

Ecosystem services and the UK seafood industry.

**An initial review of industry contributions,
withdrawals, synergies and trade-offs.**

Contents

1. Introduction and requirement	4
2. UK seafood industry	5
3. Ecosystems and services	7
3.1 Key concepts	
3.2 Systems based approaches to management	
4. Ecosystem thinking in practice	10
4.1 Mainstreaming natural capital and ecosystem services	
4.2 Ecosystem initiatives in the UK	
4.3 Ecosystem services in a marine/seafood context	
5. Evidence of ecosystem interactions with seafood and associated goods/benefits	13
5.1 Overview	
5.2 Domestic seafood	
5.3 International seafood	
6. Conclusions and next steps	19
6.1 Conclusions of the initial review	
6.2 Recommended next steps	
Appendices and References	20

Summary

This review is an initial exploration of how the UK seafood industry draws on and contributes to ecosystem services and the good/benefits to society arising from that interaction.

Focussed on understanding key ecosystem interactions relating to seafood production and consumption, the intention is to support dialogue across the UK amongst policymakers, and between policymakers and the seafood industry.

The degradation of ecosystems and the natural world resulting from human pressure has become a major concern. In response to this degradation, systems based approaches to management (e.g. 'the ecosystem approach') have been developed with the UN sponsored Millennium Ecosystem Assessment, at the turn of the century, helping to set the agenda.

More than 10 years on, a range of initiatives have advanced this agenda. Example actions include: greatly increased scientific research on ecosystem services; and redesigned policy frameworks, particularly in national accounting, planning and incentives.

In the UK, the 2011 National Ecosystem Assessment strengthened the valuation of natural capital and ecosystem service provision. Ecosystem services and natural capital are also being integrated into UK national accounting through the Office for National Statistics, and UK Treasury value for money guidance for public spending now includes natural capital.

However, despite widespread commitment to embrace natural capital and ecosystems concepts, their use in a marine context is lagging behind terrestrial ecosystems. Notwithstanding a number of difficult practicalities, recent studies have explored ecosystem services as they relate to marine environments.

The initial exploration of these studies, in this review, suggests a wider interaction of the seafood industry on ecosystems services and the broader contribution to society beyond the delivery of food. The seafood industry draws mainly upon production and species habitat services provided by the marine ecosystem, and contributes to society by producing goods in terms of food production (provisioning services), tourism, cultural well-being and health benefits (cultural services). In addition, other relationships between industry and the wider social-ecological system exist, where other important contributions are evident.

This exploration also shows that there is a paucity of evidence in marine, particularly seafood, related contexts. This is despite a growing body of research focussed on social-ecological systems, and a growing number of initiatives advancing these approaches.

A number of steps are recommended. The wider role played by industry, in the ecosystem and wider society, highlights the need to broaden the debate on the purpose and scope of seafood stakeholder actions and ambitions. Industry planning should consider key supply chains in their wider social-ecological contexts (both domestic and international supply). Policymakers should recognise industry reliance on, and contribution to, marine ecosystem services and public goods. Scientific efforts should reconsider the types of knowledge required, the means by which this knowledge is acquired, and the criteria used to ensure the quality of this knowledge.

Finally, efforts should be made to address the lack of evidence. Effort ought to be directed towards systematically producing case reviews for key seafood species, and their social-ecological contexts, in the developing portfolio of UK seafood supply.



1

Introduction and requirement

This review is an initial exploration of how the UK seafood industry draws on and contributes to ecosystem services and the good/benefits that arise from that interaction. It sets out the broad range of relevant withdrawals, contributions, synergies and trade-offs associated with seafood production and the ecosystem.

The review supports both industry operators and government policymakers in understanding key ecosystem interactions relating to seafood production and consumption. The review is to help ensure the industry is better positioned in discussion forums focussed on ecosystem services and better able to communicate priorities with policymakers. In turn the review can help support government policymakers, as an initial introduction to ecosystem services as they relate to the seafood industry.

Changes in the industry landscape can present longer-term, strategic challenges for the industry (as captured in the *Seafish industry change landscape 2017/18*). Reflecting on these developments in 2017, strategic priorities included an immediate need to respond to changes in political conditions and UK Government policy.

These changes include UK Government:

- intention to improve the sustainable management of the marine environment and natural capital to ensure healthy, clean and productive seas, as highlighted in recent publications such as the Fisheries Bill and Environment plan¹;
- redesign of public funding programmes to support the seafood industry; specifically funding provided by European Maritime and Fisheries Fund (EMFF);
- using an ecosystem perspective, or 'lens', in devising policy and designing programmes.

Furthermore, the seafood industry is less well positioned to respond to these changes. The seafood industry faces a shortcoming relative to other sectors (e.g. terrestrial sectors, other marine sectors) that - arguably - have a more mature understanding of their respective ecosystem interactions, and greater consideration of these interactions in policy (e.g. farming).

To support industry response, and address this shortcoming in the seafood context, a better grasp is required of the key relationships between natural capital, ecosystems services and the role of the seafood industry in generating goods/benefits. This review begins to set that out in the context of seafood.

The intention is to support dialogue across the UK amongst policymakers, and between policymakers and the seafood industry. More specifically, this work could support industry providing a view to UK Government on the need and design of future funding regimes, giving a UK not just devolved view.

2

UK seafood industry

This section provides a representation of the seafood industry landscape and the major regional supplies of relevance to the UK. This representation frames the investigation, discussion and agreement on ecosystem services relating to the UK seafood industry.

The UK seafood industry, being reliant on wild capture and aquaculture produced raw material, is diverse, complex and dynamic. The seafood industry is considered here to operate as many subsystems (regional, sectoral), of varying degrees of interdependence, nested within one overarching global system.

In the global context, from a UK perspective, there are at least two major seafood systems that, although overlapping, have distinct characteristics:

- A domestic system – defined as a system reliant on domestically sourced fish and shellfish (material caught from stocks in North Atlantic/ UK waters and landed in the UK, as well as material farmed in the UK). Within the ‘domestic system’, the key UK actors are: producers (farmers/vessels), agents and merchants in the UK handling fish and shellfish landed/farmed in the UK; UK processors of seafood; and the downstream supply chain in the UK of all of the former including food service companies, retailers and exporters.
- An international system – defined as a system reliant on internationally sourced fish and shellfish (material caught from stocks in the North Atlantic and elsewhere landed outside the UK, or material farmed outside the UK).

Within the ‘international system’, the key UK actors are: agents and merchants in the UK importing fish and shellfish that is caught, landed or farmed and possibly processed outside of the UK; UK processors of imported seafood; and the downstream supply chain in the UK of all of the former including food service companies, retailers and re-exporters.

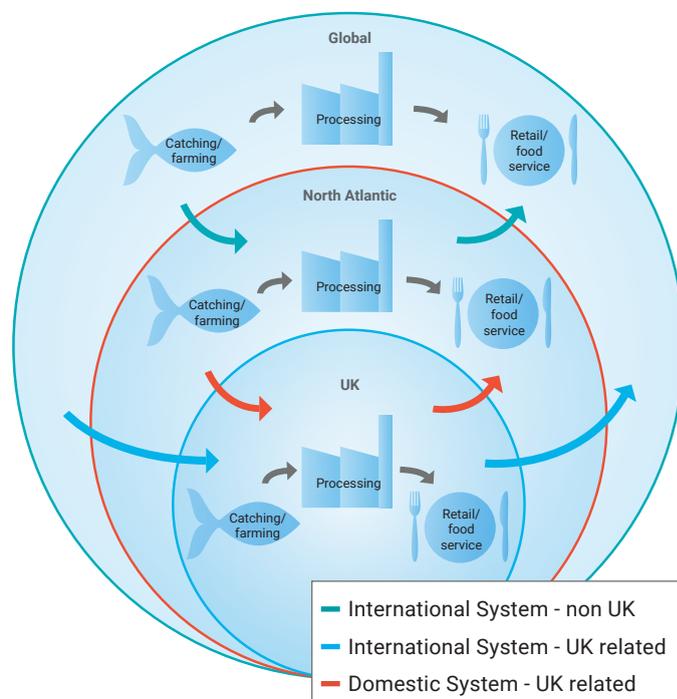


Figure 2.1 Components of the UK international and domestic systems and how they are interrelated

It is notable that from a UK perspective, imported seafood is largely for UK consumption, whilst seafood originating in the UK is generally exported for overseas consumption. The UK consumer maintains a robust preference for salmonids (farmed salmon), whitefish (cod, haddock and Alaska pollock), pelagics (tunas) and shellfish (cold-water prawn and farmed warm-water prawn). Meanwhile, UK landings volumes are dominated by mackerel and herring (pelagics), Nephrops (shellfish) and cod and haddock (whitefish).

