manufactured, social, financial (lowest).

Capitals combined (and plotted)



Potential for growth and lower limits (red lines)



Stage 4: Aligning trade-offs with policy priorities, addressing initial question, and decision making

The final stage of the process is carried out by a well-informed decision-making team, who are equipped with all the evidence tools and products developed during this process. It is recommended that a suitable decision-support tool should be developed to facilitate the modelling and exploration of trade-offs, highlighting benefits and losses of different scenarios. The use of MaPTA could be a valuable tool in supporting this stage, whilst Bayesian models, which accept non quantitative data, could be another solution.

4.1 Use scenario modelling to explore trade-offs in capital values for different sectors

The scenarios prepared by the stakeholder group with technical support are now explored. Although a decision support tool, with digital dashboard, maps, and plots, would speed up the process, it is not essential in weighing up the impact of each scenario under investigation. It is important to refer to the original question, policies, and priorities identified earlier in the process (Step 1.3) to ensure they are taken into account alongside the stakeholder weighting/values built into the model evidence tools and products developed during this process.

4.2 Final planning decision by designated authority, with justification

Once all options have been explored, the various modelled outcomes of sector and capital value trade-offs are reviewed by designated decision-making authority. Their decision will be the result of weighing up numerous related factors across sectors and five capitals, ensuring that it delivers policy objectives or priorities in the optimal manner and, where possible, also meets stakeholder interests.

'What if' examples

Original question and priorities:
How many gigawatts of wind energy can be sustainably created in the east marine plan area without serious detriment to the fishing and aggregates industries?

- Maximise opportunities for offshore wind capture in EMPA;
- Limit reduction in fishing output to x;
- Limit reduction in aggregate output to y;
- Limit impacts to marine protected areas, highly protected marine areas and GES status of EMPA.

Decision-support tool
Applied to all options, with benefits and losses estimated across capitals, with outcomes and risk-mitigation measures.

Resulting decisions made

- Increase wind lease areas by x% (new areas identified on map);
- Fishing restrictions in wind lease areas and quota reductions of y%;
- Aggregates operations uninterrupted;
- Retraining of fishing community (for wind and port sector) and new social funds;
- Growth of port facilities by z%.

6.2 Relationships between assets, registers, and sectors

The five capitals approach provides a process for identifying important assets across sectors, going beyond natural capital assets and ecosystem services, and categorising them within each of the five capitals. This approach allows for the assets, that may be linked to multiple capitals, and their linkages to other assets, to be identified. As set out in the conceptual framework above, the mapping of sector assets and their linkages through a five capitals lens enables a better understanding of trade-off implications and for more detailed and comprehensive scenarios to be developed.

Our approach to developing the assets maps was first to consult the asset registers, and visually map out the assets for each of the three sectors. Additional sector-specific assets were then added to each of the maps to build up a more detailed representation of each sector. The linkages between the assets were then identified and added to the map.

Every asset within the maps is colour coded to identify which capital the asset represents (for example, green for natural capital, orange for social capital). The arrows linking the assets indicate a general direction of flow, although further development of these linkages could include information on the types of linkages, such as circular, positive, and negative interactions. In some cases, assets are linked by a line without a direction of flow. These linkages indicate that the two linked assets either represent the same feature but through different capitals (for example, a market can be considered social capital, but it is usually located within a building, which is manufactured capital) or the same type of capital but in different forms (for example, 'fishing community' is a component of the 'local community', both of which can be considered social capital assets).

Each of the three asset networks provided a focus on a single sector (these are fishing, aggregates, and offshore wind) and the asset relationships within that sector. However, there are some assets within the maps that feature in all three sectors (for example, 'harbour/port' and 'employment'), which are represented by a thicker, dash-ringed circle. These 'shared' assets highlight important links between the sectors.

The asset networks are designed to give an indication of how the assets, and their interactions, can be visualised. They are intended to provide a high-level overview of significant assets, rather than a comprehensive representation of all assets associated with the chosen sector. However, there is potential for increasing the scope of the asset networks for each sector (for example, increase the number of assets along the supply chain), integrating assets from other sectors, and developing further the types of interactions between assets, all of which would help to inform trade-off options and scenario development.

6.2.1 Fishing sector

The fishing sector asset network (Figure 8) contains the most social capital assets of the three sectors examined. The larger representation of social capital is mostly due to the sectors role in establishing and supporting the fishing community, and the many social capital assets directly linked to it (for example, culture, tradition, and fisheries associations). In many coastal towns, the fishing community is developed over generations of fishers and can represent local culture and identity, giving it a significant social importance. The fishing community also plays an important role in developing human capital, particularly with respect to passing on fishing knowledge and experience to new generations of fishers.

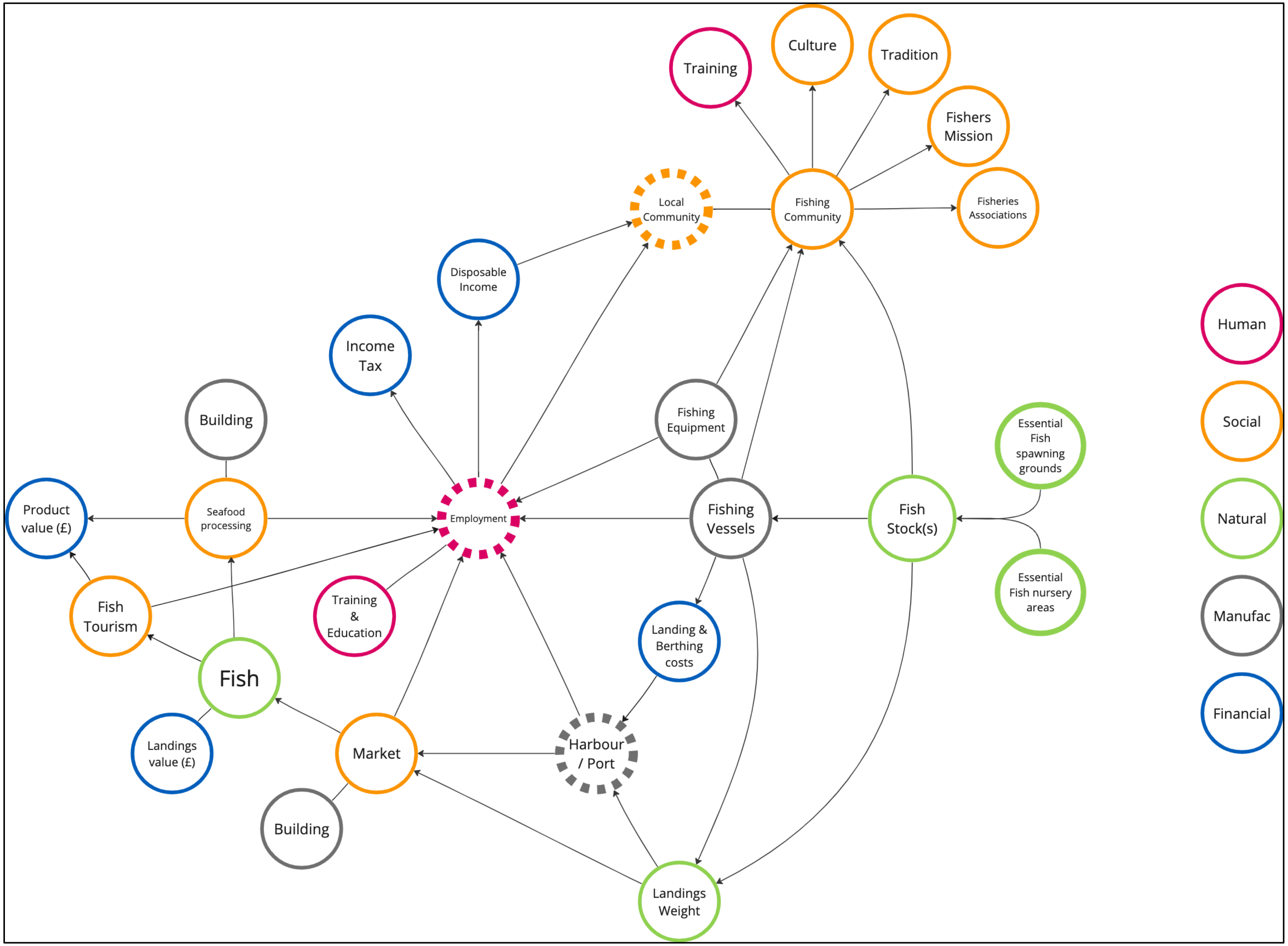
Other assets linked to the fishing sector, such as the local fish market, fish tourism (that is people visiting the area to eat locally caught seafood), and seafood processing all provide important employment opportunities, which in turn support the local community and the fishing community. The employment provided by the fishing sector, and subsequent supply chain businesses, play an important role in building the local human and social capital.

The asset network also highlights some of the most important manufactured capital assets, in particular the fishing vessels (and the types of equipment used), the harbour/port where the catch is landed, and the buildings that house the market and the seafood processing businesses. The harbour/port asset is represented by a dashed circle, due to its importance to other marine sectors, such as aggregates and offshore renewables.

The other assets linked to multiple sectors are ‘employment’ and ‘local community’. Employment is a human capital asset and represents the people employed, in this case, by fishing vessels, harbour/port, market, fish tourism and/or seafood processing. However, people from the same pool of human capital (such as the local community) will be employed by other sectors. Therefore, the human capital of the local community is considered a shared asset between all marine sectors. In turn, all employees from the local community will contribute towards building the social capital of the local community.

The most important assets in the fisheries asset networks are the ‘essential fish nursery habitats’ and ‘essential fish spawning habitat’, as they provide critical habitats that support the fish stock(s) asset. Unlike the aggregates and offshore renewables sectors, which rely on natural resources that are finite (for example, gravel) or inexhaustible (such as wind), the fishing sector is dependent on natural resources remaining healthy and productive (such as spawning and nursery habitats) and managed in a sustainable manner (in this case fish stocks). Therefore, healthy marine habitats and sustainable fishing practices are fundamental to the success of the fishing sector and the other dependent businesses (such as markets, seafood processing, and fish tourism).

Figure 8: Asset network for the fishing sector representing all five capital assets. Dashed circles represent assets used by multiple sectors.



6.2.2 Aggregates sector

The aggregates asset network (Figure 9) follows a similar structure to the fishing sector, where a physical resource is extracted from the marine environment, landed at a harbour or port, sold in a market (although this may not necessarily be located within a building), and then processed before being sold as a final product.

An important difference between the asset networks for aggregates and fisheries is the lower representation of social capital assets. The aggregates industry has not established the equivalent of a fishing community (and connected social capital), and therefore contributes less to the local social capital.

The aggregates sector still requires human capital (including employees) throughout the associated supply chain, which will contribute to the local community (social capital). However, due to the non-perishable nature of aggregates, the market and processing plants do not need to be located close to the harbour/port. Therefore, the need for human capital (such as employees) may be met at a national, rather than local scale. The lower dependence on local human capital may result in a weaker contribution to the local social capital than, for example, the fishing sector. However, the contribution to social capital will take place at a larger national rather than local scale (for example, support national corporations and communities within those organisations – identified as ‘sector community’ in the asset network).

Figure 9: Asset network for the aggregates sector representing all five capital assets. Dashed circles represent assets used by multiple sectors.

*BMAPA is the British Marine Aggregate Producers Association

6.2.3 Offshore renewables sector

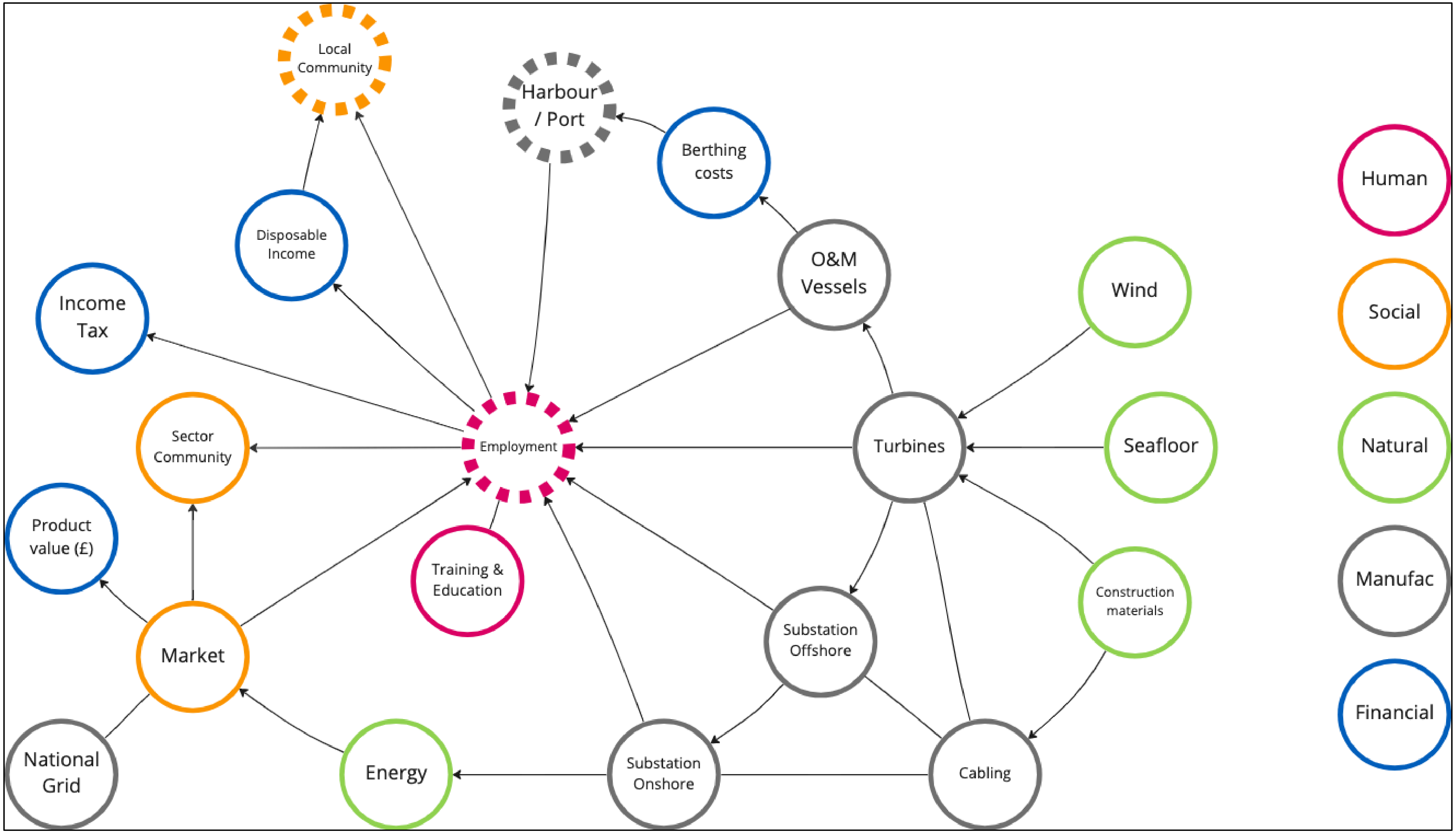
The offshore renewable sector differs from the fishing and aggregates sector in that instead of extracting a physical natural resource (fish and aggregate, respectively), it converts a natural resource (wind) into energy. Therefore, the offshore renewable asset network (Figure 10) contains more manufactured assets that enable the conversion of wind into energy and its transportation (these are wind turbines and supporting infrastructure). The human capital (for example, employment) associated with the offshore renewables sector comes largely from the operation and maintenance needs of the manufactured assets.

Similar to the other two sectors, the harbour/port is an important asset for operation and maintenance (O&M) activity, which, through employment, is the sector's most significant link to the local community (social capital).

Beyond employment through O&M activity, the offshore renewables sector has few links to the local community. The energy produced by the turbines passes through cables and substations and enters into a market and energy grid that operate at a national scale. Therefore, the linkages between the production and sale of the 'product' and local human and social capital are minimal.

However, although the contribution by the offshore renewables sector to local social capital may be small, when compared to the fishing sector, it's contribution to social and human capital on a larger regional and/or national scale, through national corporations and associated communities, may be significant.

Figure 10: Asset network for the offshore renewables sector representing all five capital assets. Dashed circles represent assets used by multiple sectors



*O&M stands for operation and maintenance

6.3 Further considerations on the development of asset networks

Asset networks can be enhanced by including additional information on the type and magnitude of the interactions between assets. For example, the link between fish habitats and fish stock is vital, providing the foundation for the whole sector. Any activities or actions that could weaken this interaction would have significant implications for all the assets within the system and should be avoided where possible. Identifying these significant linkages will play an important role in understanding the broader implications of management decisions, and assist with identifying important trade-offs, and developing informed scenarios for decision making.

In addition to identifying significant interactions, recognising which assets play important roles with the system will enable the opportunity to weight and prioritise assets in trade-off scenarios. For example, the harbour/port asset is significant for all three sectors examined (and other marine sectors) and, therefore, ensuring it is maintained, fit for purpose, and sufficiently resourced to accommodate multiple, and varied demands, will be vital.

Employment is a significant human capital asset for all sectors, which is enhanced through additional employment opportunities and training and education. In the asset networks, human capital is considered as a single asset across the sectors. However, there are important variations that should be recognised. For example, human capital within one sector may not necessarily be transferable to another sector due to different training and skill requirements. This may be particularly apparent for the fishing sector, where the skills required to be a successful fisher (for example, fishing knowledge and experience) are not requirements for the offshore renewables sector.

Further, the movement of people (human capital) from one sector to another will have implications for human and social capital. Whilst training and education will help develop the skillsets required for the transition (an increase in human capital), the movement of human capital away from one sector will result in a loss of knowledge and experience (a reduction in human capital). For example, the growth of the offshore renewables sector could acquire boat captains from the fishing sector, creating a transfer of technical boating expertise. However, the knowledge, experience, culture, and traditions of the fishing sector will be lost. In this example, the fishing knowledge and experience (human capital) would normally be passed down to younger generations within the fishing community (social capital), rather than taught in a school. Therefore, the human capital of fishing knowledge and experience would be difficult, if not impossible, to recover if lost completely.

