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Welsh National Marine Plan

A review of the potential for co-existence of different sectors in the Welsh Marine Plan Area

Author(s): Elena Mengo, Frances Mynott, Angela Muench

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Project Manager:	Stephanie Eccles
Report compiled by:	Elena Mengo, Frances Mynott, Angela Muench
Quality control by:	Andrew Gill; Adrian Judd; Rachel Mulholland
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Executive Summary

The Welsh marine environment encompasses a diversity and abundance of species, habitats and ecosystems. These natural assets provide valuable resources that are of major importance to enhance coastal populations' well-being and contribute to present and future social and economic development and prosperity. The Welsh National Marine Plan (WNMP) envisions to achieve the sustainable management of natural resources in the Welsh seas through an integrated, evidence and plan-led approach which takes into account the cumulative effects of the multiple use of the marine space (social, economic and environmental) whilst balancing different interests and ecosystem resilience. This is in order to access, enhance and sustainably use the natural resources of Wales and, in so doing, protect the future generations, whilst boosting the long-term economic and social welfare of coastal communities as also anchored in the Environment (Wales) Act 2016 and the Wellbeing of Future Generations (Wales) Act 2015.

The overall aim of this report was to enhance the evidence base regarding social and economic constraints and opportunities for the focal sectors of marine aggregates, aquaculture and energy-low carbon: wave and tidal stream energy (which can also be applied to other sectors/activities). This report has been organised around three core tasks:

1. A desk-based review of available evidence at international, UK and national (Welsh) scales, regarding social and economic constraints and opportunities for the focal sectors of strategic importance for the development of the Welsh marine area (marine aggregates, aquaculture and energy-low carbon: wave and tidal stream energy). This was followed by a desk-based review of possible co-existence opportunities and constraints between the focal sectors and other relevant maritime sectors/activities[1].

2. Production of summary tables for potential interaction in the WNMP area, within focal sectors and between focal sectors and other maritime sectors/activities. The tables have been combined with mapping of spatial overlap, and discussion about the spatial (and temporal) overlaps in relation to future planning considerations.

3. A review of policies from Plans/Frameworks at national and local levels together with legislative and policy considerations, all of which have potential relevance to the focal sectors. This task supplemented the evidence review and interaction appraisal.

The overview of the available evidence (Welsh, UK as well as international) on the potential opportunities or constraints resulting from sectoral interaction from a socio-economic angle, provided in Section 3, has been accompanied by mapping of spatial overlaps to facilitate future planning and engagement. General recommendations and recommendations based on the sector interactions have been made. These recommendations aim to inform ongoing planning

[1] The other sectors reviewed in this report include tourism and recreation (including sea angling); fisheries; ports and shipping; energy – low carbon: offshore wind; subsea cabling; and other constraining sectors e.g. military practise areas.

discussions and suitable resource areas for the planning authority to consider for future investment to support the Sustainable Management of Natural Resources (SMNR).

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1 Introduction

Over 60% of the population of Wales live and work around the coast. The total value of the economic activity within the plan area in 2015 was estimated to be over £2 billion of Gross Value Added (GVA) (Welsh Government, 2015a). The direct employment contribution, in the same year, of the maritime sectors was 31,000 jobs whilst the indirect contribution was 56,000 jobs (Welsh Government, 2015a). The positive effects of the marine environment are not limited just to the economic benefits but encompass wider social aspects, such as physical health, mental health and social well-being. Marine and coastal areas are one of the drivers of the Welsh economy and contributors of societal wellbeing (Bell et al., 2015; White et al., 2013).

Use of the marine and coastal areas have increasingly become contested over the last decades due to the increase of people living in coastal zones and the growing importance of maritime industries (e.g. low carbon energy sector) (Barragán and de Andrés, 2015; Schupp et al., 2019). The rising demand for marine and coastal zone use requires identification of priorities and objectives for the spatial and temporal use of marine and coastal environments, whose goal is to balance and coordinate competing and/or conflicting needs. Thus, marine planning is needed to both reduce the potential conflict between different users as well as assess trade-offs between environmental, social and economic impacts of activities occurring either at the same time, or within the same area (Eggenberger and Partidário, 2000; Kyvelou and Ierapetritis, 2019).

In this context, the Welsh National Marine Plan (WNMP) (Welsh Government, 2019a) - the first marine plan for Wales - represents the beginning of a planning process to support and promote the sustainable management of natural resources in Welsh inshore and offshore regions, through economic, social and ecological objectives. As part of WNMP implementation, The Welsh Government is undertaking work to develop a greater understanding of sector-specific opportunities and constraints in the context of the Resource Areas (RA)[2], including environmental, social and economic considerations.

This project contributes to the understanding of socio-economic considerations with respect to three focal sectors (1) Marine aggregates; (2) Aquaculture; and, (3) Energy – Low Carbon: Tidal stream and Wave energy. Evidence has been collected using literature applicable to Wales, UK and internationally. The evidence base feeds into a systematic appraisal of likely spatial interaction between the WNMP focal sectors and other sectors/activities mentioned in the WNMP i.e. Tourism and Recreation (including recreational sea angling); Fisheries; Ports and Shipping; Energy – Low Carbon: offshore wind and tidal range energy; Subsea Cabling; and, other potentially constraining sectors e.g. military practice areas (defence).

[2] A Resource Area (RA) is a spatially defined broad area that describe the spatial distribution of a particular resource that is, or has the potential to be, used by sector activity (in terms of technical feasibility) (Welsh Government, 2019, p. 15).

To help visualise the areas of potential conflict between and within sectors, maps have been produced with examples of identified spatial constraint (or conflict). Environmental considerations are also a critical component of planning and decision-making process, but they are being assessed in a separate project, in line with Welsh Government's commitments and obligations.

To supplement the evidence review and interaction appraisal, an overview is provided in section 5 of relevant plan policies (national to local levels) related to the focal sectors. A summary and recommendations for future research needs can be found in section 6.

2 Method

2.1 Evidence review

A review of the evidence base (primary and secondary literature), in which potential co-existence (a component of opportunities) as well as incompatibility (constraints) for the each of the focal sectors with all other sectors was undertaken. The focal sectors considered in this report are (1) Marine aggregates, (2) Aquaculture and (3) Energy - Low carbon: Tidal stream and Wave energy.

Two search strategies were adopted to identify literature for this review: keyword search and the 'snowball' approach. The keyword search engines were initially identified, starting from Google as a broad search engine to keep the search open to include, for example, government and industry reports. Then the search was narrowed down to more specific academic search engines, such as Google Scholar, Mendeley, Scopus and ScienceDirect. Once the search tools were selected, input keywords were derived from our research objectives (e.g. co-existence, co-location, constraints, marine space, case studies, pilot projects, social acceptance, social perceptions economic impact etc.) and used in combination with both the focal sectors and the other relevant sectors. With the snowball method, the search is based on relevant references or comments found in published articles or reports about the research topic subject to review. Literature available at international, UK and national (Welsh) scale was searched and reviewed to assess co-existence opportunities and potential constraints between the categorised focal marine sectors and other sectors in terms of potential social or economic outcomes.

This review builds in large part upon and expands - where possible - the work published by the Marine Management Organisation (MMO) in 2013 ("*Evaluation of the potential for co-location of activities in marine plan areas*") and in 2014 ("*Social Impacts and Interactions Between Marine Sectors*"), providing more recent examples of social and/or economic impacts of marine sectoral interaction.

The current review of sectoral interactions does not include interaction with certain sectors, such as surface water & wastewater treatment & disposal, and dredging and disposal, due to the lack of targeted evidence in the literature of the interaction of these sectors with any of the focal sectors highlighted in the WMNP.

Furthermore, it should be noted that although some sectors (e.g. subsea cable and telecommunications) are not presented as specific sections in the review, they are part of the assessment. This is in the case that interaction with the focal sectors occurs through other key marine industries. For example, a potential area for marine aggregate extraction may overlap with an existing low carbon energy array and associated cable route.

2.1.1 Spatial interaction appraisal for WNMP focal and non-focal sectors

2.1.2 Defining spatial co-existence and constraints

Co-existence is defined in the WNMP as: "*multiple developments, activities or uses can exist alongside or close to each other in the same place and/or at the same time*" (Welsh Government, 2019, p. 26). Therefore, spatial conflict (constraint) can be considered as the inability of two or more activities to take place in the same spatial area and/or occur at the same time.

The WNMP defines co-location as "*a subset of co-existence and is where multiple developments, activities or uses co-exist in the same place by sharing the same footprint or area*" (Welsh Government, 2019a). The term 'footprint' applies to some or different parts of the marine environment i.e. the sea surface, the water column and the seabed. It also depends on the structures/activities concerned (MMO, 2013a). The 'footprint' of a structure is either the footprint of the structure(s) itself, or that of the safety zone surrounding the structure, where such a zone is applicable. The 'footprint' of mobile activities is essentially the area covered by the activity e.g. the area of a ship or a ship plus the equipment it is towing (MMO, 2013a).

With an understanding of co-existence, it has been possible to identify literature of interest and gauge the potential interaction of the focal sectors and other marine sectors/activities.

2.1.3 Identifying spatial co-existence and constraints

The WNMP identifies a diversity of sectors/activities operating in Welsh waters. Whilst some of these may interact other combinations may not. Therefore, we applied 'screening' using the following questions about the likelihood of spatial interaction, and co-existence (or co-location) between the focal sectors and other marine sectors/activities (Appendix 1):

- Q1. Are the activities likely to interact (marked as possible, likely or unlikely)? If so, how do they interact?
- Q2. Can the structures/activities physically co-exist in space, recognising activities could occur in the same space yet at different times (marked as possible, likely or unlikely)?

Q1. Are the activities likely to interact (marked as possible, likely, unlikely)? If so, how do they interact?

To answer this question, the GIS layers in the Wales Marine Planning Portal[3] were initially reviewed and then additional mapping work performed in ArcGIS, for evidence of spatial intersection both between sectors as well as between sectors and the resources upon which the focal sectors depend. The GIS data used was a mixture of publicly available shapefiles e.g. downloadable from The Lle Geo-Portal and data made available for the project by Welsh Government and project partners.

Q2. Can the structures/activities physically co-exist in space, recognising activities could occur in the same space yet at different times (possible, likely, unlikely)?

Having considered the likelihood of interaction, the second question investigated is whether the structure/activity could physically co-exist. Answering the questions involved making several assumptions:

- Use of the spatial footprint approach for structures/activities that occur in or atop/along the seabed, in the water column and at the sea surface.
- Focussing only on the potential constraints and opportunities during the operation and maintenance phase of an activity/development.
- Using activities/infrastructure that sit within the marine plan sector, to ensure a full range of activities/infrastructure are captured.
- Consideration of temporal sequencing of the activities/sectors which could enable existence in the same space but at different times.

Answering the questions involved expert knowledge of the project team, primary and secondary literature regarding co-existence of maritime activities and utilising the interaction of available shapefiles for sectors of the WNMP and associated resources. The results have been compiled into tables demonstrating the following:

(i) Within focal sector comparison; and,
(ii) Cross-sector analyses.

Details of the type and source of GIS data layers used in the mapping (Section 4) are summarised in Appendix 2. The derivation of the Resource Areas (RAs) for the Welsh National Marine Plan is outlined by The Welsh Government (2019).

Having summarised information, mapping in ArcGIS 10.5 was undertaken to help with the visualisation of spatial co-existence (or lack thereof). The available ArcGIS shapefiles for focal sector RA (and other sectors), were overlaid and clipped using the ArcGIS geoprocessing tool, to generate areas of intersection. The resulting maps for combinations of sectors indicate where spatial co-existence is potentially limited and hence may need consideration in determining future use of the RAs.

[3] https://lle.gov.wales/home?lang=en [Last access: 06/04/2020].

3 Review of sector-sector interactions: co-existence opportunities and constraints

3.1 Co-existence opportunities and constraints between focal marine sectors

The review of available information sources (n = 76, literature and internet sources) highlighted the lack of local (Welsh) scale specific information on sector-sector interactions. Less than 8% of sources reviewed were Welsh, as compared to 41% at national (UK) scale and 51% at international scale. The following review and assessment of co-location and co-existence opportunities and potential constraints between the focal marine sectors in Welsh water is therefore regarded as low to medium confidence on the basis of approximately 50% of the sources being UK and Wales specific.

3.1.1 Marine aggregates and low carbon energy: wave and tidal stream energy

The marine aggregate industry in Great Britain is one of the largest and most developed sectors globally producing between 15 to 20 million tonnes of sand and gravel yearly (Bide et al., 2016; The Crown Estate, 2017). A large part (about 80%) of all marine aggregate sales in England and Wales are used as concrete aggregate. The construction industry in Wales accounts for 3% or £5.5 billion of the total value of construction in Great Britain (MPA, 2018). The sector is driven by infrastructure demands (22% of the total output), followed by new house building and commercial building (18% and 17% of the total output respectively). In the wider Great Britain, infrastructure accounts for 12% of total construction output. Marine-dredged sands and gravels are also used for coastal defence and beach replenishment projects (MPA, 2018; Newell and Woodcock, 2013).

Sand and gravel extraction activities are organized through a leasing process managed in the UK by The Crown Estate. This process spatially accommodates marine aggregate needs with those of other marine sectors and looks to minimise or mitigate the risk of conflicts (MMO, 2014). There is growing momentum for low carbon energy (tidal stream and wave energy), as demonstrated by the primary role of the sectors in the WMNP. It appears likely these two sectors could compete for sea space with the aggregate industry in the Welsh marine area. As such, the possible conflicts originating from the spatial/temporal overlap with aggregate dredging operations should be minimised for these sectors to co-exist. It is possible that sectoral developments define the sequence and timing in which activities will occur. This means that if there is an area which is potentially suitable for both sand and gravel extraction and low carbon energy development, the aggregate extraction process should ideally take place first. Once the extraction area can be surrendered, the wave or tidal stream energy arrays could be developed over the same area; this will allow for the two activities to co-exist efficiently.

Despite the potential for the marine aggregate extraction industry to compete for the use of the space with the low carbon energy sector in the Welsh marine area due to the expected increasing contribution of renewables to the energy mix, at present no evidence of sector-sector incompatibility was found.

3.1.2 Marine aggregates and aquaculture

Spatial co-existence of marine aggregates with aquaculture is not expected. There is no expectation for the aggregates sector to overlap in the future with aquaculture developments since the two activities are not compatible. This is supported by the lack, at present, of robust evidence available through literature, either for the Welsh marine area or at UK and international level.

3.1.3 Aquaculture and low carbon energy: wave and tidal stream energy

There is potential for the aquaculture and low carbon energy sectors to be combined. On the one hand, employment in aquaculture is important for several coastal communities across the UK (MMO, 2013b). In 2012, enterprises in the aquaculture sector generated a total revenue of approximately £590 million and employed over three thousand people (Jennings et al., 2016). Latest economic figures show that aquaculture in Wales generated a production valued about £3m/1.700t in total in 2017 (T. Ellis, Cefas, *pers. comms*. 23.07.2019). Thus, the aquaculture sector has the potential to contribute to the sustainable growth of the Welsh marine economy and help coastal communities diversify their activities, whilst reducing pressure on fish stocks and supporting food security (European Commission, 2012; Jennings et al., 2016). The importance of aquaculture goes beyond its socio- economic value and incorporates cultural benefits stemming from aquaculture operations. This includes knowledge transfer to future generations and opportunities for new scientific research and education (Hasselström et al., 2018).

On the other hand, low carbon marine energy is an emerging sector. The UK's marine energy industry can play a significant contribution to national economic development. According to the Marine Energy Council (2019), around 1,700 people are currently employed in the marine energy sector in the South West, Wales and Scotland. A report recently published by ORE Catapult[4], states that tidal stream energy could generate by 2030 a net cumulative benefit to the UK economy of £1.4 billion, becoming a source of significant job creation. It is anticipated that a successful transition towards a low-carbon economy will create approximately 4,000 new jobs, many of which will be in regional economies whereas the wave energy sector is expected to create around 8,000 new jobs by 2040 (Smart and Noonan, 2018).

Combined marine activities, such as aquaculture and renewable energy systems, will allow for a more efficient use of the marine space whilst reducing competition between different users. Nonetheless, the sustainable development plans for the integration of aquaculture installations with the low carbon energy industry necessitate an integrated assessment of a combined utilization of either the inshore or offshore sea space which

[4] Ore Catapult is the UK's leading technology innovation and research centre for offshore renewable energy. Source: https://ore.catapult.org.uk/about-us/ [Last access: 26.03.2020].

encompass environmental, social and economic considerations. Possible synergies between the low carbon energy sector and aquaculture development have been identified in recent years by researchers and practitioners (Aquatera, 2014; Welsh Government, 2015b), which include:

- Reduction of operating costs by using the same vessel to transfer personnel, feed, equipment etc. to and from the shared infrastructure. Lower operating costs will likely increase the competitiveness, efficiency and long-term profitability of the aquaculture sector.
- Additional costs savings can be achieved if the two interacting sectors are able to share anchor or supporting structures.

Where the facilities are located offshore, the aquaculture farm may potentially share the power supplied by the offshore low carbon renewable infrastructures (in-field power supply). According to Toner and Mathies (2002), the overall positive view the public has of low carbon renewable energy, perceived as an environmentally friendly sector, may play a crucial role in improving the image of aquaculture.

With regards to impacts of wave energy converters[5] and finfish aquaculture sites using cage structures, several pilot projects already exist. For example, in 2013 at the Isle of Muck, Scotland, a pilot project was established to test an offshore wave energy converter array (WaveNET) as a means of powering offshore aquaculture installation as well as to assess the appropriate wave energy converter sizes. This was developed by Albatern, a Scottish wave energy device developer, in collaboration with Marine Harvest Scotland.

Figure 3.1: WaveNET 6S Array off the Isle of Muck, Scotland and SQUID Series-6 Generating Unit

WaveNET arrays (Figure 3.1) are flexible floating structures made of units which react to the motion of the waves to generate electricity[6]. The project aimed to identify and meet

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[5] **Wave energy converters** were classified in the report published by SARF (2013) into one of eight different categories: attenuators, surface point absorbers, oscillating wave surge, oscillating water column technologies, overtopping devices, submerged pressure differential, bulge wave technology and rotating mass devices.
Tidal stream energy converters include instead (SARF, 2013): horizontal axis turbines, vertical axis turbines, Reciprocating Hydrofoils, the Venturi Effect devices, tidal kite and the Archimedes Screw.

[6] Description of WaveNet device: http://albatern.co.uk/wavenet/works/ [Last access: 28/02/2019].

the power requirements of offshore aquaculture installations[7]. As anticipated by Black and Hughes (2017), the energy price is likely to play an important role on future aquaculture trends. The project demonstrated that Wave NET is a secure system that can work commercially on an operating remote fish farm and the risk for the cages is minimal[8] (Dalton et al., 2019).

Another study to assess the impact of wave energy converters on an adjacent aquaculture cage installation was conducted in Portugal (Silva et al., 2018). The results of the simulation-based research based on the impact of different types of wave converters, indicate that the wave farm - whilst producing energy - simultaneously attenuates the impact of waves propagation, thus sheltering the fish farm and reducing the likelihood of damage (Silva et al., 2018). Malta and Cyprus provide other examples where aquaculture sites use wave energy devices to provide power for intensive finfish aquaculture installations (Depellegrin et al., 2019).

Currently, there are no marine finfish farms in Welsh waters. As mentioned in this report already, new offshore technologies are being developed and tested in Scotland. These could make offshore fish farming in Wales feasible in the not too distant future. Indeed, sustainable finfish farming is discussed in the WNMP, which states the goal for the aquaculture sector is "*to facilitate the development of sustainable aquaculture in Welsh waters, including promoting innovative finfish, shellfish and marine algal businesses and associated supply chains*" (Black and Hughes, 2017, p. 80).

Wave Dragon[9], Seaweed Energy Solutions (SES)[10] and BELLONA foundation[11] are working together on a combined wave and aquaculture project to be deployed in Welsh waters. The project brings together an array of wave energy converters (WEC) of a design created by the Wave Dragon, combined with a seaweed farm. The latter will benefit from calmer waters behind the wave devices and access to power for storm submergence[12], which will increase the operational days and thus make kelp production feasible in exposed waters.

Once processed, seaweed can be sold as a high value raw material for food and health products, cosmetics, animal feed markets and biofuel (Dalton et al., 2019). Furthermore, the co-existence of wave devices and seaweed farms is expected to benefit from a smoother licensing process, due to the multiple use of the marine space as well as from the perceived, positive public perception (Dalton et al., 2019). Outputs and evaluations from the combined project were, however, not available at the time of writing.

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[7] Source: Albatern WaveNet Device - http://grebeproject.eu/wp-content/uploads/2017/09/Wave-Energy-Albatern-WaveNet-Scotland.pdf [Last access: 16/12/2019].

[8] Source: Ibid.

[9] Wave Dragon39 is a private Danish/UK based company working towards the commercialisation of wave energy converter (WEC) technology to extract electricity directly from ocean waves.

[10] Seaweed Energy Solutions (SES) 40 is a Norway-based seaweed innovation and business development company.

[11] Bellona Foundation is an independent environmental NGO that aims to mitigate challenges of climate change through identifying and implementing sustainable environmental solutions.

[12] Source: Marine Investment for the Blue Economy - https://maribe.eu/wave-aquaculture/ [Last access: 06/04/2020].

3.2 Co-existence opportunities and constraints between focal sectors and other key marine sectors

3.2.1 Marine aggregates and low carbon energy: wind energy

There are opportunities for co-existence between marine aggregates and offshore wind farms (OWFs). For example, the Round 3, Zone 5 OWF development zone off the East Anglian coastline was planned with consideration of the licensed aggregates extraction areas, to ensure adequate space for both sectors to develop (MMO, 2014). In the same way, following the selection of a landfall site for the Hornsea Offshore Wind Farm at Horseshoe Point, the inshore and offshore cable route corridors were identified taking into account dredger transit routes from The Crown Estate and the British Marine Aggregates Producers Association (BMAPA) around licensed dredging areas (SMart Wind, 2013).

The Marine Aggregate Levy Sustainability Fund (MALSF) funded a project to design a tool aimed at assessing whether spatial conflicts exist between aggregate extraction areas and other uses of the marine space (Newell and Woodcock, 2013). The tool was tested in the Outer Thames to analyse the trade-offs between marine aggregate extraction and other activities taking place in the area, including offshore renewables. It was estimated that the spatial conflict between the renewable energy sector and licensed aggregate sites could result in losses for the renewable energy sector. The losses ranged from £2.9 to £4.8 million over 15 years owing to electrical energy not being produced. Moreover, the economic shortfall was expected to have a knock-on impact on employment; it was anticipated there would be 15 jobs lost during the OWF construction phase. However, no information was given on the jobs or profit generated by marine aggregates in this area (Dick et al., 2011, as cited in Newell and Woodcock, 2013).

The marine aggregate extraction sector and the offshore wind industry may have a mutual interest in exploiting the same resource area. From the perspective of the marine aggregate industry, a major drawback of spatial overlap with renewable energy infrastructure, is the area no longer being available for aggregate extraction in the medium-term, due to the presence of the foundations, turbines and cables (Eftec, 2011 as cited in MMO, 2014). There may also be impacts associated to decommissioning[13] or partial decommissioning of offshore wind installations. In fact, in case of a partial decommissioning, any infrastructure left in place (e.g. cables or foundations) may limit the potential future use of the site for other uses, such as aggregate extraction (Smyth et al., 2015).

Offshore energy developments are also likely to limit the safe passage of dredge vessels through areas occupied by infrastructure. Dredging vessel displacement may lead to increased steaming distances/times and in the case of aggregates, production will be

[13] Decommissioning refers to all the operations associated to the removal or making safe of offshore infrastructure at the end of its useful life.

moved to a more distant licensed area which translates into higher costs (e.g. additional fuel) as well as reduced revenues to the marine aggregate sector (MMO, 2014).

An example of spatial overlap between the renewable energy sector and marine aggregate extraction, where a solution to accommodate both parties was not reached, can be seen with Gwynt y Môr OWF. The area licensed for aggregate dredging was indeed amended to accommodate the wind farm (npower renewables, 2005 as cited in MMO, 2014).