The portfolio of supply to UK industry operators is diverse in species and source region. Table 2.1 shows perspectives on future production levels to 2030 within this portfolio provided by UK industry stakeholders in 2018²⁶.

Seafood system	Main species group	Species	Future production
Domestic sources	Whitefish	Cod	Light Green
		Haddock	Grey
		Saithe	Light Green
		Whiting	Light Green
		Flatfish	Light Green
	Pelagic	Mackerel	Light Green
		Herring	Light Green
	Shellfish	Nephrops	Grey
		Scallops	Grey
		Mussels	Dark Green
		Brown crab	Grey
	Salmonids	Atlantic salmon	Light Green
International sources	Whitefish	Cod, haddock (Norway)	Grey
		Cod, haddock (Iceland)	Light Green
		Cod (Canada)	Green
		Alaska pollock (USA)	Grey
		Tilapia	Green
		Pangasius	Light Green
	Pelagic	Tuna	Orange
	Shellfish	Warm-water prawn	Green
		Cold-water prawn	Red
	Salmonids	Atlantic salmon (Norway)	Light Green
		Salmon (N. America)	Grey
Atlantic salmon (Chile)		Light Green	

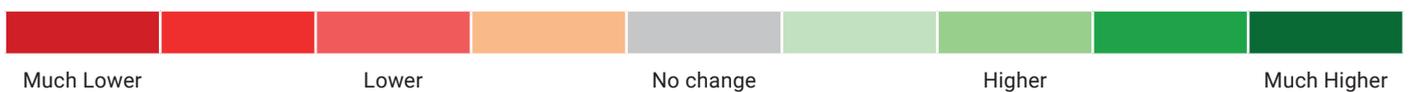


Table 2.1 Anticipated seafood supply availability to UK industry 2030 – industry perspective 2018

3

Ecosystems and services

This section introduces a number of ecosystem related concepts that have emerged over a number of decades.

This includes conceptual developments and initiatives to guide management action, including the UN sponsored Millennium Ecosystem Assessment.

3.1 Key concepts

For generations a combination of population growth, economic growth and a desire to raise living standards has increased pressure on global resources, seriously degrading the natural world and its ability to support human life^{2,3}. For several decades there has been a growing view that our world, and our place in it, is essentially interconnected and operating as a complex adaptive system.

For over 20 years there has been a mainstreaming of ideas and system-based concepts related to this general idea, specifically:

- Ecological systems (or 'ecosystems'), refer to *'the complex of living organisms, their physical environment, and all their interrelationships in a particular unit of space'*⁴. Such systems are considered to be nested, such that a specific ecosystem (e.g. a river estuary) sits within a broader regional ecosystem (a coastal basin) that, in turn, exists within a global ecosystem (the biosphere).
- Society and social change have long been thought of as involving social systems, with recent concepts referring to nested systems of individuals, groups, communities and populations⁵ with individual agents interrelating and interacting with social structures such that social life has both ordered and dynamic features⁶.
- When considering *'humans in nature'*, ecosystems and social systems are intrinsically linked and considered as an integrated concept: social-ecological systems⁷.

- The concept of 'ecosystem services' concerns the link between ecological systems and society; that is, the ecosystem and the services provided can be viewed as the life-support system that enables humans to thrive. See Figure 3.1. Ecosystem services can refer to the benefits that humans extract from ecosystems, and also the services that support or underpin the benefits that are extracted.⁸

The degradation of ecosystems and the natural world resulting from human pressure has become a major concern. Of particular note is human overexploitation of natural resources (natural capital), a view of resources disconnected from the wider ecosystem, and weak management of natural resource use.

There are several factors facilitating ecosystem degradation¹⁰:

- The contributions to human well-being from ecosystems can be unclear.
- These contributions are not traded in the marketplace.
- There are difficulties signalling changes in the contributions made; whether the service is declining, or whether the natural capital behind the service is deteriorating.
- Moreover, given exponential growth pathways, degradation may occur sooner than we think and be difficult to reverse.

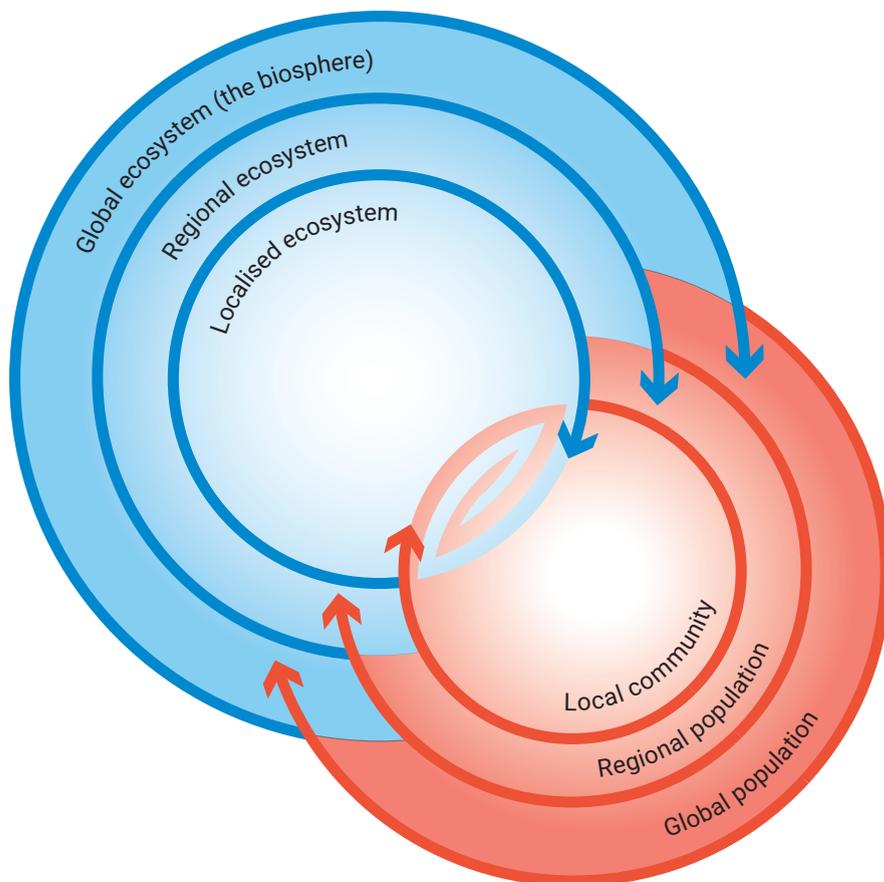


Figure 3.1 Ecological systems (ecosystems) interaction with societal systems at different levels (after Kay et al, 2000)⁹

3.2 Systems based approaches to management

In response to this degradation, systems based approaches to management (for example 'the ecosystem approach') have been developed. These provide alternative ways for society to maintain its relationship with the natural world. They involve a shift in orientation from an extractive perspective, where we see the natural world as serving our immediate human needs, to a perspective that maintains the ecosystem and its ecological integrity such that it safeguards long term human well-being. Such approaches mark a fundamental step-change: in a dynamic landscape, with high levels of uncertainty, this means navigating murky territory rather than moving steadily towards a clearly defined, and scientifically determined, destination.¹¹

At the turn of the century, the UN sponsored Millennium Ecosystem Assessment¹², played an important role in this agenda. The initiative assessed the capacity of the global ecosystem to deliver services, raising awareness of ecosystem degradation and of the role played by human action.