6.4 Future application

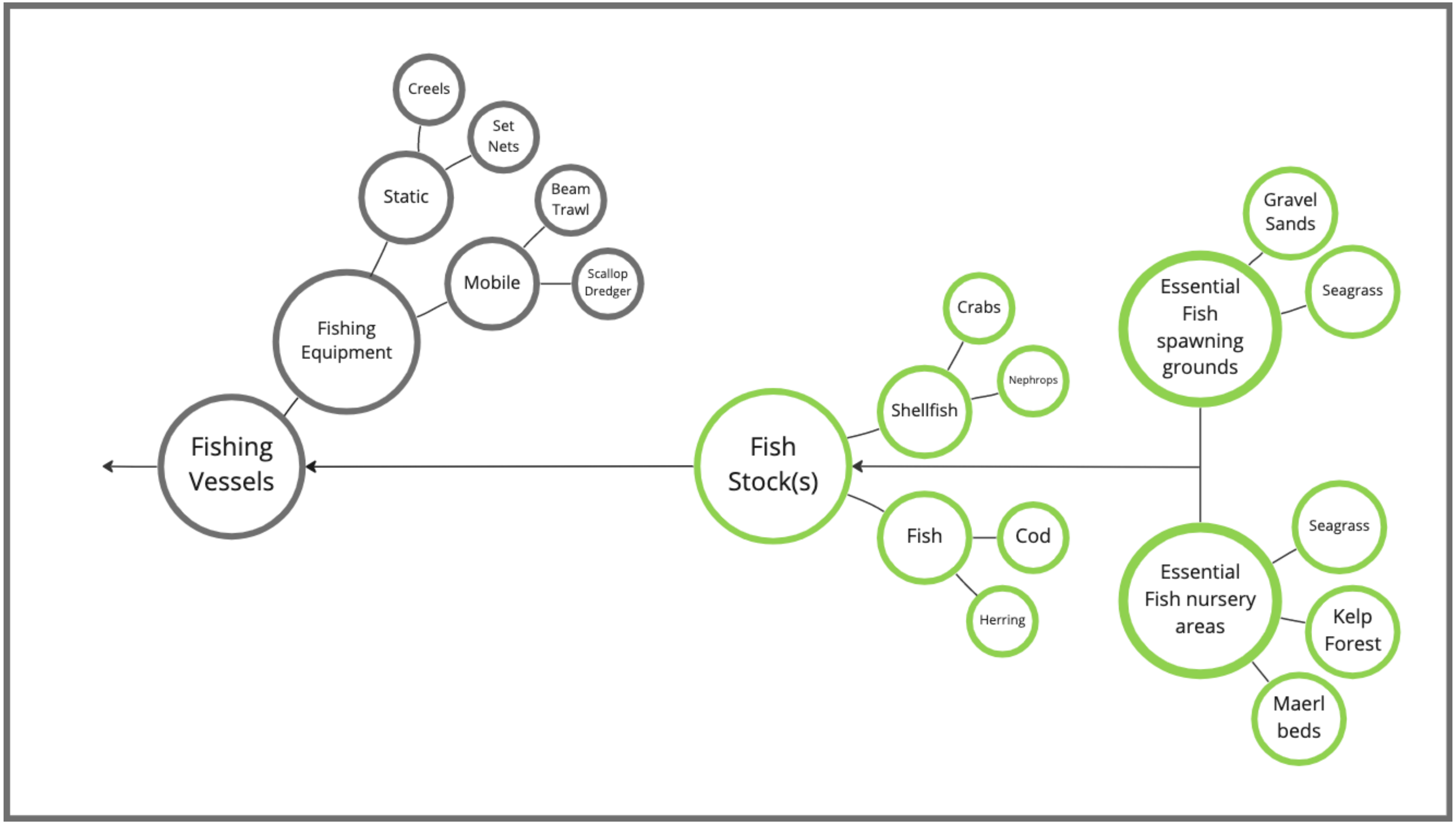
The asset networks provide a basic framework from which assets, and their interactions, for individual sectors can be captured along with shared assets used by multiple sectors. It is possible to incorporate the assets from multiple sectors into a single asset network, however this will quickly become overly complex and less beneficial as a visual tool. To overcome this challenge, the use of modelling software could, potentially, enable the development of modelled asset networks that incorporate multiple sectors, their associated assets, and their interactions.

The modelled network of nodes (assets) and edges (links) could provide the opportunity to integrate more detailed levels of information into the network. For example, it could be possible to create collapsible nodes that when closed provide a high-level overview of the sectors and assets, but when expanded allow for a deeper exploration of related information. Figure 11 provides an example of the type of information collapsible nodes could provide for fishing vessel equipment, fish stocks, and essential fish habitats. Through this type of approach, it could be possible to use already-established categories as assets and link the asset information directly to other databases. For example, information on essential fish habitats could break down into EUNIS habitat categories and link to marine natural capital asset registers.

The inclusion of collapsible nodes allows for asset value and interactions to be investigated further. For example, through a deeper exploration of the different types of fishing equipment used, it would be possible to identify which type of fishing has the most vessels (manufactured capital), employs the most people (human capital), and which species are targeted (natural capital). Similarly, refining the fish stocks asset down to only the target species of interest could provide further information on the amount of each species caught, and which habitats are essential for these species. This approach would allow for more nuanced understanding of asset values and interactions and provide increased levels of detail that would enable the development of more informed trade-off scenarios.

The information contained within the collapsible nodes could also provide insights into potential limitations and bottlenecks. For example, adding more detail to the ‘employment’ asset node could help better understand limitations of human capital available, such as number of people, education, and qualifications. Similarly, more detail on the ‘harbour/ports’ asset node could provide information on the number of harbours/ports, the facilities available, and capacity. The inclusion of limitations (such as availability of construction materials for offshore wind) into the modelled network has the potential to identify constraints across all five capitals, potential opportunities for investment (for example, increasing the size of a port), and limits, such as leasing areas for offshore wind development, to inform trade-offs.

Figure 11: Schematic of the type of information collapsible nodes could provide for fishing vessel equipment, fish stocks, and essential fish habitats. Smaller circles represent more detailed levels of information



The development of these asset networks and modelled networks could provide valuable tools for presenting different trade-off scenarios and the implications of these trade-offs to different stakeholders. However, crucial to informing trade-offs is identifying the most important interactions between assets (and their magnitude) and assigning values to the assets within the asset models. The creation of asset networks, with interactions and values that are representative, would require stakeholder-driven mapping and valuation. This process would help assign relative values to the assets and create transparency in the decision-making process. The resulting maps and modelled networks could then be used to understand how trade-offs between assets manifest across the system.

6.5 Scaling up

Within this section, the potential for scaling up the five capitals approach to incorporate other sectors within the EMPA is explored, along with its application to other marine plan areas in England. Additionally, the potential challenges of scaling up the size of the area being considered – in this case, applying the five capitals approach at a national, rather than regional scale – and the impact scale has on each of the capitals is discussed.

6.5.1 Increasing the number of sectors

The EMPA is used by a wide range of marine sectors; In addition to fishing, offshore renewables, and aggregates, it includes the following sectors:

- oil and gas, including decommissioning
- carbon capture and storage
- tidal, stream, and wave energy (expansion of offshore renewables)
- ports and shipping
- dredging and disposal
- subsea cabling
- aquaculture
- tourism and recreation.

While all these sectors operate within the same marine area, they use the space in different ways and rely on different capital assets. For example, the marine tourism and recreation sector is built around people enjoying the natural environment, whether it is visiting a beach, recreational fishing, boating, wildlife watching, or enjoying locally caught seafood. All these activities rely on natural assets in different ways, but all require the natural asset to be clean, healthy, and/or productive. A healthy marine tourism and recreation sector also requires sufficient supporting human, social, and manufactured capital, such as employees, recreational boating clubs, and hotels, respectively. For this sector, the product is the activity, experience, and wellbeing of the public (usually linked to a natural capital asset) that supports all the other connected human, social, manufactured, and financial assets.

Some sectors are very similar, although the natural capital assets they require are different. For example, the oil and gas industry is a well-established sector and has been built around the extraction of fossil fuel reserves located under the seabed. Their presence in the EPMA is largely through fixed structures (oil and gas platforms), fixed pipelines that transport the extracted oil and gas to land, and the associated operation and maintenance vessels. In terms of five capital assets, the oil and gas industry has many similarities to the offshore wind sector, although the natural capital asset extracted is different and finite.

Some marine sectors are emerging and expanding, which can make long-term planning for multiple sectors challenging. For example, the fishing, oil and gas, and ports and shipping sectors are long established sectors, but other sectors such as offshore renewables, aquaculture, and carbon capture and storage are emerging and expanding, requiring more space, more natural, human, manufactured, and financial capital, and, potentially, competing for use of shared assets (for example, ports).

Temporal changes across sectors also needs to be considered. For example, activity within the oil and gas sector will decline over time as the natural oil and gas reserves become exhausted and society moves towards a net zero target. Subsequently, the decommissioning of oil and gas platforms has become a significant activity for the sector, which requires a different set of human and manufactured capital assets. For example, the removal, dismantling, and repurposing/recycling of steel platforms could be considered an emerging sector as the skills, equipment, and infrastructure is different to those needed for oil and gas extraction.

The level of activity for most sectors will remain relatively constant throughout the year. For some sectors, in particular the tourism and recreation sector, activity is seasonal with higher levels of activity usually taking place in the summer months. Therefore, the use and pressure on capital assets associated with the sector will vary throughout the year: this will be particularly evident for human, social, and manufactured capital, as the number of employment opportunities, and the opening times of associated businesses, will increase during the tourist season. Although many of the assets associated with the tourism and recreation sector may become dormant out of season, they will still be required for the following season and, therefore, remain important. Fisheries activities also follow a seasonal pattern which could, for example, provide additional human capital to other sectors in the form of boat skippers to ferry service personnel to offshore wind infrastructure.

Capturing the variability between the sectors, their associated assets, how the assets are used, and the interactions between sectors and assets will become increasingly difficult the more sectors (and types of sectors) are included. It is possible to create asset networks for each of the sectors in the EPMA (Section 6.2), highlighting important shared assets, and combine sectors that share similar asset network structures, such as offshore renewables and oil and gas sectors. However, as the number and diversity of sectors increases, the number of shared assets will also increase and the interactions between assets and sectors will become more complex. Identifying and managing trade-offs within such an intricate system of interactions will also become more complicated, and decisions on the level of information required for informed decision making will need to be made.

If we work through the conceptual framework set out in Section 6.1, the inclusion of additional sectors would likely affect the stages as follows:

Stage 1: Defining the question and identifying aims, and priorities

At this stage, relevant sectors that operate within the defined area, and their priorities, are identified and considered within the context of the initial question. Sector priorities can be defined within national policies, regional marine plan policies, and sector-specific plans. Increasing the number of sectors considered in the five capitals approach would require all sector policies and targets to be considered when defining the initial question.

Stage 2: Identify available data and gaps

The inclusion of additional sectors would significantly increase the size of the asset register and increase the need for data on each sector, most notably:

- manufactured assets, in particular infrastructure, would need to be considered for each sector:
  - for example, tourism would require information on access to specific areas (for example, roads, paths, transport to beaches), transport infrastructure (for example, road and rail), and hospitality facilities (for example, hotels and restaurants)
  - the number of sector-specific assets would increase.
  - the number of 'shared' assets would increase.
  - the number of sectors using a specific asset could increase.
- social capital assets would increase and diversify:
  - the register could include the value of recreational space, networks of hotel associations, and tourism ratings.
  - sector-specific communities should be considered in terms of how they function, interact, and potentially overlap – this would require further work on how 'community' is defined for each sector.
- human capital, in particular employees and training and education, would increase and interchangeability across sectors should be considered within the register
- natural capital assets would increase and diversify:
  - consideration should be given to carbon storage capacity (such as blue carbon habitats).
  - value of the environment will vary depending on the sector/user – for example, a beach is valued by tourists as a place for recreation, not biodiversity or resource extraction.

Stage 3: Stakeholder participation with technical support

An increase in sectors would increase the number of linkages between assets and across sectors, represented by more complex and nuanced relationships. For example, aquaculture has the potential to compensate for the loss of fish caught, caused by offshore windfarms displacing fishers, but it also has the potential to reduce water quality and damage benthic habitats, which in turn can affect the fishing and tourism and recreation sectors.

It is therefore essential that stakeholder engagement plays a central role in identifying and understanding these interactions. When developing asset networks and assessing the magnitude of interactions between assets, it is essential that a diverse and representative group of stakeholders are consulted. While an increase in stakeholders will allow for sector-specific nuances to be identified, it could also reduce the potential for consensus on establishing relative valuations for assets.

At this stage, the linkages and relationships between assets would need to consider long-term temporal and seasonal changes in asset use and importance. This will vary between the capitals. For example, natural capital can increase in value over time if allowed to recover, whereas manufactured capital can decrease in value with use over time, unless maintained. Marine sectors will also vary over different timescales. For example, tourism has seasonal variation, whereas the oil and gas sector will show a steady decline over the coming years as the offshore renewables sector increases, and we move towards net zero.

Stage 4: Aligning trade-offs with policy priorities, addressing initial question, and decision-making

Scenario development becomes more complex as the number of sectors considered increases, and the sector implications linked to the trade-off options become more challenging to define. At this stage, the development of a model capable of capturing all assets and interactions between multiple sectors would be required.

6.5.2 Application to other marine plan areas

The focus of this project has been the EPMA, but there are eleven English marine plan areas in total, covering marine inshore and offshore waters to the limit of the UK's Exclusive Economic Zone (EEZ). Each of these marine plans will vary in terms of the environment, sector activity, and communities, which will have implications for how the five-capitals approach will be used.

The five-capitals approach presented within this project is flexible enough in its design to be applied to other marine plan areas, but consideration will need to be given to the variation in plan objectives and sector priorities. These will play an important role in prioritising certain sectors and assigning values to the different assets.

The following section provides an overview of the similarities and differences between marine plans, both in terms of plan objectives and sectors operating within the plan areas, and the implications of this for a five-capitals approach. A more detailed table covering the different policy objectives can be found in Annex B.

Overall, the objectives across the marine plans are similar, focusing on sustainable development, community functioning, and the conservation and preservation of marine ecosystems. Plan objectives that focus on development are directly aligned for the most recent (2021) marine plans (north west, north east, south west, south east inshore), with a primary focus on maximising the use of the plan area by a diverse range of economic sectors, while considering spatial competition and environmental limits. Those objectives conform with the other two marine plans (south and east), which also highlight increasing economic development.
The East Marine Plan specifically mentions the expansion of offshore windfarms, giving this sector a greater level of importance, which will be an important

consideration when assessing trade-offs. While the East Marine Plan clearly prioritises one sector, the other marine plans aim for diversified sustainable development, suggesting an equal level of importance across sectors. The five capitals approach may play a more important role in this scenario, allowing a wider range of factors to be considered (across all five capitals) when assessing weighting options to inform trade-offs.

While a diversity of sectors may be an objective, there remain some sectors that play important roles within each of the marine plans. For example, the oil and gas sector remains important within north east marine plan area and the aggregates sector has a notable presence in the south east, south and east marine plan areas, with further potential for development in the north west marine plan area. The military, another vital sector, has a considerable presence in the north east, south west, south east, and south marine plan areas and tourism and recreation is highlighted within the south and north west inshore marine plan areas. All these sectors are important for a variety of reasons specific to the marine plan region. Assigning standardised levels of importance to these sectors for all marine plans would be inappropriate, and relative values would need to be determined through the development of asset networks and stakeholder valuations.

Environmental objectives across all marine plans are based on the protection and recovery of marine ecosystems, while increasingly considering their importance in combatting and mitigating climate change impacts. Natural assets are becoming increasingly important due to their potential to capture and sequester carbon dioxide and, therefore, natural capital is taking a leading role for future development and climate change mitigation. The management of marine protected areas, which are not equally spread across marine plan areas, is also given priority, which is highlighted within the objectives of the South Marine Plan and East Marine Plan.

Social capital is considered in all plans within objectives related to improving socio-economic conditions, creating resilient communities, and making socially responsible decisions for business development. The five capitals approach has the potential to improve the integration of social capital into decision-making, and capturing the variety of communities, and the different ways they value and use the marine environment. However, scale is an important factor when considering social capital, which is discussed further in section 6.5.3.

Another distinct difference between the 2021 plans and the earlier plans, is the inclusion of specific measures and actions to mitigate and adapt to climate change, which are highlighted in the South Marine Plan and East Marine Plan. The enhancement of natural capital will play an important role here but climate change mitigation is also reflected in other capitals, such as the development of improved technologies (manufactured capital). A five capitals approach would enable the contributions of all capitals in mitigating the impacts of climate change to be considered and assessed when making trade-offs.

Only the South Marine Plan considers the displacement of activities within its objectives. In many cases, the displacement of activity may be unavoidable, however a five capitals approach would enable various scenarios to be assessed and, where necessary, spatial conflicts and trade-offs to be resolved.

While sector relevance differs between marine plan areas, there is a considerable level of interactions between sectors and different capital assets across marine plans. For example, fisheries often do not operate exclusively within the limits of a single marine plan, potentially catching fish in one marine plan area and landing it in another. The asset register (Section 5.1) and maps (Section 6.2) developed in this project focused specifically on the EPMA and did not consider assets within adjacent marine plan areas.

To better reflect reality, the asset networks should include linkages with assets that exist outside of the marine plan area. Identifying these linkages, and assessing their importance, will be important for trade-offs and future marine plan revisions. Objectives of adjacent marine plans are assessed through gap analyses, where strength, wording, and intent are considered to ensure alignment, however a five capitals approach could strengthen this. For example, the five capitals approach could help identify if the development of offshore wind in the EPMA displaces the activity of fishers who contribute significantly to the social capital of a town in an adjacent marine plan area.

Interactions between adjacent English marine plans can be challenging to manage, but achievable as there is a single governing body overseeing their development and implementation. For the north west marine plan area, the adjacent areas fall under the jurisdiction of other nations (Scotland and Wales) with different national, regional, and sector-specific objectives. A five capitals approach will enable linkages between sectors and assets to be identified and mapped, including cross-national linkages, and also identify potential weaknesses, where the achievement of an objective may be dependent on the coordination with a separate governing body.

Additionally, it is important to recognise that some assets also cross marine plan boundaries. For example, fish stocks (natural capital) are mobile and move between marine plan areas, and market/supply chains (social, manufactured, and financial capital) also expand beyond the communities within a marine region. Expansion of asset networks to include these assets and linkages could play an important role in assessing trade-offs and wider impacts beyond the marine plan area.

6.5.3 Spatial scale

At the EMPA scale, the applicability and relevance of each of the five capitals varied, with social capital in particular appearing to be more applicable at a local community scale rather than at a regional scale. When spatially scaling up the five capitals approach, it is important to consider the implications of scaling up (and down) on each of the capitals and assessing whether the five capitals approach (for example, using all five capitals) is appropriate.

It is important to recognise that the resolution of data available will vary, usually becoming more aggregated and/or less detailed at larger scales. Spatial scale will also influence which assets could be included within an asset register, as some assets may be relevant at a small community scale but not at a larger national scale (for example, number of employees at the local fish market). Therefore, the initial question and purpose of applying a five capitals approach must be defined with scale, data availability, and data relevance in mind.

It is also important to recognise that, even when the area of interest has been defined (at local, regional, or national scale), each of the five capitals could operate at different scales within that area. For example, manufactured assets can provide information relevant at a regional scale (for example, number of fishing vessels), whereas social assets may provide information relevant to a community within the region (for example, fishing community). Information on social capital at a regional scale may require the amalgamation of multiple, distinct communities, resulting in a dataset that oversimplifies the complexities of social capital and is not representative.