3.2.2 Marine aggregate and low carbon energy: tidal range energy

Significant tidal range resources have been identified in the north of Wales from north eastern Anglesey to the Dee estuary and along the southern coast from St Davids to the Severn estuary[14] (Welsh Government, 2019). The primary technology is tidal lagoons which work by utilising the tidal height difference to generate electricity. They effectively create a lagoon area either free standing within the body of an estuary or incorporated with the shoreline. They have not yet been used commercially anywhere in the world; however, they have been considered as an alternative to what is considered to be the more environmentally damaging tidal barrages (Gill, 2011).

Interaction with marine aggregates activity should be minimal given the proposed location of tidal range lagoons being close to shore and the majority of marine aggregate resource is further offshore. The spatial scale of lagoons (of the order of a few 100 km^2) and ability to adjust location within the tidal resource areas, means that positioned corrected they should allow passage of vessels (i.e. marine aggregate dredgers and support vessels).

3.2.3 Marine aggregates and shipping

Several licenced extraction areas in UK are located within or close to busy shipping lanes. Existing shipping lanes need to be properly considered during both the licensing of marine aggregate areas and with respect to ports where cargoes will be delivered. Tillin et al. (2011 as cited in MMO, 2014), report that collisions and or accidents between dredging and commercial vessels are usually prevented through communication with the shipping industry at all stages of licensing and the subsequent associated operations. Hence, risk of collision is regarded as unlikely to arise in areas with high levels of shipping activity (Tillin et al., 2011 as cited in MMO, 2014).

3.2.4 Marine aggregates and fisheries

Once licensed, marine aggregate extraction can spatially co-exist with other marine sectors, which do not involve deployment of fixed in infrastructure in the same area, e.g. shipping and fisheries, by zoning the licence area into Active Dredge Zones (ADZ). The ADZ

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[14] Source: https://www.marineenergywales.co.uk/marine-energy-in-wales/the-resource/ [Last access: 02/04/2020].

are usually specific to a licensed area as a result of a licence condition, or as a voluntary initiative introduced by the operator[15]. There can be dredging at any time in the limits of the ADZ, whilst parts of the seabed and sea space of the licence area can be accessible to other maritime users. The ADZ are intended to minimise spatial conflict with other sea users, as well as minimise environmental impacts and effective resource management. As such, co-existence can be viewed as a possibility for the aggregate licence areas that are new but occur in an environment of existing activities. Moreover, the production and distribution of charts with regional Active Dredge Areas (ADA) contributes to minimising spatial conflict with other sea users, as well as minimising environmental impacts and effective resource management.

Feasibility of co-existence between marine aggregate extraction and fisheries depends on the long-term effects of sand and gravel dredging on fisheries activities (MMO, 2013a). In the short term, however, co-existence is possible if such activities do not occur at the same time. Thus, it is expected that fishing with either mobile or static gears can continue outside of the active extraction periods.

Cooperation between the aggregate industry and local fishermen can arise through informal arrangements between the interested sectors, i.e. through mutual consultation and local stakeholders' knowledge. A necessary pre-condition for the arrangement to work is that both parties voluntarily agree to comply to a set of pre-determined guidelines (MMO, 2013a).

Fisheries displacement, as suggested by Kyvelou and Ierapetritis (2019), has to be addressed through intelligent and innovative cooperative ways; such as the arrangements established by the East and South Coast Dredging-Fishing Liaison Committees. Such arrangements allow the two activities to operate within the same space at different times and represent an example of cross-sectoral cooperation. These measures include (MMO, 2013a):

- The communication of the active dredge zone to allow fishing access to the wider licence area;
- Measures to allow aggregate extraction to take place within International Maritime Organization (IMO) Traffic Separation Schemes; and,
- Establishing buffer distances for existing cable infrastructure to ensure fishing gear and cable infrastructure are not damaged.

Hence, marine aggregate dredging co-existing in the same space with fishing activities, as long as they do not take place at the same time. However, if this is not the case then marine aggregate production displaces fishing and this can increase social tension and reduced community cohesion. A study carried out by Cooper (2005) indicates that perceived risk of damaged static gears (nets and pots) may cause fishermen to avoid

[15] Source: https://bmapa.org/issues/other_sea_users.php [Last access: 06/04/2020].

certain areas around aggregate extraction sites, hence may lead to increased fishing pressure on alternative grounds adjacent to the dredging site.

An additional concern for fishermen relates to alterations of the seabed topography resulting from sand and gravel extraction, that may affect the migration routes of crabs and lobsters as well as flat fish movement (Cooper, 2005; Posford Duvivier Environment and Hill, 2001). This may impact the catch rate and, ultimately, fishers' revenues. However, alterations in flat fish movement patterns or abundance due to dredging activities are not supported by scientific evidence (Cefas, *pers. Comm.*).

It is also anticipated that increased demand for aggregate products can lead to larger quantities extracted for longer periods of time, which can result in conflict with the fishing sector in cases where extraction activities limit the activities of the fishing vessels (MMO, 2013a). Dick et al. (2011, as cited in Newell and Woodcock, 2013) applied a tool for the assessment of social and economic impacts associated with a proposed extraction site and other activities. The study quantified the costs to local fishermen of exclusion, if their activities overlap with extraction of sand and gravel in the Outer Thames Estuary site. The assessment estimated the present value (PV) of aggregate extraction to be between £22.4 - £35.0 million over a 15-year period. The PV of fisheries over the 15-year licensing period was estimated to be between £27,000 and £81,000. The figures may change if sensitivities are tested. In this case, after there was agreement for the inclusion of a 1 km buffer area to account for the impact on sediment transport, the PV of fisheries in the study area increased to £131,000 over the same period.

Licensing an area for extraction of marine sand and gravel is likely to affect employment as well. Dick et al. (2011, as cited in Newell and Woodcock, 2013) deduced that 22 people would benefit from direct employment in the area under investigation and, equally, direct employment would be also positively impacted from the support of 28 indirect jobs. Effects on fisheries employment at the site appear to be marginal, with less than a single job lost as a direct consequence of dredging and extraction activities.

3.2.5 Marine aggregates and recreational activities

Dredging for sand and gravel interacts with a range of recreational activities which span from recreational angling to scuba diving and sailing (MMO, 2014; Newell and Woodcock, 2013). Sea angling, for instance, may occur in areas coinciding with aggregate extraction. For example, the Overfalls, a site that lies approximately 18 km east of the southern part of the Isle of Wight, was acknowledged to provide an important habitat for various fish species of importance for local anglers. Prior to designation, it emerged that the site was near three aggregate extraction sites and coincided with an aggregate application site. This overlap raised concerns amongst sea anglers about the possible impact of sand and gravel extraction on their catches. After consultation, The Crown Estate chose to not licence aggregates extraction from the Overfalls area for 21 years following designation in January 2016 (MMO, 2013a).

In the Outer Thames Estuary example (mentioned above), it was anticipated that extraction activities may cause displacement of recreational sea anglers, albeit economic losses were not quantified as data relating to participation were available only at high level (Dick et al., 2011, as cited in Newell and Woodcock, 2013).

Marine aggregates extraction could diminish the view of a pleasant landscape/seascape of residents if dredgers operate close to the shore (Custódio et al., 2019; Gentry et al., 2019). Recreational use of the area can equally be impacted negatively where dredging operations disrupt the activities of recreational anglers or divers, e.g. if the activity occurs near to a wreck diving site.

3.2.6 Marine aggregate and defence sector

With reference to the defence sector, military practices in Wales cover approximately 37% of the Welsh Zone (Judd and Wood, 2018), hence sectoral interaction with any other sector is likely. Marine aggregate dredging includes the implementation of fixed infrastructure. Therefore, any new development needs to be approved by the Minister of Defence (MoD) as it might be considered to create navigational risks and potentially obstruct defence activities (Welsh Government, 2019, pp. 85–87). Hence, marine aggregate dredging is likely to be constrained by the defence sector. At present, however, evidence is lacking from literature, either specific to the Welsh context or at UK or international level with regards to the impact of actual or potential sector-sector interaction.

3.2.7 Low carbon energy: wave and offshore wind energy

The UK has the largest operating offshore wind capacity in the world (The Crown Estate, 2017). In September 2019, The Crown Estate launched the fourth round of Offshore Wind Leasing. The seabed areas made available to the market in Round 4, known as Bidding Areas, are: the Dogger Bank Bidding Area, the Eastern Regions Bidding Area, the South East Bidding Area, and Northern Wales and Irish Sea Bidding Area. Designating more areas for OWF development requires optimal decision making over the use of the space, especially in the offshore waters of the Northern Wales and Irish Sea[16]. The Crown Estate - after the completion of the plan level Habitats Regulations Assessment (HRA) to evaluate the potential impact of proposed wind farm extensions in 2017 – has also granted seven project extension applications, which included the extension to the existing Gwynt y Môr Offshore Wind Farm[17].

The Welsh Government is actively involved in the development of marine energy technologies and pre-commercial projects. The Pembrokeshire Demonstration Zone (PDZ), a 90km^2 area of sea leased from The Crown Estate by Wave Hub Ltd and located

[16] Source: https://www.thecrownestate.co.uk/en-gb/media-and-insights/news/2019-the-crown-estate-launches-the-uk-s-first-major-offshore-wind-leasing-round-in-a-decade-opening-up-the-opportunity-for-at-least-7gw-of-new-clean-energy/ [Last access: 18/12/2019].

[17] Source: https://www.thecrownestate.co.uk/en-gb/media-and-insights/news/2019-28-gw-of-offshore-wind-extension-projects-to-progress-following-completion-of-plan-level-habitats-regulations-assessment/ [Last access: 19/03/2020].

between 15 and 21 kilometres off the south Pembrokeshire coast[18], has been expanded to include a floating offshore wind demonstration project (Carbon Trust, 2018).

The analysis of co-location of wave energy converters and offshore wind turbines into a single renewable energy farm has been undertaken in Italy (Azzellino et al., 2019). The researchers use a spatial planning approach to identify optimal locations for future wind-wave energy infrastructures, in a context of existing human-driven pressures (e.g. commercial shipping, mariculture activities, cable routes, etc.) and environmental factors (e.g. designated marine protected areas). This is within a sea area around Italy, including the Adriatic Sea, Ligurian Sea, Tyrrhenian Sea, and partially the Ionian, Sardinia Sea, as well as the northern part of the Strait of Sicily. The study identified a weak correlation in local and temporary conditions of wind and wave, which may, nonetheless, be exploited for efficient joint production of low carbon renewable energy. The results of the wind-wave climatic analysis indicate that appropriate conditions occur in the western and southern part of the study area, in both coastal and offshore deep waters. Additionally, where there is the potential for development of combined wind and wave energy installations, the approach enabled the identification of optimal sites and sites with a low cumulative human impact (Azzellino et al., 2019).

Assessing the benefits of combining wind energy with wave energy at various locations around Ireland, it was shown that wave and wind resources are very low correlated on the South and West Coast, where the waves are dominated by the presence of high energy swells generated by remote westerly wind systems (Fusco et al., 2010). This means that the co-location of wind and wave farms, at these locations, allows the achievement of a more reliable, less variable and more predictable electrical power production. Similar, results were shown along the California coast where offshore wind resource is high. Aggregating offshore wind and wave energy farms generate less variable power output than a wind or wave farm operating separately (Stoutenburg et al., 2010). Considering the feasibility of joint exploitation of wave and offshore wind power in the Statfjord field in the North Sea, positive outcomes resulted mainly from the reduction of capital investment costs and increased power production (Muliawan et al., 2013).

3.2.8 Low carbon energy: wave/tidal stream energy and tidal range energy

The low carbon energy resources along the Welsh coastal and offshore waters is estimated to be able to supply 6.4 GW of power[19]. This significant resource is available via wave, tidal stream and tidal range power. As tidal stream power comes from the movement of water, whereas the tidal range power comes from the difference in tidal height, these resources are spatially separate in Welsh waters (Welsh Government, 2019). There is overlap in terms of resource on the south coast off Porthcawl and to Penarth, however tidal range resource is focussed to a specific location close to shore where a tidal lagoon can be constructed. Tidal stream devices, on the other hand, are

[18] Source: https://www.marineenergywales.co.uk/marine-energy-in-wales/demonstration-zones/pembrokeshire-demonstration-zone/ [Last access: 19/03/2020].
[19] Source: https://www.marineenergywales.co.uk/marine-energy-in-wales/the-resource/ [Last access: 02/04/2020].

discrete and relatively small structures which can be deployed within the water column. Hence, there is clear opportunity to have both operating in coastal waters, if located appropriately.

For wave devices, the identified wave resource in Welsh waters is confined to the south west coastal and offshore waters. There is therefore very little spatial overlap with the identified tidal range resource and therefore little opportunity for co-existence or conflict.

3.2.9 Low carbon energy: wave/tidal stream energy and shipping

Literature regarding interactions between wave and tidal stream energy and other sectors is scarce. Offshore low carbon renewable developments could interfere with other uses of the sea causing hazards to shipping. Associated social impacts include loss of potential future employment due to interaction with these sectors, and which could constrain development opportunities of renewable energy arrays (MMO, 2013a).

The presence of structures above, on or below the sea surface poses a risk to all vessels through collision or snagging of vessel lines with structures and their moving parts while the vessel is either underway or anchoring (The Scottish Government, 2013). For offshore renewable developments, it is the outer structures that are most exposed to shipping collision related to vessels navigating in restricted visibility, or those with inadequate bridge watch keeping, or vessels adrift and/or not under command. However, any development would be identified on a chart and appropriately marked with buoyage as a hazard. The effectiveness of these controls relies on vessels monitoring up to date charting information and maintaining an effective watch whilst at sea (The Scottish Government, 2013).

To minimise the danger posed by offshore renewable energy installations to navigation and communication of shipping and emergency rescue, renewable energy developers seeking consent for marine works must consider the latest marine guidance notes issued by the Maritime and Coastguard Agency (MCA)[20].

3.2.10 Low carbon energy: wave/tidal stream energy and fisheries

Renewable energy arrays have the potential to displace fishing activities due to lost or reduced fishing grounds and/or increase vessels density in the vicinity of the licenced area towards shore. As a result of fisheries displacement outside the renewables development, there is an increased risk of collision and subsequent safety issues and delays/restrictions on the extent of fishing activities (de Groot et al., 2014; MMO, 2014).

3.2.11 Low carbon energy: wave/tidal stream energy and defence

Any new development of the low carbon energy sector (wave/tidal stream energy) would encompasses fixed infrastructures, hence the Ministry of Defence (MoD) might oppose these new development due to generating potential navigational risks and obstruction to

[20] Source: https://www.gov.uk/government/collections/marine-guidance-notices-mgns [Last access: 26/03/2020].

the defence activities, respectively (Welsh Government, 2019, pp. 85–87). At present, however, evidence is lacking from literature, either specific to the Welsh context or at UK or international level with regards to the impact of actual or potential sector-sector interaction.

3.2.12 Aquaculture and low carbon energy: offshore wind energy

The idea of bringing together aquaculture installations and OWFs has gained considerable attention over the years not only in the UK, but also across other European countries, such as Germany, the Netherlands, France and Belgium. For a multi-use system to be economically advantageous, OWF developers need to maintain the energy output of an OWF at the maximum economic level, but also guarantee the overall commercial viability of offshore aquaculture (Michler-Cieluch et al., 2009), or add value through accounting for the ecosystem services provided by species like bivalves and macroalgae (Buck et al., 2018).

Naylor and Burke (2005) suggested targeting lucrative species for large-scale aquaculture operations or niche markets. Overall, increased efficiency could be achieve through shared logistics and infrastructures as well as restrictions for other types of activities to reduce the risk of collision with the shipping sector (Gimpel et al., 2015; Michler-Cieluch et al., 2009).

Buck et al. (2018) state that social acceptance of multi-use facilities, combining wind farms and aquaculture, may increase as a result of:

- the perceived footprint reduction of the two activities combined;
- the potential job creation opportunities; and,
- additional income, especially for more vulnerable sectors (e.g. inshore fisheries), through livelihood diversification and access to new markets.

However, co-existence is not immune from skepticism and may cause conflicts between the interested parties.

Various projects have investigated potential synergies between these two sectors (Griffin et al., 2015) and there are several examples of pilot demonstration projects, where wind farms and different aquaculture types have been co-located. Studies assessing co-location of aquaculture and wind farms have mainly investigated the feasibility of cultivating species like seaweed or bivalves (Buck and Langan, 2017). Whereas there is scarcity of available information on the possibility of co-locating finfish farms with OWFs (OECD, 2016, p. 135). Experiences of existing OWFs and aquaculture sites in the German North Sea, indicate that offshore operations and maintenance (O&M) can be five-to-ten times more expensive (Buck et al., 2017; Christie et al., 2014; Michler-Cieluch et al., 2009). Table 3.1 summarises constraints of mariculture and offshore windfarm operators during the O&M activities which make co-location of these two sectors more costly.

Survey results revealed that the main concerns expressed by OWF developers/operators and fishers in Germany, range from socio-cultural issues to policy issues, as well as issues of economic and technical feasibility (Michler-Cieluch et al., 2009).

The challenges of integrating aquaculture with energy production through a social lens requires differentiating between offshore[21] and inshore areas. Buck et al. (2018) argue this is due to differences in the types of activities and resource uses in the two areas, which entails different political as well as economic considerations. Conflicts between stakeholders over the use of the offshore space are likely to be addressed more readily by policy makers, since the actors involved are more powerful and influential than stakeholders operating inshore whose resources are more limited. Given these differences between these power relationships of stakeholders, Buck et al. (2018) conclude that co-location of aquaculture and offshore energy installations demands a different governance and management approach to nearshore co-location.

Table 3.1: Issues for Operation & Maintenance of large-scale offshore wind farms and offshore aquaculture.

OWF Aquaculture co location
Operation costs
Limited accessibility – weather windows
Distance to farm site
Higher offshore labor costs
Difficult logistics for operations and maintenance/ Difficult logistics for maintenance and harvesting
Reliability of the turbines/Reliability of culture devices
Uncertain regulatory and permit requirements

Mee (2006) investigated the possibility of combining finfish aquaculture and OWFs from the point of view of the stakeholders in the wind energy industry across the UK. Results of the telephone interviews and questionnaires show scepticism amongst stakeholders about the idea of co-location of OWFs with fish aquaculture because of several factors. For example, it was mentioned the possible conflicts with the local fishing community, problems with wind farm maintenance work and the specific environmental criteria which must be met for the co-location of these sectors within the same sea space. Additional concerns include issues regarding statutory approval, more health and safety burdens and restrictions to access the wind farms (Mee, 2006).

Dalton et al. (2019) confirm that OWFs stakeholders are hesitant to share space due to perceived added risks to health and safety as well as the large investments required for the business endeavour to be economically feasible. The "complex, fragmented and inconsistent" regulatory framework (Black and Hughes, 2017, p. 26) and the depth of information required for licence applications (Wood et al., 2017) may dissuade prospective investors.

[21] Offshore aquaculture is defined as: "*the transfer of farm installations from a sheltered environment to a more exposed location as well as the establishment of new aquaculture enterprises in exposed sites*" (Buck et al., 2018, p. 2).

Additionally, social acceptance of OWFs and aquaculture installations may be adversely affected by the presence of such structures (Ladenburg and Lutzeyer, 2012; Wood et al., 2017). This is especially if located adjacent to areas frequently visited by recreational boaters or if visible from land, due to the perceived negative impact on aesthetics. Negative impacts encompass also community harmony and local fishing industry (Firestone and Kempton, 2007). This is confirmed by the findings presented by Börger et al. (2015), where a welfare loss is expected as result of more visible wind farm turbines. Not surprisingly, welfare loss was higher for respondents in coastal locations but diminishing with increasing distance from the coast.

3.2.12.1 Bivalve aquaculture and low carbon energy: offshore wind energy

Research projects combining mariculture and OWFs in the German Bight started in 2001. Shellfish aquaculture industry in the North Sea was identified as a primary candidate for co-location within windfarms (Syvret et al., 2013). Buck et al. (2010) calculated costs and net returns of moving mussel cultivation close to German OWFs across four case scenarios. Results indicate that a baseline scenario with two full mussel plots, corresponding to 2,380 tons of consumption mussels per year and with investment into a new vessel, would generate net returns for an average 4-year period. This is approximately equal to 4.6 million euros.

Net returns were calculated to be four times higher in the case of farming mussels using existing equipment. Scenarios 3 and 4 explored mussel production as being less labour intensive. Scenario 3, however, included investment costs for the purchase of a new vessel and net returns of approximately 77.7 thousand euros. In contrast, scenario 4 did not anticipate the purchase of a vessels, thus returns were estimated to be higher at 1.5 million euros.

In Wales, a practical blue mussel cultivation trial was designed in 2010 by Deepdock Ltd. with assistance from Seafish (Sea Fishing Authority) at the North Hoyle Wind Farm site off Rhyl to investigate aquaculture co-location with OWFs. The OWF contains 30 monopiles in 10 meters of water (at low tide) and was constructed in 2003. The information provided in the final report prepared by Seafish shows that mussels grew well, but unexplainable mortality occurred at harvest which requires further investigation (Syvret et al., 2013).

This trial demonstrated that aquaculture activities could be carried out without a negative impact on wind farm operations. Further commercial-scale trials were recommended to both refine the technology to grow mussels offshore on fixed gear and assess environmental impacts and economic performance. Anticipated socio-economic benefits from co-locating aquaculture within OWFs include (Syvret et al., 2013):

- Job creation and employment opportunities;
- Potential for expanding seafood provision from UK waters;
- More space left in the see for other economic or recreational activities in the region; and,
- Knowledge and experience acquired through the trial to mitigate impact on local fishing grounds.

To our knowledge, no offshore co-location trial combining mussel farming and OWFs is going on currently in Welsh waters. The mussel aquaculture sector appears to have the greatest current potential to be combined with offshore wind arrays, and thus meeting economic, environmental and technical requirements (Jansen et al., 2016).

3.2.12.2 Seaweed aquaculture and low carbon energy: offshore wind energy

Seaweed demand in the UK has been met thus far by harvesting of wild resources. However, the anticipated rise in biomass use (Bosch et al., 2015) will increase the demand of seaweed biomass, which will likely be achieved by farming rather than natural harvest (Capuzzo et al., 2019). Furthermore, seaweed demand may increase as a result of the current consumers preferences in healthy food, food supplements, new protein sources and novel bioactive compounds, which has led to further research of the chemicals found in seaweeds (Buck and Langan, 2017; Capuzzo et al., 2019).

The seaweed sector is still in its infancy in the UK, yet the predicted increase in demand of high-value products is expected to generate new market opportunities in the UK and in Europe, especially for seaweed offshore cultivation. Studies looking into integration of seaweed aquaculture with offshore renewable energy arrays have been carried out, but currently a high level of uncertainty exists regarding operational aspects such as access to suitable onshore facilities and infrastructure for processing/transport to markets (Jansen et al., 2016; Linley et al., 2008).

Currently, offshore seaweed production in the North Sea is not economically profitable in the vicinity of an offshore wind farm. Results indicate that the seaweed production in the offshore wind farm would result in a loss of about US$24,000 per hectare per year (van den Burg et al., 2016). A sensitivity analysis was employed to assess how much seaweed price should rise to be profitable. The findings show that with a price of US $1,747/metric ton seaweed production becomes a profitable venture. The study presents some limitations; it is acknowledged that offshore cultivation of seaweeds is not common in the North Sea, hence there is uncertainty about some of the input parameters used for the economic modelling. Additionally, there could be possible costs savings due to expected synergies with offshore wind energy (van den Burg et al., 2016).

3.2.13 Aquaculture and low carbon energy: tidal range energy

For many years, lagoons have been linked with aquaculture in several parts of the world (e.g. extensively for centuries in the Mediterranean (Cataudella et al., 2015)). Being close to shore allows easy access and management of the resource area. The management of traditional aquaculture and capture fisheries activities in lagoons has been identified as a main instrument to maintain the ecological features of lagoons and to prevent the degradation of their sensitive habitats, both from an environmental and socio-economic point of view.