The assessment helped:

- Strengthen and promote the natural world as a capital asset (natural capital).
- Describe and evaluate the full range of services derived from this asset (categorising and classifying ecosystem services).
- Identify steps to reduce the degradation of ecosystem services, such as:
 - Effective policies where natural costs have been taken into account into decision-making. This includes rewarding of stakeholders for practices that protect ecosystem services.
 - The importance of natural assets being recognised more centrally in government (in departments of finance, agriculture and industry, not just being the preserve of environmental departments).
 - Local community action informed by their involvement in decision-making over use of natural resources.

More than 10 years on, a range of initiatives have advanced this agenda (see next section), although much remains to be done to achieve these aspirations. For example, bringing natural capital and ecosystems services into diverse decisions remains elusive; the exception, not the rule³.

4

Ecosystem thinking in practice

This section provides some examples of actions taken to mainstream ecosystem thinking. This includes initiatives in the UK and challenges faced by initiatives in the marine context.

4.1 Mainstreaming natural capital and ecosystem services

Numerous efforts have tried to advance the recommendations of the Millennium Ecosystem Assessment³. These include:

- Greatly increased scientific research on ecosystem services. The scientific community has developed new knowledge of ecosystem services, metrics, data and tools to help explore trade-offs and consequences in decision-making.
- Efforts in policymaking, particularly in national accounting, planning and incentives. More specifically:
 - Broadening national accounting to reflect not only economic indices but also natural capital and value of ecosystem services. For example, the World Bank Wealth Accounting and Valuation of Ecosystem Services initiative, United Nations Statistics Division experimental ecosystem accounts, and Chinese plans for tracking natural capital and ecosystem services alongside GDP.
 - Incorporating the ecosystem approach in planning. A number of initiatives are underway in South Africa, Belize, Portugal, Sweden and USA.
 - Introducing payments for ecosystem services. These have been advanced in China, Cost Rica, and Latin America.
 - The introduction, in the EU, of the Marine Strategy Framework Directive (MSFD). The MSFD establishes a framework within which member states take all the necessary measures to achieve or maintain Good Environmental Status (GES) in the marine environment by the year 2020.

4.2 Ecosystem initiatives in the UK

In the UK, a number of actions have helped advance the ecosystem agenda^{13,14}. These relate to strengthening the valuation of natural capital and ecosystem service provision:

- A national scale assessment of status and trends of ecosystems, services, and impacts across the through the UK National Ecosystem Assessment 2011. This was *'the first analysis of the UK's natural environment in terms of the benefits it provides to society and continuing economic prosperity'*¹⁵.
- Several natural capital initiatives including the Natural Capital Committee (established in 2012, running until 2020, to provide Government with independent advice on protecting and improving natural capital in England) and the Scottish Forum on Natural Capital (an initiative seeking to protect and rebuild Scotland's natural capital).
- Integration of natural capital into mainstream UK national accounting through an Office for National Statistics/Defra initiative. The aim is to develop natural capital accounts for the UK and incorporate natural capital into UK environmental accounts by 2020.
- Updated value for money guidance for public spending which explicitly incorporates natural capital. The latest guidance being provided in the UK Treasury Green Book 2018 (building on precursors, Green Book 2003 and Green Book 1984).
- Incorporation of natural capital and ecosystem services into policy frameworks, such as Defra's 25 year plan for the environment¹. These concepts are perhaps most evident in the terrestrial sector, and agricultural policy in particular. See, for example, the recent future of farming consultation¹⁶ that emphasises the incorporation of natural capital principles into farming practice and 'public money for public goods' into incentives

4.3 Ecosystem services in a marine/ seafood context

Despite widespread commitment to embrace natural capital and ecosystems concepts, their use in a marine context is lagging behind terrestrial ecosystems¹⁷. This is partly due to the complexity of marine processes that can cut across geographical boundaries, and the mobility of particular marine resources. It is also a result of the difficult practicalities involved in studying and assessing these resources, including; lack of data, methodological challenges and short marine planning timeframes¹³. Much of this requires the scientific community to also broaden their perspective in terms of how scientific enquiry is conducted, with greater emphasis on 'learning by doing' and engaged scholarship^{9,20} – a fundamental challenge¹.

Notwithstanding these difficult practicalities, a number of recent studies have explored ecosystem services as they relate to marine environments^{18,19} using the framework provided by the UK National Ecosystem Assessment (which included a marine component). These studies adopt a matrix approach to demonstrate ecosystem services provision by species, firstly in relation to habitats and species within UK marine protected areas, and secondly in relation to UK seabird species. Such a matrix approach could be useful to explore the provision of ecosystems services relating to UK seafood (domestic and international sourced seafood). Taking this approach would enhance understanding of ecosystem services relating to seafood but also support overlay and comparison with other marine interests (viz. MPAs and seabirds)

Figure 4.1 puts the UK seafood industry in the broader context of marine ecosystems and the goods/benefits provided to society. In addition to showing the main dimensions of these systems, it also shows the role of the seafood industry in drawing on specific services and delivering particular benefits (in italics). Following Turner et al (2015)²⁰:

- **Ecosystem services** include intermediate services, whose ecological processes and functions support all life, and, by definition all other services and final services: the outcomes from ecosystems that directly lead to good(s) that are valued by people²¹.
- **Goods/benefits** provided to society cover all use and non-use, material and non-material outputs from ecosystems that have value for people²².

Within Figure 4.1, a number of specific items are detailed under the main dimensions of ecosystem services and goods/benefits. This provides an overview of the range of factors operating within the social-industrial-ecological complex. Further information on these items, as defined by Turner et al (2015), is available in Appendix 2.

For the purposes of this review, and to simplify matters, we refer only to ecosystem services (conflating intermediate and final services) and goods/benefits arising from these.