The five capitals approach can be applied at a variety of scales and in different ways, depending on the question. For example, at a broad scale, this approach can provide a framework from which to assess national policies and assess whether they complement one another or work against each other in achieving a shared vision. Information on financial, manufactured, human, and natural capital can be relevant at this scale. On a smaller scale, the five capitals approach can be applied to assess the impacts of a proposed project (for example, aquaculture development) to inform licensing decisions. Social capital, in particular, will be more relevant at this scale and feature more prominently at the licensing stage of the planning process (for example, stakeholder engagement).

This could also identify important linkages between scales that can support the achievement of a national target. For example, a national target may be to achieve net zero. At a regional scale, the five capitals approach can assist with identifying options on how net zero can be achieved (for example, development of wind farms) and at a local scale provide information on the availability of other capital assets, such as skilled labour (human capital), required for delivery.

The five capitals approach can also work in a cyclical fashion, where local information on the five capitals (for example, limitations) can feed back into actions at larger scales. Following the previous net zero example, if human capital was identified as a limiting factor (for example, not enough skilled labour), this could lead to investment into training facilities at a regional scale, and the establishment and promotion of an offshore wind training programme at a national scale.

Understanding how scale influences each of the capitals, and at which scale the different capitals are most relevant, will be important for determining whether information on all five capitals is required to address the initial question, and when each of the five capitals is best applied within the decision-making process.

7 Conclusion and recommendations

Applying a five capitals approach to marine planning provides a new opportunity to deliver a transparent, robust and stakeholder-informed process that could be applied in complex situations, with multiple actors and many potential outcomes. It suits a question driven approach that seeks to solve a particular problem, or to target a desired outcome, providing a means to fairly weigh up multiple options created from a varied evidence base, across the five capitals, while engaging stakeholders in a meaningful way throughout. Thus, applying a five capitals approach to marine planning makes a ‘missing link’ between a varied evidence base, stakeholder groups and decision-making processes.

However, a five capitals approach to marine planning comes – at least initially - with added complexity and the potential to be more time consuming and resource heavy than existing processes. It has taken nearly twenty years for natural capital approaches to be integrated into decision-making and adding further capitals will take considerable time to get right. At this stage, it is not a silver bullet to further our understanding of carrying capacity, but rather could be used to set targets or identify limits to inform and improve trade-off decisions in a meaningful way. We recommend several areas for further investigation, culminating in a small pilot to test the conceptual framework against a current policy driver.

7.1 Estimating value of assets

- An essential component of the five capitals approach is assigning values to the different assets identified in the asset networks. While some of these assets can be assigned monetary value, others cannot, which makes comparisons and trade-offs challenging. As suggested in this report, stakeholder participation in assigning relative values (for example, on a scale of 1-10) is one approach to addressing this. It is recommended that further research is carried out on different approaches to valuing assets and further explore methods for agreeing relative value.

- In this report, we have provided simple examples of how to capture and visualise sector assets in a map. While these asset networks are informative, their focus is largely on a single sector. Integrating additional sectors, and their assets, into these maps would quickly result in them becoming overly complex and difficult to use. To overcome the issue of complexity, it is recommended that research is carried out to design an interactive model that can capture the complexity of multiple sectors, their assets, the linkages between the assets, and the cross over between natural capital cultural values, social capital, and human capital. Such a model could provide the basis for developing various trade-off scenarios.

7.2 Evidence needs and data gaps

- It is recommended that the asset registers are further developed to incorporate all sectors within the EMPA and to identify important sector assets that represent each of the capitals. Through this activity, data gaps and challenges with identifying relevant assets that can be measured will become apparent. Actions should be taken to address these data gaps, but also to assess the amount of data required to inform a five capitals approach – for example, what is the minimum amount of data required and can the five capitals approach still be effectively applied with incomplete evidence?
- It became evident through the literature review, workshops, and asset register development that social capital was the most challenging of the capitals to define and measure. For example, defining ‘community’ can vary considerably depending on the context. Further research is recommended on how social capital is best captured within a five capitals approach for marine planning, and

at which scale it is most appropriately applied. Human wellbeing and how this is captured across multiple capitals should also be explored.

7.3 Threats to assets, their condition and management limits

- Understanding the condition of assets will be important for informing trade-offs and measuring impacts. However, identifying appropriate criteria for determining asset condition can be challenging as assets are used and valued differently by different stakeholders. It is recommended that further research is carried out on whether it is necessary to understand asset condition to inform asset value. If so, who is best positioned to make decisions on asset value and condition, this includes who decides the red lines: a bottom-up approach that involves relevant stakeholders or a top-down approach led by the government?
- It became apparent within this project that, while the five capitals approach could inform carrying capacity in the future, it was too difficult to define in a meaningful way to support marine planning decisions. Instead, we propose that carrying capacity may not be required and that further research is required into how to define meaningful targets or limits for each of the capitals independently and in combination that can inform decision making.

7.4 Policy linkages

- We recommend that ongoing work in government and academia on natural capital and a multiple capitals approach is reviewed, including Natural England and MMOs exploration of the use of natural capital evidence in Sustainability Appraisal through work in the marine Natural Capital Ecosystem Assessment (mNCEA) programme, the MMO project on characterising decision making and SMMR (Sustainable Management of Marine Resources) projects such as Diverse Values. The review should be used to facilitate join up, identify evidence products that can support a five capitals approach and understand any divergences.
- Using a five capitals lens, it is possible to review marine plan policies and objectives to assess whether they adequately consider the five capitals and important assets (as identified by stakeholders). Through this approach, though retrospective, it can be possible to assess how policies interact, both positively and negatively, and whether delivery of all policies would result in achievement of a broader plan vision. It is recommended that an assessment of existing marine plan policies (including the High Level Marine Objectives in the Marine Policy Statement) to determine how well they capture each of the five capitals and how they interact (similar to the assessment of SDGs by Nilsson et al. 2016, highlighted in Figure 2, Section 4.1.4).

7.5 Trial application of a five capitals approach

- The underlying complexity in applying a five capitals approach is considerable and it would be a difficult task to apply it to a marine plan area in its current form. It is recommended that trialling a small-scale version of a policy question, such as a priority question under the Offshore Wind Environmental Improvement Package, could be used to test the conceptual framework presented in Section 6.1. The trial should focus on a manageable level of complexity with a limited number of data rich and engaged sectors. A suggested approach to the framework trial is:

1. Define context and scale: a specific policy question
2. Set up asset register, for example for a few sectors
    i. Define scale of asset register and data needs
    ii. Identify data gaps and needs
    iii. Check for existing projects/initiatives that can feed into it
3. Value assets
    i. Test stakeholder approach
4. Define asset interactions, trade-offs, limits, etc.
    i. Map assets
    ii. Scenario mapping
5. Recap on issues encountered, practicality, and usefulness of framework

- Scale is a significant consideration when applying the five capitals approach. It is recommended that further research is carried out on the effect scale has on each of the five capitals, and at which scale each of the five capitals is most appropriately applied. It is likely that these will differ and be context specific, but it is essential that these differences can be managed in a way that still makes the five capitals approach useable.

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9 Annex A (Literature review)

9.1 Introduction

9.1.1 Purpose of the Project

The Marine Management Organisation (MMO) is responsible for marine planning in England under the Marine and Coastal Access Act (2009). The East Marine Plans were the first to be adopted in 2014 and have been through two review cycles. In 2023 these plans will be amended as per the recommendation of the Secretary of State. Increasing competition for space, driven by the accelerated roll-out of offshore wind in line with the British Energy Security Strategy (BESS) must be considered alongside the need to protect and restore biodiversity and maintain other livelihoods, as is currently being addressed through the Marine Spatial Prioritisation Programme. To support these considerations, more robust methods must be developed to consider the carrying capacity of the east marine plan area (EMPA) and consequent trade-offs between competing sectors to ensure this is not exceeded.

Carrying capacity is a complex construct which, in a marine context, has mainly focused on the ability of the environment to support human activities, more recently through a natural capital lens. The addition of human, social, manufactured, and financial capital to natural capital – the five capitals approach – broadens the range of assets and services to be considered when assessing carrying capacity, with the potential to create a more comprehensive, systems-based framework for decision making.

This report provides a detailed literature review and critical analysis of the five capitals approach, including overviews of each of the five capitals, examples of how they have been used to support decision makers, and applications of the broader five capitals approach. It also provides an overview of how carrying capacity and trade-offs are used in decision making and assesses the capacity for the five capitals approach to inform both approaches.

This literature review fulfils Task 2.1. of the *MMO1336: A five capitals approach to defining the carrying capacity of English seas* project. It will be used to inform the design of a workshop aimed at exploring the main findings in more detail with a variety of experts. This report will also inform, and be incorporated into, the project's final report.

9.1.2 Five Capitals Summary

The five capitals approach is a concept developed by Jonathan Porritt (Forum for the Future, 2011) that allows for multiple types of 'capitals', and their interactions, to be assessed when making decisions. The five capitals approach provides a "basis for understanding sustainability in terms of the economic concept of wealth creation or 'capital' by considering the following five types of capitals (Forum for the Future, 2023):

1) **Natural capital**: any stock or flow of energy and material that produces good and services, including:
    - Resources – renewable and non-renewable materials
    - Sinks – that absorb, neutralise or recycle waste

- Processes – such as climate regulation

2) **Human capital**: people's health, knowledge, skills and motivation.

3) **Social capital**: institutions that help us maintain and develop human capital in partnership with others, for example, families, communities, businesses, trade unions, schools and voluntary organisations.

4) **Manufactured capital**: material goods or fixed assets which contribute to the production process rather than being the output itself.

5) **Financial capital**: enables the other types of capital to be owned and traded. It has no value itself, but is representative of natural, human, social or manufactured capital.

Further detailed information on each of the five capitals can be found in appendices A, through to E.

The rationale for taking a five capitals approach is to enable businesses, governments, and organisations to maintain and, where possible, enhance capital assets, rather than deplete or degrade them. Recently, the five capitals approach has gathered interest within environmental management (see Section 4 for further details), to understand whether the approach can inform and support better decision making.

To date, the application of a multiple capitals approach to marine environmental management has been limited, largely focusing on interactions between two sectors (for example, fishing and offshore wind) or the socio-economic impacts of an activity or decision (such as the impact of marine protected areas on the local fishing industry). An exception to this is the Sustainability Appraisal process, which considers social and economic issues alongside environmental effects (Khanna et al., 1999).

This literature review provides an overview of the five capitals approach and assesses whether it is a helpful framework for assessing carrying capacity and informing trade-off scenarios in marine planning.

9.2 Carrying Capacity

9.2.1 Background

The term 'carrying capacity' has been used in a variety of disciplines and can be defined in multiple ways. Within the context of the use and management of the natural environment, the carrying capacity of a region, comprising its supportive and assimilative capacities, is defined as *"the ability to produce desired outputs from a constrained resource base to achieve a higher and more equitable quality of life, while maintaining desired environmental quality, and ecological health." (UK Government, 2020a)*

In all applications, carrying capacity refers to a defined space containing a finite amount of resource. Where there are multiple demands on the resources within the defined space, identifying the maximum amount of resource use that can take place without diminishing resource condition is an important challenge for marine planners. While the concept of 'carrying capacity' has been well defined, it remains open to being interpreted in many ways when applied to decisions on how we use our natural environment. Some examples are set out below:

- **Ecological** carrying capacity
  - With regard to the Earth's capacity to sustain human life: "*the margin of the habitat's, or environment's ability to provide the resources necessary to sustain human life*" (Geores, 2001)
  - In aquaculture production: *"the amount of production that can be maintained without leading to unsustainable changes to ecological processes, services, species, populations, or communities in the environment."* (Falconer et al. 2018)
  - In conservation: *"the maximum use that the biota or the physical processes of an area can withstand before becoming unacceptably or irreversibly damaged."* (McLachlan and Defeo, 2018)
- **Physical** carrying capacity
  - Aquaculture development: *"the total area of marine farms that can be accommodated in the available physical space."* (McKindsey et al., 2006)
  - Conservation and management: *"a design concept, based on the number of use units (people, cars, boats, and vehicles) that can physically be accommodated in a certain area.*" (McLachlan and Defeo, 2018)
- **Production** carrying capacity
  - In aquaculture developments: *"the stocking density of bivalves at which harvests are maximised."* (Falconer et al., 2018)

- **Social** carrying capacity
  - Recreational activities: *"the level of recreational use an area can sustain without an unacceptable degree of deterioration of the character and quality of the resource or of the recreation experience."* (McLachlan et al. 2018)
  - Aquaculture development: "*the level of farm development that causes unacceptable social impacts".* (Falconer et al., 2018)

- **Economic** carrying capacity
  - Global carrying capacity: "*the biophysical properties of a finite earth and the realities of economic transformation determine the economic carrying capacity of our planet Economic carrying capacity takes the form of maximum global economic welfare derivable from the sustainable throughput flows of the ecosphere."* (Wetzel and Wetzel, 1995)
  - Fisheries management: *"There also has been a distinction made between "ecological carrying capacity," which refers to the limitation of a population due to resources, and a management-oriented, maximum sustainable yield for a population, referred to as an "economic carrying capacity," which is usually lower than ecological carrying capacity.*" (Hartvigsen, 2001)
  - Tourism: "*the capability of both tourism destinations and protected areas to accommodate recreational use."* (McCool and Lime, 2001)

The above examples demonstrate how 'carrying capacity' can be applied in multiple ways, often with the same form of carrying capacity being interpreted in different ways depending on the interests and perspective of the applicant – for example, conservation of marine life, sustainable management of tourism, or marine development.

Although carrying capacity can take many forms, the above examples are not mutually exclusive, with many including similar factors to determine limitations: for example, tourism, economic, and social carrying capacity can all incorporate impacts on communities, and recreational, tourism, and ecological carrying capacity can all incorporate impacts on nature. Similarly, developers from a single sector, such as aquaculture, can rely on multiple forms of carrying capacity to identify suitable locations for development. The range of factors used to determine carrying capacity depends largely on the interests of the applicant and the type of activity proposed.

However, despite the varying interpretations and applications, all the above definitions set out to define the acceptable limits within which an activity can take place. These limitations can be very clearly defined and informed by empirical data, such as the physical limitations of a site for aquaculture or wind farm development, or they can be more subjective and qualitative, for example the acceptable level of social impact of a development is determined by the community being impacted.

It is important to note that, as defined above, carrying capacity focuses on the present capacity and does not incorporate the potential for increasing, or decreasing, capacity over time. In some cases, the carrying capacity may be defined by a firm limit, such as the area of space identified for an activity. But in other cases, it can be more changeable, such as ecological carrying capacity, which can be degraded by commercial activity or potentially enhanced through restoration.

In the UK, the Government is committed to achieving good environmental status (GES) of its marine environment[2], which is defined as "*the environmental status of marine waters where these provide ecologically diverse and dynamic oceans and seas which are clean, healthy and productive'* (European Commission, 2023). Achieving GES requires that '*the different uses made of the marine resources are conducted at a sustainable level, ensuring their continuity for future generations'* and that *'ecosystems, including their hydro-morphological, physical and chemical conditions, are fully functioning and resilient to human-induced environmental change'.*

To achieve GES (and the objectives of the East Marine Plans), it is essential that acceptable levels of resource use are identified, through assessing multiple forms of carrying capacity (for example, ecological, social, and economic). Similarly, the UK Marine Policy Statement states that, with respect to considering benefits and adverse effects of marine planning, the "*marine plan authority will need to assess the impacts of their proposals for the marine plan area. These may be identified as anticipated benefits, including the contribution that the proposals would make to policy objectives, or anticipated adverse effects. These benefits and adverse effects may be economic, social, and environmental in nature."* (UK Government, 2020b)

The five capitals approach aligns well with the multiple forms of carrying capacity and has the potential to provide the data required to inform carrying capacity

[2] Note, GES targets are under review since UK's departure from the EU, and the UK Marine Strategy is the legal instrument this is currently sitting under.

assessments, identify important interactions, and integrate carrying capacity into the decision-making process.

9.2.2 Application of Carrying Capacity in decision making

In practice, the application of ecological carrying capacity to inform environmental management decisions is challenging, as it is difficult to quantify, likely to vary over time, and may not be representative of the actual species population size (Rachlow, 2008). With regard to environmental management, carrying capacity is difficult to define and has largely been used to describe a theoretical ecological limitation. While it is possible to use a theoretical limitation to support decision making, it may not provide the level of accuracy required and be open to scrutiny.

However, the use of carrying capacity has been applied in identifying acceptable limits for the impact of tourism activities on nature, local amenities, local communities, and public health. For example, during the COVID 19 pandemic, the number of people visiting beaches increased significantly but there were strict guidelines on social distancing. Zielinski and Botero (2020) suggested that the carrying capacity of a beach can be identified using the social bubble concept and spatial distribution patterns, as well as a grid system to manage distance between visitors. The information required to inform tourism carrying capacity can be a combination of quantitative (for example, number of visitors to a beach, amount spent in local shops, number of additional cars on the road) and qualitative (for example, enjoyment of experience, local community views, visual impact) information.

The use of carrying capacity has been explored within the academic literature for informing discrete development activities. For example, McKindsey et al. (2006) recommend the use of four types of carrying capacity: physical, production, ecological and social carrying capacities in a hierarchical approach: to identify suitable sites for aquaculture developments:

1) **Physical carrying capacity**: the initial site identification that includes area suitability, species to be farmed, and physical characteristics of the environment. This information can provide an indication of the total area potentially available for aquaculture.

2) **Production carrying capacity**: the maximum production that can take place in the identified area, which can inform stocking density. This is usually assessed at a farm level.

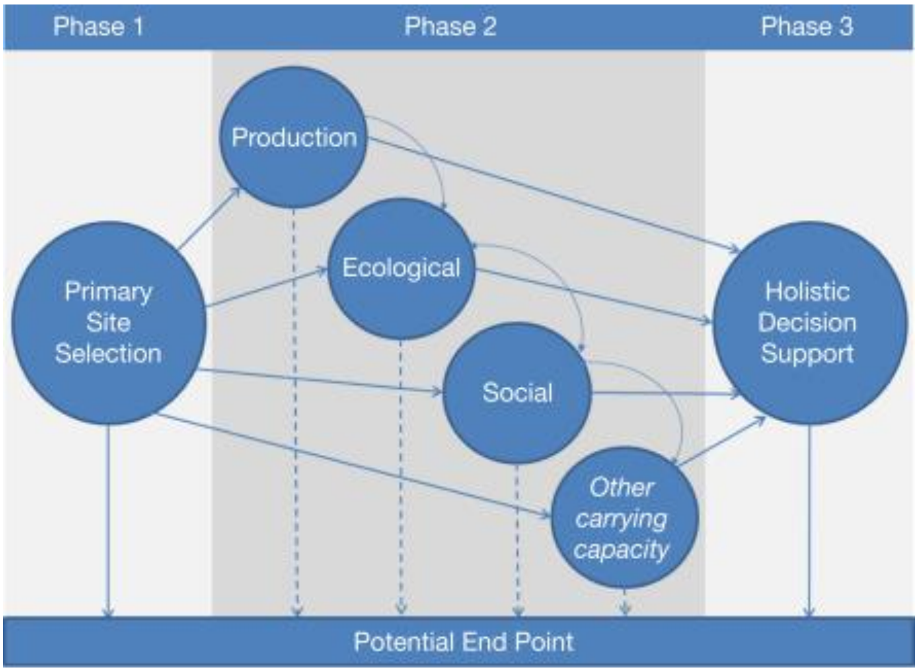
3) **Ecological carrying capacity**: the amount of production that can be maintained without causing unsustainable changes to ecological processes, services, species, populations, or communities in the environment.