The aquaculture resource area in Welsh marine waters is extensive and overlaps with both the northern and southern tidal range resource areas. Furthermore, the predominant aquaculture in Wales is molluscs in shallow, nearshore waters. There is therefore the potential for co-existence between lagoon-type aquaculture and marine energy (Buck and Langan, 2017), such as tidal range power lagoons.

3.2.14 Aquaculture and fisheries

Akyol et al. (2019) investigated the interaction between finfish aquaculture and fisheries activities, to ascertain conflicts stemming from the adverse social interactions. The study focussed on the perspective of both local fishermen and fish farmers. The researchers interviewed small-scale fishers, face to face, in 48 randomly selected fish farms, 28 fishery cooperatives, and 33 fishing ports, located close to aquaculture sites in the Aegean Sea. Results showed that about three-quarters of small-scale fishers had a problem with sea-cage fish farms, and almost half of the fish farmers had issues with small scale coastal fishers. The latter highlighted the main problems as the pollution caused by finfish farms, the space limitation for fishing, recreational fishers, and net damage caused, in particular by dolphins and monk seals.

Similar research, carried out in Portugal, investigated fishing communities' perceived impact of an finfish aquaculture pilot project off the Armona coast (Ramos et al., 2015). A total of fifty fishermen were interviewed and small-scale fishers claimed they were the most affected by the establishment of offshore aquaculture. A decrease in the available area for fishing was perceived as a negative effect of finfish aquaculture development together navigational disturbance associated to longer routes to reach fishing grounds which correspond to increased time at sea and fuel costs.

In another study, multi-use conflicts associated with finfish and shellfish aquaculture were investigated in Ireland and The Netherlands (Steins, 1998). The researcher claims, in line with the finding of Ramos et al. (2015), that the development of aquaculture in the Irish coastal zone resulted in a number of conflicts over the access to marine space, mostly associated with fishing grounds. In fact, several locally important shellfish, lobster and white fish grounds were allocated to aquaculture production and fishers felt they lost territory over aquaculture producers.

3.2.15 Aquaculture and tourism and recreation

Either inshore or offshore aquaculture developments may generate potential conflicts with stakeholders representing other key segments of the recreational sector.

Potential constraints may arise for inshore aquaculture due to competition for space and resources with recreational activities and coastal aesthetics (MMO, 2013a; Naylor and Burke, 2005). A study undertaken in Cyprus (Stephanou, 1999), suggested potential conflicts between aquaculture and tourism include:

- The tourism industry may compete for the use of land and sea space;
- Visual impacts of aquaculture installations close to the coastline;
- Navigational hazards between leisure boats and aquaculture structures; and,
- Conflict between aquaculture farms and other user groups e.g. recreational fishing, scuba diving.

Visual impacts can be a major barrier to social acceptance of the offshore installations (Ladenburg and Lutzeyer, 2012; Wood et al., 2017). Steins (1998) states that the Irish tourism industry perceives that finfish aquaculture conflicts with tourism development since aquaculture installations located in front of beaches and in scenic areas, are considered to clash with the natural character of Ireland's rural areas. Additionally, aquaculture development has restricted access to marine leisure activities, such as angling, sailing and windsurfing (Steins, 1998).

Conversely, there are examples from other European countries (Spain, Italy, Slovenia, Greece and Malta) where aquaculture and tourism can be harmoniously combined. So, for example, shellfish and finfish farmers take tourists to visit their farms for educational and recreational purposes, e.g. fishing and diving (Depellegrin et al., 2019). In other cases, however, fish farmers complained about the increase in recreational fisheries occurring due to small scale fishers getting tourism licenses to work as a charter for recreational fishers (Akyol et al., 2019).

3.2.16 Aquaculture and oil and gas energy

Research and trials are not only limited to the feasibility of combining aquaculture and renewable energy arrays, but encompass other offshore energy production structures, such as oil and gas platforms. In the Gulf of Mexico (GoM), for instance, trials of multi-use systems in offshore areas started in the 1990s (Kaiser and Chambers, 2017).

An economic feasibility study regarding the use of oil and gas structures in the GoM for aquaculture (Kaiser et al., 2011), concluded that co-location was not a cost-effective venture. The major hurdles encountered by the oil and gas operators were associated with liability and decommissioning of the structures (Kaiser et al., 2011). Average costs of decommissioning a four-pile platform in shallow waters lie between $US 1.5 and $US 2.5 million (Kaiser and Pulsipher, 2008). Liability can equally be a significant burden for both the aquaculture operator and the original owner of the platform, especially in cases where the platform is destroyed or severely damaged (Kaiser et al., 2011; Kaiser and Pulsipher, 2008).

Potential advantages envisaged for the aquaculture operators include opportunities for job creation and abated costs arising from the oil and gas platform, that will reduce the number of trips required to the offshore farm as a result of the increased farm supply vessel payload (Jin, 2008 as cited in Kaiser et al., 2011). The farm will also benefit from the 24 hours on-site surveillance and monitoring of offshore platforms, which constitutes a deterrent against vandalism and theft (Kaiser et al., 2011).

Attempts to combine offshore platforms and finfish aquaculture have also been investigated in in the Caspian Sea, Russia in 1987. Nonetheless, in this case the high operating costs led to the cessation of this venture at a very early stage (Buck and Langan, 2017).

3.2.17 Aquaculture and defence

Any new development within areas considered as strategic important for the defence sector needs approval of the Ministry of Defence (MoD). New developments which include fixed infrastructure which might create navigational risks and potentially obstruct defence activities may therefore be constrained within these areas. (Welsh Government, 2019, pp. 85–87). Thus, all the types of aquaculture which include fixed infrastructure (e.g. finfish, seaweed, bivalve -cage/rope-systems) can be considered as a likely constraint. Mussel bed relaying, which is currently the dominant form of aquaculture within Welsh waters (Hambrey and Evans, 2016), can be considered as compatible with defence activities, as long as they do not interfere with strategic defence interests. Hence, they are likely subject to temporal restrictions on access during operational test and military training periods (Welsh Government, 2019, pp. 85–87). At present, however, evidence is lacking from literature, either specific to the Welsh context or at UK or international level with regards to the impact of actual or potential sector-sector interaction.

3.3 Summary of key findings and marine planning considerations

The knowledge gathered through the evidence-based literature review suggests that there are resource areas in the Welsh waters where the concept of spatial and temporal multiple use of the sea can be sustainably developed. This could allow for the identified focal marine sectors and other sectors to co-exist or co-locate. It should be noted the majority of the studies presented in this review are desk-studies coming from a U.K. or international perspective; there is a limited availability of evidence produced for the Welsh context, hence in-country studies and more ad-hoc research and evidence are required.

Drawing on the literature review findings, the sectors which present greater opportunities for co-existence, in particular with respect to co-location, are aquaculture and offshore low carbon energy (OWFs mostly). This is given the case studies identified and investment into research and innovation of these sectors in recent years. This finding aligns with the objective of the WNMP and the sectors identified in the WNMP as sectors with the highest potential for sustainable development (Welsh Government, 2019a, p. 25).

From a socio-economic angle, the co-location in Welsh waters of shellfish and/or macroalgae aquaculture installations with low carbon energy arrays, present several advantages: lower operating costs and increased competitiveness of the commercial aquaculture sector. Additional societal benefits for Welsh coastal regions include additional jobs which are not restricted to farmers but encompass the wider community. For example, income diversification opportunities for small scale fishers (Syvret et al., 2013).

However, spatial co-existence between aquaculture resources and tidal stream and wave energy resources) in Welsh waters, at present, is considered unlikely, hence no conflicts between key stakeholders are currently expected.

Marine aggregate resources are widely distributed throughout Welsh waters and the sector is set to play a strategically important role in the Welsh economy. The demand for marine aggregates for infrastructure projects is expected to increase. Aggregate resources will also supply material for soft engineering defences (such as beach replenishment), and for coastal flood and erosion defence. It is expected that "*the use of offshore aggregates resources could support larger extraction licences with longer-term duration*" (Welsh Government, 2019, p. 76). This anticipated sectoral expansion will necessitate careful consideration of co-existence, by minimising possible spatial conflicts with other users of the maritime zone which may arise due to existing spatial and/or temporal occurrence, such as commercial fisheries, port and shipping routes, oil and gas platforms.

It should be noted that these sector-sector interactions do not just represent an opportunity for marine sectors and coastal communities to benefit from but also potential sources for conflicts. There is evidence at UK and international level that, for example if spatial interaction occurs between recreation, aquaculture and fisheries sector, conflict between interested parties is a possibility. As such, strategies and approaches should be developed that take into consideration the diverse interests of all parties involved and is aimed at reducing or mitigating them. Moreover, any new development which incorporates fixed structures and are envisioned in areas of importance for the defence sector are subject to approval of the Ministry of Defence, hence development might be constrained due to conflicting interests.

The relationship between society and the maritime environment has come to the forefront of international policy development and scientific research. In particular, the need to understand and account for the social as well as cultural components of this relationship has gained momentum in recent years in science (Lacroix et al., 2016; McKinley et al., 2019; Twomey and O'Mahony, 2019) and policy (e.g. WFGA). Evidence from marine planning documents and frameworks indicates that marine and coastal governance is developing globally towards more participatory, integrated and increasingly holistic approaches (Twomey and O'Mahony, 2019). At EU level, the "Roadmap for Maritime Spatial Planning: Achieving Common Principles in the EU" (European Commission, 2008) state that stakeholders should be involved at each stage of the marine spatial planning process, from the development of marine and coastal plans to the process of monitoring and review. This is key not only because of economic and environmental drivers but also to keep track of possible social impacts, thereby balancing different outcomes). Likewise, the WMNP consider early engagement with stakeholders, local communities and public authorities a requirement to facilitate opportunities for sector- sector co-existence or co-location, where possible (Welsh Government, 2019). Integrative, and participatory approaches are crucial to foster good governance for marine planning.

4 Spatial interaction appraisal for WNMP focal and non-focal sectors

The spatial extent of resources for the RA of focal sectors have been appraised for spatial interaction potential with a range of other sectors/activities within Welsh waters. For each focal sector, The Welsh Government has been working in consultation with a panel of expert stakeholders, on determining if there is a 'Case for Proceeding' to seek to develop strategic resource areas (SRA). The Case for Proceeding is intended to support the respective focal sector safeguarding policy and the implementation of the policy as appropriate.

Following the evidence review, the interaction between focal sectors and other marine activities have been systematically appraised for spatial interaction potential in terms of opportunities or potential constraints. The activities and definitions are in Appendix 1 and the focal sectors considered are listed as follows:

- Marine aggregates;
- Energy – Low Carbon: Wave energy;
- Energy – Low Carbon: Tidal stream (fixed and floating); and,
- Aquaculture for finfish (cages), shellfish (bottom cultivation, rope, trestles) and macroalgae (rope). Resources in the mapping distinguish between seabed resources. bottom cultivation of shellfish, and water column resources e.g. rope cultivation of shellfish.

The range of other sectors/activities considered are:

- Energy – Low Carbon: Tidal range energy;
- Energy – Low Carbon: Offshore wind energy;
- Energy – Oil and gas;
- Fisheries (mobile and static) – indicative only;
- Ports and shipping;
- Subsea cables;
- Surface water and wastewater treatment and disposal;
- Dredging and disposal;
- Defence; and,
- Tourism and recreation.

Due to the lack of published evidence regarding impacts of actual or potential sector-sector interactions, tidal range energy interaction with the focal sectors of marine aggregates, tidal stream energy and wave energy are not considered further. There is consideration (in Section 4.4) of aquaculture and tidal range energy interaction due to the potential risk of interaction for these sectors.

The appraisal has considered findings of the Evidence Review (Section 3), and the evidence and conclusions of the Case for Proceeding (Welsh Government, *in prep.*) for each of the focal sectors of wave energy, tidal stream energy and aquaculture in Welsh waters.

Screening the long list of activities/sectors for potential spatial interaction, involved formulating and answering questions about the likelihood/ possibility of spatial interaction, and spatial co-existence between the focal sectors and other marine sectors/activities. The questions asked were:

Q1. Are the activities likely to interact (marked as possible, likely or unlikely)? If so, how do they interact?

Q2 Can the structures/activities physically co-exist in space, recognising activities could occur in the same space yet at different times (possible, likely or unlikely)?

During the screening work, there has been consideration of existing consenting/regulatory requirements that govern sectors/activities and hence which may affect the potential and likelihood of sectors interacting spatially. It is recognised that changes or updates to these consenting/regulatory requirements in the future, may change the interactions and could even enhance opportunities for co-existence and co-location of sectors/activities.

The outcomes of the screening exercise are shown in Table 4.1 to Table 4.6, with accompanying rationale. Likely or possible co-existence between activity is shown and the application of the criteria has been based on expert judgement and available evidence at the time of writing. References to locations and activities in Wales has been included for context. Future potential for co-existence has been factored in where appropriate. If co-existence is considered unlikely then the rationale has been provided.

It is recognised that sequencing/timing of the activities/sectors can influence co-existence potential (or lack thereof). It is possible that some activities can occur at different times yet in the same location. With available information, it has been possible to highlight temporal constraints as an issue in the following sections, but it has not been discussed comprehensively. This is mainly because of uncertainty over the timing of future activities as well as considering timing variations for existing/on-going activities.

To integrate the screening exercise with the outcome of the Evidence Review (Section 3) and help visualise spatial interactions (constraints or opportunities), we have included summaries and maps for each sector. These are for marine aggregate resources (Section 4.1 and Table 4.1); low carbon energy resources: tidal stream energy (Section 4.2 and Table 4.2) and wave energy resources (Section 4.3 and Table 4.3). Also, aquaculture seabed and water column resources, covering shellfish aquaculture on the seabed (Section 4.4.1 and Table 4.4), rope-based aquaculture (Section 4.4.2 and Table 4.5) and finfish aquaculture (Section 4.4.3 and Table 4.6). There are examples for intersection where spatial and temporal conflicts and constraints could arise and examples for co-existence for intersecting activities/sectors.

4.1 Marine aggregate resources

A summary of interaction appraisal for marine aggregates and other sectors is shown in Table 4.1.

Spatial co-existence of marine aggregates and tidal stream energy developments, and marine aggregate and wave energy development is considered unlikely (Table 4.1). The leasing of seabed areas is typically for one activity. Whereas fixed infrastructure of the tidal stream and wave devices and associated cabling, generally preclude safe aggregate extraction.

It is, however, recognised that the sequencing/timing of the activities can have a bearing on co-existence. For instance, if an aggregate resource is fully exploited in a licenced seabed area and the licenced area is relinquished then the seabed could be made available for wave or tidal stream infrastructure.

Mapping indicates areas off the north coast of Anglesey, off the Pembrokeshire coast and in the Inner Bristol Channel, where resources for marine aggregates and tidal stream resources spatially overlap (

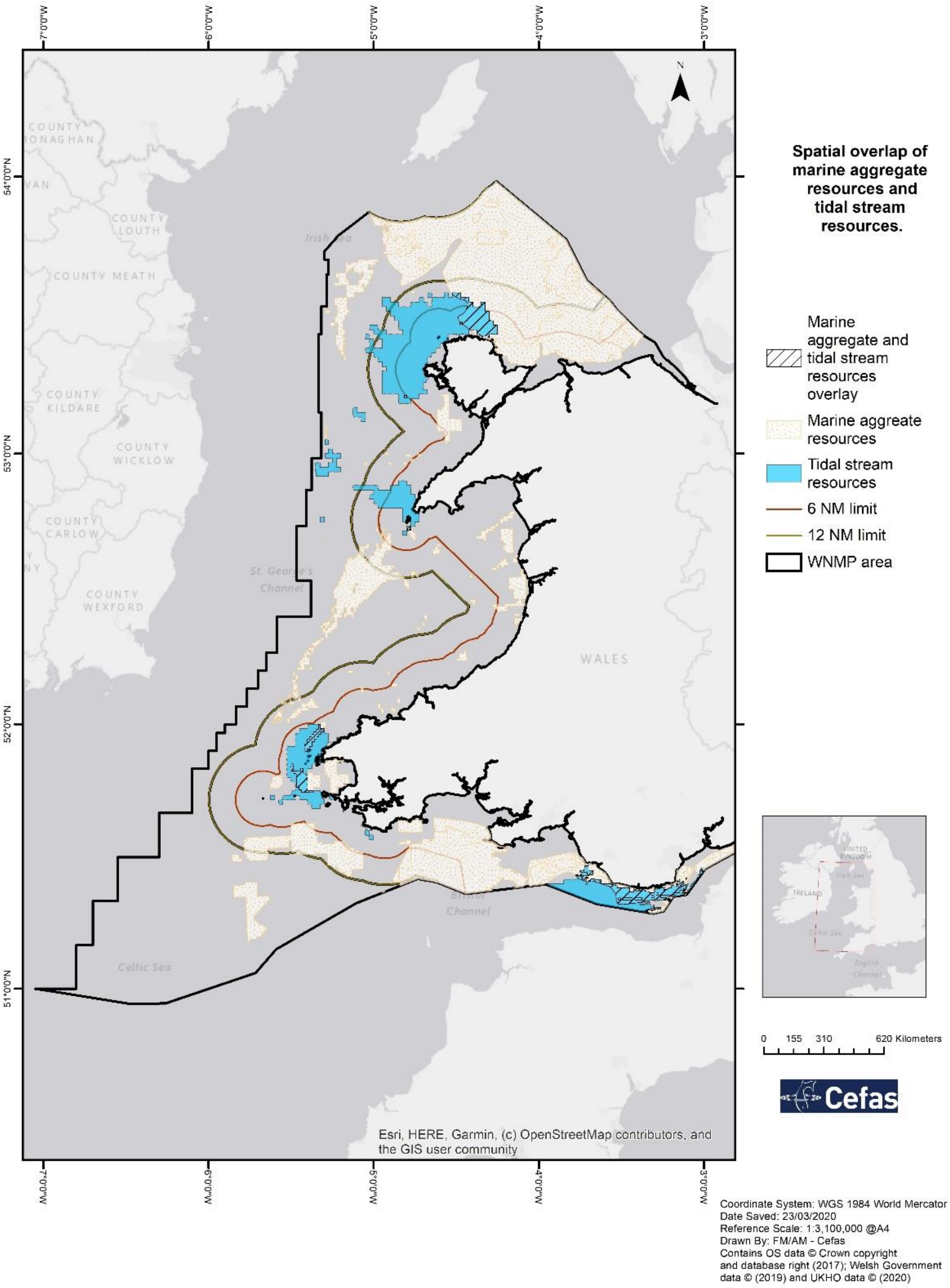

Figure 4.1). It is unlikely that these two sectors could temporally co-exist because floating or seabed mounted energy devices would effectively preclude access to the aggregate resource.

However, spatial and temporal management could be applied to sequence the activities of each sector. Such future planning would benefit from dialogue between the respective sectors and their associated regulators. Having these resource overlaps mapped (Figure 4.1) and considering the interactions (Table 4.1) will help to target this dialogue on forward-looking, proactive and spatial planning. This resource overlap and sector interactions will also be important for the planning authority when developing criteria for the development of any SRA (and applying safeguarding policy) for these two sectors.

Areas to the west and south-west of Pembrokeshire are further identified on the maps as areas where marine aggregate and wave energy resources overlap (Figure 4.2). As for tidal stream energy, this could mean a potential issue for future use and so the same considerations apply in terms of forward-looking, proactive and spatial planning.

Spatial co-existence of marine aggregates with aquaculture is considered unlikely at present. This applies to resources for seabed-based aquaculture and water-column aquaculture e.g. rope grown seaweed. For safety and operational reasons, there is typically a separation of aggregate extraction in licensed areas and sites for aquaculture. Mapping indicates areas all around the Welsh coastline where marine aggregate resource and aquaculture on the seabed and/or in the water column resources overlap (Figure 4.3). Whilst the operational characteristics of the two sectors precludes co-existence at the same time, forward-looking, proactive and spatial planning approaches could be applied to consider options for sequencing activities within any area of resource overlap.

If the aquaculture sector in Welsh inshore and offshore waters were to expand, there could be opportunity for co-existence. This is given the flexibility in siting aquaculture locations relative to aggregate resource and extraction, to optimise spatial co-existence. Mapping resource overlap (Figure 4.3) and examining sector interactions (Table 4.1) will be important for the planning authority when developing criteria for the development of any SRA (and applying safeguarding policy) for these two sectors. It will also help facilitate dialogue between the sectors and their regulators.

With regards to the spatial overlap between focal sectors, the marine aggregate resources covers an area of ca. 9,675 km^2, of which ca. 4.45% (ca. 430 km^2) overlaps with tidal stream resources, ca. 9.8% (ca. 950 km^2) with wave energy resources, ca. 13.75% (ca. 1,330 km^2) with seabed aquaculture resources and ca. 29.2% (ca. 2,824 km^2) with water column aquaculture resources.

Spatial co-existence of marine aggregates with subsea cables is considered unlikely (Table 4.1; Figure 4.4). Currently for consenting, safety and operational reasons, aggregate extraction is usually separate from subsea cables, offshore wind farms and the associated cable routes (Figure 4.4). Physical interaction between the resource and cable infrastructure is typically avoided because of risks for operations and mechanical integrity (for the cables and dredgers). Mutually acceptable proximity limits and proximity agreements can be used by aggregate and subsea cable operators, on a case-by-case basis, to keep the activities/infrastructure separate and thus minimise spatial conflict[22]. Whilst the operational characteristics of the two sectors precludes co-existence simultaneously, forward-looking, proactive and spatial planning approaches could be

[22] Source: TCE and BMAPA Good Practise Guidance https://bmapa.org/documents/BMAPA_TCE_Good_Practice_Guidance_04.2017.pdf [Last access: 06/04/2020].

applied to consider options for sequencing activities within any area of resource overlap. Mapping resource overlap and examining sector interactions (Table 4.1), will be important for the planning authority when developing criteria for the development of any SRA (and applying safeguarding policy) for these two sectors. It will also help facilitate dialogue between the sectors and their regulators.

As discussed in section 3 and indicated in Table 4.1, there is potential for spatial co-existence of marine aggregates with several sectors, including commercial fishing and shipping (Figure 4.5 and Figure 4.6, respectively). This is achieved primarily through spatial zoning and mutual co-operation between sectors. This could mean an opportunity for optimising spatial co-existence and should be considered as part of the SRA determination process. Mapping resource overlap (Figure 4.5 and Figure 4.6) and sector interactions (Table 4.1) will be important for the planning authority when developing criteria for the development of any SRA (and applying safeguarding policy) for these sectors, and will help facilitate dialogue between the sectors and their regulators.

It is recognised in the summary in Table 4.1 and section 3.2, that marine aggregate resource will become available once the resource is extracted, hence there is a flexibility associated with the extraction history.

Due to its potential to create a navigational barrier, new marine aggregate dredging in Cardigan bay and off the south-west coast of Pembrokeshire would need permission from the Ministry of Defence (Figure 4.7).