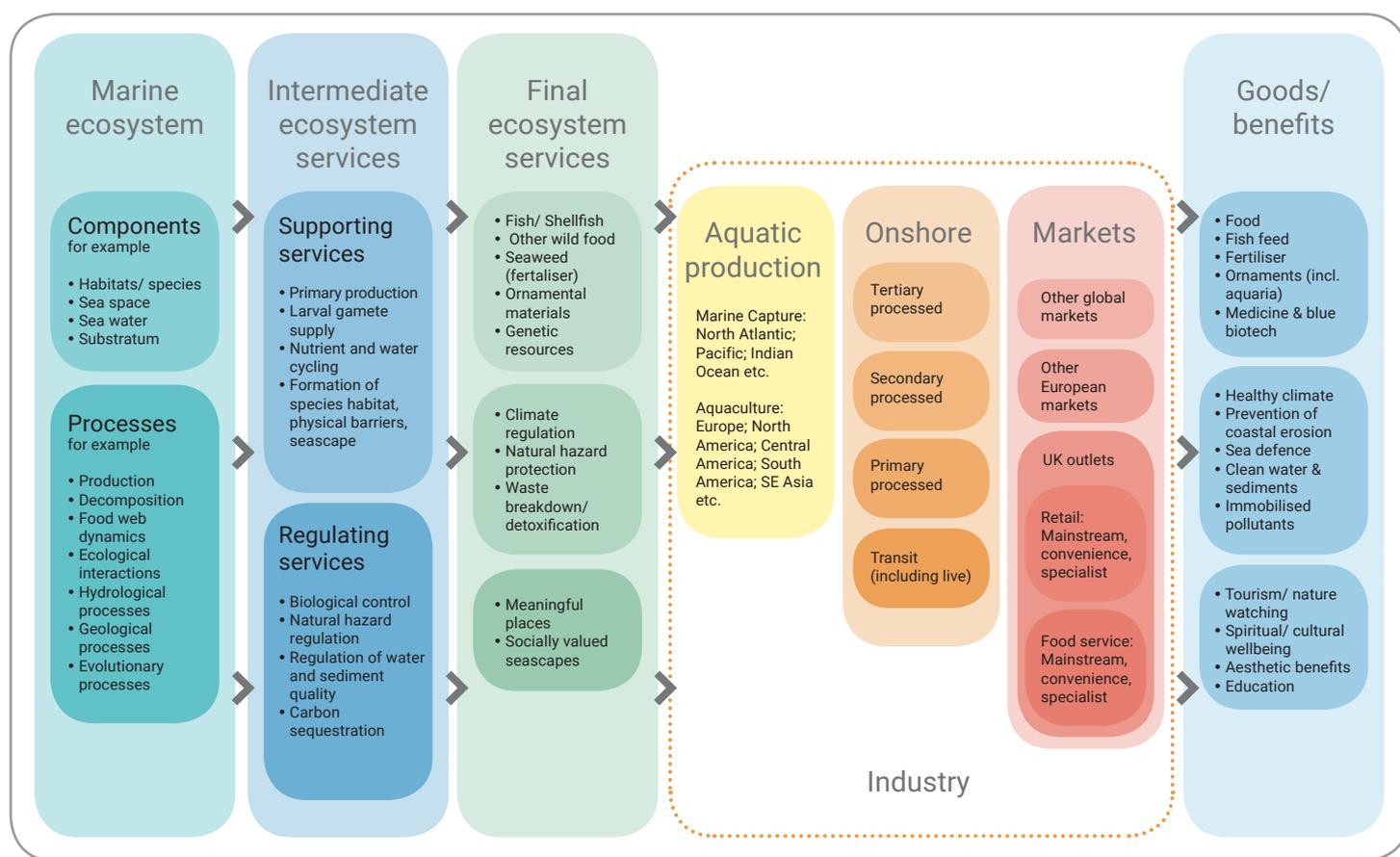


Figure 4.1 The UK seafood industry in the broader context of marine ecological systems (ecosystems), and the associated services and benefits provided to society.

1 The challenge concerns more fundamental epistemological, rather than methodological, questions such as; what counts as knowledge (different types of knowledge) for the purpose at hand, particularly given the stakeholders involved in the system? An interesting example of how this challenge might be encountered is the Defra national shark, skate and ray conservation plan aimed at the maintenance of viable and sustainable fisheries and biodiversity under the MSFD. The collaborative research projects carried out by Cefas under this programme are a partnership between the government, fishers and scientists aimed at supporting these goals. <http://randd.defra.gov.uk/Default.aspx?Module=More&Location=None&ProjectID=19725>.

5

The most relevant items to seafood, and their (modified) definitions, are:

- **Production:** *the synthesis of organic matter by coastal & marine biota from atmospheric or aqueous carbon dioxide e.g. quantity and/or quality of production from a given area of saltmarsh or volume of seawater.*
- **Formation of species-habitat:** *the contribution of coastal & marine biota to habitat formed by one species but providing suitable niches for other species e.g. change in the formation of mussel beds, kelp forests, cold-water coral reefs.*
- **Waste breakdown and detoxification:** *the presence of coastal & marine biota which have the potential to remove contaminants and organic inputs e.g. the presence of reedbeds, mussels beds, etc.*
- **Food provision (wild, farmed):** *the extraction of coastal & marine biota for human consumption e.g. fish landed for human consumption.*
- **Tourism and nature watching:** *benefits from recreation, leisure driven by coastal seascapes and their associated coastal & marine biota e.g. benefits from watching seabirds, marine mammals.*
- **Spiritual and cultural wellbeing:** *the ability to enjoy preferred lifestyle, culture, heritage, folklore, religion, creative inspiration, and spirituality; sense of place (use-driven) based on ecosystem aspects e.g. the importance of coastal & marine environments in cultural traditions or folklore.*
- **Health benefits:** *the human physical and psychological health benefits associated with the direct and indirect use of the coastal and marine environment e.g. increased psychological well-being from direct or indirect experience of the coastal & marine environment; increased physical well-being resulting from engagement with coastal & marine environment, such as exercise.*

Evidence of ecosystem interactions with seafood and associated goods/benefits

This section describes how ecosystem services interact with the seafood industry and the goods/benefits arising from that interaction. This is based on the findings of a short review exercise of seafood cases in both domestic and international contexts.

The available evidence is limited, so the information is *illustrative* rather than *comprehensive*. Note, the interactions shown in the following cases could apply to other similar species. As such, some cases are drawn from a wide range of sources, not just those within the UK seafood supply portfolio.

5.1 Overview

Notwithstanding the challenges of the marine context (see section 4.3), marine ecosystem related publications have grown exponentially since 2005. However, many have focussed on particular dimensions at the expense of others e.g. provisioning and regulating services rather than cultural services²³.

This short review considered seafood and ecosystem related publications in the academic literature since 2014 to provide some initial evidence of ecosystem interactions with the seafood industry. The review covered 16 academic papers and generated over 20 seafood related cases. Table 5.1 provides a summary of ecosystem services, and the associated goods/benefits, related to a number of seafood cases as identified by these published studies. The table also identifies the broad nature of the interactions; as withdrawals, contributions, or trade-offs.

Across domestic and international aspects, the seafood industry consistently draws upon marine ecosystems services to produce goods and benefits for society. In line with previous studies, table 5.1 shows the range of services and goods/benefits associated with whitefish, pelagic, shellfish species groups. Specifically, and somewhat unsurprisingly, the seafood industry:

- Draws mainly upon *production* and *species habitat* services provided by the marine ecosystem.
 - *Production* is often regarded negatively as a withdrawal, reflecting concerns about unsustainable fishing depleting the natural resource and undermining production.
 - *Species habitat* is rather more mixed where industry not only draws on services but also contributes to service provision specifically in aquaculture and particularly in shellfish aquaculture.

- Contributes to societal goods in terms of *food provision* (provisioning services), *tourism*, *cultural well-being* and *health benefits* (cultural services).
 - *Food provision* is regarded as a beneficial good generated for society as a result of industrial activity. In a few instances, food provision is considered negatively in those cases where production is declining (stocks are depleted).
 - *Tourism* is regarded generally as a beneficial good, except in certain circumstances where there are trade-offs e.g. where industrial activity creates a physical barrier or otherwise undermines tourism activity.
 - *Cultural wellbeing* is similarly considered beneficial, reflecting the fundamental part this plays in fishing communities. This includes heritage, sense of place and identity - in some instances sacred and/or religious.
 - *Health benefits* in terms of the nutritional value of the food.

However, other relationships between industry and the wider system should not be overlooked. Although limited, the evidence indicates industry activity – particularly in shellfish - makes additional contributions within the following;

- ecosystem services such as; *nutrient and water cycling*, *the regulation of water*, *sediment quality*, and *carbon sequestration*.
- societal goods in terms of regulating benefits such as *coastal erosion*, *clean water* and *sediments*, as well as cultural benefits such as *aesthetic benefits* and *education/research*.