4) **Social carrying capacity**: the amount of aquaculture development that can take place without unacceptable social impacts, which can include visual impact, traditional fishing rights, and the needs of other marine users. This can often be balanced out by factors such as job creation and income generation.

The hierarchical approach provides a systematic and stepwise approach to determining the limitations of a location within which an aquaculture farm must operate. Falconer at al. (2018) expanded upon the hierarchical approach by integrating linkages between the different carrying capacities and introducing end points within the process: for example, if the physical carrying capacity assessment identifies the site as unsuitable, the process ends before the next stage begins (Figure 1). The five capitals approach, as well as each of the capitals individually, has the potential to inform each of the stages of the proposed decision-making process.

The hierarchical approach allows for specific carrying capacities to be prioritised, determined by the order of which they feature within the process (for example, first being the priority), and for each progressive step in the process to be based on a sound understanding of the preceding stage. The sequence that each of the carrying capacities are placed within the decision-making process can be informed by policy targets and plan objectives, which can link directly to how each of the five capitals are weighted in importance.

Figure 1: Relationships and sequencing of different carrying capacities within the site selection process for aquaculture developments (Falconer et al., 2018).



9.2.3 Thresholds

Thresholds have been used in a wide range of disciplines and generally denote a point on a scale where the measured characteristic begins to experience a notable change. In marine environmental management, ecological thresholds are regularly used to identify the point at which there is *"an abrupt change in an ecosystem quality, property or phenomenon, or where small changes in an environmental driver produce large responses in the ecosystem."* (Groffman et al. 2006)

Thresholds can be clearly defined using field observations and laboratory experiments, such as the effects of water temperature on coral bleaching events (Douglas, 2003), or the level water content in soil that begins to affect plant survival (permanent wilting point) (Tolk, 2007). However, thresholds can also be set using a precautionary approach when data is lacking and there is a level of uncertainty regarding the threshold response.

Groffman et al. (2006) identified three main ways threshold concepts have been applied in ecology:

- analysis of dramatic and surprising ‘‘shifts in ecosystem state,’’ where a small change in a driver causes a marked change in ecosystem condition

- the determination of ‘‘critical loads,’’ which represent the amount of pollutant that an ecosystem can safely absorb before there is a change in ecosystem state and/or in a particular ecosystem function

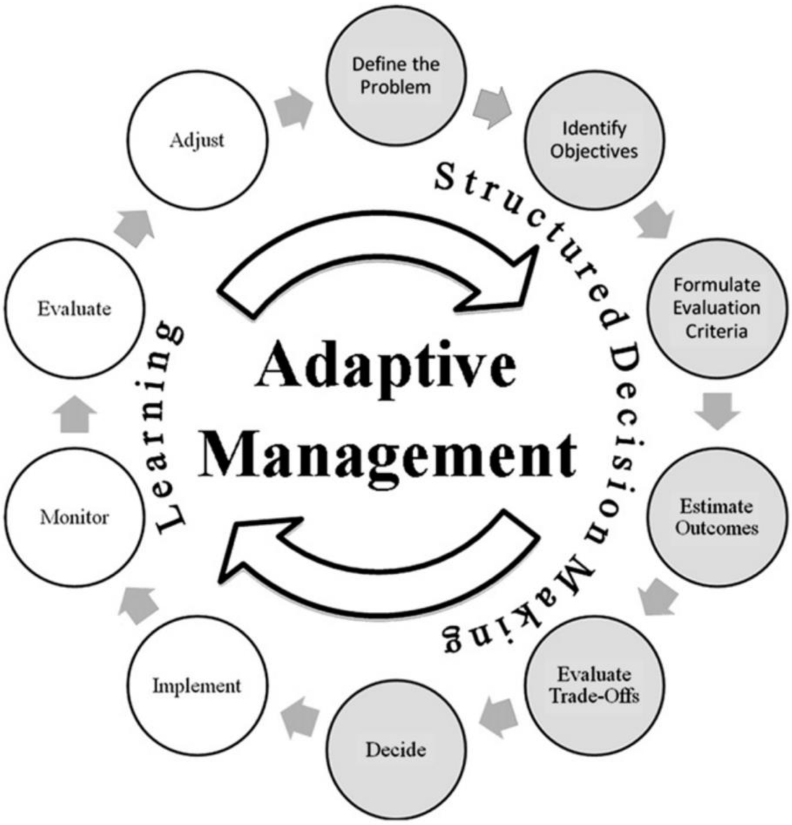
- analysis of ‘‘extrinsic factor thresholds,’’ where changes in a variable at a large scale alter relationships between drivers and responses at a small scale.

The core principles of the three concepts identified by Groffman et al. (2006) can be applied more broadly across the five capitals as they require an understanding of interactions within a system, and how an activity can affect other components within that system, such as nature, communities, or infrastructure. The foundational role of natural capital, from which ecosystem services derive, places additional importance on ecosystem thresholds, but thresholds for social, human, manufactured, and financial capital (for example, acceptable levels of tourists visiting a beach, available skilled labour, infrastructure capacity, and financial investment, respectively) will have important implications for decision making. A five capitals approach would enable the thresholds of all five capitals to be defined and applied to the decision-making process.

Ehler (2008) highlighted the need to make existing knowledge relevant to marine spatial planning, emphasising that ecosystems have real thresholds and limits which, when exceeded, can affect major system restructuring and cause irreversible changes. It is therefore critical that management objectives, and associated criteria and reference points, are developed further and that methods for incorporating the diverse, dynamic, and multi-scalar social landscape into marine spatial planning requires new methods that document ‘‘at-sea’’ locations, interests, and dependencies of specific communities and groups of stakeholders.

Incorporating thresholds into the decision-making process can help guide planning and action. For example, thresholds can help identify objectives, examine consequences, and evaluate trade-offs within an adaptive management approach (Figure 2). As new threshold information becomes available, management can be adjusted.

Figure 2: The adaptive management process (Allen et al., 2011)



9.2.4 Cumulative Effects Assessments

Cumulative effects assessments (CEAs) are a form of environmental assessment aimed at identifying how the effects of human activities contribute towards environmental change. This approach has many similarities to determining thresholds, informing trade-offs, and identifying the carrying capacity of a specified area, where multiple interacting factors and systems must be considered in assessing how human activities will affect change in social-ecological systems.

The concept of cumulative environmental change indicates towards CEAs needing to identify, measure, mitigate and manage the effects of multiple human activities on the environment. Wilsteed (2019) identified the following considerations that need to be applied when applying CEAs:

- **Ecological connectivity**: the practicalities of CEA are complicated by a complex reality of interactions between causations, processes, and organism populations, and of human activities, past and present, combining to simultaneously affect numerous areas of study.

- **Temporal accumulation:** An important consideration is recognising that effects can accumulate over time in a continuous, periodic, or irregular manner and occur over long or short timescales.

- **Spatial accumulation:** where the effects of perturbations overlap in space, resulting in cumulative change, as the space between perturbations is less than that required to disperse the disturbance.

- **Effects interaction:** a critical knowledge gap is the potential for non-linear effects, where responses to stressors vary across geographic scales, suggesting site and species-specific cumulative effects responses.

- **Endogenic and exogenic sources of pressure:** pressures can have single and multiple sources that can originate from within (endogenic) the system of study, which can be managed, or those that emanate from outside the system, or operate at scales larger than the system (exogenic), such as climate change.

- **Placing receptors at the centre of assessments:** a main criticism of CEAs is that they are stressor-, rather than receptor-led. Receptors experience multiple stressors and effects accumulate over broad temporal and spatial scales. Placing receptors at the centre of an assessment forces a broader, more integrative perspective.

The above considerations emphasise the complexity of assessing environmental impacts from multiple stressors, and the need for further understanding of interactions (including their magnitude), the temporal and spatial scales at which effects occur, and the need to consider effects that emanate from outside the area of management. With regard to the EMPA, this could include the global-scale effects of climate change or the effects of activities in adjacent marine plan areas.

Judd et al. (2015) suggest that developing an understanding of the relationships (risks) between the source of a pressure, the pathways by which exposure might occur, and the environmental receptors that could be harmed is vital. This can be achieved by assessing source-pressure-pathway-receptor linkages for marine activities (Table 1).

Table 1. Examples of source-pressure-pathway-receptor linkages to inform Cumulative Effects Assessments

Activity	Source	Pressure	Pathway	Receptor
Offshore windfarm construction	Pile-driving	Underwater noise	Underwater acoustics	Sedentary marine species Marine mammals
Mineral extraction	Dredging	Removal of seabed habitat	Mechanical disturbance	Sedentary marine species

While the example provided by Judd et al. focuses on ecological receptors from marine activities, the linkages concept could be built upon within the five capitals approach, expanding out to incorporate social, human, manufactured, financial receptors.

Judd et al. (2015) recommend that a four-step framework, based around the principles of environmental risk assessment, is applied to cumulative effects assessment, whereby:

- the purpose of the cumulative effects assessment is clearly defined (formulating the problem)
- the likely combinations of activities, pressures and ecosystem components are identified, the associated risks identified, and the nature and scale of any cumulative effects assessed
- the options to manage the outputs of the cumulative effects assessment are evaluated to determine if/how management actions may alter the level of risk, and
- the implementation of the management action is monitored (and further remedial actions identified and implemented).

Although Judd et al. (2015) focused on the cumulative effects for ecosystems, the recommended four-step framework could provide a useful starting point for framing the purpose of a five capitals approach, identifying, and assessing linkages between capitals and activities, and how to act on the resulting findings.

Wilsteed (2019) and Judd et al. (2015) both highlight the importance of identifying the purpose of carrying out a cumulative effects assessment, as this will influence the approach taken, the receptors included and, therefore, the output. This is also an important consideration for applying the five capitals approach. Given the broad, complex, and comprehensive nature of the five capitals approach, clarifying it's intended purpose will be critical for ensuring it functions efficiently and works towards achieving the desired outcomes.

9.3 Trade-offs

9.3.1 Background

The concept of trade-offs originates from a business context to inform decisions on the most responsible uses of resources, but over time it has been adopted by a range of disciplines, including evolutionary biology, socio-economics, and marine planning.

When used in its original economic context, trade-offs are required due to the "*basic economic fact that limitation of the total resources capable of producing different commodities necessitates a choice between relatively scarce commodities*" (Samuelson, 1970). The core elements of this definition, which can be applied more broadly are:

- there is a finite amount of human and natural resources available

- humans need to make choices about how to utilise resources

- choices involve a 'sacrifice' represented by the foregone production of goods and services each choice entails. (Turkelboom et al., 2018)

Within the context of spatial planning, trade-offs occur when the needs or wishes of multiple stakeholders, within a shared space or system, are incompatible, and the achievement of one desired outcome is detrimental to another. Additionally, national targets and priorities can be important drivers in trade-off assessments, particularly in the context of spatial prioritisation of one activity over another.

To ensure trade-offs are effective and well informed, decision makers require a good understanding of the sought-after resources, the role these resources play with respect to ecosystem services, the interactions between resources and marine users, and the interactions between marine users.

In marine planning, spatial management and identification of conflicting uses of the marine space can influence the achievement of multiple objectives (for example, conservation, renewable energy production, food production, and natural resource extraction). The most direct need for trade-offs occurs when the desired resources of multiple stakeholders exist within the same space, requiring (either consideration of co-existence or) the prioritisation of access to one sector and resulting in a cost to the competing activity.

The loss of benefit to competing stakeholders can result in value trade-offs, which define how much must be gained in the achievement of one objective to compensate for a lesser achievement on a different objective. Value trade-offs that adequately express a decision maker's values are essential both for good decision making in multiple-objective contexts and for insightful analyses of multiple-objective decisions (Keeny, 2002).

However, a value trade-off does not necessarily need to be valued in a single currency (for example, pounds sterling). It is possible to compare decisions based on changes in sectoral values (in absolute or percentage terms), which would allow for distinctly different ecosystem services to be compared, including those that rely on non-market values, such as aesthetics or conservation." (White et al., 2012)

In the draft MMO1274 East Marine Plan Spatial Assessment, a spatial analysis of the EMPA to understand suitability of specific locations to support different sectors, states that "*Policy interventions will be focused on marine plan policies, but where there is interrelation with wider government policies, these will be outlined at a high-level. They are likely to include or relate to:*

- *policies that encourage co-location between certain sectors*
- *spatial policies giving priority to certain sectors in certain areas*
- *policies that insist on collaboration for environment protection and enhancement.*" (MMO1274 Report)

The inclusion of co-location and prioritisation to certain sectors highlights the importance of trade-offs within the spatial management of the EMPA. Ensuring these spatial, sector trade-offs are well-informed, evidence-based, incorporate trade-offs between the five capitals, and align with the marine plan objectives will be critical for delivering sustainable use of the marine area.

9.3.2 Examples within the literature

MPA design

Stewart and Possingham (2005) found that through using the spatial distribution and intensity of commercial rock lobster catch in South Australia, they could integrate socio-economic and biophysical information into marine reserve design. Their proposed approach highlights the potential to design representative, efficient and practical marine reserves that minimise potential loss to commercial users.

Public perception of industry development vs conservation and recreation

Aanesen and Armstrong (2019) explored how people in Arctic Norway trade off industrial activities, supplying provisioning services, for cultural and supporting services using choice experiment surveys and willingness-to-pay assessments. The first survey investigated willingness to protect cold-water corals and the second investigated willingness to pay for stricter regulations of industrial activity in the inshore, allowing more space for recreational activities. Both studies show a strong conservation preference and a willingness to forego blue industrial growth.

These results were further assessed across socio-economic characteristics (for example, age, gender, education and income) and found that preferences were heterogeneous, with education identified as the factor that most distinctly separates the population: greater preference for coral-reef protection so long as areas are not important for oil and gas or offshore fisheries.

Public perception of offshore windfarms vs marine protection

Karlõševa et al. (2016) used choice modelling to investigate the relative gains and losses from siting new windfarms off the coast of Estonia, relative to the option of creating a new marine protected area. The results show that the general public are willing to pay for both “environmentally friendly” windfarms and the designation of new MPAs. They are also willing to pay to avoid the siting of conventional windfarms on marine shoals. The authors recognise that MPAs come at an economic cost to producers whose activities are restricted, and that such costs would need to be weighed against the benefits to citizens from MPA creation to determine which action maximises social benefits over time.

Tourism, climate change, and fish consumption

Wabnitz et al. (2018) used a quantitative social-ecological framework to explore the current and future impacts of tourists on reefs, through diving activities as well as fish consumption, and ascertain consequences for local lifestyles against a backdrop of climate change.

This study provides a framework to assess the impacts of different sectors on reef’s socio-ecological long-term health, and tangible inputs for the development of suitable guidelines and management strategies to safeguard the long-term sustainable use of marine resources, to better inform the sustainable growth of tourism, to maximise revenue generation, and to ensure local food security.

Conservation, fisheries, and marine renewable energy

Yates et al. (2015) identified priority areas for multiple ocean zones, which incorporate goals for biodiversity conservation, two types of renewable energy and three types of fishing. They developed an approach to evaluate trade-offs between industries and further investigated the impacts of co-locating some fishing activities within renewable energy sites. Their results show non-linear trade-offs between industries and that the different subsectors within those industries investigated (for example, different fishing sectors) experienced very different trade-off curves. The authors also found that incorporating co-location resulted in significant reductions in cost to the fishing industry, but also altered the optimal location for renewable energy zones.

Marine spatial planning

White et al. (2012) assessed multiple ecosystem services and the values they provide to sectors using a robust, quantitative, and transparent framework to identify potential conflicts among offshore wind energy, commercial fishing, and whale watching in Massachusetts. The results were used to identify and quantify value from choosing optimal wind farm designs that minimise conflicts among these sectors.

White et al. found that the value of marine spatial planning increased with the greater the number of sectors considered and the larger the area under management. The authors further suggest that making trade-offs explicit improves transparency in decision-making, helps avoid unnecessary conflicts attributable to perceived but weak trade-offs, and focuses debate on finding the most efficient solutions to mitigate real trade-offs and maximize sector values.

9.3.3 Trade-off mechanisms

In their paper on assessing trade-offs in large marine protected areas, Davies et al. (2018) identified four mechanisms that may give rise to trade-offs:

- **Management priorities:** decisions that prioritise certain objectives and invest more in associated activities.
  For example, MPAs typically prioritise management that benefits ecosystems, resulting in a trade-off between protection and resource use. Weak management of resource-use results in a lack of species recovery.

- **Everyday resource use decisions**: trade-offs that arise between extraction and short-term well-being, or resource conditions and long-term sustainability.
  For example, overfishing can result in short-term benefits at the expense of the resource condition. However, conservation of harvested resources can improve resource condition but at the expense of short-term well-being.

- **Externality of resource use**: trade-offs that occur as an unintended consequence of resource use where the exploitation of one resource has impacts on others.
  For example, some fishing techniques damage habitats that other resources depend on.

- **Biophysical relationships**: conditions of one environmental good or service are dependent on the condition of other environmental goods or services.
  For example, trophic cascades can occur as a response to protection (for example, increased sand eel populations can improve health and abundance of seabirds).

While the examples provided above focus on natural capital benefits linked to MPAs, the proposed mechanisms can be applied to all five capitals, independently and collectively, and assist with developing multiple scenarios to inform trade-offs. Management of priorities will be an important component of the five capitals approach, as these will reflect policy objectives and provide a basis for weighting each of the capitals in decision making. Similarly, a five capitals approach will provide the foundations for assessing the externality (direct and indirect impacts) of resource use, providing a more comprehensive understanding of implications of management decisions.

9.3.4 Interactions

A critical component of developing trade-off scenarios is the identification and understanding of interactions, both direct and indirect, between assets, ecosystem services, human activity, and human well-being. A greater understanding of these interactions will provide the foundations required to identify immediate and broad impacts associated with an activity or decision, mitigation opportunities, and opportunities for multiple benefits.

Davies, et al. (2018) identified three types of trade-offs while assessing the impacts of large marine protected areas:

- between different ecological resources (supply trade-offs)
- between ecological resources and the well-being of resource user (supply-demand trade-offs)
- between well-being outcomes of different users (demand trade-offs)

While these trade-offs focus on the interactions between natural capital assets and the asset users, the categorisation of supply and demand, or provider and beneficiary, can be applied across all five types of capital asset.