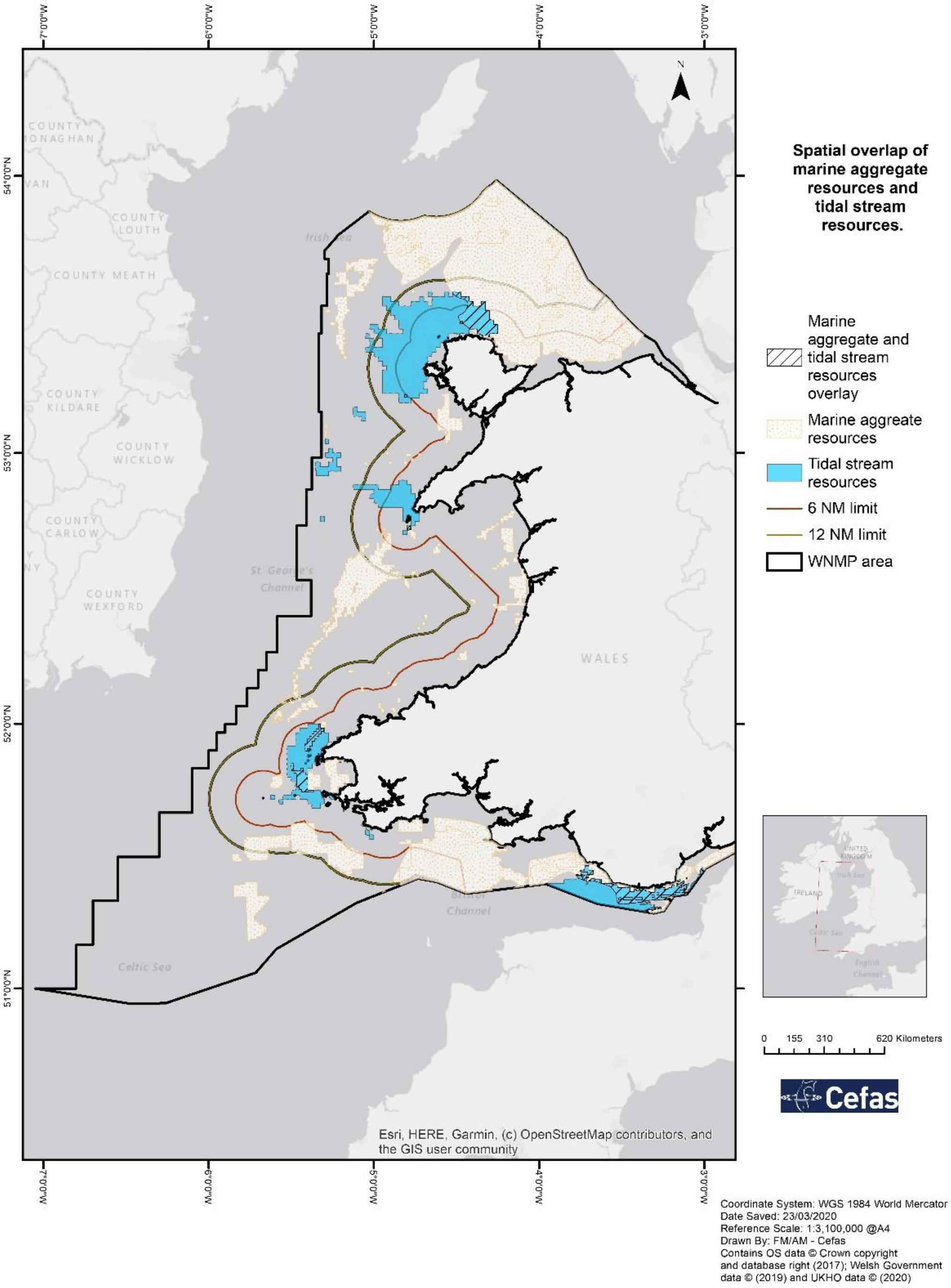

Figure 4.1: Spatial overlap of marine aggregate and tidal stream resources.

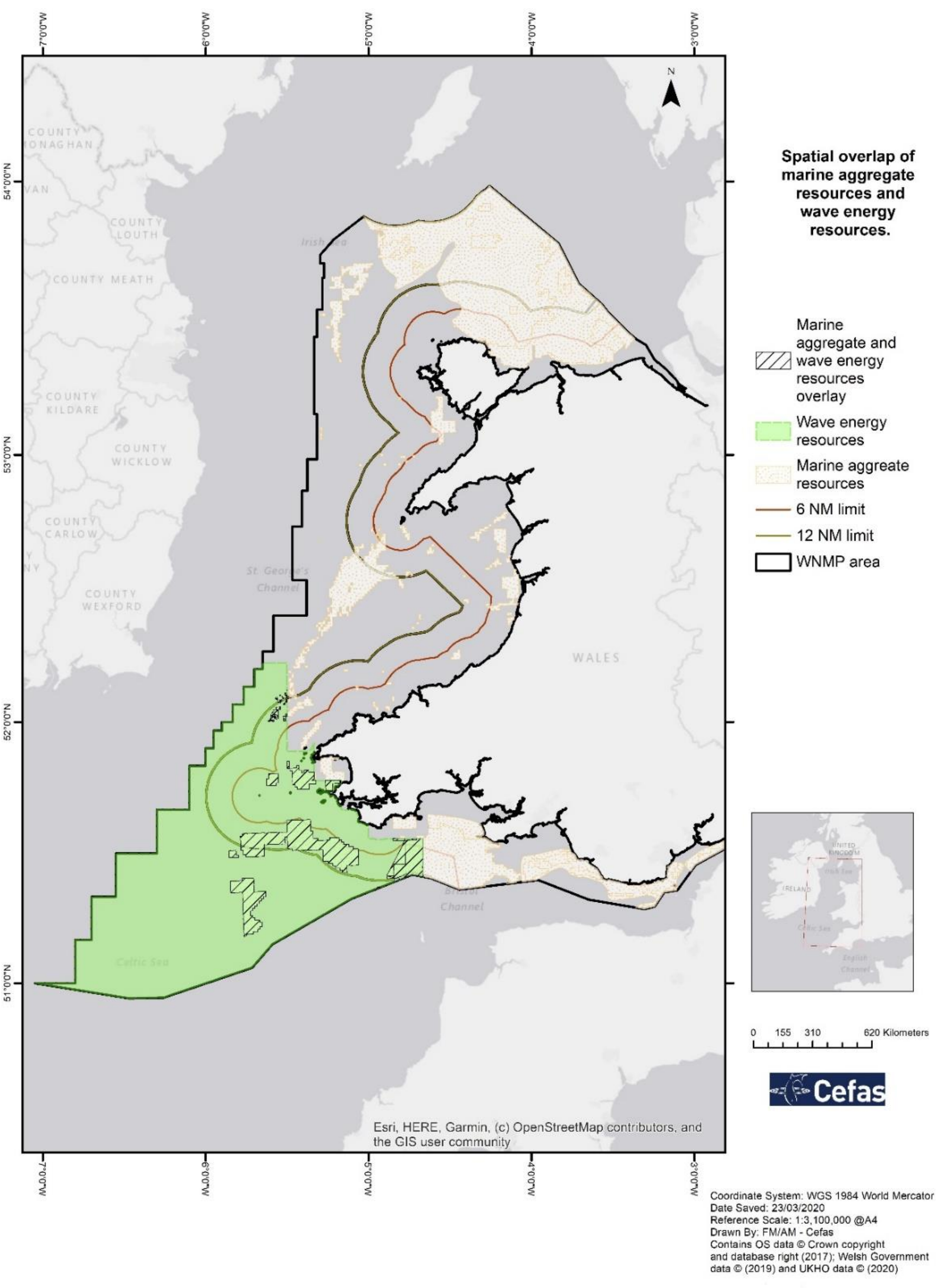

Figure 4.2: Spatial overlap of marine aggregate and wave energy resources.

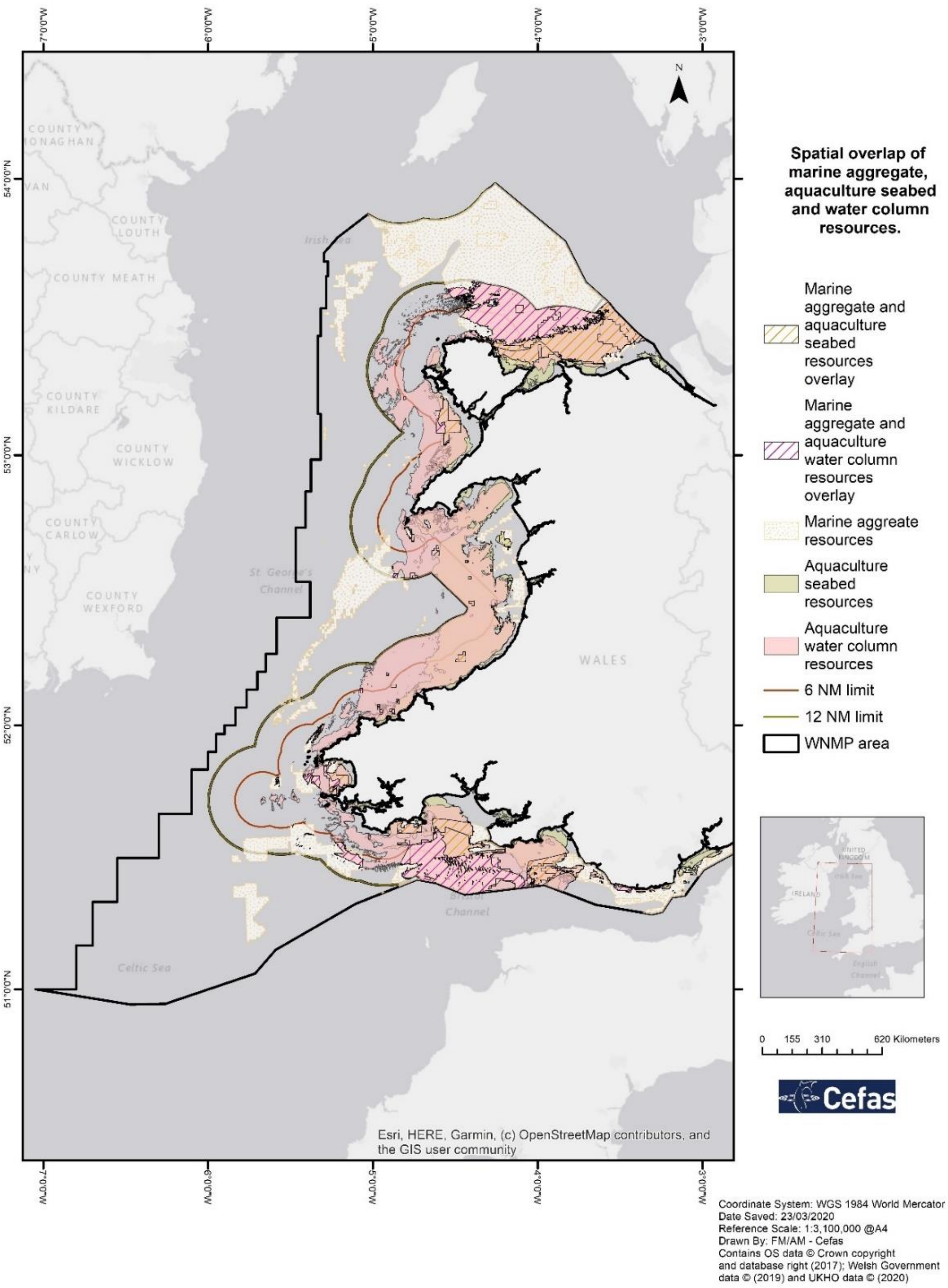

Figure 4.3: Spatial overlap of marine aggregate resources and resources for seabed and water column aquaculture.

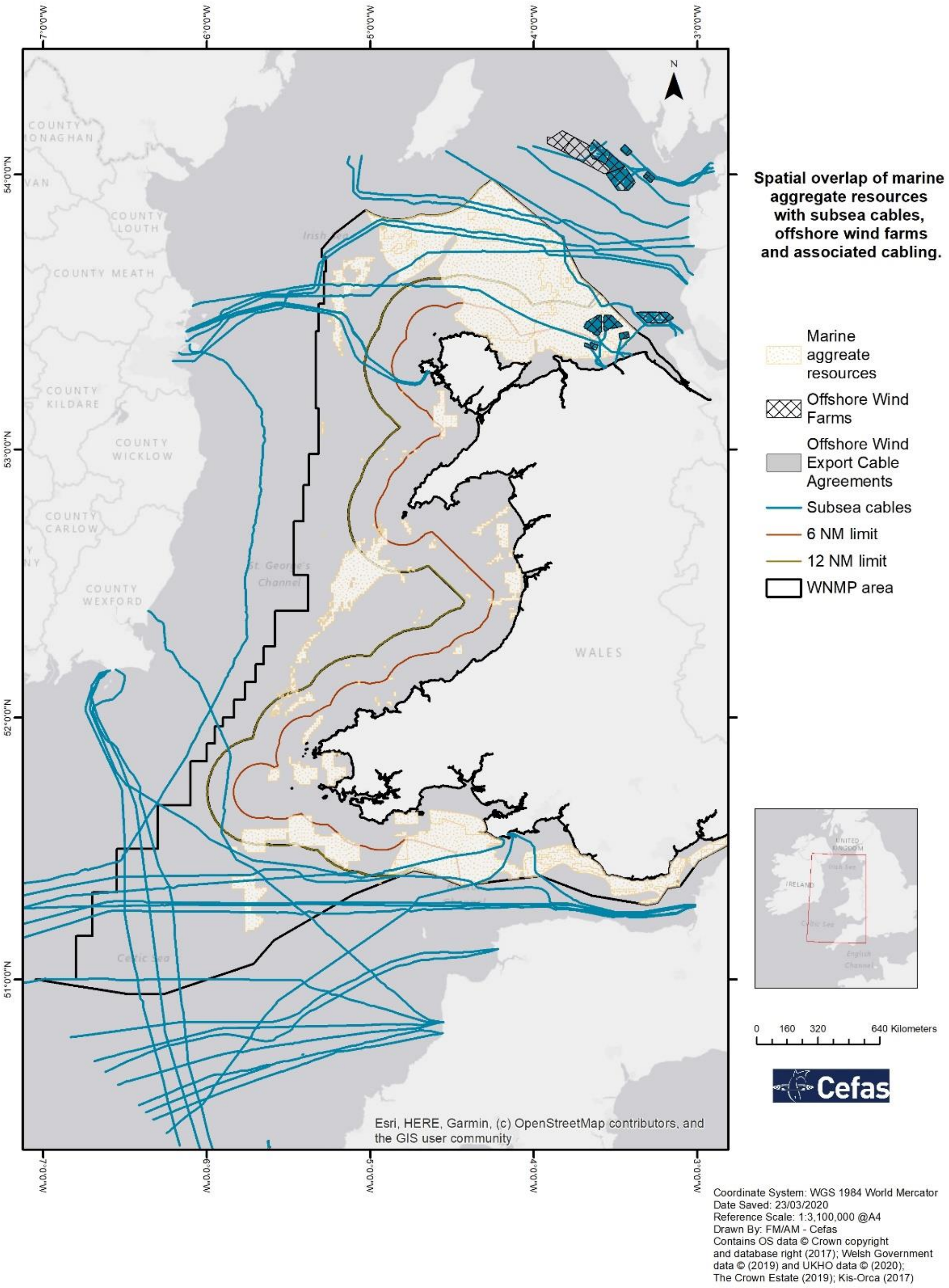

Figure 4.4: Spatial overlap of marine aggregate resources with subsea cables and with consented offshore wind farms (as of 2017) and associated export cabling.

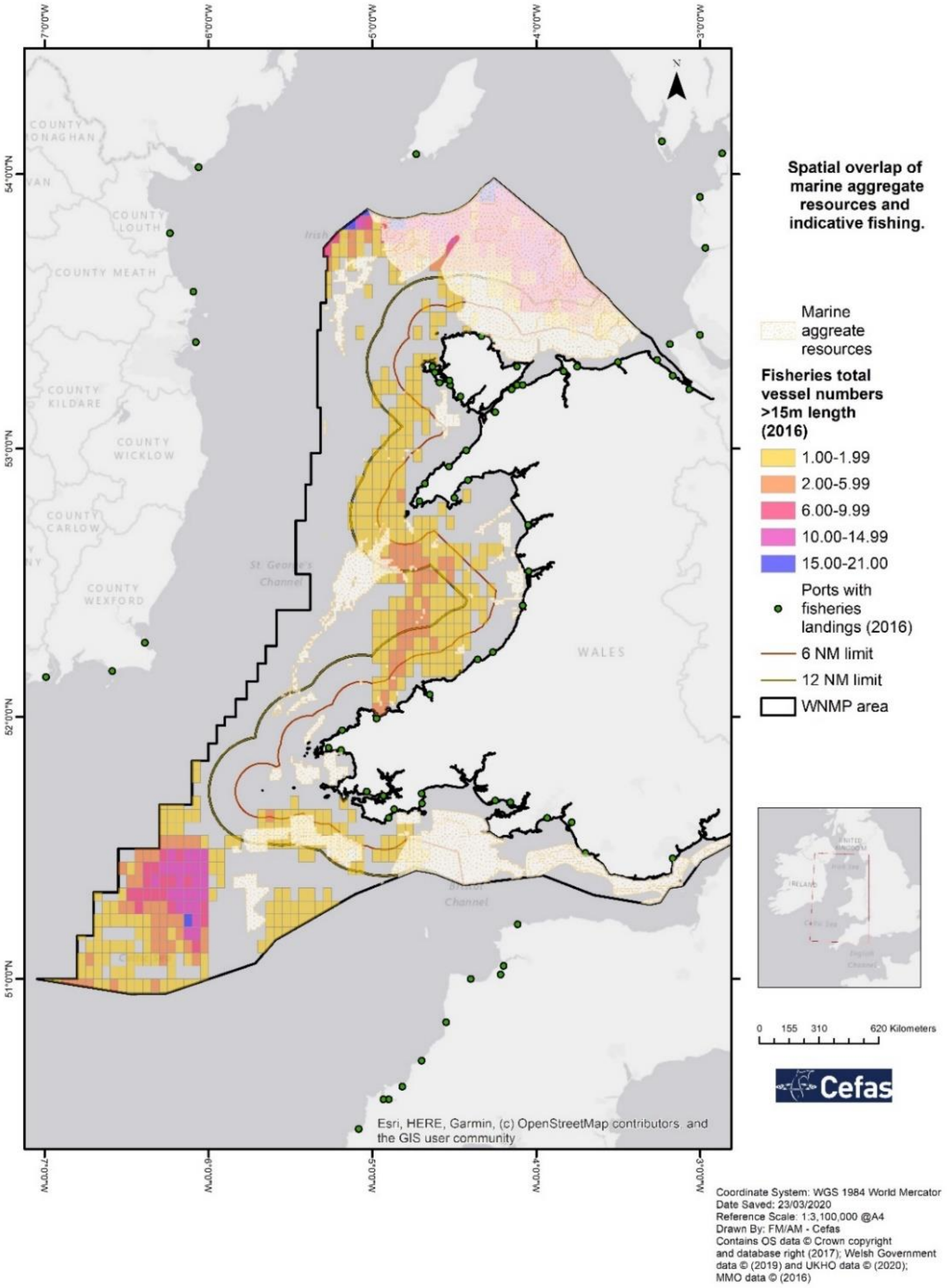

Figure 4.5: Spatial overlap of marine aggregate resources and fisheries[23].

The map is indicative only and shows ports with recorded landings (in 2016) and total vessel numbers (≥15m vessel length) recorded per ICES sub-rectangle[24].

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[23] Fishing is considered a mobile activity that could occur in many locations within a given season/year, and over successive years. Data for the activity of vessels <15m, notably the inshore commercial fleet working in the 0-6NM limit, is not represented in the maps due to data availability and limitations. However, the inshore nature of the fisheries and associated vessel activity, are important considerations for spatial-temporal interaction with the focal and non-focal sectors discussed.

[24] There are recognised caveats in the process used to generate fishing activity data within ICES sub-rectangles around Wales and England. The process uses Vessel Monitoring System data and logbook data for recorded landings, to generate indicative fishing activity data.

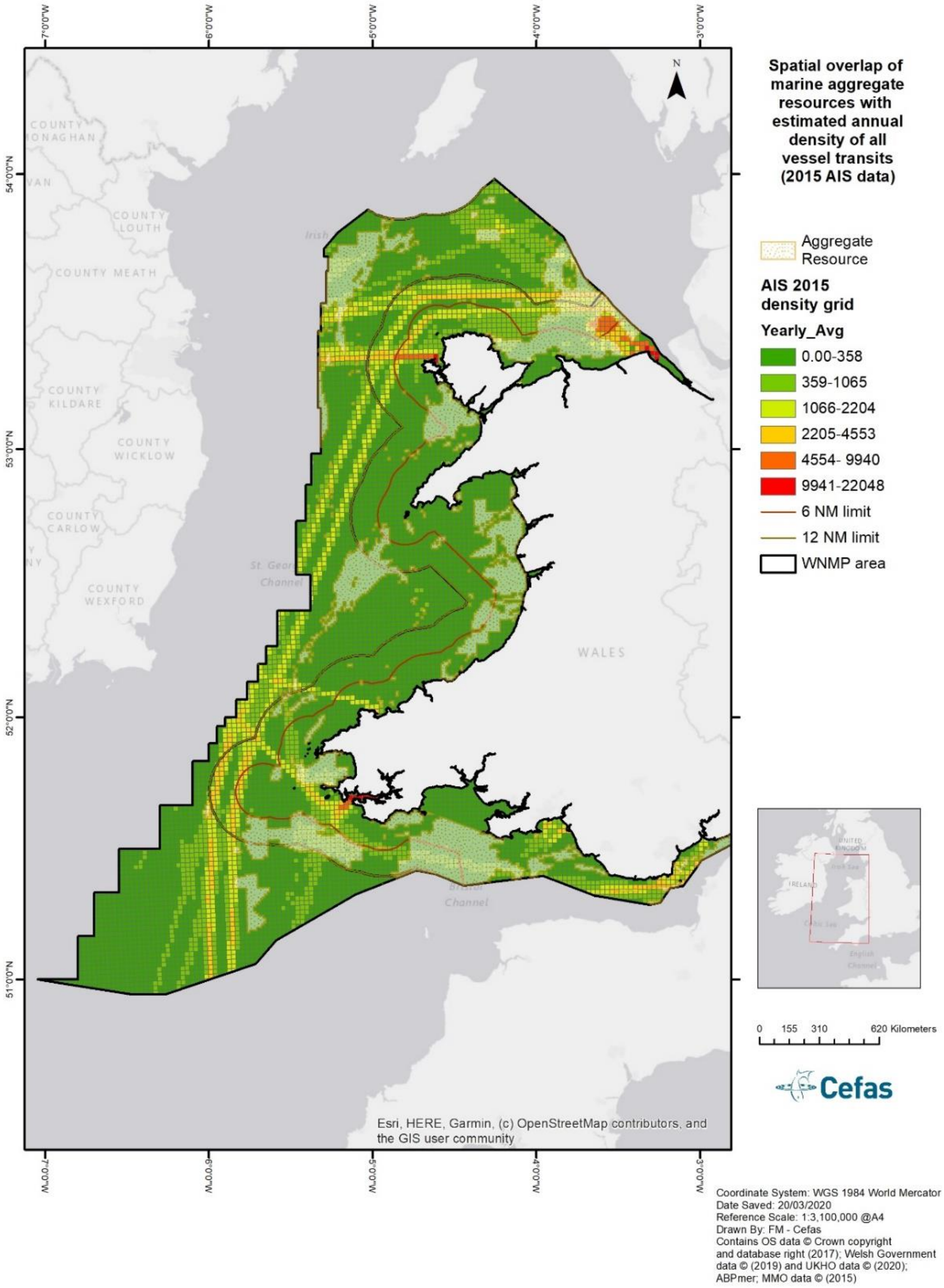

Figure 4.6: Spatial overlap of marine aggregate resources and shipping.

Shipping activity represented by estimated annual density of all vessel transits from Automatic Identification Systems data (available in 2015).