Table 5.1 Ecosystem services and the seafood industry: contributions and withdrawals
 (● = contributions, ● = withdrawals)

Seafood system	Main species group	Species	Services								Good/benefits																			
			Supporting services				Regulating services				from Provisioning services					from Regulating services					from Cultural services									
			Production	Larval and gamete supply	Nutrient cycling	Water cycling	Formation of species habitat	Formation of physical barriers	Formation of seascape	Biological control	Natural hazard regulation	Regulation of water and sediment quality	Carbon sequestration	Food provision (wild, farmed)	Food provision (wild, farmed, bait)	Fertiliser and biofuels	Ornaments (including aquaria)	Medicines and blue biotechnology	Healthy climate	Prevention of coastal erosion	Sea defence	Clean water & sediments	Immobilisation of pollutants	Tourism and nature watching	Spiritual and cultural wellbeing	Aesthetic benefits	Education, research	Health benefits		
Domestic	Seafood	General	●	●			●						●	●	●					●									●	
		General	●	●			●							●	●	●					●								●	
		General	●	●			●							●	●	●					●								●	
	Pelagic	Blue whiting, herring, others	●	●											●	●														
		Oysters			●										●	●					●									
		Mussels													●	●					●									
		General													●	●					●									
		General													●	●					●									
		General													●	●					●									
		General													●	●					●									
International	Whitefish	Hake	●											●	●															
		Sea bass													●	●					●									
		Tuna	●												●	●														
	Pelagic	Tuna	●												●	●														
		Tuna	●												●	●														
		Tuna													●	●														
		Sardine, horse mackerel, anchovy, sea bream	●												●	●														
	Shellfish	Shrimp	●												●	●														
		Shrimp	●												●	●														
		Krill													●	●														
		Pacific oysters													●	●														
		Clams, cockles	●												●	●														
		Octopus	●												●	●														

5.2 Domestic seafood

The evidence concerning the UK domestic seafood industry and ecosystem services is limited. The evidence available in this review concerns a small number of cases focussing on:

- Seafood generally (in the context of Scotland, and the North Sea).
 - Seafood draws on *production* in the marine environment, and if left unchecked (by, for example, failing to protect important grounds, closing fisheries by season, or area, control of fish catches and fishing effort and other management measures etc) unsustainable fishing intensity can deplete fish populations. Well managed fisheries can help support *production* (maintaining fish and shellfish spawning and nursery grounds) through healthy *functioning seabed habitats*, recognising that unsustainable fishing practices that damage the habitat, and result in unwanted by-catch, can undermine ecosystem services.
 - Fisheries and aquaculture, being centrally concerned with *food provision* and incomes to fishing communities, represent important sectors to local economies. However, this can be undermined if industry is regulated inappropriately and this leads to a decline in seafood related employment and outward migration from local areas. Fisheries are often central to *cultural well-being* contributing to the social fabric and cultural identity of local communities with fishing passed down from generation to generation in fishing families.
 - Seafood has extensive *health benefits*, having significantly higher quantities of valuable protein, vitamins and essential fatty acids, when compared to other food types.
- Pelagic fish (capture of blue whiting, herring, mackerel, other species in ICES areas).
 - *Production* and hence *food provisioning* capacity of fish stocks is influenced by responsible fisheries management but also to a large extent by large natural variability in recruitment of young fish and by short and long term trends in environmental factors. Some analyses suggests a decrease over time in the productivity and hence *food provisioning* capacity of Northeast Atlantic stocks, as assessed by ICES 1999-2012, in spite of generally improving management. Although a short time series, other evidence also shows variations in stocks being related to environmental changes. As *food-provisioning* capacity in this context is driven to a very large extent by only a few large pelagic stocks, there is concern that variation in the natural processes in the ecosystem could jeopardise this provisioning.
- Shellfish (farmed oysters in the UK and mussels in the SW of England).
 - Oyster reefs help support ecosystem services provision, for example creating important *habitat* for a range of species, and, as bio-filters, improving *water quality* and *nutrient cycling*.
 - Both mussels and oysters make an important contribution to *food production*, and to local economies. Both mussel and oyster reefs can deliver coastal protection by stabilising shorelines and *preventing coastal erosion*. Over and above this, mussels and oysters make an important contribution to *tourism* and *cultural well-being*. This is demonstrated in festivals celebrating oyster harvest and consumption, such as the 'Whitstable Oyster Festival' and the 'Falmouth Oyster Festival'. Likewise mussel cultivation, alongside local fisheries, contributes to the social fabric and cultural identity of the villages, ports and harbours around the coast of SW England. These contributions - alongside products with local provenance - give local areas their distinct identities and provide meaningful experiences for tourists seeking a 'sense of place'.

5.3 International seafood

The evidence concerning seafood and ecosystem services in an international context is similarly limited. The evidence includes a small number of cases focussing on:

- Seafood in a general sense (globally and in specific contexts such as Chile and Australia).
 - Ecosystems services make important contributions to global food provisioning through local production. Seafood from marine social-ecological systems is a prominent example of this as '*seafood contributes significantly to the global food supply, constituting almost 20% of the average per capita intake of animal protein for more than 3.1 billion people, and representing one of the most-traded segments of the world food sector*'²⁴.
 - *Food provision* can be increased in the near term, for example by harvesting more fish, but the trade-off is the potential running down of natural capital and *production* (depleting stocks) if inappropriately managed.
 - In some instances there are synergies between different goods/benefits, for example where *food provisioning* (fishing, aquaculture etc) is closely linked with *cultural well-being* (heritage, identity and social relations), or where wider provisioning services (fishing, aquaculture, energy production etc) provide the industrial infrastructure and technology that supports access to other types of goods/benefits. In other instances there are trade-offs between provisioning and cultural goods/benefits, for example where there is competition between industrial and marine recreational use and where industry is perceived to degrade seascapes.
- In the context of an ecosystem with declining health, the Great Barrier Reef, the trade-off can lead to marine policy shifts underpinning provisioning goods/benefits (for example *fishing and food provision*) in favour of activities supporting regulating and cultural goods/benefits (for example *tourism*).
- Whitefish (hake capture in Namibia, and farmed sea bass in Spain).
 - *Production* in the Cape hake and deep water hake fisheries is central for Namibia in terms of *food provision* elsewhere i.e. as a high value product for export to satisfy high global demand. Although the fisheries are considered to be well managed, a decline in hake stocks in Namibia, suggests evidence of a trade-off between local production and *food provision* in other parts of the world.
 - *Production* of seabass, farmed in reconstructed wetlands combining extensive and semi extensive culture systems, contributes to *food provision* and support for the local economy through cultural goods/benefits (*tourism* and *education/scientific research*). Production contributes to the *formation of species habitats* complementing natural wetlands to sustain a diverse water bird community, improves *water quality* through nutrient absorption, and acts as a net *carbon sink*.

- Pelagic fish (tuna capture in Western and Central Pacific and small pelagic capture in Portugal).
 - *Production* in tuna fisheries in Western and Central Pacific is central to small island developing states as a *food provision* good with *nutritional* benefit for markets elsewhere (60% of the world's tuna). Tuna is a high value export meeting substantial global demand, an important source of local revenue (including government income) and employment, whilst fishing practices are associated with symbolic and spiritual values.
 - However, *food provisioning* of tuna faces a trade-off with *production* as increasing vessel numbers and new technology pressurise offshore resources. Much work is underway to sustain ecosystem services by ensuring responsible practices in some fisheries (e.g. some fisheries are considered to be sustainably managed such as the PNA skipjack fishery and the MSC certified free-school skipjack fishery) however services are still being undermined by unsustainable practices in other fisheries.
 - Fishers of the Northern Portuguese small pelagic seine fishery (including sardine and anchovy) contribute to *seafood provisioning* (generating income and employment). These activities also contribute fundamentally to local communities in terms of cultural goods, including; *tourism* (heritage and identity, as well as a sense of place) and *spiritual well-being* (fishers associations have their own symbolic and religious devotions), and *health benefits* (nutrition). Provisioning does involve trade-offs with cultural goods/benefits, however, as capital assets (tractors, fishing gear, and vessels) engaged in *food provisioning* undermine *tourism* (degrading the quality of beaches and seascapes valued by recreational users).
- Shellfish (capture and farmed shrimp in Mozambique and Spain, farmed oysters in Canada, clams, cockles, and octopus capture in Portugal, and krill capture in the Southern ocean).
 - *Production* of farmed shrimp in Spanish wetlands contributes to *food provision, tourism* and *education/scientific research*, whilst also contributing to *species habitats* to sustain a diverse water bird community, *water quality*, and acting as a net *carbon sink*.
 - The Mozambique shrimp fisheries are important sources of *primary production* and *food provisioning* of Indian white prawn and speckled shrimp for consumption by coastal communities and for export. However, the *formation of species habitat* can be undermined by unsustainable fishing practices (examples include fishing close to shore where there are potential impacts on estuarine mangrove nursery areas, and use of illegal small mesh nets).
 - The Northern Portuguese octopus pot fishery contributes to *seafood provisioning* (generating income and employment) and cultural goods/benefits including; *tourism, spiritual well-being* (through heritage and identity, a sense of place) and *health benefits* (nutrition). However there is a trade-off between *food provisioning* and *formation of species habitats* where plastic, rather than clay, pots are used in the octopus fishery. Lost plastic pots do not easily degrade, and this may negatively affect seabed conditions, and over the long term, undermine local habitats and species. There is also a trade-off with cultural goods/benefits, specifically *tourism* and recreation on the coast where diving and snorkelling compete in the same space as fishing vessels, nets, and pots, etc. engaged in *food provisioning*.
 - Finally, ecosystem services in the Southern ocean associated with krill *production* include *health benefits*, specifically krill oil for the growing high-end market in health supplements.