While Davies et al. focused on asset-user interactions, Nilsson, et al. (2016) focused on the interactions between policy objectives, namely the delivery of Sustainable Development Goals (SDG), and how the pursuit of one goal influences the achievement of another. For example, the pursuit of converting land use from agriculture to bioenergy production (SDG 7 – Affordable Clean Energy) might counteract food security (SDG 2 – Zero hunger) and poverty reduction (SDG 1 – No Poverty). Understanding these interactions can help guide the development of new policies and strategies and optimise efforts towards achieving SDGs. More broadly, the identification of these interactions will inform the five capitals approach, as the SDGs incorporate environmental, social, human, manufactured and financial capital.

To support decision makers, Nilsson et al. developed a seven-category scale of how SDGs could influence each other, both positively and negatively (Figure 3). Where interactions between SDGs fall within the three negative categories, trade-offs will be required.

Figure 3: Scale of influence the delivery of SDGs have on each other (Nilsson et al., 2016)

GOALS SCORING

The influence of one Sustainable Development Goal or target on another can be summarized with this simple scale.

Interaction	Name	Explanation	Example
+3	Indivisible	Inextricably linked to the achievement of another goal.	Ending all forms of discrimination against women and girls is indivisible from ensuring women's full and effective participation and equal opportunities for leadership.
+2	Reinforcing	Aids the achievement of another goal.	Providing access to electricity reinforces water-pumping and irrigation systems. Strengthening the capacity to adapt to climate-related hazards reduces losses caused by disasters.
+1	Enabling	Creates conditions that further another goal.	Providing electricity access in rural homes enables education, because it makes it possible to do homework at night with electric lighting.
0	Consistent	No significant positive or negative interactions.	Ensuring education for all does not interact significantly with infrastructure development or conservation of ocean ecosystems.
–1	Constraining	Limits options on another goal.	Improved water efficiency can constrain agricultural irrigation. Reducing climate change can constrain the options for energy access.
–2	Counteracting	Clashes with another goal.	Boosting consumption for growth can counteract waste reduction and climate mitigation.
–3	Cancelling	Makes it impossible to reach another goal.	Fully ensuring public transparency and democratic accountability cannot be combined with national-security goals. Full protection of natural reserves excludes public access for recreation.

Building on Nilsson et al., Scherer et al. (2018) focused their research on the trade-offs that occur between achieving specified objectives, namely between achieving socio-economic and environmental SDGs. Their paper found that pursuing social goals (for example, SDG1 poverty alleviation and SDG10 reduction in inequality) can lead to higher disposable income and increased consumption (for example, food and energy), which is, generally, associated with higher environmental impacts, working contrary to the achievement of SDG 13 (carbon reduction), SDG 15 (land) and SDG 6 (water); an example of a 'cancelling' interaction.

Scherer et al. (2018) emphasise that "interactions are highly heterogeneous in both location and impact type, highlighting the importance of quantitative assessments and specific locational responses", and that understanding the magnitude of the interaction is critical in policy development.

The East Inshore and Offshore Marine Plans contain 11 objectives, which include:

- **Objective 1**: *To promote the sustainable development of economically productive activities, taking account of spatial requirements of other activities of importance to the east marine plan areas.*

- **Objective 3**: *To realise sustainably the potential of renewable energy, particularly offshore wind farms, which is likely to be the most significant* *transformational economic activity over the next 20 years in the east marine plan areas, helping to achieve the United Kingdom's energy security and carbon reduction objectives.*

- **Objective 4**: *To reduce deprivation and support vibrant, sustainable communities through improving health and social well-being.*

- **Objective 5**: *To conserve heritage assets, nationally protected landscapes and ensure that decisions consider the seascape of the local area.*

- **Objective 6**: *To have a healthy, resilient, and adaptable marine ecosystem in the east marine plan areas.* (UK Government, 2014)

Reviewing how the delivery of the East Marine Plans' objectives interact and influence one another, informed by the five capitals approach and using a similar approach to Nilsson et al.'s seven-category scale, could help identify important challenges and synergies. This can also be broadened out to consider how the Marine Policy Statement's High Level Marine Objectives interact.

9.3.5 Trade-offs and the Five Capitals Approach

Trade-off interactions can take place at multiple scales and at different stages of the decision-making process, from policy development down to direct activity interactions. To date, most examples of trade-offs in the literature have focused on sector-environment, sector-sector, and policy objective interactions. The five capitals approach has the potential to create more informed and comprehensive trade-off scenarios that incorporate direct and indirect interactions, which can be weighted to reflect government policy objectives. Understanding the interactions between the different capitals can also inform cumulative impact assessments, which can be factored into the different trade-off scenarios.

Furthermore, the five capitals approach provides the opportunity to incorporate the limitations of social, human, and manufactured assets into the trade-off process. For example, the development, operation, and maintenance of an offshore wind farm could be restricted by the availability of skilled labour and/or supporting infrastructure (for example, space in ports to accommodate operations and maintenance vessels).

Traditionally, trade-offs are presented as a win-lose scenario, where actions to deliver one desired outcome is detrimental to the delivery of another. The comprehensive scope of the five capitals approach, and the ability to investigate a broader range of potential beneficial outcomes (for example, social, human, and financial benefits), provides the opportunity to investigate and identify scenarios where multiple benefits are created and impacts are minimised or mitigated.

9.4 The Five Capitals Approach

9.4.1 Capitals concept

"Capital" may be best defined as the sum of assets that create services and flows benefiting society (Maack and Davidsdottir, 2015). There are several forms of capital within the literature, but the five most referred to are natural, social, human, manufactured and financial capital (see Appendices A through to E for further details on each of these capitals).

The concept of capital was first applied in an environmental context as humanity eventually realised that increasing demand for economic growth was severely impacting the earth's natural resources. By better understanding the flow of natural capital assets, the services they provide, and their benefits to society and the economy (which includes human, social, manufactured, and financial capital), a holistic approach can be developed that places the environment at the core of decision making (Goodwin, 2003).

Capital approaches initially focused on the economic valuation of natural resources, often accompanied by a cost-benefit analysis of investment versus output. While this approach can support decision-making, if all costs are not known and integrated into the evaluation, the chance of poorly informed decisions increases. Identifying all associated costs has proven to be particularly challenging when making decisions on the use of our environment. More recent thinking involves taking an integrated approach that considers the interconnectivity between capitals within the context of human well-being (Stebbings et al., 2021).

9.4.2 What is the Five Capitals Approach?

The five capitals approach is rooted in the pillars of sustainability, which were originally defined in 1987 by the World Commission on Environment and Development in their report called "Our Common Future" (Brundtland, 1987). In the report, development is defined in terms of economic, environmental, and social concerns, which were subsequently complemented by cultural concerns.

The concept of using five capitals to inform decisions on resource use has been in discussion for several years. For example, in 2003, Goodwin highlighted the value in considering five capitals for sustainable development, suggesting that the productivity of all capital stocks, including natural capital, must be maintained or increased (Goodwin, 2003).

In 2008, Ekins et al. proposed a four-capital model as part of an EU project on sustainable development evaluation (Ekins et al., 2008), which explored the various interrelations and interactions between services within the context of economic processes (such as, production, consumption, and utility/distribution (welfare)). Such interactions allow for capital stock to be substituted between certain capitals, however noting that natural capital cannot be generated by human activity.

Ekins et al identified two approaches to measuring whether development is moving towards sustainability: a framework approach that uses a set number of indicators, and an aggregate approach that uses information on multiple assets. Both approaches, however, come with limitations. For example, for indicators to be effective they are all required to work in a single direction to allow a framework to be applied. Similarly, measurements for an aggregated approach need to be collected in a unified way to allow assets to be compared.

A third approach is to measure the current *status quo* against set sustainable standards (Ekins et al. in 2003). This approach was also taken on board in the five capitals approach by the Association for Consultancy and Engineering (ACE) report (ACE, 2020), which assigns a 3-level ranking approach for each capital against a policy target for sustainability.

The five capitals approach incorporates the interconnectivity of all five capitals, rather than assessing each in isolation (Edwards-Jones et al., 2022), and provides a framework to assess the wider extent of policy decisions, which includes the environment, communities, economic sectors, and industries. Through this approach, the sustainability of decisions and overall policy implementation can be assessed (Forum for the Future, 2023).

The five capitals approach can be applied at different stages and levels in relation to services, operations, and products. It aims to create a basis to assess services, processes, and outcomes (for example, products) in an integrated way, which includes assigning values to enable comparability.

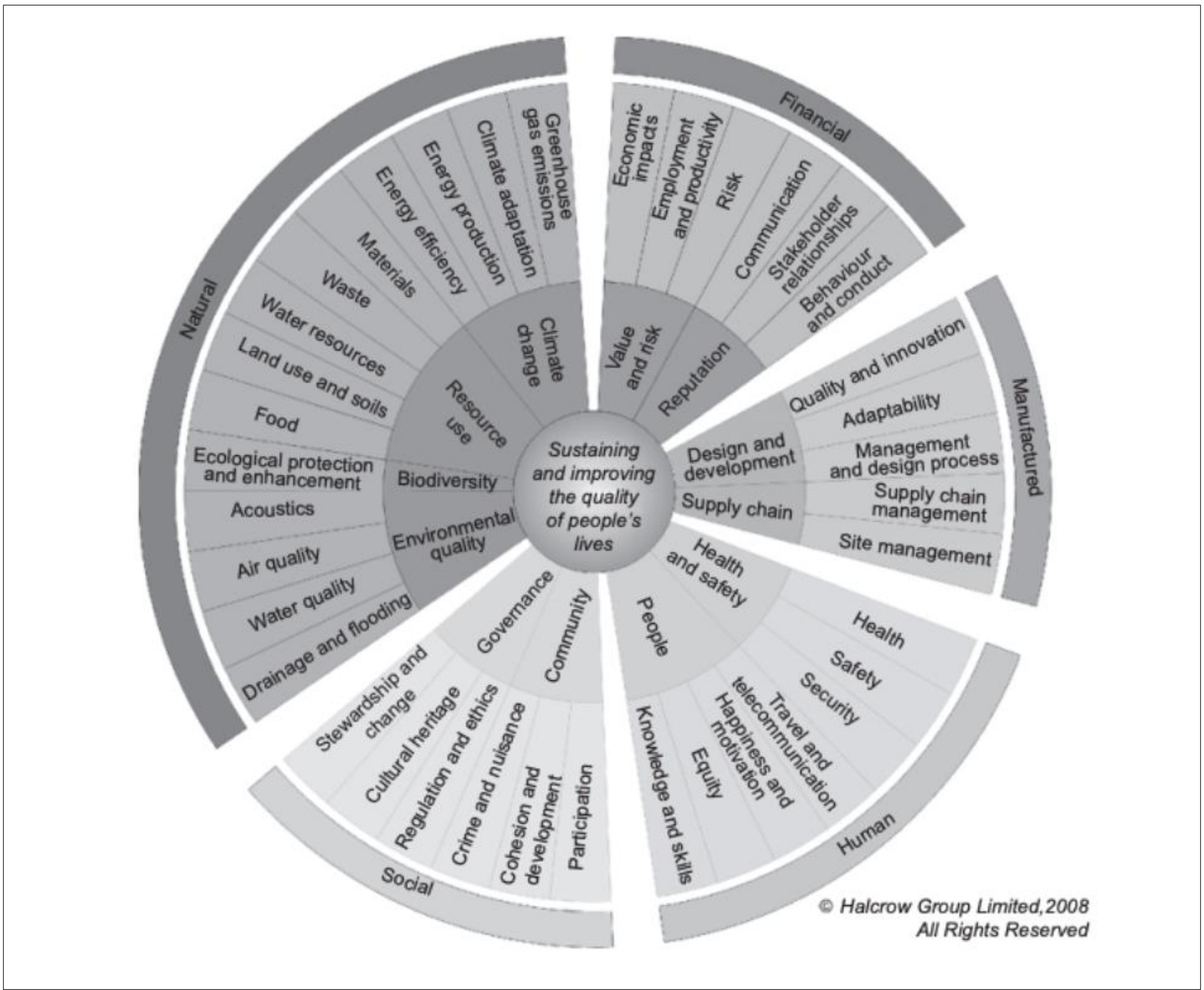
The application of the five capitals approach to decision making requires the following considerations:

- relationships and (inter) dependencies between capitals
- spatial, temporal, and quantitative limitations and boundaries, as well as thresholds exist and require determination
- inter-/intra-capital trade-offs depending on political priorities and risk thresholds
- operationalising and valuing different capitals may be at different scales/units – qualitative and quantitative.

The five capitals approach may be applied for different developments and strategies, which can include time-bound projects and programmes, as well as strategic policy plans. The ACE report provides an insight into individual capitals and their application, while discussing the application of a combined capitals approach (ACE, 2020). Within this context, each capital is evaluated on a scoring index against a specific policy target, standard or intended outcome. Furthermore, the ACE report provides a perspective on how the five capital approach fits within the context of the UN Sustainable Development Goals (SDGs) and their delivery.

A proposed framework and sequence of steps developed by Halcrow Group Limited, known as the Halcrow Sustainability Toolkit and Rating (Halstar) system, provides an overview of details they believe need to be considered for each capital and a step-by-step evaluation. Included within the system is the Halstar Sustainability Wheel (Figure 4), which breaks down important components for each of the five capitals.

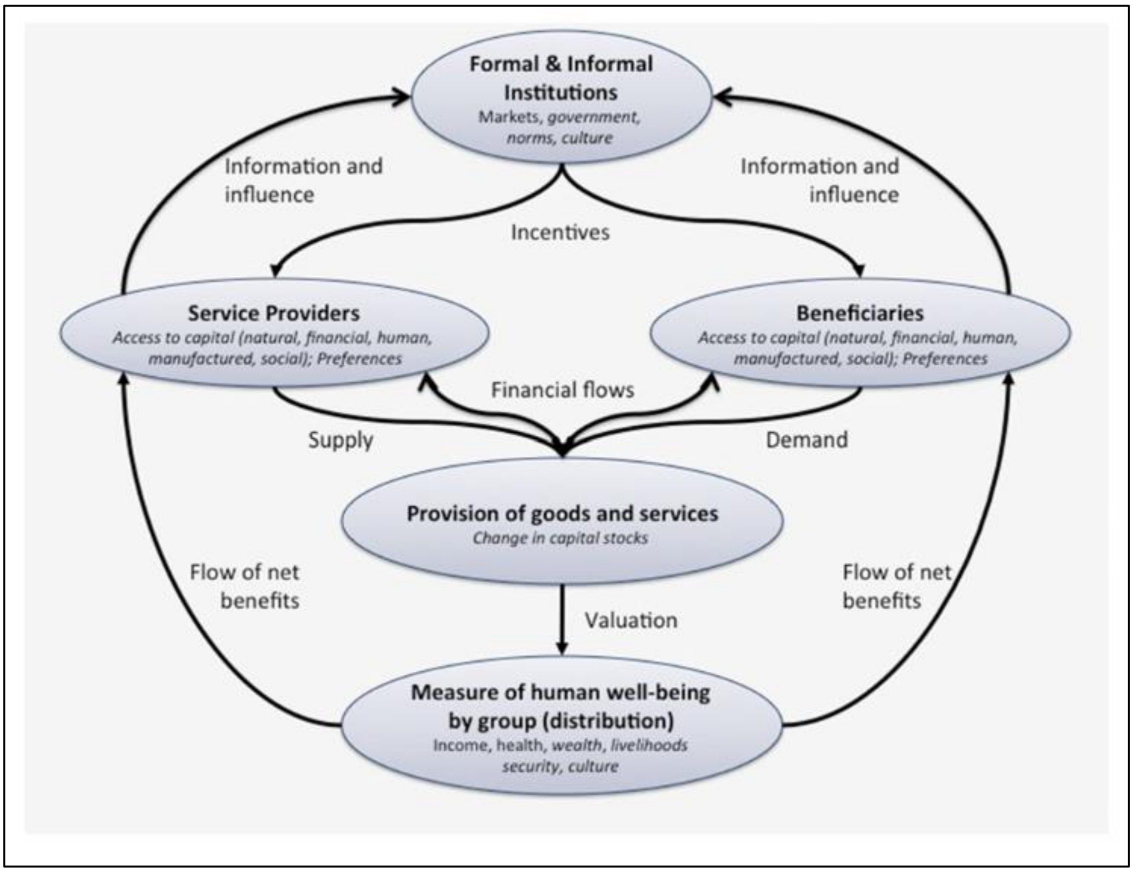
Figure 4: Halstar Sustainability Wheel



Important aspects that can be drawn from this approach are that sustainability integration in decision-making is context-specific and may be applied at different scales to facilitate a manageable process and outcome. In this regard setting an appropriate scale and scope are important (Pearce et al., 2012; Stebbings et al., 2021) as they should determine the criteria applied within the assessment (Grafton et al., 2005).

Several theoretical frameworks have been developed to integrate multiple capitals in decision-making (for example, Grafton et al, 2005; Pearce et al., 2012; Da Silva et al., 2020; Stebbings et al., 2021, Harris et al., 2022). For example, the integrated approach proposed by Guerry et al. (2015) is shown in Figure 5.

Figure 5: The integration of a natural capital approach in decision-making, according to Guerry et al., 2015.



Commonalities between such approaches in operationalising a five capital approach include the following steps:

- defining a (spatial) scale and period at which the assessment is carried out
- defining specific objectives and considering prioritisation of certain capitals
- taking stock of all capitals involved to understand the status quo, interactions, goods and service flows, and other conditions (for example, asset registers, natural capital accounts, etc.)
- valuing and weighing assets
- creating scenarios (for example, trade-off decisions) including potential consequences (for example, impact on the environment)

Placing values on assets creates a basis for decision-making (for example, by consideration of trade-offs) and is unavoidable. By combining valuations of market and non-market benefits and costs of different spending opportunities, policy makers are given options (Bateman and Mace, 2020). Integrating non-monetary values, which could be argued are equally as important as monetary values, into this process remains a challenge. Weighting can be based on existing literature, as well as international and national standards and policy targets (Stebbings et al., 2021, Da Silva et al., 2020).

Crucially, successful application of a five capitals approach requires inter-disciplinary and inter-institutional cooperation and coordination (for example, Causon et al., 2022; Bateman and Mace, 2020; Stebbings et al., 2021).

9.4.3 Five Capitals Approach: Case studies

Although there are examples of the evaluation of single capitals or combined capitals; currently, there are only a few that have fully integrated the five capitals approach.

Business

Harris et al. (2022) investigated the integration of natural capital into the UK's Office of National Statistics (ONS) accounting system and found substantial knowledge gaps on valuing such capital. They also found that integrating natural capital in decision-making provides an opportunity to create public trust through increased transparency, demonstrating the consideration of environmental impacts and challenges of decisions.

The ONS uses two approaches for this through 1) integration of prices corresponding to ecosystem service contributions to the economy, 2) in the case there is no market for such services, price estimation of an ecosystem service based on a theoretical market. The model includes depreciation rates for natural capital and was updated in 2019 to account for more dynamic processes.