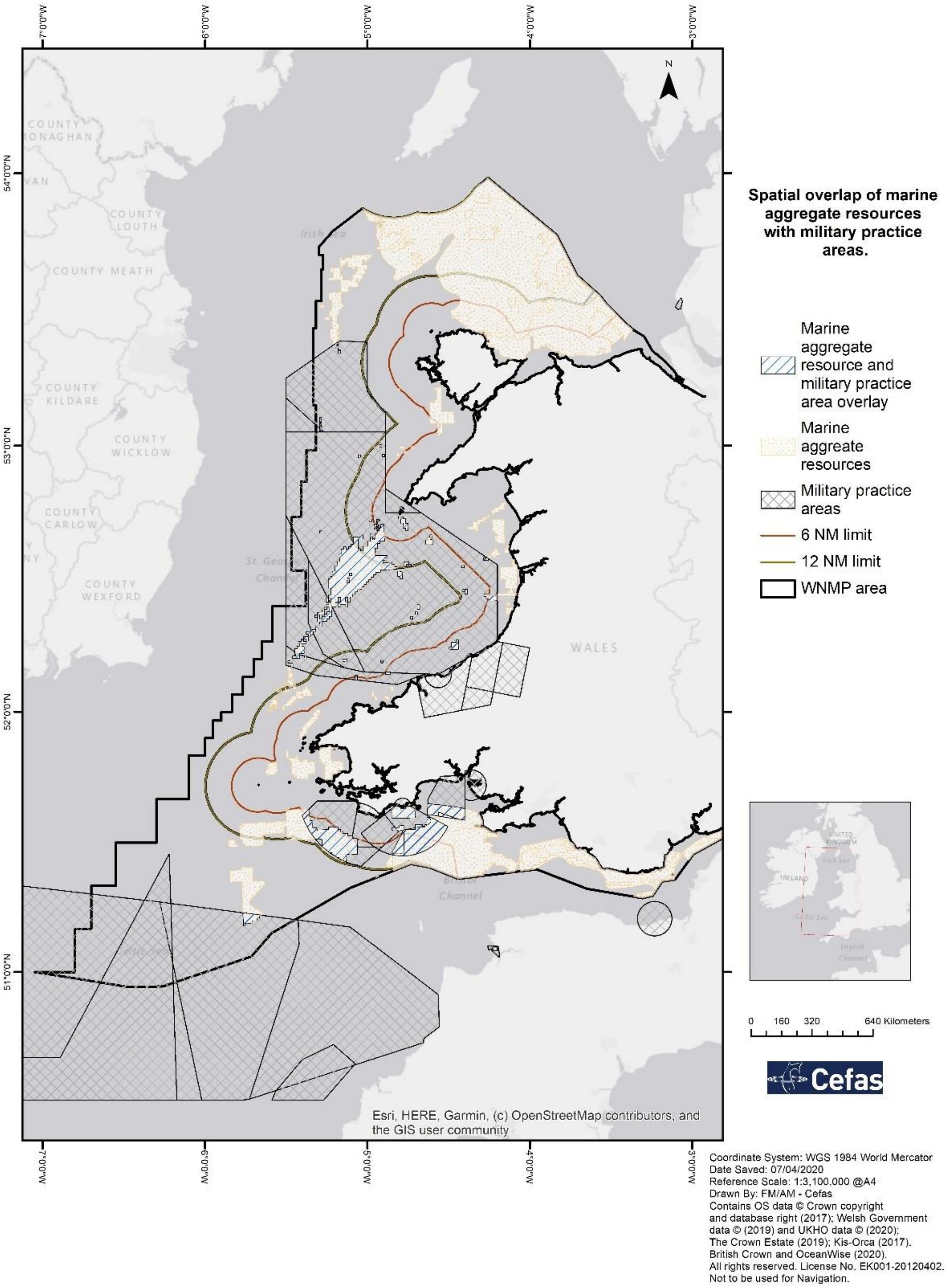

Figure 4.7: Spatial overlap of marine aggregate resources and military practice areas.

Table 4.1: Summary of marine aggregate interaction with other focal and non-focal sectors.

Marine Plan Sector	Activity/Sector	Are the two activities likely to interact spatially (possible, likely or unlikely)? If so, how do they interact?	Can the structures/activities physically co exist in space, recognising activities could occur in the same space, yet at different times (possible, likely or unlikely)?[25]
Energy	Wave **Refer to Figure 4.2 for the indicative sector interaction map.**	**Possible**– Resources for aggregates and wave energy coincide to the south and south-west of Pembrokeshire.	**Unlikely** – Currently for consenting, safety and operational reasons, aggregate extraction is typically separate from wave devices and associated infrastructure, present on the sea surface/ water column.
	Tidal stream (fixed and floating) **Refer to Figure 4.1 for the indicative sector interaction map.**	**Possible** – Resources for aggregates and tidal stream energy coincide in several areas: north coast of Anglesey, south-west Pembrokeshire, Bristol Channel; off the coast of Cardiff round to Porthcawl.	**Unlikely** – Currently for consenting, safety and operational reasons, aggregate extraction is currently separate from tidal stream devices and associated infrastructure, present along or on the seabed, or in the water column.
	Wind turbines (fixed and floating) Offshore wind farms (fixed and floating) **Refer to Figure 4.3 for the indicative sector interaction map.**	**Possible** – Resources for aggregates overlap with wind energy resource areas around all of Welsh waters. Notably, existing OWF and proposed extensions sited off the North Wales coastline are adjacent to aggregate resource areas and licensed extraction areas.	**Unlikely** – Currently for consenting, safety and operational reasons, aggregate extraction is usually separate from fixed/floating turbines (and turbines together in a wind farm), where the structures exist at the sea surface, through the water column and with a base that can be atop or within the seabed (if not floating structure). However, if marine aggregates were to occur, cease and then the seabed area made available for wind energy, potential exists for occupation of same space at different times.
	Oil and Gas (incl. submarine pipelines and other infrastructure)	**Likely** – Resources for aggregates off the North Wales coast, within Liverpool Bay, overlap with oil and gas infrastructure and petroleum licensing areas.	**Unlikely** – Consenting, safety and operational reasons including asset protection (oil and gas rounds), aggregate extraction separated from oil and gas structures atop the sea surface and pipelines/well heads etc on/along the seabed.
	Miscellaneous (incl. overhead power lines, power station, substations)	**Unlikely** – Marine aggregate extraction at sea, whereas the structures are coastal based.	**Possible** – Maritime occurrence of aggregate dredging and use of established navigational routes for vessel transits. Whereas miscellaneous structures present at the coast or not sited directly in footprint of the licensed area.

[25] Areas of marine aggregate resource will become available once the resource has been full exploited, hence there is flexibility in spatio-temporal associated with extraction history.

Marine Plan Sector	Activity/Sector	Are the two activities likely to interact spatially (possible, likely or unlikely)? If so, how do they interact?	Can the structures/activities physically co exist in space, recognising activities could occur in the same space, yet at different times (possible, likely or unlikely)?[25]
Aquaculture	Bottom culture – shellfish **Refer to Figure 4.3 for the indicative sector interaction map.**	**Unlikely** – Aggregate resources overlap with resources for seabed aquaculture (shellfish bottom cultivation), in several areas: north-east Anglesey, off North Wales, south Pembrokeshire, and Carmarthen and Swansea Bay. However, interaction is unlikely since the activities typically each occupy a relatively small footprint.	**Unlikely** – Safety and operational reasons, aggregate extraction is usually separate from shellfish cultivated on the seabed. In the future if bottom culture of shellfish expands, there is considered to be flexibility in the location of the activity relative to marine aggregate resources.
	Cage culture – finfish **Refer to Figure 4.3 for the indicative sector interaction map.**	**Possible** – Aggregate resources overlap with resources for cage-based finfish cultivation in locations such as off the north coast and south-west of Anglesey, south Pembrokeshire, and Carmarthen and Swansea Bay.	**Unlikely** – Safety and operational reasons, aggregate extraction is usually separate from finfish culture in cages. Commercial finfish aquaculture in cages is not occurring in Wales at present. In the future if cage cultivation of finfish expands which could be offshore then there is considered to be flexibility in the location of the activity relative to marine aggregate resources.
	Rope culture – shellfish **Refer to Figure 4.3 for the indicative sector interaction map.**	**Possible** – Aggregate resources overlap with resources for rope culture of shellfish, for instance, off the north coast and south-west of Anglesey, south Pembrokeshire, and Carmarthen and Swansea Bay.	**Unlikely** – Safety and operational reasons, aggregate extraction is usually separate from shellfish rope culture. In the future if rope cultivation of shellfish expands potentially offshore, there is likely to be flexibility in the location of the aquaculture activity relative to marine aggregate to enable co-existence potential.
	Rope culture – seaweed **Refer to Figure 4.3 for the indicative sector interaction map.**	**Possible** – Aggregate resources overlap with resources for rope culture of seaweed, for instance, off North Wales coast, south-west of Anglesey, around the Llŷn Peninsula, south Pembrokeshire, Carmarthen and Swansea Bay and coastal to Cardiff.	**Unlikely** – Safety and operational reasons, aggregate extraction is usually separate from seaweed rope culture. In the future if rope cultivation of seaweed expands potentially offshore, there is likely to be flexibility in the location of the aquaculture activity relative to marine aggregate to enable co-existence potential.
	Trestle culture - shellfish	**Possible** – Aggregate resources overlap with resources for trestle-based shellfish cultivation within the Inner Bristol Channel, (coastal from Cardiff to Newport).	**Possible** – Spatial separation of aggregate extraction areas at sea and intertidal nature of trestle cultivation.
Fisheries	Mobile mid-water gear	**Likely** – Areas fished with mobile mid-water gear could coincide with suitable aggregate resources.	

Marine Plan Sector	Activity/Sector	Are the two activities likely to interact spatially (possible, likely or unlikely)? If so, how do they interact?	Can the structures/activities physically co exist in space, recognising activities could occur in the same space, yet at different times (possible, likely or unlikely)?[25]
	Refer to Figure 4.5 for the indicative sector interaction map for fisheries (based on 2016 fishing activity of >15m vessels, without division of activity by gear types).		**Likely** – But only where mobile fishing occurs outside of the Active Dredge Zones (ADZ) in licensed aggregate extraction areas.
	Mobile bottom gear	**Likely** – Possible that areas fished with mobile bottom gear coincide with suitable aggregate resources.	
	Static gear (pots, lines, nets etc)	**Likely** – Possible that areas fished with static gear could be where suitable aggregate Resources occur.	**Likely**– But only where static gear is placed outside of the ADZ in licensed aggregate extraction areas.
	Hydraulic dredging	**Likely** – Possible that areas fished with hydraulic dredging (mainly for bivalves) coincide with suitable aggregate resources.	**Likely** – But only where the hydraulic dredging occurs outside of the ADZ in licensed aggregate extraction areas.
	Rod and lining	**Likely** – Possible that areas fished commercially with rods and lines could be where suitable aggregate resources occur.	**Likely**– But only where the rod and lining occur outside of the ADZ in licensed aggregate extraction areas.
	Hand gathering	**Unlikely** –Hand gathering is primarily intertidal in contrast to the subtidal extraction of aggregate.	**Likely** – Spatial separation from aggregate extraction areas at sea and intertidal nature of hand gathering.
Ports and Shipping	Shipping - navigation routes **Refer to Figure 4.6 for the indicative sector interaction map.**	**Likely** – Aggregate resources coincide with vessel traffic routes including to/from Newport and Cardiff in the Bristol Channel, Swansea Bay, Pembroke/Milford Haven, Holyhead on the north Anglesey coast, and Liverpool port and Liverpool Bay.	**Likely** – Aggregate dredgers may utilise existing navigational routes to access a licensed area. However, statutory navigational measures and best practise measures in place whilst a dredger is active in the ADZ. Co-existence potential with navigational measures in place.
	Anchorage areas	**Likely** – Aggregate resources coincide with anchorage areas including off Cardiff and Newport, Bristol Channel.	**Unlikely** – Where anchorage areas are already present before marine aggregates, the potential for co-location on operational and safety grounds is limited.
Subsea cables	Cables and telecommunications **Refer to Figure 4.4 for the indicative sector interaction map.**	**Likely** – Aggregate resources coincide with subsea cable routes within the Inner and Outer Bristol Channel, and within inshore and offshore areas of Liverpool Bay.	**Unlikely** – Physical disturbance of seabed not compatible for the dredging activity or subsea cables. On safety and operational basis, proximity limits and proximity agreements utilised between aggregate and subsea cable

Marine Plan Sector	Activity/Sector	Are the two activities likely to interact spatially (possible, likely or unlikely)? If so, how do they interact?	Can the structures/activities physically co exist in space, recognising activities could occur in the same space, yet at different times (possible, likely or unlikely)?[25]
			operators. A separation of approximately 1 nm, is considered good practice[26].
Surface water and wastewater treatment and disposal	Intakes and outfalls, including licensed discharges	**Possible** – Aggregate resources coincide with coastal pipelines including from Cardiff and Newport.	**Possible** – Surface water and wastewater treatment and disposal developments usually coastal or inshore, hence minimal interaction with marine aggregate extraction. But future developments of the surface/wastewater infrastructure may need to ensure these are sited and with agreements to achieve co-existence with aggregate areas.
Dredging and Disposal	Designated disposal sites (Active)	**Likely** – Aggregate resources coincide with licensed disposal sites within Liverpool Bay, off the north-east Anglesey coast and within areas of the Bristol Channel.	**Unlikely** – Safety and operational reasons, including burial of and contamination of potential resource, mean that aggregate extraction is usually separated from designated dredging locations and disposal sites.
Defences	Military exercise areas/ammunition disposal sites **Refer to Figure 4.7 for the indicative sector interaction map.**	**Likely** – Aggregate resources coincide with Military Practise Areas in Cardigan bay, off the Llŷn Peninsula, off the south-west coast of Pembrokeshire and in Carmarthen Bay.	**Unlikely** – Safety and operational reasons, defence areas typically separate from the aggregate extraction. Future development for marine aggregates areas would need to be in dialogue with MoD, as per the WNMP defence sector policy.
Tourism and Recreation	Recreational Sea Angling (RSA)	**Possible** – Aggregate resources coincide with RSA undertaken from chartered vessels around seabed features/wrecks.	**Possible** – But likely only where the RSA occurs outside of the ADZ in licensed aggregate extraction areas.
	RYA marinas and sailing routes	**Possible** – Possible that sailing routes pass by or through resource areas. Unlikely for coastal based marinas unless directly adjacent to wharves.	**Possible** - But dredgers may utilise existing navigational routes to access a licensed area. However, statutory navigational measures and best practise measures in place whilst dredger is active in the ADZ, hence no immediate spatial co-existence. But outside of dredging, spatial interaction not present.
	Water sports (e.g. surfing, kite surfing, diving, rafting)	**Possible** – Possible use of the sea surface or water column for water sports. Although diving may be	**Possible** – Safety and operational reasons, aggregate extraction occurring in the ADZ. But outside of dredging the area could be available and accessed by water sports.

[26] Source: TCE and BMAPA Good Practise Guidance https://bmapa.org/documents/BMAPA_TCE_Good_Practice_Guidance_04.2017.pdf [Last access: 06/04/2020].

Marine Plan Sector	Activity/Sector	Are the two activities likely to interact spatially (possible, likely or unlikely)? If so, how do they interact?	Can the structures/activities physically co exist in space, recognising activities could occur in the same space, yet at different times (possible, likely or unlikely)?[25]
		affected by poor visibility if dredging results in high turbidity.	
	Shore based activity (e.g. coasteering, hiking, dog walking, kites)	**Unlikely** – Extraction occurring away from the shoreline and hence unlikely for the activities to intersect. However, landings made to wharfs along the coast e.g. Penryhn, Pembroke, Port Talbot, Swansea could mean the vessel traffic is visible to shore-based activities.	**Possible** – Spatial separation from active aggregate extraction areas at sea and activities on/by the shore. Also, dredgers transiting to/from licence areas and port, using established navigational routes, may be visible from shore.
	Wildlife watching - shore based	**Unlikely** – Extraction occurring away from the shoreline and hence unlikely for the activities to intersect. However, landings made to wharfs along the coast e.g. Pembroke, Port Talbot, Swansea could mean the vessel traffic is visible to shore-based activities.	**Possible** – Spatial separation from active aggregate extraction areas at sea and activities on/by the shore. Also, dredgers transiting to/from licence areas and port, using established navigational routes, may be visible from shore.
	Wildlife watching - boat based	**Possible** – Possibly with passage of wildlife boats through licensed areas, though not within ADZ whilst dredger present. Also, consider where dredging related operations, may not be conducive to the presence of wildlife of interest e.g. seabirds.	**Possible** – Safety and operational reasons, aggregate extraction occurring in the ADZ. But outside of dredging the area could be available and accessed by wildlife watching boats.

4.2 Low Carbon Energy: tidal stream resources

A summary of interaction appraisal for tidal stream and other sectors is shown in Table 4.2.

As mentioned in section 3.1.1, spatial co-existence of marine aggregates and tidal stream energy is considered unlikely, but the sequencing/timing of the activities has a bearing on co-existence potential. For instance, full aggregate exploitation in a licenced area, preceding the placement and operation of tidal stream infrastructure.

Mapping indicates an area off the west of Pembrokeshire where tidal stream and wave energy resources spatially overlap (Figure 4.8). It is unlikely that these two sectors could temporally co-exist in the same space, because floating or seabed mounted energy devices would effectively preclude access to each other. Whilst the operational characteristics of the two sectors precludes co-existence at the same time, forward-looking, proactive and spatial planning approaches could be applied to consider options for sequencing activities within any area of resource overlap.

Mapping indicates spatial overlap of resources for tidal stream energy and seabed and water column-based aquaculture resources (Figure 4.9). The sequencing/timing of the activities can have a bearing on co-existence potential and there is also the matter of regulatory changes to enable consenting of combined aquaculture and tidal stream energy developments, ideally operating on a commercial level.

Spatial and temporal management could be applied to sequence the activities of each sector (tidal stream, wave energy and aquaculture). Such future planning would benefit from dialogue between the respective sectors and their associated regulators. Having these resource overlays mapped (Figure 4.8 and Figure 4.9) and considering the interactions (Table 4.2) will help to target this dialogue on forward-looking, proactive and spatial planning. This resource overlap and sector interactions will also be important for the planning authority when developing criteria for the development of any SRA (and applying safeguarding policy) for these two sectors.

With regards to the spatial overlap between focal sectors, the tidal stream resources cover an area of ca. 2,164 km^2, of which ca. 19.9% (ca. 430 km^2) overlaps with marine aggregate resources, ca. 10.8% (ca. 233 km^2) with wave energy resources, ca. 1.26% (ca. 27 km^2) with seabed aquaculture resources and ca. 21.6% (ca. 466 km^2) with water column aquaculture resources.

As referenced in Table 4.2, there is potential for spatial co-existence of tidal stream energy with several other sectors, including subsea cabling and shipping (Figure 4.10 and Figure 4.11), tourism and recreation e.g. recreational sea angling and sailing (Figure 4.12). This could mean an opportunity for optimising spatial co-existence and should be considered as part of the SRA determination process. Mapping resource overlays (Figure 4.10 to Figure 4.12) and sector interactions (Table 4.2) will be important for the planning authority when developing criteria for the development of any SRA (and applying safeguarding policy) for these sectors, and will help facilitate dialogue between the sectors and their regulators.

New tidal stream developments would need the permission of the Ministry of Defence if planned in the area off Llŷn Peninsula (Figure 4.13), due to its potential to create navigational hazards for military practices.

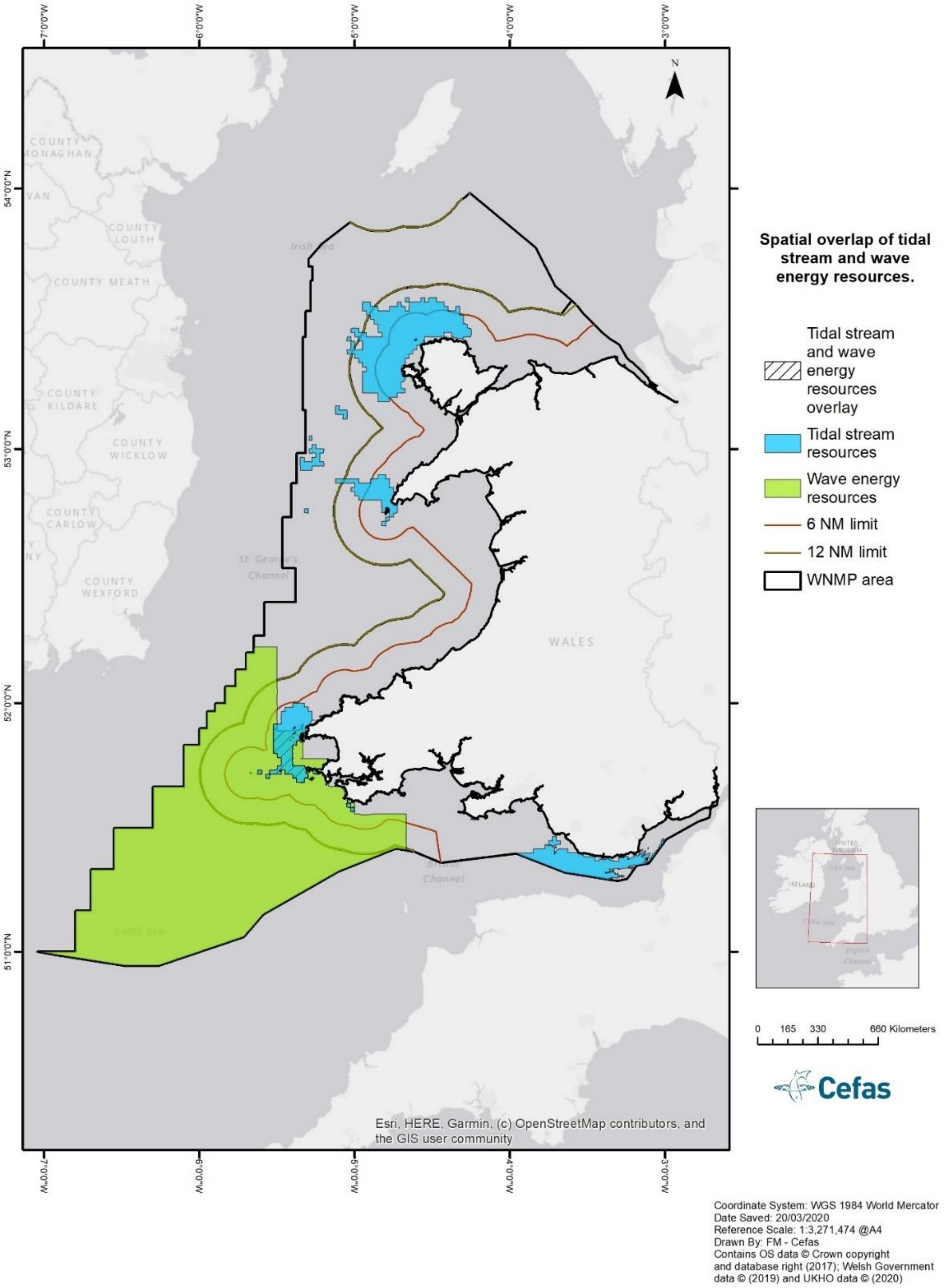

Figure 4.8: Spatial overlap of tidal stream and wave energy resources.

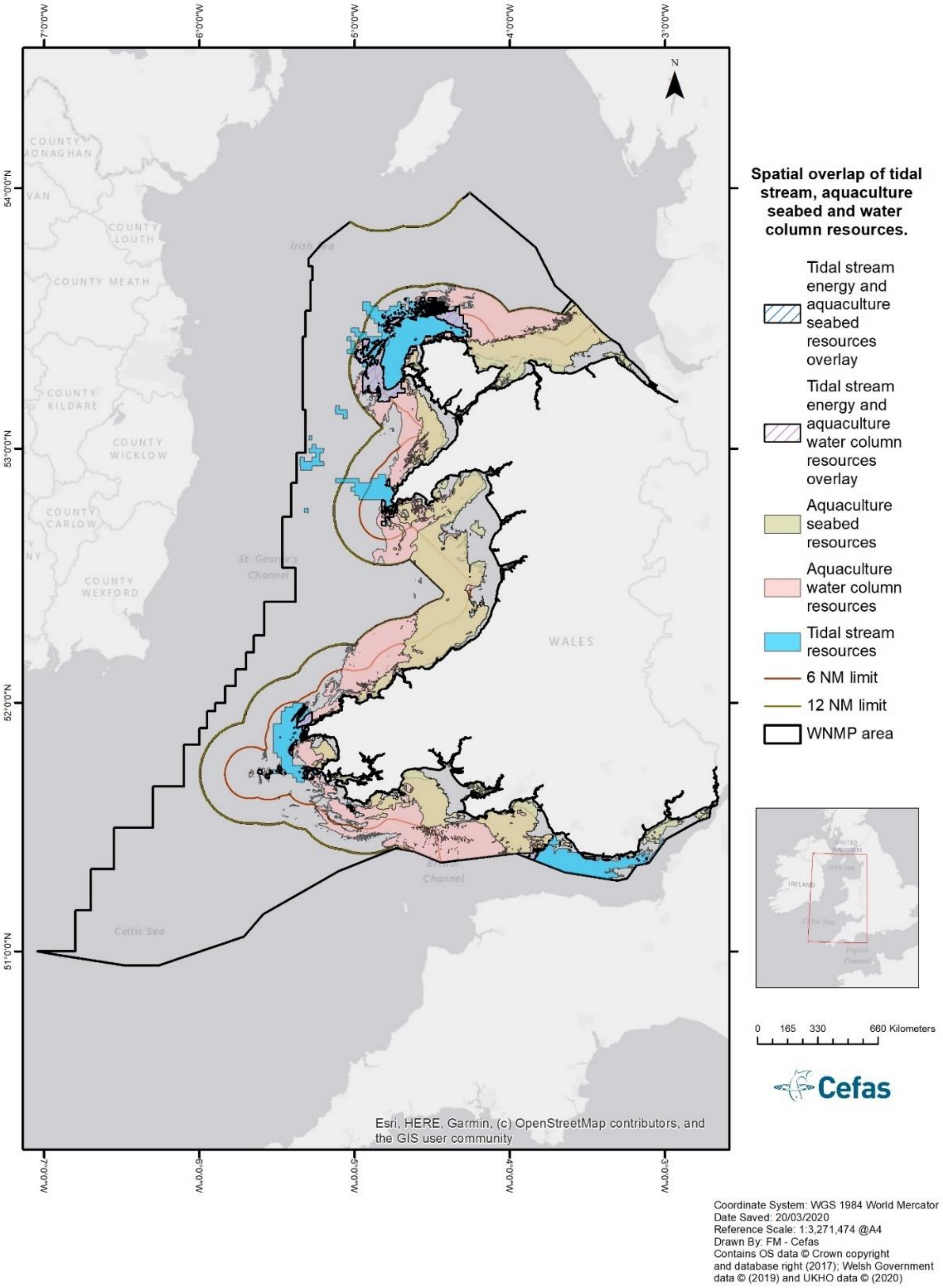

Figure 4.9: Spatial overlap of tidal stream energy and aquaculture (seabed and water column) resources.