6

Conclusions and next steps

6.1 Conclusions of the initial review

There is a growing body of research focussed on social-ecological systems, and a growing number of initiatives advancing these approaches. However, there is a paucity of evidence in marine, particularly seafood, related contexts.

Initial exploration suggests a wider interaction of the seafood industry on ecosystems services and the broader contribution to society beyond the delivery of food. On the basis of this short review:

- The seafood industry draws mainly upon *production* and *species habitat* services provided by the marine ecosystem, and contributes to society by producing goods in terms of *food production* (provisioning services), *tourism*, *cultural well-being* and *health benefits* (cultural services).
- Other relationships between industry and the wider social-ecological system exist, where other important contributions are evident, and these should not be overlooked.

When considered from this system perspective, the wider role played by the seafood industry is understated, whilst the scope of ambition in industry plans, academic priorities and government policy is overly narrow. That is, the seafood industry is drawing upon and/or sustaining a range of ecological services (not just the food resource) and delivering a broader set of benefits to society (beyond seafood products). This is particularly important in international supply chains, where the ecological services in the jurisdiction of one social community are being drawn upon for the benefit of another community in a separate jurisdiction (often on the other side of the world)²⁵.

6.2 Next steps

The wider role played by industry suggests the need to broaden the debate on the purpose and scope of stakeholder actions and ambitions.

Specifically this would help reframe:

- Industry planning to consider key supply chains in their wider social-ecological contexts (both domestic and international). This would help capture the wider ecosystem services and good/benefits associated with the supply and consumption of specific species.
- Policy to recognise industry reliance on, and contribution to, marine ecosystem services and public goods. This could reframe policy and performance from fisheries management through to trade, as well as government funding and value for money (public funds for public goods).
- Scientific efforts to reconsider the types of knowledge required (e.g. moving beyond explicit knowledge to include tacit knowledge), the means by which this knowledge is acquired (e.g. data collection in real time by *industry operators*), and the criteria used to ensure the quality of this knowledge (e.g. moving beyond *academic* peer review towards broader stakeholder review).

Efforts to address the lack of evidence, ought to be directed towards systematically producing case reviews for key seafood species, and their social-ecological contexts, in the developing portfolio of UK seafood supply²⁶:

- In the near term the lack of evidence could be addressed by canvassing expert opinion from amongst seafood stakeholders.
- Longer term, research efforts should focus on frameworks that track ecosystem withdrawals, contributions, synergies and trade-offs whilst simultaneously capturing near term changes in the dynamic landscape.

Appendices and References

Appendix 1 - Case references

Seafood system	Main species group	Species	Reference
Domestic sources	Whitefish	General	Hattam et al (2015) ²⁷
		General	Cavanagh et al (2016a) ¹⁷
		General	Brooker et al (2018) ²⁸
	Pelagic	Blue whiting, herring, mackerel, others	Piet et al (2017) ^{29/30/31}
	Shellfish	Oysters	Lemasson (2017) ³²
		Mussels	Willis et al (2018) ³³
International sources	Seafood	General	Carcamo et al (2014) ³⁴
		General	Andersson et al (2014) ³⁵
		General	Ban et al (2015) ³⁶
		General	Guerry et al (2015) ³
		General	Rodrigues et al (2017) ²³
	Whitefish	Hake	Bladon et al (2014a) ³⁷
		Sea bass	Walton et al (2015a) ³⁸
	Pelagic	Tuna	Bladon et al (2014c) ³⁷
		Tuna	Cavanagh et al (2016b) ¹⁷
		Tuna	Drakou et al (2018) ²⁴
		Sardine, horse mackerel, anchovy, sea bream	Outerio et al (2017c) ³⁹
	Shellfish	Shrimp	Bladon et al (2014b) ³⁷
		Shrimp	Walton et al (2015b) ³⁸
		Krill	Cavanagh et al (2016c) ¹⁷
		Pacific Oysters	Guerry et al (2012) ²
		Clams, cockles	Outerio et al (2017a) ³⁹
		Octopus	Outerio et al (2017b) ³⁹

Appendix 2 - Definitions

Table A2.1 Definitions of intermediate and final ecosystem services and associated goods and benefits (Turner et al, 2015)		
Intermediate services – those services whose ecological processes and functions support all life, and, by definition all other services (UKNEA 2011). They may include non-fundamental ecosystem processes and functions.		
Service	Definition	Example
Primary production	The synthesis of organic matter by coastal & marine biota from atmospheric or aqueous carbon dioxide	Quantity and/or quality of primary production from a given area of saltmarsh or volume of seawater
Larval and gamete supply	The production and supply of larvae and gametes from coastal & marine biota	Quantity and/or quality of larvae or gametes supplied to a given coastal or marine location
Nutrient cycling	The influence of coastal & marine biota on the movement or exchange of organic and inorganic matter	Change in the concentration of nitrates/ phosphates in coastal or marine waters/ sediments
Water cycling	The influence of coastal & marine biota on the movement or exchange of water between the coastal & marine environment and adjacent environments (including the atmosphere)	Change in the amount of water retained within a coastal saltmarsh or reedbed
Formation of species- habitat	The contribution of coastal & marine biota to habitat formed by one species but providing suitable niches for other species	Change in the formation of mussel beds, kelp forests, cold-water coral reefs
Formation of physical barriers	The contribution of coastal & marine biota to the formation of physical barriers	Changes in reef extent by reef- forming organisms (e.g. Sabellaria spp.), impacting on the local hydrographic regime
Formation of seascape	The contribution of coastal & marine biota to supporting the formation of different coastal and marine views ('seascapes')	Changes in area per type of seascape e.g. algae-covered rocky shore, kelp forest
Biological control	The contribution of coastal & marine biota to the maintenance of population dynamics, resilience through food web dynamics, disease and pest control	Oystercatchers controlling intertidal cockle population numbers; cleaner fish (e.g. ballan wrasse) removing sea lice from salmon
Natural hazard regulation	The area of suitable coastal & marine habitat which is available to absorb energy	Width or area of saltmarsh/mudflat/reedbed/ sea grass
Waste breakdown and detoxification	The presence of coastal & marine biota which have the potential to remove anthropogenic contaminants and organic inputs	The presence of reedbeds, mussels beds, etc.
Carbon sequestration	The net capture of carbon dioxide by coastal & marine biota	Change in the net amount of carbon stored within an area of coastal saltmarsh within a certain period
Final services – the outcomes from ecosystems that directly lead to good(s) that are valued by people (UKNEA 2011)		
Service	Definition	Example
Coastal & marine biota	The flow of coastal & marine biota	Change in the quantity/quality of North Sea cod population, seaweed stock, genetic material, ornamental materials, etc. over time
Climate regulation	The contribution of coastal & marine biota to the maintenance of a favourable climate through the regulation of greenhouse gases	Healthy climate
Natural hazard protection	The contribution of coastal & marine biota to the dampening of the intensity of environmental disturbances such as storms, flooding and erosion	The reduction in the intensity of environmental disturbances resulting directly from coastal & marine ecosystem structures such as saltmarsh and sea grass beds
Clean water and sediments	The contribution of coastal & marine biota to the provision of clean water and sediments	Quantity of waste (tonnes) that is recycled or immobilised by coastal & marine biota over a period of time
Places and seascapes	The contribution of coastal & marine biota to places and seascapes	Number of coastal sites designated for internationally important seabird colonies