Environmental Management

Tinch et al. (2015) used an integrated assessment platform (CLIMSAVE) to model different options for land use and economic activity under different climatic and socio-economic scenarios. The CLIMSAVE approach was to ground the capacity model in the capitals framework so that the capacity index was based on a combination of capitals that are (in principle) measurable and for which data at national levels are available. The project demonstrated the feasibility of using the five capitals framework for scenario development with stakeholders, for representing limiting factors for adaptation options (adaptive capacity), and for constructing an index of coping capacity. Tinch et al. (2015) note that further research is needed to determine the scaling properties of adaptive and coping capacity measures, and how their differences can be represented at local and sectoral scales.

Tinch et al. (2015) also note that all capital types respond differently to use and that their depletion is not automatic – in some cases use of a capital can enhance it. Tinch et al. (2015) made the following observations on each of the capitals:

- Financial reserves are run down by expenditures, but expenditure can also have a stimulating effect on an economy, with different multipliers depending on the kind of expenditure.

- Manufactured capital may be depleted by use, or may be used only temporarily (for example, machinery used for emergency flood defence work) and then returned to the pool of resources.

- Natural capital can be sustainably or unsustainably managed, and many forms of use need not deplete the capital; in some cases, use may be essential in order to maintain the productivity of the capital (for example, agricultural land, which may decline in agricultural value and potentially in other values if abandoned).

- Human capital may be used to a specific end but can also be enhanced by being used (for example, through training and knowledge transfer benefits, adaptive management and learning by doing).

- Social capital is complex and may sometimes be enhanced through use, or subject to a 'use it or lose it' aspect but could also be reduced by overuse (for example repeated calls for non-reciprocated aid).

Another example of the five capitals approach is the assessment for a recreational plan at the Little Don reservoir by Yorkshire Water (Yorkshire Water, 2017). An asset register was developed for six capitals (including intellectual capital) to determine and prioritise management interventions. With scenario mapping of different decisions, using the asset register as baseline, pros and cons for each intervention were identified, which enabled a shortlisting of the most desirable options. This evaluation was based on a Capitals Valuation Tool. However, they also noted existing data restraints for natural capital, especially in relation to the energy and fishing sector.

Development

Maack and Davidsdottir (2015) assessed the applicability of the five capitals model to energy development and found that there is increasing efforts to integrate natural capital into welfare and economic growth consideration, for example, Index of Sustainable Economic Welfare (ISEW), thereby moving away from a traditional cost-benefit analysis.

Campbell et al. (2020) applied the five capitals model to identify how off-site manufacturing can mitigate and respond to climate change issues and applied the model based on target objectives for manufacturing (Figure 6).

Figure 6: Five Capitals Model for Off-site Manufacturing by Campbell et al. (2020).

TABLE 2: OSM and five-capitals model of sustainability

NATURAL CAPITAL	HUMAN CAPITAL	SOCIAL CAPITAL	MANUFACTURED CAPITAL	FINANCIAL CAPITAL
Building less Using OSM as part of enabling building reuse with lightweight system or with logistics-constrained refurbishment	**Multi-skilled workforce** Ability to engage both skilled and semi-skilled workers providing more flexible career pathway	**Reskilling and apprenticeships** Cross-industry skills transfer with new opportunities to attract more people to a high-quality industry with a broader purpose	**Reduced whole-life impacts** Improved airtightness and thermal efficiency Extend building use through durability	**Faster delivery** Earlier return on investment and better cashflows
Using biogenic materials Working with renewable natural materials to reduce non-renewable resource consumption, reduced extraction impacts on biodiversity, and enhanced carbon pools	**Improved and regular working conditions** Safer and healthier working environments More regular and local work Shift patterns and flexible working for more inclusive employment across all ages	**Diverse routes to delivery** Alterative models for small and self-build to diversify opportunities	**Optimised products** Product optimisation and production waste reduction particularly with platform-based systems	**Route to embodied carbon reductions** Optimisation for net-zero-carbon materials and limitation of future carbon pricing or governance impacts
DfMA+D Disassembly within the product design and greater standardisation allows for greater material reuse	**Digitalisation uptake** Increased adoption of innovative digital processes for manufacturing simulation and supplier coordination via platform systems Digital twin benefits maximised through end of first use and then reuse with retained information	**Design quality** Avoiding 'sameness' in the built environment through design quality, mass customisation and digitally enabled flexible manufacturing	**User-focused** Designed to suit changing user needs and adaptability over time, including climate resilience and lifestyles	**Reduced rework** Remedial costs reduced by right first time approach

9.4.4 Capital Asset Registers

An asset register is a structured stock-take of a capital's assets (goods, services, resources) in quantity and/or quality at a defined point in time, at a defined scale. More advanced asset registers can incorporate additional information on the assets' condition, functionality, assigned units and values, flows, and potential interchangeability with other capitals (for example, trade-offs). Flows in this regard can be evaluated over a certain period to inform and monitor changes in capital assets.

There are few examples of publicly available asset registers that incorporate multiple capitals, but natural capital asset registers are becoming increasingly available. For example:

- In Scotland, a Natural Asset Register Data Portal was developed by the James Hutton Institute with the aim of providing open access to spatial data relating to Scotland's terrestrial natural assets (Donelly et al., 2021). The research data sets are produced by researchers in six Scottish Environment, Food and Agricultural Research Institutes (SEFARI, 2023).

- The JNCC developed an asset register for the Turks and Caicos Coastal-Marine Area and defined a conceptual framework with five principles elements: Habitats; Species; Supporting Services; Final Services; and Goods and Benefits (Figure 7) (Hooper et al., 2021). The outputs from the project provide information on natural capital assets, an asset-service matrix, and ecosystem service delivery maps. The work builds on the marine evidence base of the Turks and Caicos Islands and provides practical tools and enhanced capabilities to consider biodiversity, conservation, and understand natural capital approaches by decision makers and local communities.

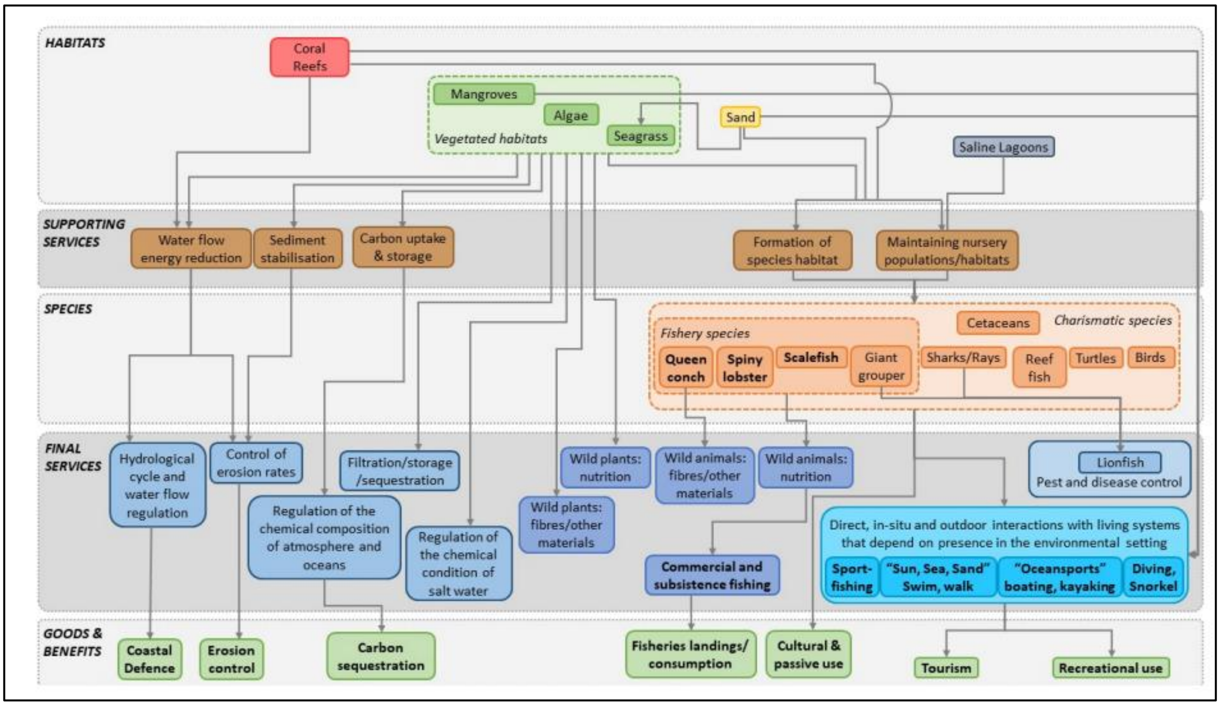
- In 2011, a Natural Capital Asset Index (NCAI) was created for Scotland, which provides information on the changes within assets for terrestrial, freshwater, and coastal habitats, and is updated continuously as more information on biodiversity indicators becomes available (NatureScot, 2023). The NCAI tracks changes in the capacity of Scotland's terrestrial ecosystems to provide benefits to people. It does not include monetary values but is composed in a way which reflects the relative contribution of habitats to human well-being.

- In 2019, a feasibility study was carried out by NatureScot to assess the potential for expanding the NCAI to include marine natural capital. The study found that, although it would be feasible to develop such a register, substantial data gaps for the marine environment remain and that national weighting and valuing of natural capital would require a different approach and extension of the register (Tillin et al., 2019). It is important to note that a basic asset register would not require weighting or valuation.

Manufactured capital asset registers should be relatively straightforward to create as they provide a record of man-made assets, however they are made more complex as they should account for depreciation and deterioration of assets over time through usage, as well as the role and function of the assets in the delivery of processes (flow) (Davis, 2016).

Financial asset registers should contain information on ownership and dependencies on other financial stocks. Depending on the scale, interlinking financial asset registers with other existing registers, and making them transparent and open to several users, should be considered (Mack, 2022).

Figure 7: Asset-service matrix (Hooper et al., 2021).



9.5 Early Conclusions

Having reviewed the literature, we have reached some early conclusions on how a five capitals approach can help inform our understanding of carrying capacity in a marine planning context. Further informed by a workshop held on 27th February 2023, these conclusions will inform the next stage of this project which will develop asset registers for the EMPA across the fisheries, aggregates, and offshore renewables sectors, and consider how the five capitals approach can be scaled up and applied to multiple sectors and plan areas.

9.5.1 Benefits

As highlighted within this review, there are already multiple examples where one or more of the five capitals have been used to assess impacts and inform decision making. The use of all five collectively is a relatively new concept, yet there are a few examples using this approach. The findings of this literature review indicate that the five capitals approach has the potential to build on current approaches of assessing trade-offs and carrying capacity in the marine environment. Most notably, the five capitals approach brings the following additional benefits to marine planning:

- Provides a more comprehensive scope to inform trade-offs and determining carrying capacity by including the assets and interactions of social, human, manufactured, and financial capital. This broader assessment can assist with identifying direct and indirect interactions, multiple-benefit outcomes, and opportunities for mitigation.

- The development of asset registers for the five capitals can inform assessments of the current state of capital assets and highlight risks and thresholds that can inform trade-offs and carrying capacity assessments.

- The five capitals approach can be applied to the planning process in a variety of ways, from the development of policy targets and objectives to managing direct conflicts for marine space.

- There are opportunities to apply the five capitals approach in a structured, stepwise way that allows for the capitals to be prioritised to reflect policy targets and marine plan objectives.

- The five capitals align well with, and can support the delivery of, the UN Sustainable Development Goals as well as the delivery of Good Environmental Status.

9.5.2 Challenges

The five capitals approach has the potential to provide multiple benefits to marine planning, but there are several challenges that need to be addressed to ensure the five capitals approach is efficient and informative:

- The five capitals approach is not a one-size-fits-all solution and will need to be developed on a case-by-case basis depending on the location, activities covered, and the purpose for its use.

- Data availability, in particular ecological data, is critical to inform the five capital asset registers, which form the basis of the approach.

- Valuing and weighting indicators to measure different capitals is an essential step to determining trade-offs and making information useable and accessible to decision makers. However, as this step determines and prioritises importance of different assets it is one that requires comprehensive consideration and further investigation.

- Incorporation and comparison of different types of value – monetary and non-monetary - becomes increasingly complex as more capitals are considered.

- The five capitals approach requires an understanding of a range of different aspects, namely: the functionality of services, interactions between assets for different capitals, outside impacts (for example, climate change), and interchangeability and substitutability.

- Determining which data are required, and at which scale, is essential for ensuring the five capitals approach functions efficiently and towards the desired outcomes.

- Ecological carrying capacity is least well understood, yet, from a five capitals perspective, is the most important given its foundational role in supporting the other capitals. However, there is potential for linking ecological carrying capacity with the descriptors for GES.

- Addressing temporal scale is a challenge for trade-off assessments and cumulative effects assessments, in particular the cumulative effects of small, but constant, impacts over a long period of time. Incorporating multiple systems that operate over different timescales will be a significant challenge for the five capitals approach.

- The ability of environmental thresholds (and carrying capacity) to support decision-making and deliver successful environmental management has been questioned, as they are an *“appealing conceptual way of looking at ecosystems”* but with *“no real potential for practical application”.* (Groffman 2006) It is unclear whether the five capitals approach has the potential to address these concerns.

9.6 Appendix A – Natural Capital

Definition

Natural capital includes certain stocks of the elements of nature that have value to society, such as forests, fisheries, rivers, biodiversity, land and minerals and includes both the living and non-living aspects of ecosystems (HM Treasury, 2022). These components, or groups of components, are known as natural capital assets (Natural Capital Committee, 2017). These stocks provide flows of environmental or 'ecosystem' services over time. Services, often in combination with other forms of capital (human, social, manufactured, and financial), provide benefits to people which include economic wealth and human well-being (Hooper et al., 2019).

Some benefits are actively sought out by humans, for example, seafood, while we passively benefit from others, for example, clean air (Culhane et al., 2018). Benefits can be obtained by interacting directly with natural capital (known as 'use values'), for example, when fishing or snorkelling, but not all benefits require direct interaction (known as 'non-use values'), for example, enjoyment felt simply from the knowledge that a particular marine species exists (HM Treasury, 2022; Culhane et al., 2018).

The ability of ecosystems to supply ecosystem services depends on the quantity, quality, and location of natural capital assets, which can be affected by pressures and management decisions (Defra, 2021). A system that is rich in biodiversity, healthy and resilient can generate all the natural capital components required to provide the flows of ecosystem services humans rely on (Buonocore et al., 2018), although this flow can vary seasonally, and with environmental conditions.

Marine environments are increasingly under threat from multiple anthropogenic stressors and the impacts of human activities, for example, unsustainable fishing, habitat degradation, pollution, and climate change (Halpern et al., 2008). While many forms of natural capital can regenerate, failure to manage these renewable stocks sustainably can lead to their degradation or decline, and the decline or loss in the benefits obtained from them (European Environment Agency, 2020).

Application

The concept of natural capital has evolved considerably over time. Early applications mainly focused on assigning monetary values to services provided by natural resources based on consumer perceptions while, more recently, integrated frameworks have been developed in efforts to grasp the complexity and extent of natural capital (for examples see Costanza, 2020; Bateman and Mace, 2020; Stebbings et al., 2021). The creation of inventories and accounting systems for natural assets has led to more informed and sustainable decision-making and development (for example, Hein et al., 2020, Hooper et al., 2019). Within the context of sustainability, Barbier (2019) highlighted the need for considering compensation for losses of natural capital assets that have been irreversibly depleted, highlighting the differences between 'weak' and 'strong' sustainability (Figure 8) (Barbier, 2019).

Figure 8: Characteristics of 'strong' and 'weak' sustainability based on Barbier (2019).

Table 1: Weak versus strong sustainability

Weak sustainability	**Strong sustainability**
Natural, human, and reproducible capital can be substituted for each other.	Cannot always substitute for natural capital with reproducible or human capital.
Natural, human, and reproducible capital are an aggregate, homogeneous stock.	Cannot view natural, reproducible, and human capital as a homogeneous stock.
Natural capital should be used efficiently over time. As long as depleted natural capital is replaced with even more valuable reproducible and human capital, then the value of the aggregate stock will increase.	Certain environmental sinks, processes, and services are unique and essential, subject to irreversible loss, and there is uncertainty over their future value and importance.
Maintaining and enhancing the value of this aggregate capital stock is sufficient for sustainability.	Maintaining and enhancing the value of the value of the aggregate capital stock is necessary but not sufficient. Sustainability also requires preserving unique and essential natural capital.

In 2017, the Natural Capital Committee published a natural capital workbook (Natural Capital Committee, 2017) in response to the Government's commitment to be "the first generation to leave the natural environment of England in a better state than that in which we found it" (H.M. Government, 2011). The guide, which is aimed at planners, communities , and landowners, provides the blueprint for:

- Measuring the natural capital in a particular area and the benefits it can provide
- Identifying threats and opportunities to natural capital
- Weighing up the available options and opportunities to make improvements
- Developing practical plans.

Within the workbook is a proposed five step model aimed at supporting decision makers to protect and improve the environment and natural capital. The proposed five step model involves:

- definition of an objective or vision
- understanding and evaluating (collection evidence) the current state
- collection of evidence
- identification of options (scenarios, trade-off determination)
- implementation and subsequent valuation of a decision.

Examples of natural capital application

Fisheries and offshore wind development

Causon et al. (2022) demonstrated through applying a natural capital approach to wind farm development that the prohibition of trawl fisheries would allow for benthic asset recovery. They also considered mitigating options for the loss of food supply due to this fishing restriction, which could be compensated by sustainable aquaculture. However, this study noted existing limitations in the application of a natural capital approach, which are further explained under the “Challenges” section below.

Multiple marine sectors

Stebbings et al. (2021) applied a natural capital focused framework to several activities and developments in the UK marine environment, namely seafood production, offshore wind energy, wildlife watching and water sports. They identified a set of indicators to describe existing capitals for each of the sectors and proposed a weighting system, based on available literature and policy targets, to determine a relative importance for each indicator. However, they also noted some limitations, as described below.

Benefits

Natural capital is the driver and limiting factor in the development of all other forms of capital, thereby building the foundations for sustainable development. In understanding the resource limitations and critical thresholds of ecosystem services, and their value to society, sustainability can be incorporated into policies, plans, and developments. The integration of natural capital in decision making does not only contribute to the sustainability of human activities, but also creates accountability and transparency of the management of natural assets (Hein et al., 2020). Costanza (2020) and Bateman and Mace (2020) noted the need for the integration of fundamental principles of sustainability in a natural capital approach, including the fair and efficient allocation and distribution of natural assets, which can contribute to equitable benefit sharing and overall increase of wellbeing at different levels (for example, community, wider society, etc.).

A natural capital approach could support the implementation of common policy targets, such as the UN Sustainable Development Goals (SDGs) and facilitate risk management to avoid ‘points of no return’ in resource use. This can improve our understanding of critical ecosystem thresholds beyond which the functioning of the marine environment can no longer be guaranteed, and our ability to identify areas where recovery actions should be prioritised (for example, Causon et al., 2022, Bateman and Mace, 2020).