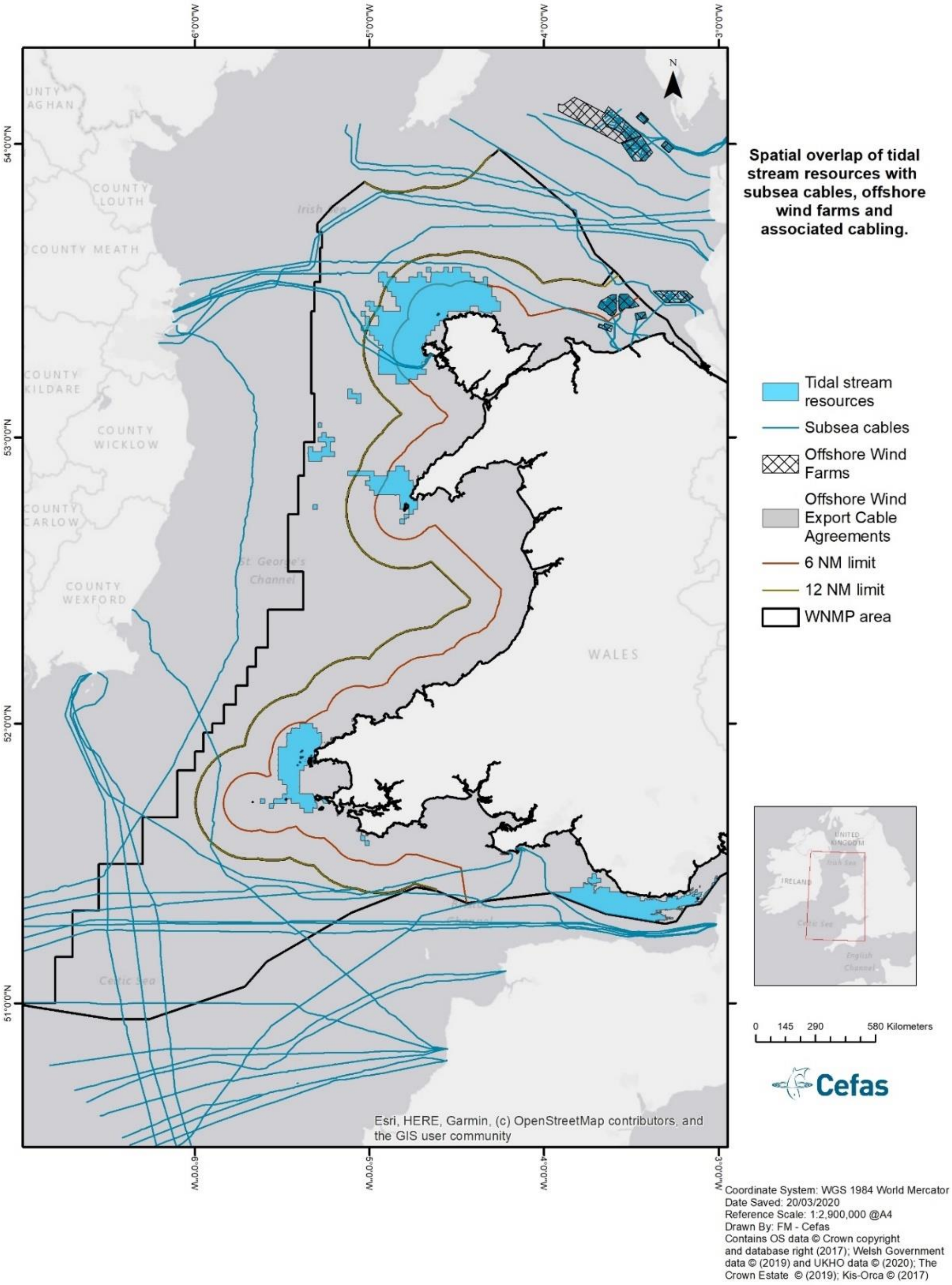

Figure 4.10: Spatial overlap of tidal stream resources and cables and with consented offshore wind farms (as of 2017) and associated export cabling.

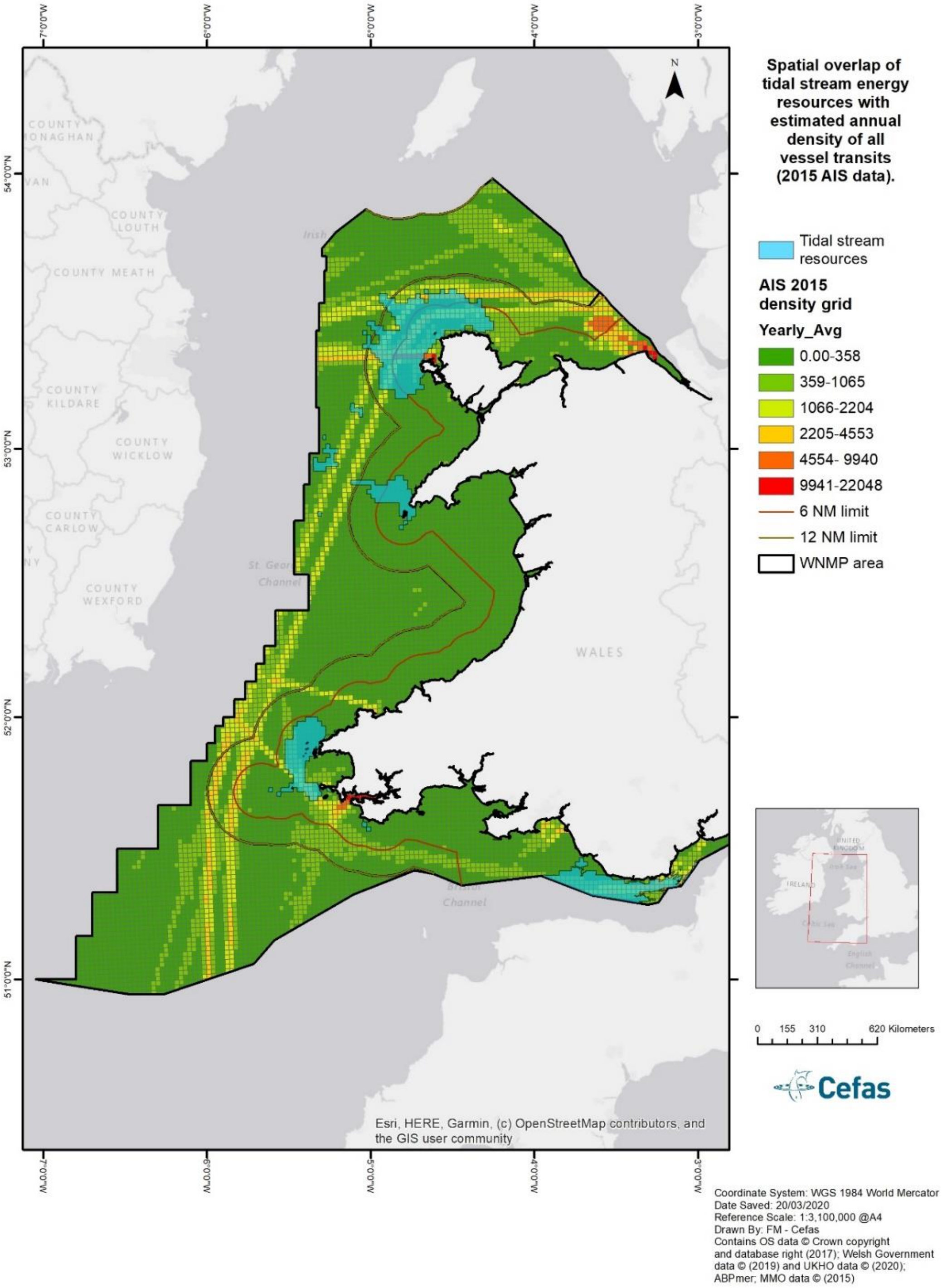

Figure 4.11: Spatial overlap of tidal stream resources and shipping.

Shipping activity represented by estimated annual density of all vessel transits from Automatic Identification Systems data (2015).

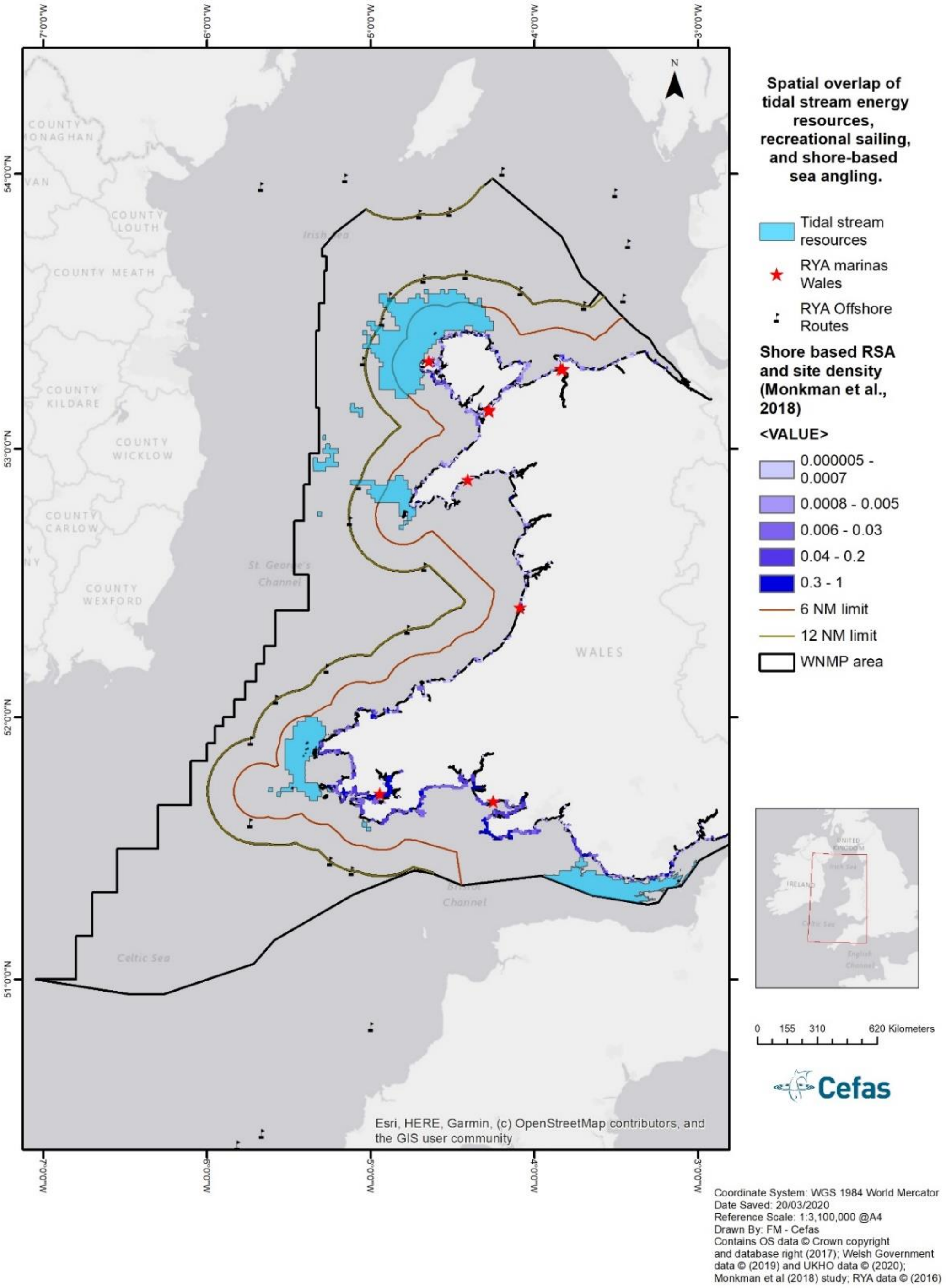

Figure 4.12: Spatial overlap of tidal stream energy and recreational activities.

Examples given for sailing and shore locations for recreational sea angling (source: Monkman et al., 2018).

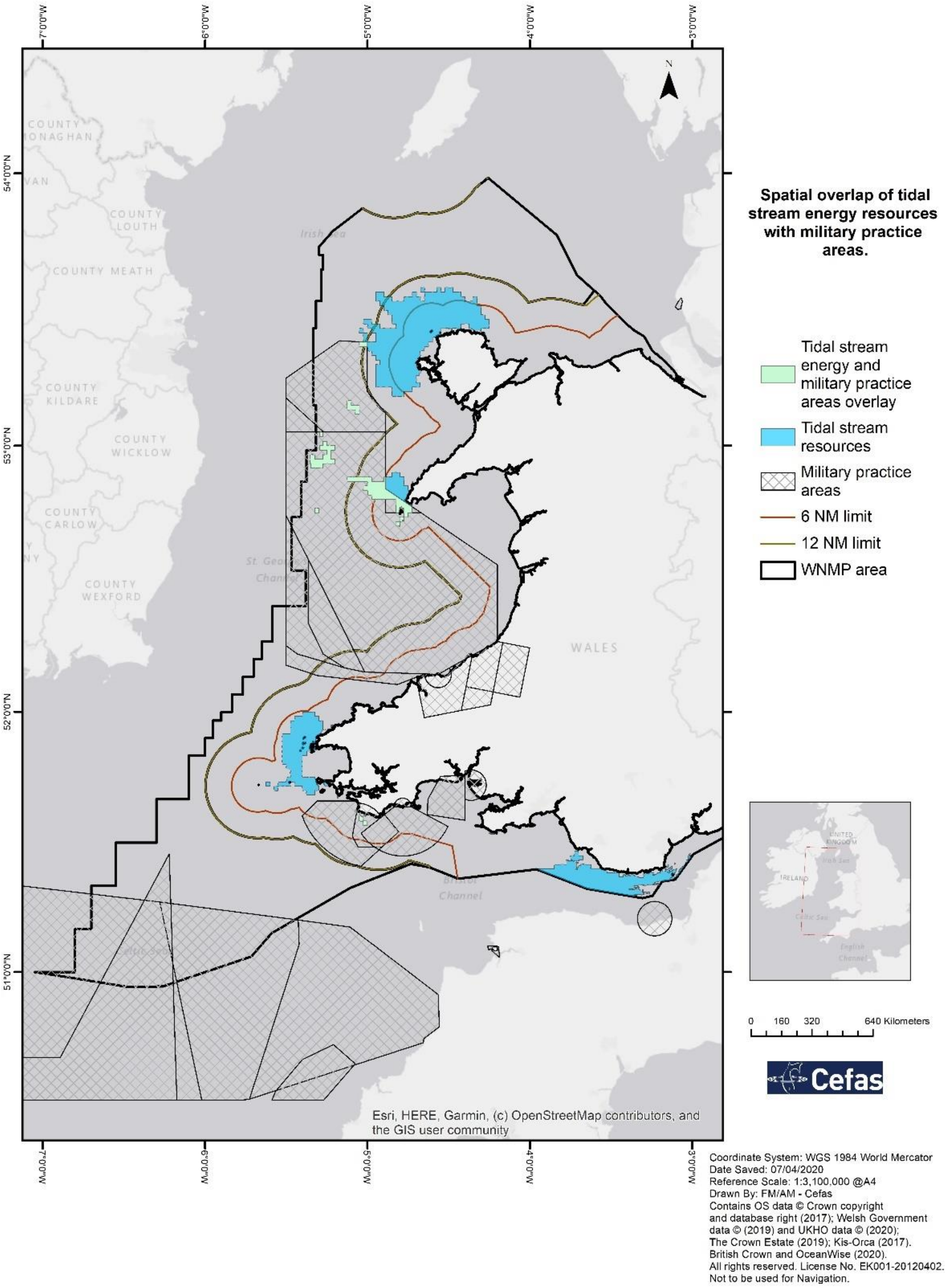

Figure 4.13: Spatial overlap of tidal stream energy and military practice areas.

Table 4.2: Summary of tidal stream energy interaction with other focal and non-focal sectors.

Marine Plan Sector	Activity/Sector	Are the two activities likely to interact (possible, likely or unlikely)? If so, how interact?	Can the structures/activities physically co exist in space, recognising activities could occur in the same space yet at different times (possible, likely or unlikely)?
Marine minerals	Marine aggregates	**Possible** – Tidal stream resources coincide with aggregate resources off north Anglesey, Pembrokeshire and within the Inner Bristol Channel.	**Unlikely** – Currently for consenting, safety, and operational reasons, licensed aggregate extraction spatially separate from tidal stream devices present on the sea surface/in the water column.
Energy	Wave energy **Refer to Figure 4.8 for the indicative sector interaction map.**	**Possible** – Tidal stream resources coincide with wave resources off the Pembrokeshire coast.	**Unlikely** – Currently for consenting, safety and operational reasons, spatial separation of tidal stream devices present along/on the seabed, or in the water column wave devices on the sea surface/in the water column.
	Wind turbines (fixed and floating) Offshore wind farms (fixed and floating)	**Possible** – Tidal stream resources overlap with wind energy resources off north Anglesey, around the Llŷn Peninsula, south Pembrokeshire, Carmarthen and Swansea Bay and coastal to Cardiff.	**Unlikely** – Currently for consenting, safety and operational reasons, tidal stream devices spatially separate from fixed/floating turbines (and turbines together in a wind farm) and wind farms.
	Oil and Gas (incl. submarine pipelines and other infrastructure)	**Possible** – Petroleum licensing area off the Llŷn Peninsula intersect. However, otherwise overlap of tidal stream resources and existing oil and gas infrastructure is considered to be limited.	**Unlikely** – Safety and operational reasons, tidal stream devices usually spatially from oil and gas structures atop the sea. Proximity agreements/crossing agreements utilised by the operators where the device cables intersect pipelines.
	Miscellaneous (incl. overhead power lines, power station, substations)	**Possible**– Deployment of tidal stream device at sea whereas miscellaneous infrastructure predominantly at or on the shore.	**Likely** – Maritime occurrence of tidal stream devices, whereas miscellaneous structures present at the coast or in the case of substations (e.g. for operational renewable developments), tend not to be sited directly in footprint of the tidal stream devices or associated cabling.
Aquaculture	Bottom culture – shellfish **Refer to Figure 4.9 for the indicative sector interaction map.**	**Possible**– Tidal stream resources overlap with resources for seabed aquaculture (shellfish bottom cultivation), in locations such as off the Llŷn Peninsula, Pembrokeshire, and coastal sites in South Wales.	**Unlikely** – Safety and operational reasons, tidal stream devices (especially seabed anchored) are likely to be separate spatially from shellfish cultivated on the seabed.
	Cage culture – finfish	**Possible** – Tidal stream resources overlap with resources for cage-based finfish cultivation in	**Unlikely** – At present the chosen tidal stream regimes for devices are not considered optimal for caged fish farm operations (SARF, 2014).

Marine Plan Sector	Activity/Sector	Are the two activities likely to interact (possible, likely or unlikely)? If so, how interact?	Can the structures/activities physically co exist in space, recognising activities could occur in the same space yet at different times (possible, likely or unlikely)?
	Refer to Figure 4.9 for the indicative sector interaction map.	locations such as off Anglesey, the Llŷn Peninsula, Pembrokeshire, and coastal sites in South Wales.	
	Rope culture – shellfish **Refer to Figure 4.9 for the indicative sector interaction map.**	**Possible** – Tidal stream resources overlap with resources for rope culture of shellfish, for instance, off Anglesey, the Llŷn Peninsula, Pembrokeshire, and coastal sites in South Wales near Cardiff.	**Possible** – Known examples of combining rope-based aquaculture and tidal stream energy are absent from Wales at present. However, there is scope for a potential co-location (multi-use of space) in the future.
	Rope culture – seaweed **Refer to Figure 4.9 for the indicative sector interaction map.**	**Possible** – Tidal stream resources overlap with resources for rope culture of seaweed, mainly off Anglesey.	
	Trestle culture - shellfish	**Unlikely** – Operational tidal stream devices at sea unlikely to interact with intertidal trestle cultivation.	**Possible** – Spatial separation from tidal stream devices at sea and intertidal nature of trestle cultivation.
Fisheries	Mobile mid-water gear	**Likely** - Where suitable tidal stream resources coincide with locations where mobile gears are fished.	**Unlikely** – Safety and operational reasons, tidal stream devices (notably seabed mounted) and associated anchors/lines, are likely to be kept spatially separate from grounds fished by mobile fishing gears.
	Mobile bottom gear		
	Static gear (pots, lines, nets etc)	**Likely** - Where suitable tidal stream resources coincide with locations targeted by fishers with static types of gears.	**Unlikely** – Safety and operational reasons, tidal stream devices (notably seabed mounted) and associated anchors/lines, likely to be kept spatially separate from grounds fished by static gear fishing gears. However, potential benefits from hard substrata of tidal stream devices as artificial reef for fauna to be considered.
	Hydraulic dredging	**Likely** – Where suitable tidal stream resources coincide with locations for hydraulic dredging (mainly for bivalves).	**Unlikely** – Safety and operational reasons, tidal stream devices (notably seabed mounted) and associated anchors/lines, likely to be spatially separate from hydraulic dredging operations.
	Rod and lining	**Likely** – Possible that areas fished commercially with rods and lines could have tidal stream resources.	**Unlikely** – Safety and operational reasons, wave devices (notably seabed mounted) and associated anchors/lines, likely to be spatially separate from rod and lining.