Appendix 2 - Definitions

Goods/benefits – all use and non-use, material and non-material outputs from ecosystems that have value for people (UKNEAFO 2014)		
Goods/benefits	Definition	Example
Food (wild, farmed)	Extraction of coastal & marine biota for human consumption	Tonnes of cod landed for human consumption
Fish feed (wild, farmed, bait)	Extraction of coastal & marine biota for non-human consumption	Tonnes of sandeel harvested to be processed into fishmeal; volume of mackerel caught for use as bait in crab/lobster pots
Fertiliser and biofuels	Fertiliser (biocides) or energy sourced from coastal & marine biota	Biomass of algae harvested to be processed into fertiliser
Ornaments and aquaria	Extraction of coastal & marine biota for decoration, fashion, handicraft, souvenirs etc. or for display in aquaria	Number of European lobster extracted for display in aquarium exhibits; amount of skins, shells, corals, plants, extracted from the coastal & marine environment for decoration, fashion etc.
Medicines and blue biotechnology	Extraction of coastal & marine biota in order to produce medicines, pharmaceuticals, animal and plant breeding and biotechnology	Marine-derived pharmaceuticals such as the use of sea lettuce (<i>Ulva lactuca</i>) in cosmetic and personal care items including make-up remover, shampoo and shaving lotion
Healthy climate	Improvements to human well-being as a result of a healthy climate	Bodily harm avoided as a result of natural carbon sequestration by coastal & marine biota
Prevention of coastal erosion	Reduction in hazards resulting from the natural prevention of coastal erosion by coastal & marine biota	Prevention of gradual damage to property and land by dunes
Sea defence	Reduction in flooding related hazards as a result of the natural protection provided by coastal & marine biota	Saltmarsh providing a natural form of sea defence in the coastal region
Waste burial/ removal/ neutralisation (*)	Contribution of coastal & marine biota to achieving pre-defined policy standard related to waste levels in water by natural waste burial, removal and neutralisation	Natural waste breakdown by coastal & marine biota such as reedbeds – in contexts in which pre-defined regulations/ standards apply
Tourism and nature watching	Benefits from recreation, leisure driven by coastal seascapes and their associated coastal & marine biota	Benefits associated with watching seabirds, marine mammals
Spiritual and cultural wellbeing	Ability to enjoy preferred lifestyle, culture, heritage, folklore, religion, creative inspiration, and spirituality; sense of place (use- driven) based on ecosystem aspects	The importance of coastal & marine environments in cultural traditions (e.g. traditional cobble fisheries on east coast) or folklore (e.g. sea shanties)
Aesthetic benefits	Enjoyment of the beauty of coastal & marine seascapes	Higher house prices in coastal locations
Education, research	Enjoyment of formal and informal education, research and science, knowledge systems, etc. in which coastal & marine biota play a role and are a source of information	Amount of funding secured for research on coastal & marine biota; number of scientific research papers published which focus on coastal & marine biota
Health benefits	Human physical and psychological health benefits associated with the direct and indirect use of the coastal and marine environment	Increased psychological well-being from direct or indirect experience of the coastal & marine environment; increased physical well-being resulting from engagement with coastal & marine environment, e.g. exercise.

References

- ¹ HM Government (2018) *A Green Future: Our 25 Year Plan to Improve the Environment*. Defra, London.
- ² Guerry, A.D., Ruckelshaus, M.H., Arkema, K.K., Bernhardt, J.R., Guannel, G., Kim, C-K., Marsik, M., Papenfus, M., Toft, J.E., Verutes, G., Wood, S.A., Beck, M., Chan, F., Chan, K.M.A., Gelfenbaum, G., Gold, B.D., Halpern, B.S., Labiosa, W.B., Lester, S.E., Levin, P.S., McField, M., Pinsky, M.L., Plummer, M., Polasky, S., Ruggiero, P., Sutherland, D.A., Tallis, H., Day, A., and Spencer, J. (2012) *Modeling benefits from nature: using ecosystem services to inform coastal and marine spatial planning*, *International Journal of Biodiversity Science, Ecosystem Services & Management*, 8:1-2, 107-121.
- ³ Guerry, A.D., Polasky, S., Lubchenco, J., Chaplin-Kramer, R., Daily, G.C., Griffin, R., Ruckelshaus, M., Bateman, I.J., Duraiappah, A., Elmquist, T., Feldman, M.W. Folke, C., Hoekstra, J., Kareiva, P.M., Keeler, B.L., Li, S., McKenzie, E., Ouyang, Z., Reyers, B., Ricketts, T.H., Rockström, J., Tallis, H., and Vira, B. (2015) *Natural capital informing decisions*. *Proceedings of the National Academy of Sciences* Jun 2015, 112 (24) 7348-7355.
- ⁴ Encyclopaedia Britannica (2018) *Ecosystem: Definition, Components, & Structure*. Britannica.com (<https://www.britannica.com/science/ecosystem>). Accessed November 2018.
- ⁵ Bronfenbrenner, U (1977) *Toward an Experimental Ecology of Human Development*. *American Psychologist* 32. pp513-531.
- ⁶ Giddens, A. (1984) *The Constitution of Society*. University of California Press.
- ⁷ Berkes, F., Colding, J. and Folke, C. Eds (2003) *Navigating social-ecological systems: building resilience for complexity and change*. Cambridge University Press. p3
- ⁸ Bommarco, R., Kleijn, D., and Potts, S. G. (2013) *Ecological intensification: harnessing ecosystem services for food security*. *Trends in Ecology & Evolution*, Volume 28, Issue 4, 230 - 238
- ⁹ Kay, J., and Rieger, H. (2000) *Uncertainty, complexity and ecological integrity: Insights from an Ecosystem Approach* in Crabbe, P., Holland, A., Ryszkowski, L., Westra, L. (eds) Implementing Ecological Integrity: Restoring Regional and Global Environmental and Human Health, Kluwer, NATO Science Series, Environmental Security pp. 121-156.
- ¹⁰ Daily, G.C., Alexander, S., Ehrlich, P.R., Goulder, L., Lubchenco, J., Matson, P.A., Mooney, H.A., Postel, S., Schneider, S.H., Tilman, D., and Woodwell, G.M. (1997) *Ecosystem Services: Benefits Supplied to Human Societies by Natural Ecosystems*. *Issues in Ecology [Issues Ecol.]*. Vol. 1, no. 2, pp. 1-18.
- ¹¹ Waltner-Toews, D., and Kay, J. (2005) *The evolution of an ecosystem approach: the diamond schematic and an adaptive methodology for ecosystem sustainability and health*. *Ecology and Society* 10(1): 38.
- ¹² Millennium Ecosystem Assessment (2005) *Living Beyond Our Means: Natural Assets & Human Well-Being*, Statement from the Board. MEA, March 2005.
- ¹³ Borger, T., Beaumont, N.J., Pendleton, L., Boyle, K.j., Cooper, P., Fletcher, S., Haab, t., Hanemann, M., Hooper, T.L., Hussain, S.S., Portela, R. Stithou, M., Stockill, J., Taylor, T., and Austen, M.C. (2013) *Incorporating Ecosystem Services in Marine Planning: The Role of Valuation* NI WP 13-08. Durham, NC: Duke University.
- ¹⁴ Faccioli, M. and Blackstock, K. L. (2017). *Review of UK Natural Capital Initiatives*. James Hutton Institute, 22 pages.
- ¹⁵ UK National Ecosystem Assessment (2011) The UK National Ecosystem Assessment Technical Report. UNEP-WCMC, Cambridge.
- ¹⁶ Defra (2018) *Consultation on "Health and Harmony: the future for food, farming and the environment in a Green Brexit"* (<https://www.gov.uk/government/consultations/the-future-for-food-farming-and-the-environment>).