The potential for nature recovery has also been recognised by the United Nations Decade on Ecosystem Restoration, which could facilitate an improved understanding of how human wellbeing and natural capital are connected and allow for future investment in recovery actions where most needed (Farrell et al., 2022).

Challenges

To fully realise the benefits a natural capital approach can provide, an ‘as accurate as possible’ understanding of existing assets, service flows, changes, and interaction with other capitals is required. Currently, there is no standardised framework for assessing this flow of assets, or the relative importance of associated indicators; the latter is impeded by data gaps, which is often substituted for with expert opinion (Stebbings et al., 2021). There is a need for further research on valuing and weighting marine natural capital (Costanza, 2020) as there are limited proxies for the marine environment that can be applied (Causon et al., 2022).

Hooper et al. (2019) highlight that significant data gaps have hindered progress in the application of a natural capital approach to development activities in the marine environment, which likely explains the limited availability of practical examples in decision-making (Hooper et al., 2019; Costanza, 2020). A significant data gap is the baseline condition of natural assets pre and post developments, which requires substantial financial input form the developer (Causon et al., 2022).

The complex interrelationships between natural capital assets at an ecosystem level make it challenging to identify and determine trade-offs in decision making (Barbier, 2019). This is considered in more detail in Section 2 of this document.

9.7 Appendix B – Human Capital

Definition

Human capital focuses on the skills and capacities of individuals. Weatherly (2003) defined human capital as “the collective sum of the attributes, life experience, knowledge, inventiveness, energy and enthusiasm that its people choose to invest in their work”. In short, the basic characteristics for human capital are education, knowledge, and experience (Augusto Felicio et al., 2014). Human capital has been defined in different contexts. Although the general focus remains with the skills and knowledge of individuals, there is also consideration of the sum of knowledge held by employees and additional considerations of human health (Mauerhofer, 2013).

Within the context of evaluating organisational resilience, human capital has been defined as a dynamic asset that brings a competitive advantage (Mubarik et al., 2020). Yami et al. (2021) distinguished between different forms of human capital: formal education and experiences, which can be classified as ’general human capital’ and ’task-based competencies’, respectively.

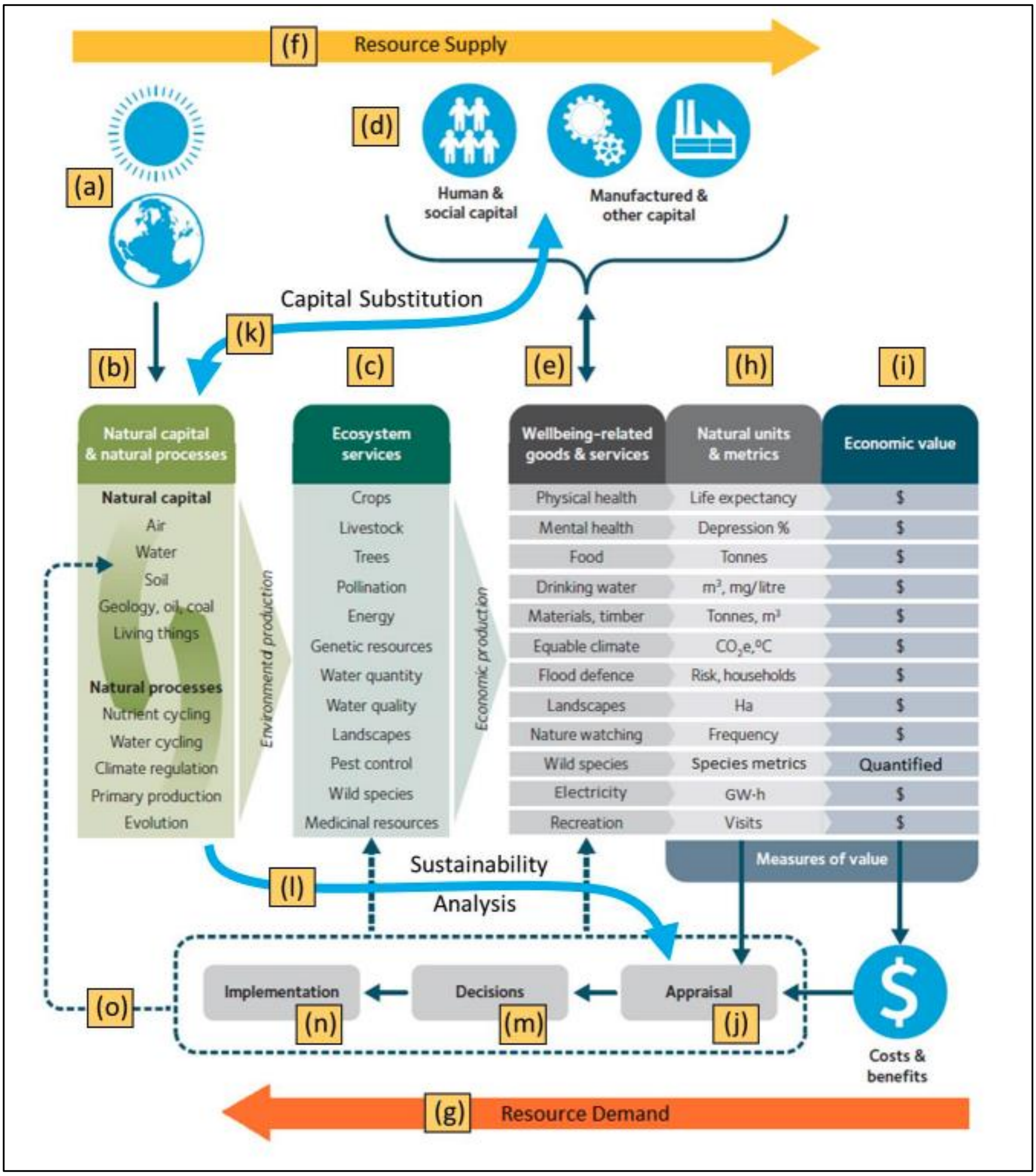
Application

Human capital has largely been applied within a business context and can help to determine a companies’ performance and determine gaps in skills and knowledge that require addressing (Felicio et al., 2014). There are several proxies that can be measured to assess human capital, which includes ‘years of education’ or ‘education level’ as proxy for knowledge; years and type of employment as proxy for skills; and age as proxy for experience (Goodwin, 2003). Furthermore, Ekins et al. (2008) described additional indicators for human capital, namely health status, motivation and productivity, employment rate, and ‘interventions’ taken (for example, through training).

Recent literature has expanded the concept of human capital to incorporate intrinsic values possessed by members of an organisation, which include attitude and commitment to work (Mubarik et al., 2020). The application of a human capital approach has also been extended to evaluate other additional aspects, such as the positive relationship between human capital and organizational resilience (Shela et al., 2023).

Human capital is directly dependent on natural capital and interlinked with social capital (Bateman and Mace, 2020), as shown in Figure 9.

Figure 9: Natural Capital Framework developed by Bateman and Mace (2020) showing the linkages between human, social, and manufactured capital.



Rasheed (2020) reviewed literature relating to MPAs to assess how well human well-being is integrated into MPA design, assessment, and effectiveness, which included factors such as education, health, MPA manager capacity, and provision of alternative livelihoods. The results highlight the need for a systematic, holistic, and integrative approach to assess MPA outcomes and their contribution to human well-being. Such an approach would allow for cross-MPA comparisons, a better understanding of MPA outcomes, and support the future design of MPAs.

Benefits

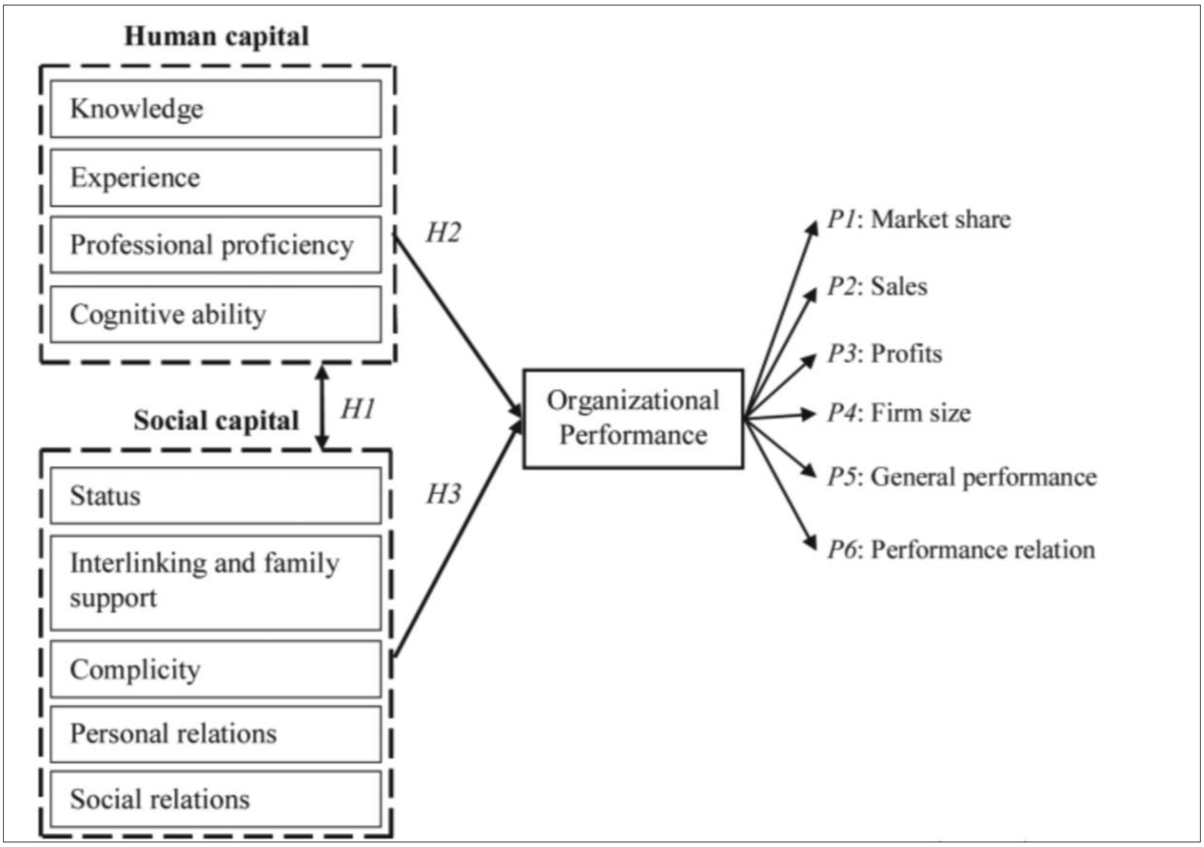
Given its widespread application, there are several established human capital indicators available which could be extended to a marine context, as shown by Rasheed (2020). There is also a wide range of literature available such as the World Bank's Human Capital Project (World Bank, 2023), which provides further insights into human capital through the development of a Human Capital Index. Human capital can be created through capacity building (Morrison et al., 2013) and can support the creation of equality and fairness in resource distribution in a marine planning context, as well as help prioritise efforts for creating and extending such capital (Bateman and Mace, 2020).

Challenges

Augusto Felicio et al. (2014) highlight, within an organisation context, the two-way interactions between human and social capital, and how both capitals influence organisational performance differently. One challenge in determining human capital is separating the link between investment in human capital and output/benefit (for example, business performance) from other influencing factors (Costa, 2012) and social capital, as shown in Figure 10.

Human capital, and the interaction with social capital, will inherently be different between countries, and at different spatial scales, where access to education, development level, quality of educational programmes, and access to health care can be highly variable (Morrison et al., 2013, World Bank, 2023).

Figure 10: Schematic overview of the relationship between human and social capital, and organisation performance constructs (Felicio et al., 2014). The H1 hypothesis is “different factors of human capital are related to different factors of social capital.”



The status of human capital, which in a wider context includes human wellbeing, is directly related to the status of natural capital, such as air quality or water supply, and the ecosystem services it provides. Therefore, depletion and degradation of the environment from human activity will, in turn, have a direct impact on human capital. Capturing and valuing these services and benefits, can be challenging and, therefore, difficult to integrate into the decision-making process on environmental management. These linkages become even more challenging when considering the marine environment, as many of the ecosystem services provided by marine natural capital are less apparent, indirect or poorly understood.

9.8 Appendix C - Social Capital

Definition

Social capital relates to the relationships and functioning of society at different levels. Goodwin (2003) refers to the value of trust, relationships, social networks, mutual understanding, and community structures, when describing the characteristics of a society or community. This definition has been expanded over time to include other factors describing society, such as relationships, norms, values, and networks in which they operate (Mauerhofer, 2013).

There are some important aspects of social capital that distinguish it from other forms of capital, which, according to Brondizio et al. (2009), include:

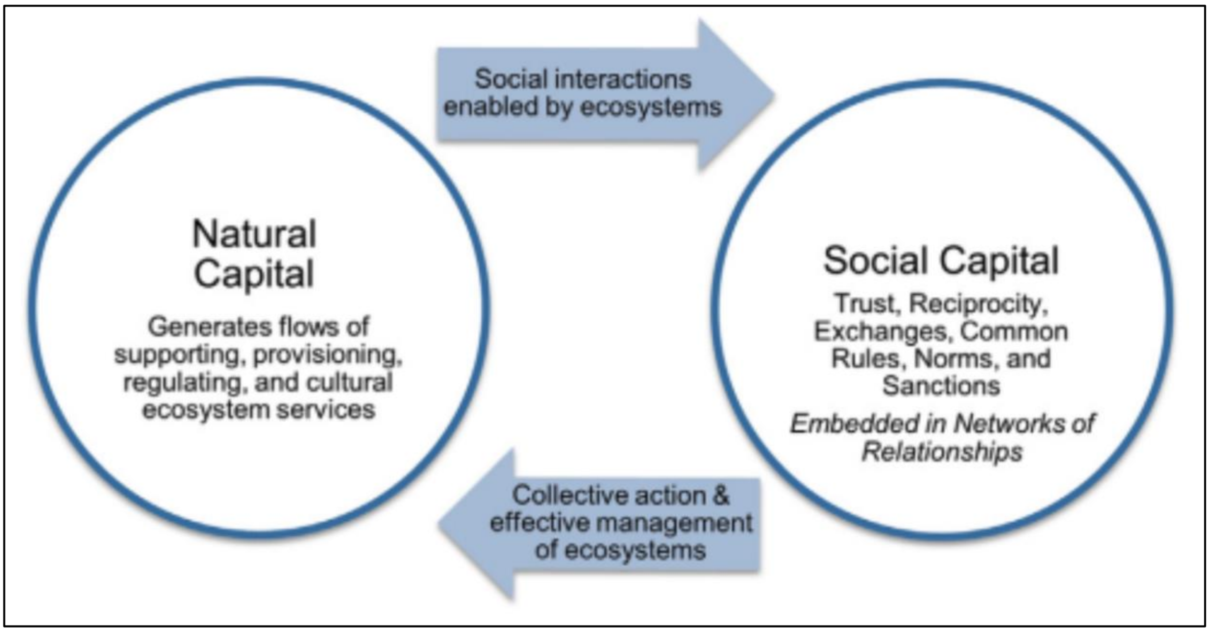
- Social capital does not wear out with use but rather improves with proper use and deteriorates rapidly with disuse.
- Social capital is not easy to see and measure.
- Social capital is hard to construct through external interventions.
- Social capital operates most effectively when it is organized in complementary forms at multiple levels.

Noting Brondizio et al, creating social capital, especially in the case of marine planning, requires new ways of building bridges between different types of stakeholders and governments (Jacob et al., 2023).

Application

General application of social capital is largely through social science methods – mainly interviews and questionnaires ranking local perception of networks, trust, and social cohesion (Barnes-Mauthe et al., 2015). These studies aim, for example, to understand how an increase in social capital can support governance decisions (Grafton et al., 2005), or company performance in relation to investment in social capital (Crona et al., 2017). As demonstrated by Barnes-Mauthe et al. (2015), marine protected areas can create a direct link between social and natural capital (Figure 11).

Figure 11: Dependencies between natural and social capital (Barnes-Mauthe et al., 2015).

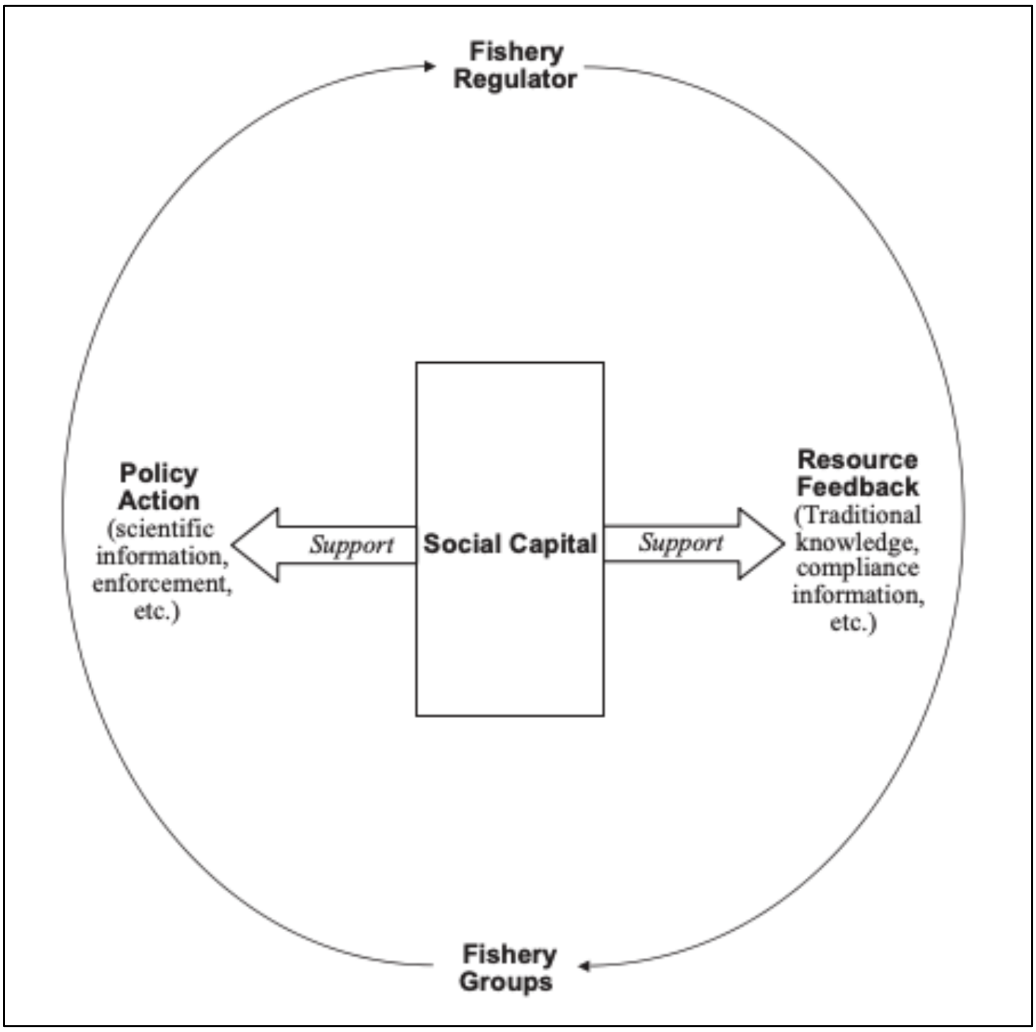


Bakker et al. (2019) investigated how fishermen use social capital to influence marine spatial planning (MSP). Through literature reviews, field observations, and target interviews within the local fishing communities they evaluated how these communities use ‘bonding’, ‘bridging’ and ‘linking’ as forms of social capital. ‘Bonding’ describes interlinked values, norms, and practices within a community, ‘bridging’ refers to collaborations across different communities, and ‘linking’ represents the process of building connected social capacity at various levels of governance. The study found that although the local fishing communities have strong bonding, the linking potential remains low, thereby reducing their impact on MSP.