Marine Plan Sector	Activity/Sector	Are the two activities likely to interact (possible, likely or unlikely)? If so, how interact?	Can the structures/activities physically co exist in space, recognising activities could occur in the same space yet at different times (possible, likely or unlikely)?
	Hand gathering	**Unlikely** – Where hand gathering is primarily intertidal compared with the placement of tidal stream devices at sea.	**Unlikely** – Spatial separation from wave devices at sea and intertidal nature of hand gathering
Ports and Shipping	Shipping - navigation routes **Refer to Figure 4.11 for the indicative sector interaction map.**	**Likely** – Tidal stream resources coincide with vessel traffic routes including to/from Newport and Cardiff in the Bristol Channel, Swansea Bay, Pembroke/Milford Haven, Holyhead on the north Anglesey coast.	**Likely** – Vessels involved with construction and operations and maintenance of the devices, may utilise existing navigational routes and statutory navigational measures. Co-existence potential with measures in place.
	Anchorage areas	**Likely** – Tidal stream resources are considered to be adjacent to but not situated in anchorage sites.	**Unlikely** – Where anchorage areas are already present before tidal stream device deployments, the potential for co-location on operational and safety grounds is limited.
Subsea cables	Cables and telecommunications **Refer to Figure 4.10 for the indicative sector interaction map.**	**Likely** – Tidal stream resources to the north/north-west of Anglesey coincide with subsea cabling between Anglesey and Ireland.	**Likely** – A separation of approximately 1 nm is considered good practice between offshore renewable installations and subsea cable infrastructure. However, if the distance is <1 nm then proximity agreements/crossing agreements, utilised by the operators[27].
Surface water and wastewater treatment and disposal	Intakes and outfalls, including licensed discharges	**Unlikely** – On the basis of intakes/outfalls being distant from at sea tidal stream devices.	**Likely** – Surface water and wastewater treatment and disposal developments usually coastal or inshore, hence minimal interaction with tidal stream devices at sea. But future developments of the surface/wastewater infrastructure may need to ensure these are sited and with agreements to achieve co-existence with tidal stream developments.
Dredging and Disposal	Designated disposal sites (Active)	**Likely** – Tidal stream resources to the north/north-west of Anglesey coincides with a licensed disposal site.	**Unlikely** – Safety and operational reasons, tidal stream devices (notably seabed mounted) and associated anchors/lines, likely to be kept spatially separate from designated disposal sites.

[27] Source: European Subsea Cables Association (2016) Guideline No.6 – The Proximity of Offshore Renewables Energy installations & Submarine Cable Infrastructure in UK Waters. Online available: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=2ahUKEwiSl5moxNToAhV2TRUIHcM3DE8QFjAAegQIBBAB&url=https%3A%2F%2Fwww.escaeu.org%2Fdownload%2F%3FId%3D123%26source%3Dguidelines&usg=AOvVaw3-Ny4ahHcAdGFxt76wunC7 [Last access: 06/04/2020].

Marine Plan Sector	Activity/Sector	Are the two activities likely to interact (possible, likely or unlikely)? If so, how interact?	Can the structures/activities physically co exist in space, recognising activities could occur in the same space yet at different times (possible, likely or unlikely)?
Defences	Military exercise areas/ammunition disposal sites **Refer to Figure 4.13 for the indicative sector interaction map.**	**Likely** – Overlap of tidal stream resources off Llŷn Peninsula with an existing Military Practise Area.	**Unlikely** – Safety and operational reasons, defence areas usually kept separate from tidal stream devices. Future development for tidal stream areas would need to be in dialogue with the MoD.
Tourism and Recreation	Recreational Sea Angling (RSA) **Refer to Figure 4.12 for the indicative interaction map.**	**Possible** – RSA undertaken from chartered vessels around seabed features/wrecks, and islands, could overlap with tidal stream resources.	**Possible**- Boat-based RSA considered possible around devices, subject to accessibility and safety. Also, possibility of wave energy devices in the areas of suitable resource, could act as fish aggregating devices which may draw RSA to fish in the area.
	RYA marinas and sailing routes **Refer to Figure 4.12 for the indicative interaction map.**	**Possible** – Sailing routes overlap with tidal stream resources at sea. Unlikely overlap with coastal based marinas.	**Possible**- Devices and recreational sailing routes could co-exist, subject to safety measures e.g. device lighting and marking, safe clearance above devices for recreational craft. Also recognising the mobile nature of the recreational activity relative to the requirements for siting tidal stream devices (and arrays).
	Water sports (e.g. surfing, kite surfing, diving, rafting)	**Possible** – Possible use of the sea surface or water column for water sports, in proximity to tidal stream resources.	**Possible –** For safety and operational reasons, water sports are not likely to occur in the footprint of the devices but may occur around the device (and associated arrays for upscaled tidal stream energy in the future).
	Shore based activity (e.g. coasteering, hiking, dog walking, kites)	**Unlikely** – Shore-based activities compared with tidal stream resources located at sea.	**Possible** – Activities on/by the shore would not directly in the footprint of the devices or arrays. Also, energy cables from the devices to shore would be buried and only affect shore activities and access, should they need to be accessed for repairs/maintenance.
	Wildlife watching - shore based		
	Wildlife watching - boat based	**Possible** – Tidal stream resources and boat-based tourism could overlap. Potential for boat-based tourism in proximity to the tidal stream devices, due to the device being of interest, attracting wildlife or through proximity to islands that are wildlife hotspots.	**Possible** – Devices (and future arrays of the devices) could co-exist with boat-based wildlife tourism. Though this is likely to be subject to safety measures e.g. device lighting and marking, safe clearance above devices for vessels. Boat-based tourism may also be flexible in locations and visited areas to accommodate tidal stream devices and arrays.

4.3 Low Carbon Energy: wave energy resources

A summary of interaction appraisal for wave energy and other sectors is shown in Table 4.3.

As mentioned in section 3.1.1, spatial co-existence of marine aggregates and wave energy is considered unlikely, but the sequencing / timing of the activities can have a bearing on co-existence potential.

Mapping (Figure 4.4) indicates an area off the west of Pembrokeshire where there is overlap of tidal stream and wave energy resources. Whilst the operational characteristics of the two sectors precludes co-existence at the same time, forward-looking, proactive and spatial planning approaches could be applied to consider options for sequencing activities within any area of resource overlap.

Mapping (Figure 4.14) indicates an area off the west of Pembrokeshire where there is overlap of wave energy resources and water column resources for aquaculture. There is currently limited evidence for spatial co-existence of wave energy and aquaculture of bivalves on the seabed and finfish. There is, however, a growing interest for combining wave energy devices and rope-based aquaculture, as demonstrated through the recent Maribe H2020 project (Dalton et al., 2019). Nonetheless, the sequencing / timing of the activities for wave developments and aquaculture may have a bearing on co-existence potential. There is also the matter of regulatory changes to enable consenting of combined aquaculture and wave energy developments.

With regards to the spatial overlap between focal sectors, the wave energy resources covers an area of ca. 9,731 km^2, of which ca. 9.8% (ca. 950 km^2) overlaps with marine aggregate resources, ca. 4.4% (ca. 233 km^2) with tidal stream energy resources, ca. 0.32% (ca. 31 km^2) with seabed aquaculture resources and ca. 5.7% (ca. 552 km^2) with water column aquaculture RA.

Combining wave energy and offshore wind could be a potential co-existence opportunity, with recognition of both the synergies and challenges posed by the integration of the energy infrastructure (Pérez-Collazo et al., 2015).

As referenced in Table 4.3 and Table 4.2, there is potential for spatial co-existence of wave energy with several other sectors, including subsea cabling (Figure 4.15), shipping (Figure 4.16) as well as tourism and recreation. Examples are provided for recreational sea angling from shore and sailing (Figure 4.17). This could mean opportunities for encouraging spatial co-existence. Mapping resource overlap (Figure 4.15 to Figure 4.17) and sector interactions (Table 4.3) will be important for the planning authority when developing criteria for the development of any SRA (and applying safeguarding policy) for these sectors, and will help facilitate dialogue between the sectors and their regulators.

New wave energy projects off Pembrokeshire, in the Outer Bristol Channel (Figure 4.18) would need permission from the Ministry of Defence due to potentially creating a navigational hazard for military practices.

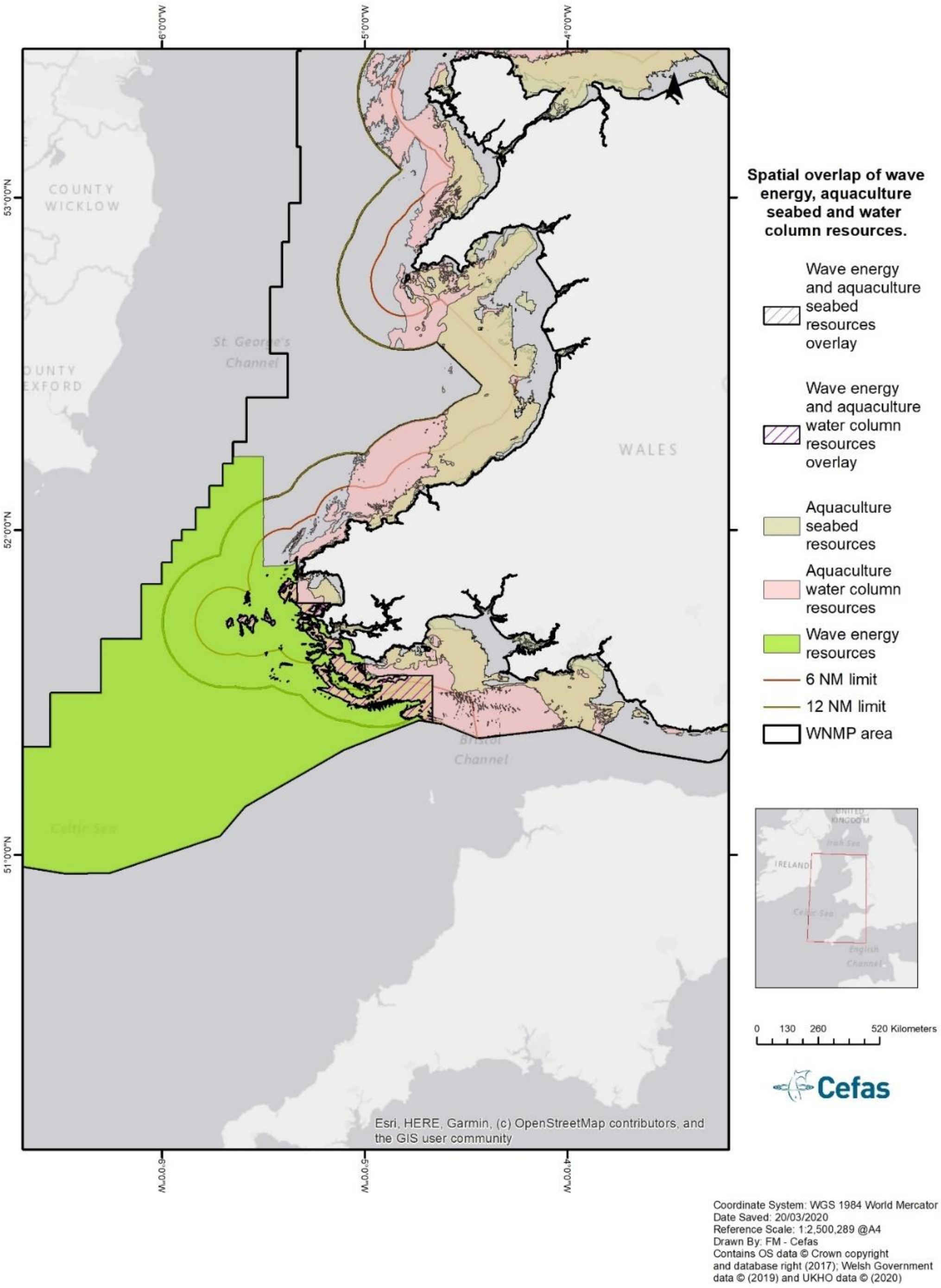

Figure 4.14: Spatial overlap of wave energy resources and aquaculture (seabed and water column) resources.

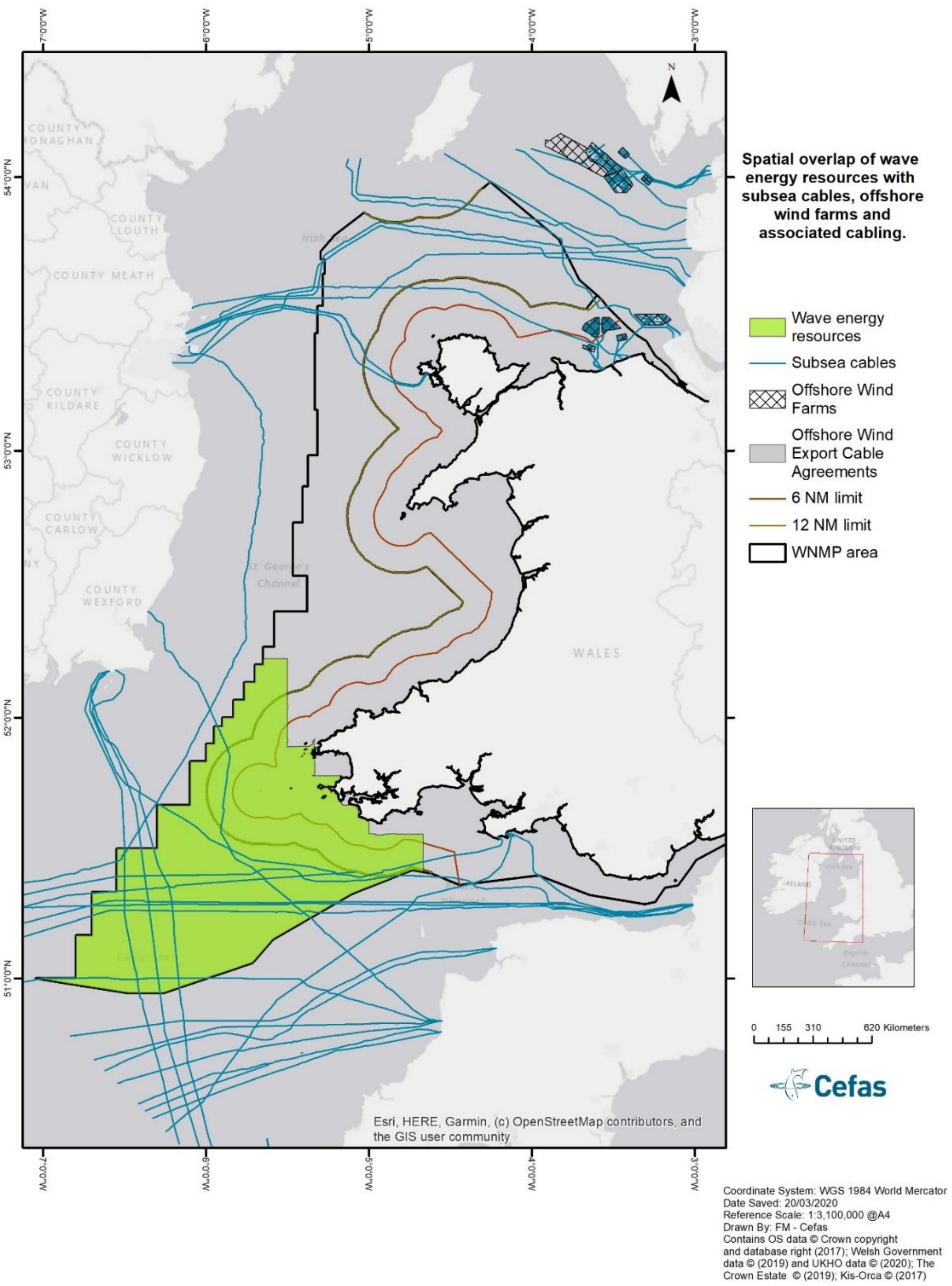

Figure 4.15: Spatial overlap of wave energy resources and subsea cabling.

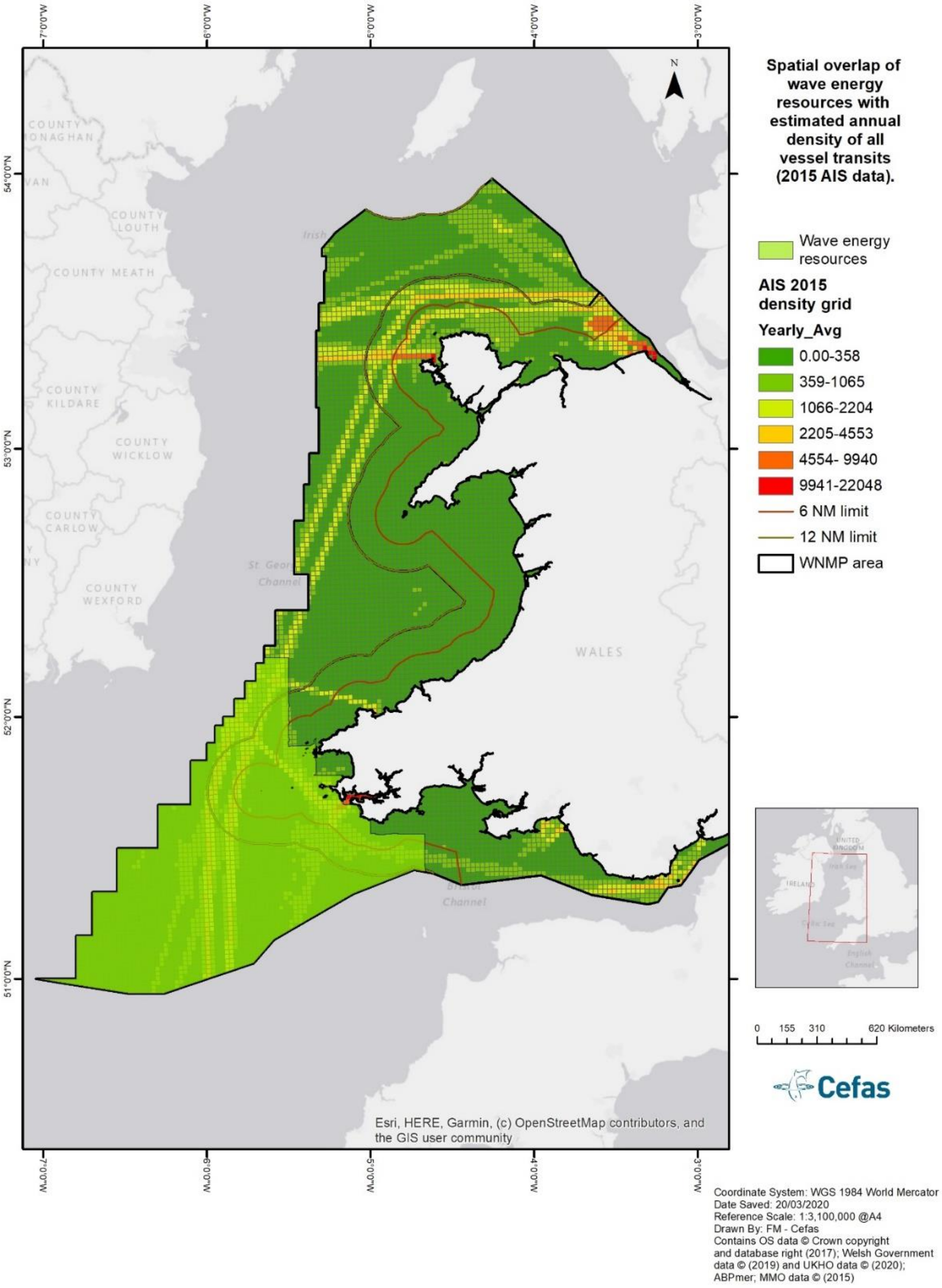

Figure 4.16: Spatial overlap of wave energy resources and shipping.
Shipping activity represented by estimated annual density of all vessel transits from Automatic Identification Systems data (2015).

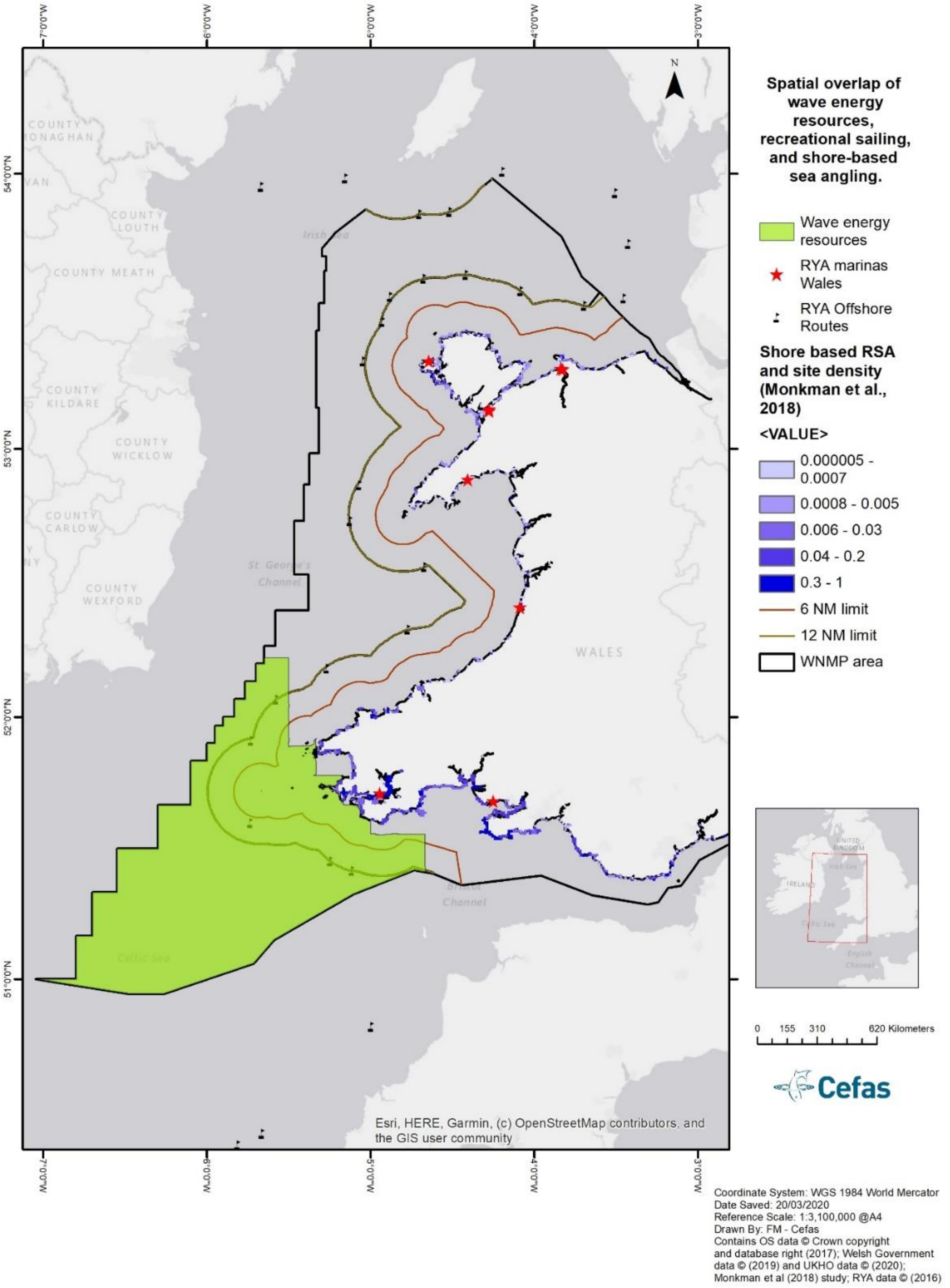

Figure 4.17: Spatial overlap of wave energy resources and recreational activities.
Examples given for sailing and shore locations for recreational sea angling (source: Monkman et al., 2018).