- ¹⁷ Cavanagh, R.D., Broszeit, S., Pilling, G.M., Grant, S.M., Murphy, E.J., and Austen, MC. (2016) *Valuing biodiversity and ecosystem services: a useful way to manage and conserve marine resources?* Proc. R. Soc. B 283: 20161635.
- ¹⁸ Potts, T., Burdon, D., Jackson, E., Atkins, J., Saunders, J., Hastings, E., and Langmead, O. (2014). *Do marine protected areas deliver flows of ecosystem services to support human welfare?* Marine Policy, 44, 139-148.
- ¹⁹ Burdon, D., Potts, T., Barbone, C., and Mander, L. (2017) *The matrix revisited: A bird's-eye view of marine ecosystem service provision*, Marine Policy, Volume 77. Pages 78-89.
- ²⁰ Turner, R.K., Schaafsma, M., Mee, L., Elliott, M., Burdon, D., Atkins, J.P., and Jickells, T. (2015) *Chapter 2: Conceptual framework*. In Turner, R.K., and Schaafsma, M. (eds) (2015) Coastal zones ecosystem services: from science to values and decision-making. Studies in Ecological Economics. Volume 9.
- ²¹ UK National Ecosystem Assessment. (2011). *The UK national ecosystem assessment technical report*. Cambridge: UNEP-WCMC.
- ²² UK National Ecosystem Assessment Follow-On. (2014). The UK national ecosystem assessment follow-on: Synthesis of the Key findings. Cambridge, UK: UNEP-WCMC, LWEC.
- ²³ Garcia Rodrigues, J., Conides, A., Rivero Rodriguez, S., Raicevich, S., Pita, P., Kleisner, K., Pita, C., Lopes, P., Alonso Roldán, V., Ramos, S., Klaoudatos, D., Outeiro, L., Armstrong, C., Teneva, L., Stefanski, S., Böhnke-Henrichs, A., Kruse, M., Lillebø, A., Bennett, E., Belgrano, A., Murillas, A., Sousa Pinto, I., Burkhard, B., and Villasante, S. (2017) *Marine and Coastal Cultural Ecosystem Services: knowledge gaps and research priorities*. One Ecosystem 2: e12290.
- ²⁴ Drakou, E., Virdinb, J., and Pendleton, L. (2018) *Mapping the global distribution of locally-generated marine ecosystem services: The case of the West and Central Pacific Ocean tuna fisheries*. Ecosystem Services 31 (2018) 278–288.
- ²⁵ Weighell, T. (2011) Chapter 21: *UK Dependence on non-UK Ecosystem Services*. In: The UK National Ecosystem Assessment Technical Report. UK National Ecosystem Assessment, UNEP-WCMC, Cambridge.
- ²⁶ Garrett, A., and Caveen, A. (2018) *UK seafood supply base to 2030*. Seafood Strategic Outlook. Seafish.
- ²⁷ Hattam, C., Atkins, J.P., Beaumont, N., Börger, T., Böhnke-Henrichs, A., Burdon, D., de Groot, R., Hoefnagel, E., Nunes, P.A.L.D., Piwowarczyk, J., Sastre, S., and Austen, M.C. (2015) *Marine ecosystem services: Linking indicators to their classification*. Ecological Indicators, Volume 49, Pages 61-75.
- ²⁸ Brooker, E., Devenport, E., Hopkins, C.R., Hennige, S., Roberts, J.M., and Duncan, C. (2018) *Scotland as a case study for how benefits of marine ecosystem services may contribute to the commercial fishing industry*. Marine Policy, Volume 93. Pages 271-283.
- ²⁹ Piet, G.J., van Overzee H.M.J., Miller, D.C.M., and Royo Gelabert, E. (2017) *Indicators of the 'wild seafood' provisioning ecosystem service based on the surplus production of commercial fish stocks*. Ecological Indicators 72 (2017) 194–202
- ³⁰ Hatun, H., Payne, M. R, Beaugrand, G., Reid, P C., Sando, A B., Drange, H., Hanson, B., Jacobson, J A., Bloch, D (2009) *Large bio-geographical shifts in the north-eastern Atlantic Ocean: From the subpolar gyre, via plankton, to blue whiting and pilot whales*. Progress in Oceanography Vol 80; 149-152.
- ³¹ Nikolioudakis, N., Skaug, H. J., Olafsdottir, A. H., Jansen, T., Jacobsen, J. A., and Enberg, K. (2018) *Drivers of the summer-distribution of Northeast Atlantic mackerel (Scomber scombrus) in the Nordic Seas from 2011 to 2017; a Bayesian hierarchical modelling approach*. ICES Journal of Marine Science, doi:10.1093/icesjms/fsy085.

- ³² Lemasson, A.J., Fletcher, S., Hall-Spencer, J.M., and Knights, A.M. (2017) *Linking the biological impacts of ocean acidification on oysters to changes in ecosystem services: A review*, Journal of Experimental Marine Biology and Ecology, Volume 492, 2017, Pages 49-62.
- ³³ Willis, C., Papathanasopoulou, E., Russel, D., and Artioli, Y. (2018) *Harmful algal blooms: the impacts on cultural ecosystem services and human well-being in a case study setting*, Cornwall, UK. Marine Policy, Volume 97. Pages 232-238.
- ³⁴ Carcamo, P.F., Garay-Fluhmann R., Squeo F.A., and Gaymer, C.F. (2014) *Using stakeholders' perspective of ecosystem services and biodiversity features to plan a marine protected area*. Environ. Sci. Policy.
- ³⁵ Andersson, E., McPhearson T., Kremer, P., Gomez-Baggethun, E., Haase, D., Tuvendal, M., and Wurster, D. (2014) *Scale and context dependence of ecosystem service providing units*. Ecosystem Services.
- ³⁶ Ban, N. C., L. S. Evans, Nenadovic, M., and Schoon, M. (2015) *Interplay of multiple goods, ecosystem services, and property rights in large social-ecological marine protected areas*. Ecology and Society 20(4):2.
- ³⁷ Bladon, A.J., Short, K.M., Mohammed, E.Y., and Milner-Gulland, E.J. (2016) *Payments for ecosystem services in developing world fisheries*. Fish and fisheries, 17, 839–859.
- ³⁸ Walton, M.E.M., Vilas, C., Cañavate, J.P., Gonzalez-Ortegon, E., Prieto, A., van Bergeijk, S.A., Green, A.J., Librero, M., Mazuelos, N., and Le Vay, L. (2015) *A model for the future: Ecosystem services provided by the aquaculture activities of Veta la Palma, Southern Spain*, Aquaculture, Volume 448. Pages 382-390.
- ³⁹ Outeiro, L., Ojea, E., Rodrigues, J.G., Himes-Cornell, A., Belgrano, A., Liu, Y., Cabecinha, E., Pita, C, Macho, G., and Villasante, S. (2017) *The role of non-natural capital in the co-production of marine ecosystem services*. International Journal of Biodiversity Science, Ecosystem Services & Management, 13:3, 35-50.







Seafish
18 Logie Mill
Logie Green Road
Edinburgh
EH7 4HS

+44 (0)131 558 3331
www.seafish.org
seafish@seafish.co.uk

©Seafish 2019