Benefits

Social capital depends very much on the spatial context in which it is evaluated (Brondizio et al., 2009, Jacobs et al., 2023). In principle, social capital can be created with relatively low investment costs (for example, through community and stakeholder engagement activities), but requires a systematic and thought-through approach to connect people (Jacobs et al., 2023). In understanding the existing social capital in the context of decision-making, and investing in its creation, regulatory bodies can create long-term relationships with local communities and industry, which, in return, support compliance with intended regulations and thereby can reduce enforcement costs (Grafton et al., 2005), as demonstrated in Figure 12.

Figure 12: Relationships between policy actions and resources in social capital in the context of fisheries governance (Grafton et al., 2005).



Challenges

Despite expanding research on social capital evaluation and application, there remains limited consensus on approaches. There is general agreement that social capital is the most difficult of the five capitals to apply and measure, as it is heavily reliant on human perception (Mauthe et al., 2015). Although social capital can support policy implementation, it may not be the best measure to determine overall governance success (Crona et al., 2017). A coherent assessment of social capital requires:

- the determination of boundaries between organisations,
- application of spatial units for environmental and institutional boundaries,
- consideration of applicable jurisdictional limitations,
- combination of information from different sources, and
- consideration of non-compliance in policy implementation (Brondizio et al., 2009).

Barnes-Mauthe et al. (2015) recognise the linkages between social capital and ecosystems, and that many articles often consider social capital as an important ecosystem service. Yet, few ecosystem service assessments or economic valuations consider social capital. Suggested reasons for this include social capital being inherently complex, multidimensional, and a somewhat intangible concept. Therefore, when considering trade-offs, social capital is often overlooked for more tangible and quantifiable factors.

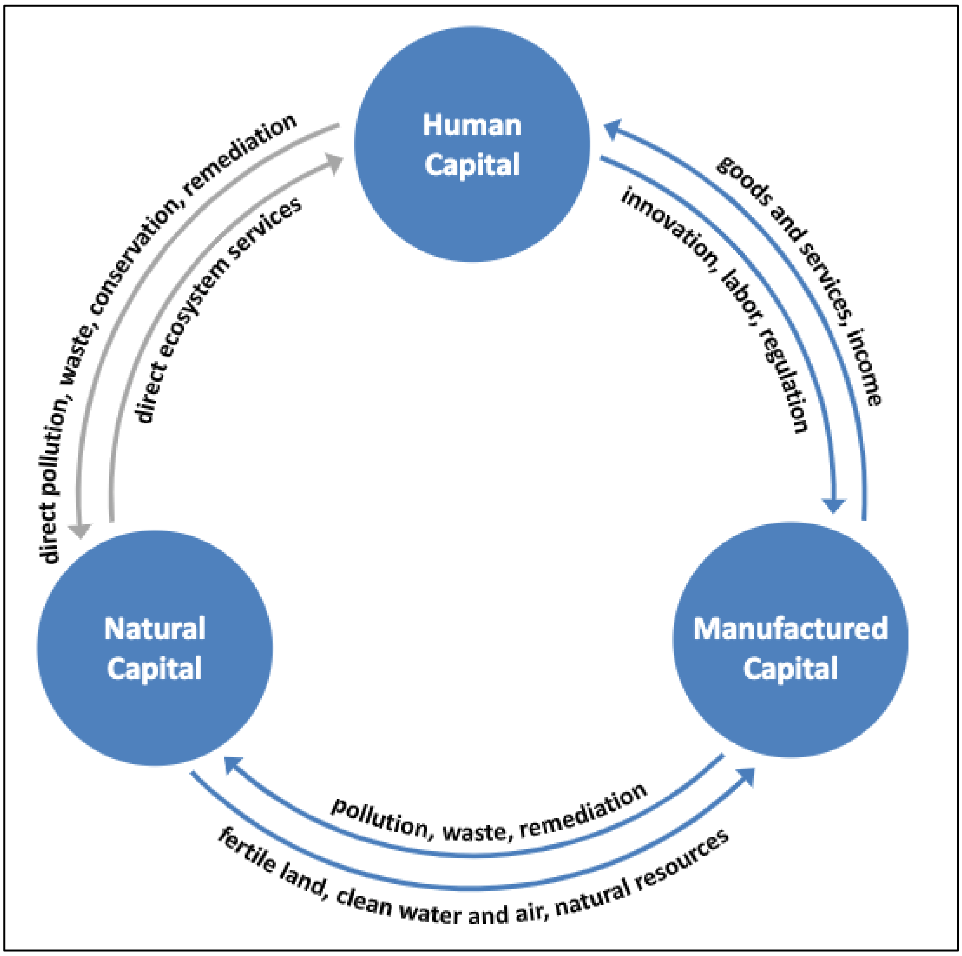
Social capital can function at multiple scales, but most often it is assessed at the local community scale. A notable challenge for marine planning, and working across a marine plan area, will be identifying which scale is most appropriate for informing trade-offs with other capitals while still capturing enough detail on the variability and distribution of social capital throughout the plan area.

9.9 Appendix D - Manufactured Capital

Definition

Manufactured capital refers to goods, materials, and fixed assets that hold value and have, usually, originated from natural capital stocks. Examples include machinery, infrastructure, and furniture. Manufactured capital can also be referred to as 'built' or 'physical' capital and directly depends on natural and human capital (Weisz et al., 2015; Da Silva, 2020), as shown in Figure 13.

Figure 13: Interactions between different capitals (Weisz et al., 2015).



Application

Manufactured capital has been part of economic stock taking for centuries. However, beside the determination of such capital in relation to stocks of goods, there is a 'moral dimension' to manufactured capital, which, according to the ACE report (ACE, 2020), should consider its value in relation to achieving sustainability targets (for example, net zero, lowest possible carbon footprint). In addition, components of manufactured capital and their estimated capital costs should be considered across different economic life stages, including operation and dismantling phases (Maack and Davidsdottir, 2015).

In an economic context manufactured capital has been determined by in-use product stock approaches, which aim to determine the use of products, their substitution, and usage limitations across their life cycle (Chen and Graedel, 2015). In relation to decision-making and achieving sustainability, Weisz et al. (2015) state that "*the capability to produce and re-produce the manufactured capital reflects the ability of modern societies to mobilize and transform materials and energy at that massive scale*."

Benefits

Manufactured capital has been widely applied and there is a general understanding in how to measure it and assign monetary values. Chen and Graedel (2015) state, one benefit of manufactured capital is that *"the determination of long-term in-use stocks of manufactured products can complement existing monetary approaches to measuring manufactured capital and helps to explore the linkage between manufactured capital and natural capital in terms of materials transfer."*

In the context of offshore wind, windfarm developers will have exact information on the materials required to build the windfarm (natural capital), where to source them from (including natural resource or supply chains), the monetary value of the materials/products (and required financial capital), their expected lifespan, and the maintenance requirements and costs throughout that lifespan. Additional considerations will most likely have been made regarding the required supporting infrastructure (for example, ports, vessels), and the number of employees and skillsets required (human capital).

Through the invention of new materials, manufactured capital has the potential to create more sustainable solutions to human resource use (Weisz et al., 2015) and manufactured capital can also be considered in the context of a circular economy (Hira et al., 2022).

Challenges

Manufactured capital is directly dependent on natural capital and, therefore, an important challenge needing to be addressed is the finite nature of most – but not all – natural capital assets and the impact manufactured capital production has on them. The DPSIR (Drivers, Pressures, States, Impacts, Responses) framework (Learning for Sustainability, 2023) is a widely adopted approach used to describe and understand these complex interactions (Patricio et al., 2016).

For example, the marine environment is an important resource for aggregates and their extraction can often conflict with marine conservation efforts and other marine users. The extraction of this natural capital asset will have knock on effects for other marine sectors (such as the fishing industry), many of which will be direct and measurable, while others may be indirect and less apparent (for example, impacts on social capital through reduced fishing opportunities). Conversely, the material coming from aggregate extraction could provide essential products that other marine sectors and stakeholders depend on (such as building material for a harbour used by the fishing sector).

Unlike other capitals, manufactured capital assets will naturally depreciate over time, resulting in a poorer condition, a reduced economic value (financial capital), and a requirement to invest in repair and maintenance. Determining whether depreciation and maintenance costs need to be incorporated into trade-off assessments and, if so, how this can be achieved, will be an important consideration.

9.10 Appendix E - Financial Capital

Definition

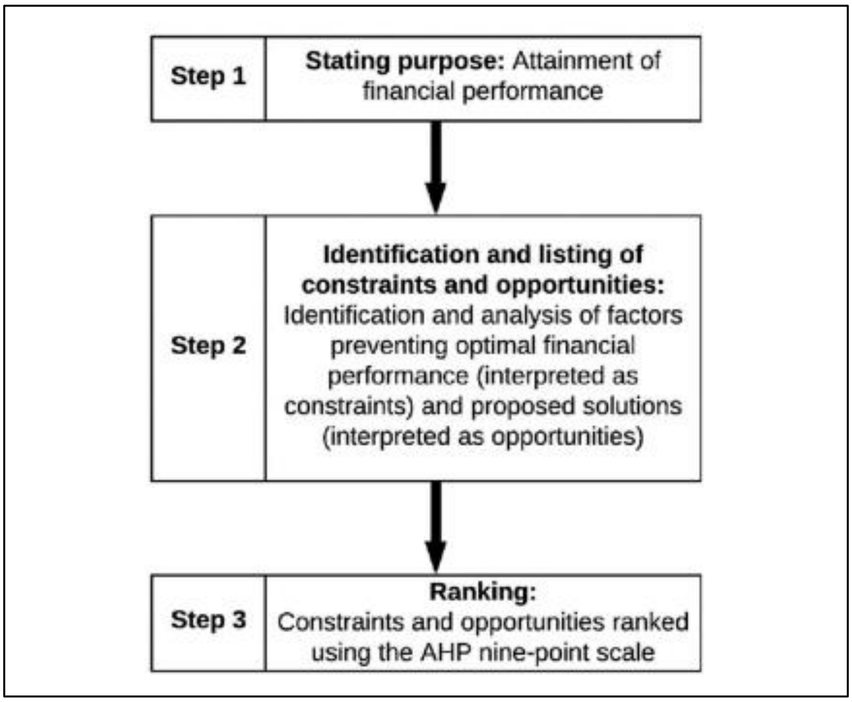
Financial Capital is generally defined as stock and flow of money and financial assets, which, in relation to other capitals, enables trading and ownership (Edwards-Jones et al., 2022).

Application

Financial capital is at the core of global economies and has therefore been widely applied and integrated into economic evaluations and processes, whether using a country's Gross Domestic Product, availability of funds/bonds/credits, or direct stock of money. This form of capital is generally determined in the development of economic sectors.

In relation to marine planning, financial capital assessments can support trade-off decisions and help to identify financial constraints and opportunities, such as in the value chain of a small-scale fisheries, as applied by Kimani et al. (2020), shown in Figure 14.

Figure 14: Analytical Hierarchical Process (Kimani et al., 2020).



Benefits

Financial capital is likely the easiest to measure of all five of the capitals in both terrestrial and marine environments because there are multiple data sources to determine such capital. Due to its wide-ranging application in industry and the economy, it is well understood in this realm. Understanding financial capital in the context of marine management can help to identify financial needs, limitations, and opportunities to invest.

Challenges

Financial capital does not hold real value *per se* but enables trade and ownership of financial resources that represent other capitals. Financial capital, therefore, directly links to all forms of capitals, but only if monetised values are applied. However, financial capital cannot substitute other capitals and its flows and credits need to be understood in the context of sustainable development.

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10 Annex B (Overview: marine plans)

Table 2. Overview of marine plans

Marine Plan Area	North West Inshore and North West Offshore Marine Plan (2021)	North East Inshore and North East Offshore Marine Plan (2021)	South West Inshore and South West Offshore Marine Plan (2021)	South East Inshore Marine Plan (2021)	South Inshore and South Offshore Marine Plan (2018)	East Inshore and East Offshore Marine Plans (2014)
Size	Inshore: 4,900 km2	Inshore: 6,000 km2	Inshore: 16,000 km2	3,900 km2	Inshore: 10,500 km2	Inshore: 6,000 km2
	Offshore: 2,200 km2	Offshore: 50,000 km2	Offshore: 68,000 km2		Offshore: 10,800 km2	Offshore: 49,000 km2
Objectives	Infrastructure is in place to support and promote safe, profitable and efficient marine businesses.				To encourage effective use of space to support existing, and future sustainable economic activity through co-existence, mitigation of conflicts and minimisation of development footprints.	To promote the sustainable development of economically productive activities, taking account of spatial requirements of other activities of importance to the east marine plan areas.
	The marine environment and its resources are used to maximise sustainable activity, prosperity and opportunities for all, now and in the future.				To manage existing, and aid the provision of new, infrastructure supporting marine and terrestrial activity.	To support activities that create employment at all skill levels, taking account of the spatial and other requirements of activities in the east marine plan areas.
	Marine businesses are taking long-term strategic decisions and managing risks effectively. They are competitive and operating efficiently.				To support diversification of activities which improve socio-economic conditions in coastal communities.	To realise sustainably the potential of renewable energy, particularly offshore wind farms, which is likely to be the most significant transformational economic activity over the next 20 years in the east marine plan areas, helping to achieve the United Kingdom's energy security and carbon reduction objectives.

	Marine businesses are acting in a way which respects environmental limits and is socially responsible. This is rewarded in the market place.	To support marine activities that increase or enhance employment opportunities at all skills levels among the workforce of coastal communities, particularly where they support existing or developing industries within the south marine plan areas.	To reduce deprivation and support vibrant, sustainable communities through improving health and social well-being.
	People appreciate the diversity of the marine environment, its seascapes, its natural and cultural heritage and its resources and can act responsibly.	To avoid, minimise, mitigate displacement of marine activities, particularly where of importance to adjacent coastal communities, and where this is not practical to make sure significant adverse impacts on social benefits are avoided.	To conserve heritage assets, nationally protected landscapes and ensure that decisions consider the seascape of the local area.
	The use of the marine environment is benefiting society as a whole, contributing to resilient and cohesive communities that can adapt to coastal erosion and flood risk, as well as contributing to physical and mental wellbeing.	To maintain and enhance inclusive public access to, and within, the south marine plan areas appropriate to its setting.	To have a healthy, resilient and adaptable marine ecosystem in the east marine plan areas.
	The coast, seas, oceans and their resources are safe to use	To support the reduction of the environmental, social and economic impacts of climate change, through encouraging the implementation of mitigation and adaptation measures that: • avoid proposals' indirect contributions to greenhouse gas emissions • reduce vulnerability • improve resilience to climate and coastal change • consider habitats that provide related ecosystem services	To protect, conserve and, where appropriate, recover biodiversity that is in or dependent upon the east marine plan areas.

	The marine environment plays an important role in mitigating climate change.	To identify and conserve heritage assets that are significant to the historic environment of the south marine plan areas.	To support the objectives of Marine Protected Areas (and other designated site around the coast that overlap, or are adjacent to the east marine plan areas), individually and as part of an ecologically coherent network.
	There is equitable access for those who want to use and enjoy the coast, seas and their wide range of resources and assets and recognition that for some island and peripheral communities the sea plays a significant role in their community.	To consider the seascape and its constituent marine character and visual resource and the landscape of the south marine plan areas.	To facilitate action on climate change adaptation and mitigation in the east marine plan areas.
	Use of the marine environment will recognise, and integrate with, defence priorities, including the strengthening of international peace and stability and the defence of the United Kingdom and its interests.	To support marine protected area objectives and a well-managed ecologically coherent network with enhanced resilience and capability to adapt to change.	To ensure integration with other plans, and in the regulation and management of key activities and issues, in the East marine plans, and adjacent areas.
	Biodiversity is protected, conserved and, where appropriate, recovered, and loss has been halted.	To complement and contribute to the achievement or maintenance of Good Ecological Status or Potential under the Water Framework Directive and Good Environmental Status under the Marine Strategy Framework Directive, with respect to descriptors for marine litter, non-indigenous species and underwater noise.	To continue to develop the marine evidence base to support implementation, monitoring and review of the East marine plans.
	Healthy marine and coastal habitats occur across their natural range and are able to support strong, biodiverse biological communities and the functioning of healthy, resilient and adaptable marine ecosystems.	To safeguard space for, and improve the quality of, the natural marine environment, including to enable continued provision of ecosystem goods and services, particularly in relation to coastal and seabed habitats, fisheries and cumulative impacts on highly mobile species.	
	Our oceans support viable populations of representative, rare, vulnerable, and valued species.		

Main sectors	Energy production through oil and gas, nuclear power, and renewables (6 offshore windfarms)	Energy production through oil and gas, and renewables (2 offshore windfarms)		Renewable energy (7 offshore windfarms)	Energy production through nuclear power, and renewables (tidal streams and wind farms)	Renewable energy (Offshore wind)
	Freight transport by shipping	Freight transport (incl. port infrastructure)	Freight transport (incl. port infrastructure)	Shipping (highest number of ports and harbours in England)	Shipping (incl. ports of Southhampton and Portsmouth)	Shipping/freight traffic (including port infrastructure)
	Shellfish fishery	Commercial shellfish and finfish; ports for important for fisheries landings	Fishing (home to greatest number of fishing vessels)			Commercial shellfish and finfish; ports for important for fisheries landings
					Aquaculture	Aquaculture
				Marine aggregate extraction	Marine aggregate extraction	Marine aggregate extraction
		Submarine cables	Submarine cables		Submarine cables	
		Military exercise and operations (60,000 km2)	Largest Naval base in Western Europe and home to royal navy	Military exercise and operations (800 km2)	MOD danger and exercise areas and home to Royal Navy's surface fleet	

	Tourism and recreation	Tourism and recreation	Tourism and recreation	Tourism and recreation		Tourism and recreation
Site potential/ remarks	Expansion and diversification of tourism			Fishing relatively low	High levels of boating activity	Expansion of offshore wind
	Aggregate extraction potential					