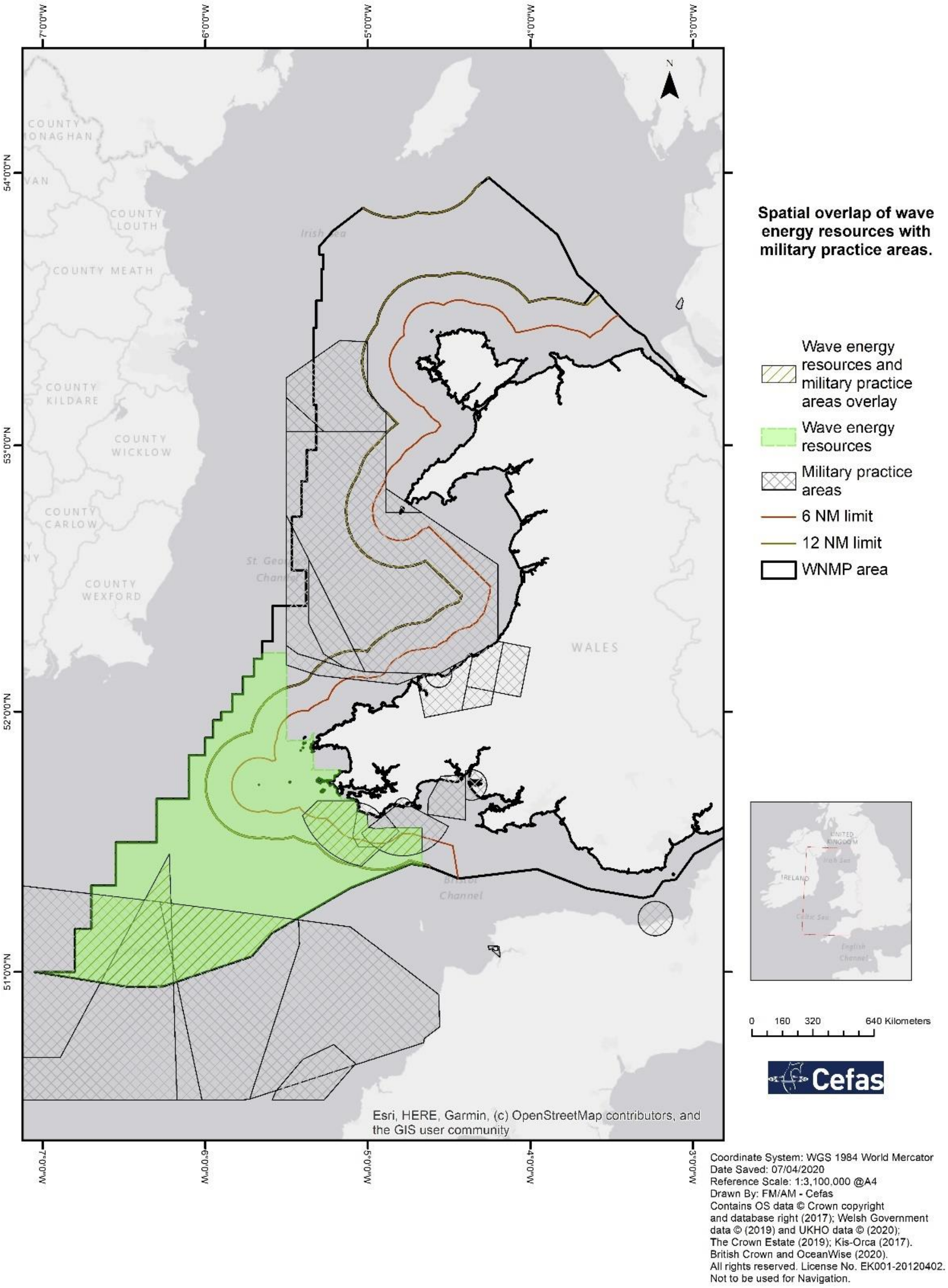

Figure 4.18: Spatial overlap of wave energy resources and military practice areas.

Table 4.3: Summary of wave energy interaction with other focal and non-focal sectors.

Marine Plan Sector	Activity/Sector	Are the two activities likely to interact (possible, likely or unlikely)? If so, how interact?	Can the structures/activities physically co exist in space, recognising activities could occur in the same space yet at different times (possible, likely or unlikely)?
Marine minerals	Marine aggregates	**Possible** – Wave energy and aggregate resources overlap off the coast of Pembrokeshire.	**Unlikely** – For consenting, safety and operational reasons, licensed aggregate extraction spatially separate from wave devices present on the sea surface/ water column
Energy	Tidal stream (fixed and floating)	**Possible**– Wave energy and tidal stream resources overlap off the coast of Pembrokeshire, located in the Outer Bristol Channel.	**Unlikely** – For consenting, safety and operational reasons, spatial separate of wave devices on the sea surface/water column and tidal stream devices present along or on the seabed, or in the water column.
	Wind turbines (fixed and floating) Offshore wind farms (fixed and floating)	**Possible** – Wave energy resources overlap with wind energy resource off Pembrokeshire, located in the Outer Bristol Channel.	**Possible** – Currently for safety and operational reasons, wave devices spatially separate from fixed/floating turbines (and turbines together in a wind farm) and wind farms. But in the future, potential exists for co-location of wave devices and wind farms. Particularly where operations are in more high energy environments and cost incentives to share infrastructure.
	Oil and Gas (incl. submarine pipelines and other infrastructure)	**Likely** – Wave energy resources coincide with well and petroleum licensing blocks off Pembrokeshire, located in the Outer Bristol Channel.	**Unlikely** – For safety and operational reasons, wave devices usually spatially from oil and gas structures atop the sea. Proximity agreements/crossing agreements utilised by the operators where the device cables intersect pipelines
	Miscellaneous (incl. overhead power lines, power station, substations)	**Possible** – Wave energy resources and deployment of wave energy devices at sea, whereas miscellaneous infrastructure predominantly at or on the shore.	**Likely** – Maritime occurrence of wave devices, whereas miscellaneous structures present at the coast or in the case of substations (e.g. for operational renewable developments), tend not to be sited directly in footprint of the wave devices or associated cabling.
Aquaculture	Bottom culture - shellfish	**Possible** – Wave energy resources overlap with resources for seabed aquaculture (shellfish bottom cultivation). This is mainly off the coast of Pembrokeshire, located in the Outer Bristol Channel.	**Unlikely** – For safety and operational reasons, licensed wave devices (especially seabed anchored) are likely to be separate spatially from shellfish cultivated on the seabed.
	Cage culture - finfish	**Possible** – Wave energy resources overlap with resources for cage-based finfish cultivation. This is mainly off the coast of Pembrokeshire, located in the Outer Bristol Channel.	**Possible** - At present the wave regime required for wave devices is not consider suitable for fish farm sites, and there may be limited financial incentives for co-location. But in the future, there is potential for overlap, should finfish aquaculture (notably

Marine Plan Sector	Activity/Sector	Are the two activities likely to interact (possible, likely or unlikely)? If so, how interact?	Can the structures/activities physically co exist in space, recognising activities could occur in the same space yet at different times (possible, likely or unlikely)?
			on-growing aspects of production) and wave devices move offshore into more extreme, high energy conditions[28].
	Rope culture - shellfish	**Possible** – Wave energy resources overlap with resources for rope culture of shellfish, mainly off the coast of Pembrokeshire (located in the Outer Bristol Channel).	**Possible** – Wave regime required for wave devices may not be suitable for shellfish rope cultivation, and there may be limited financial incentives for co-location. But in the future, there is potential for overlap should the rope cultivation and wave devices move offshore into more extreme, high energy conditions[9]. Notably, potential for combining wave energy and seaweed aquaculture. Recognised by partnership of Wave Dragon, Seaweed Energy Solutions (SES) and BELLONA Foundation, which is seeking to progress combined project to commercialisation[29] (also see Dalton et al., 2019).
	Rope culture - seaweed	**Possible** – Wave energy resources overlap with resources for rope culture of seaweed, mainly off the coast of Pembrokeshire (located in the Outer Bristol Channel).	
	Trestle culture - shellfish	**Unlikely** –Presence of trestle cultivation internally compared with wave energy resources in coastal and offshore waters.	**Possible** – Spatial separation from wave devices at sea and intertidal nature of trestle cultivation.
Fisheries	Mobile mid-water gear	**Likely** - Where wave energy resources coincide with locations where mobile gears are fished.	**Unlikely** – Safety and operational reasons, wave devices (notably seabed mounted) and associated anchors/lines, are likely to be kept spatially separate from grounds fished by mobile fishing gears.
	Mobile bottom gear		
	Static gear (pots, lines, nets etc)	**Likely** - Where suitable wave resources at surface coincide with locations targeted by fishers with static types of gears.	**Unlikely** – Safety and operational reasons, wave devices (notably seabed mounted) and associated anchors/lines, likely to be kept spatially separate from grounds fished by static gear fishing gears.
	Hydraulic dredging	**Likely** – Where suitable wave resources coincide with locations for hydraulic dredging (mainly for bivalves).	**Unlikely** – Safety and operational reasons, wave devices (notably seabed mounted) and associated anchors/lines, likely to be kept spatially separate from hydraulic dredging operations.

[28] Source: Aquatera (2014).

[29] Source: Wave Energy & Offshore Aquaculture in Wales, UK (http://maribe.eu/wave-aquaculture) [Last access: 06/04/2020].

Marine Plan Sector	Activity/Sector	Are the two activities likely to interact (possible, likely or unlikely)? If so, how interact?	Can the structures/activities physically co exist in space, recognising activities could occur in the same space yet at different times (possible, likely or unlikely)?
	Rod and lining	**Likely** – Where suitable wave resources coincide with locations for rod and lining.	**Unlikely** – Safety and operational reasons, wave devices (notably seabed mounted) and associated anchors/lines, likely to be kept spatially separate from rod and lining.
	Hand gathering	**Unlikely** – Where hand gathering is primarily intertidal compared with wave energy resources at sea.	**Unlikely** – Spatial separation from wave devices at sea and intertidal nature of hand gathering
Ports and Shipping	Shipping - navigation routes **Refer to Figure 4.16 for the indicative sector interaction map.**	**Likely** – Wave energy resources coincide with vessel traffic routes including to/from Pembroke/Milford Haven, Pembrokeshire.	**Likely** – Safety zone and navigational measures in place immediately around devices to minimise risks for shipping traffic. Vessels used during operation and maintenance activities for the wave devices may utilise existing navigational routes and statutory navigational measures.
	Anchorage areas	**Likely** – Wave energy resources and partial overlap with coastal anchorage sites off the Pembrokeshire coast, located in the Outer Bristol Channel.	**Unlikely** – Where anchorage areas are already present before wave device deployment and, the potential for co-location on operational and safety grounds is limited.
Subsea cables	Cables and telecommunications **Refer to Figure 4.15 for the indicative sector interaction map.**	**Likely** – Wave energy resources off Pembrokeshire coincide with several subsea cable routes landing into south wales and areas of south-west England.	**Likely –** A separation of approximately 1 nm is considered good practice between offshore renewable installations and subsea cable infrastructure. However, if the distance is <1 nm then proximity agreements/crossing agreements, utilised by the operators[8].
Surface water and wastewater treatment and disposal	Intakes and outfalls, including licensed discharges	**Unlikely** – On the basis of intakes/outfalls at the coastline or nearshore, being distant from the wave energy resources.	**Likely** – Though most infrastructure inshore at present hence minimal spatial interaction. But if surface water and wastewater treatment and disposal developments were to coincide with wave energy resources, there is scope for the two to co-exist.
Dredging and Disposal	Designated disposal sites (Active)	**Likely** – Wave energy resources offshore of Pembrokeshire, in the Outer Bristol Channel, coincides with designed disposal sites.	**Unlikely** – Safety and operational reasons, wave devices (notably seabed mounted) and associated anchors/lines, likely to be kept spatially separate from designated disposal sites.
Defences	Military exercise areas/ammunition disposal sites	**Likely** – Wave energy resources off Pembrokeshire, in the Outer Bristol Channel, coincide with parts of existing Military Practise Areas.	**Unlikely** – Safety and operational reasons, defence areas usually kept separate from wave devices. . Future development for wave energy areas would need to be in dialogue with the MoD.

Marine Plan Sector	Activity/Sector	Are the two activities likely to interact (possible, likely or unlikely)? If so, how interact?	Can the structures/activities physically co exist in space, recognising activities could occur in the same space yet at different times (possible, likely or unlikely)?
	Refer to Figure 4.18 for the indicative sector interaction map.		
Tourism and Recreation	Recreational Sea Angling (RSA) **Refer to Figure 4.17 for the indicative sector interaction map.**	**Possible** – Wave energy resources likely to coincide with RSA undertaken from chartered vessels around seabed features/wrecks, and islands e.g. Skomer.	**Possible –** Boat-based RSA considered possible around devices, subject to accessibility and safety. Also, possibility of wave energy devices in the areas of suitable resource, could act as fish aggregating devices which may draw RSA to fish in the area.
	RYA marinas and sailing routes **Refer to Figure 4.17 for the indicative sector interaction map.**	**Possible** – Sailing routes overlap with wave energy resources at sea. Unlikely overlap with coastal based marinas.	**Possible** - Devices and recreational sailing routes could co-exist, subject to safety measures e.g. device lighting and marking, safe clearance above devices for recreational craft.
	Water sports (e.g. surfing, kite surfing, diving, rafting)	**Possible** – Possible use of the sea surface or water column for water sports, in proximity to wave energy resources.	**Possible –** For safety and operational reasons, water sports are not likely to occur in the footprint of the devices but may occur around the device.
	Shore based activity (e.g. coasteering, hiking, dog walking, kites) Wildlife watching - shore based	**Unlikely** – Shore-based activities compared with wave energy resources occurring out at sea.	**Possible** – Activities on/by the shore would not directly in the footprint of the devices. Also, energy cables from the devices to shore would be buried and only affect shore activities and access, should they need to be accessed for repairs/maintenance.
	Wildlife watching - boat based	**Possible** – Wave energy resources and boat-based tourism could overlap. Potential for boat-based tourism in proximity to the devices, due to the device being of interest, attracting wildlife or through proximity to islands that are wildlife hotspots.	**Possible** – Devices could co-exist with boat-based wildlife tourism. Though this is likely to be subject to safety measures e.g. device lighting and marking, safe clearance above devices for vessels. Boat-based tourism may also be flexible in locations and visited areas to accommodate wave devices.

4.4 Aquaculture resources

4.4.1 Seabed resource for shellfish aquaculture

A summary of interaction appraisal for seabed resource and shellfish aquaculture (bottom cultivation) and other sectors is shown in Table 4.4.

As mentioned in section 3.1.2 and 3.1.3, there is unlikely to be spatial co-existence between seabed aquaculture resources and marine aggregate, tidal stream and wave energy resources. Although as already discussed, the timing/sequencing of the sectors could influence these interactions and potential constraints imposed for other sectors.

For seabed cultivation, there is unlikely to be a spatial co-existence with other sectors that could disturb seabed within the harvesting area; for instance fishing with mobile and static gear, or dredging and disposal (Figure 4.21). There is also unlikely to be a spatial co-existence where there is also a risk of contamination, such as sewage outfalls (wastewater infrastructure) or smothering or contamination from dredging and disposal of marine sediment.

It is recognised existing production (mainly of shellfish) occurs chiefly in areas designated through a Several Order where fishing rights are exclusive to the area, or through a Regulating Order. As such, were the aquaculture sector for seabed cultivation to expand in the future, a smaller area of the indicated resource area could likely be utilised, thereby potentially minimising spatial conflict potential with other sectors.

Spatial and temporal management could be applied to sequence the activities of each sector. Such future planning would benefit from dialogue between the respective sectors and their associated regulators. Having these resource overlaps mapped (e.g. Figure 4.21) and considering the interactions (Table 4.4) will help to target this dialogue on forward-looking, proactive and spatial planning.

With regards to the spatial overlap between focal sectors, the aquaculture seabed resources covers an area of ca. 4,209 km^2, of which ca. 31.6% (ca. 1,330 km^2) overlaps with marine aggregate resources, ca. 0.65% (ca. 27 km^2) with tidal stream energy resources, 0.74% (ca. 31 km^2) with wave energy resources and ca. 83.4% (ca. 3,512 km^2) with water column aquaculture resources.

As mentioned in section 3.2.12 and in Table 4.2, there is potential for co-location of seabed cultivation of bivalves and offshore wind energy. Likewise, a co-existence potential of seabed cultivation with rope-based aquaculture. There is also potential co-existence with several other sectors including fisheries (Figure 4.19 and Figure 4.20), shipping (Figure 4.21), tourism and recreation (Figure 4.23) as well as tidal range energy (Figure 4.24). Overall, this could mean an opportunity for maximising spatial co-existence between these sectors and future planning would benefit from dialogue between the respective sectors and their associated regulators.

Depending on the characteristics of potential new shellfish sites, development with fixed structures would need the permission of the Ministry of Defence when considered to be located in Cardigan Bay, around the Pembrokeshire coast, off Tenby and in Carmarthen Bay (Figure

4.25) due to creating potential navigational hazard for military practice. Mussel relaying practice can, however, continue to co-exist with the defence sector.

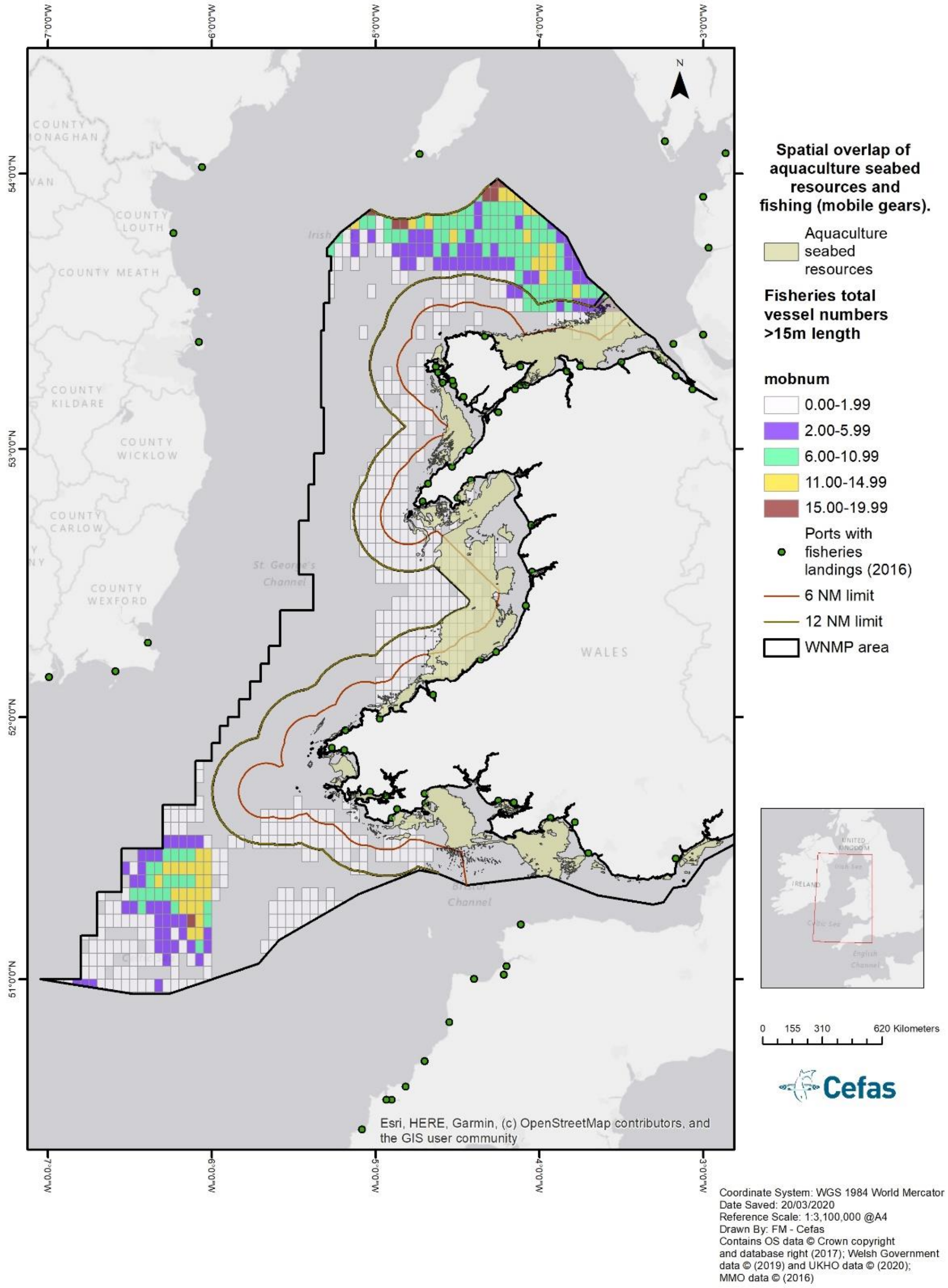

Figure 4.19: Spatial overlap of aquaculture seabed resources and fisheries (mobile gears e.g. trawls)[20].

The map is indicative and is based on fisheries activity from 2016 data and depicts ports with recorded landings (in 2016) and total vessel numbers (≥15m vessel length) recorded per ICES sub-rectangle[21].

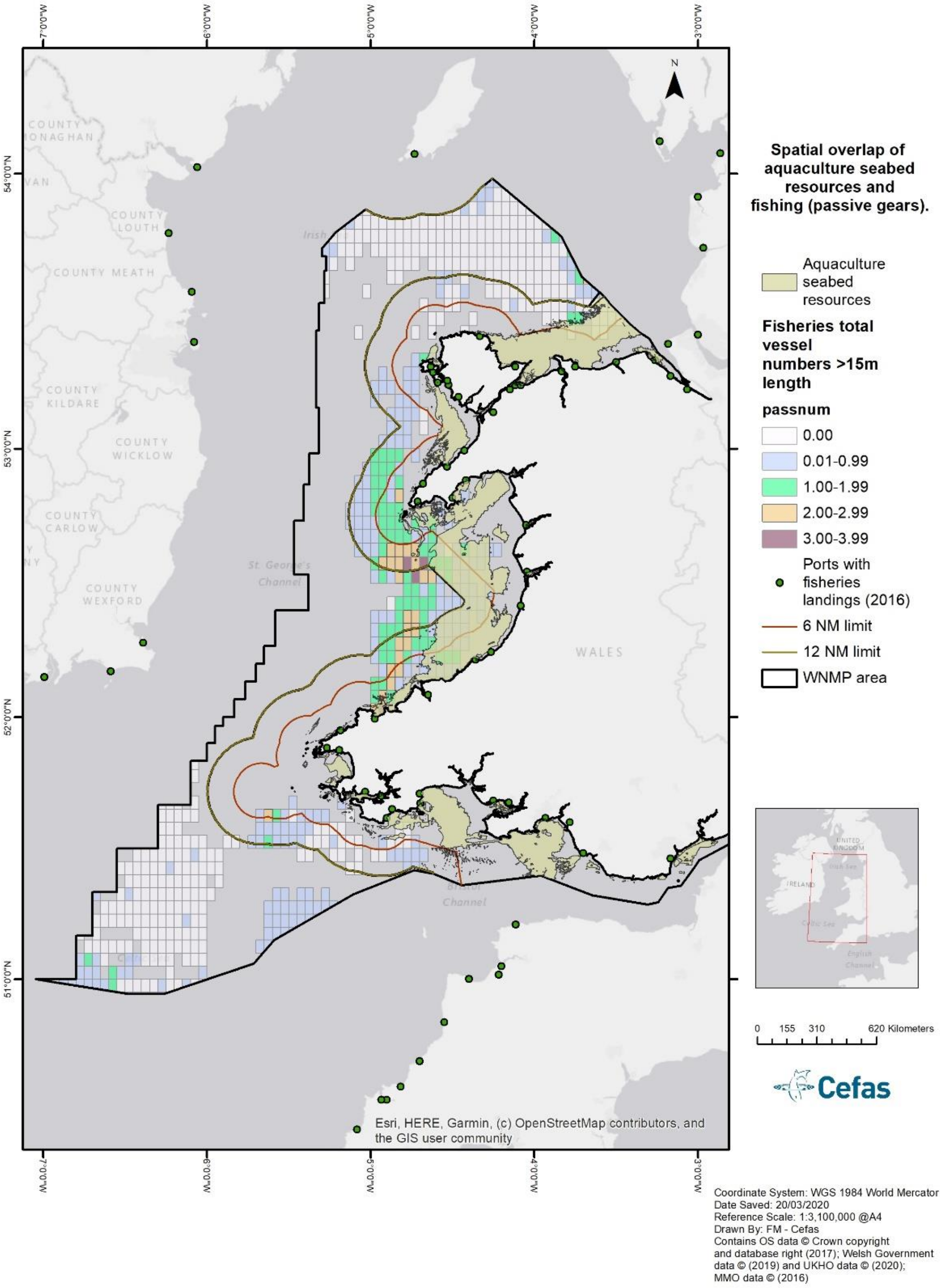

Figure 4.20: Spatial overlap of aquaculture seabed resources and fisheries (passive gears e.g. pots/lines)[20].

The map is indicative and is based on fisheries activity from 2016 data and depicts ports with recorded landings (in 2016) and total vessel numbers (≥15m vessel length) recorded per ICES sub-rectangle[21].

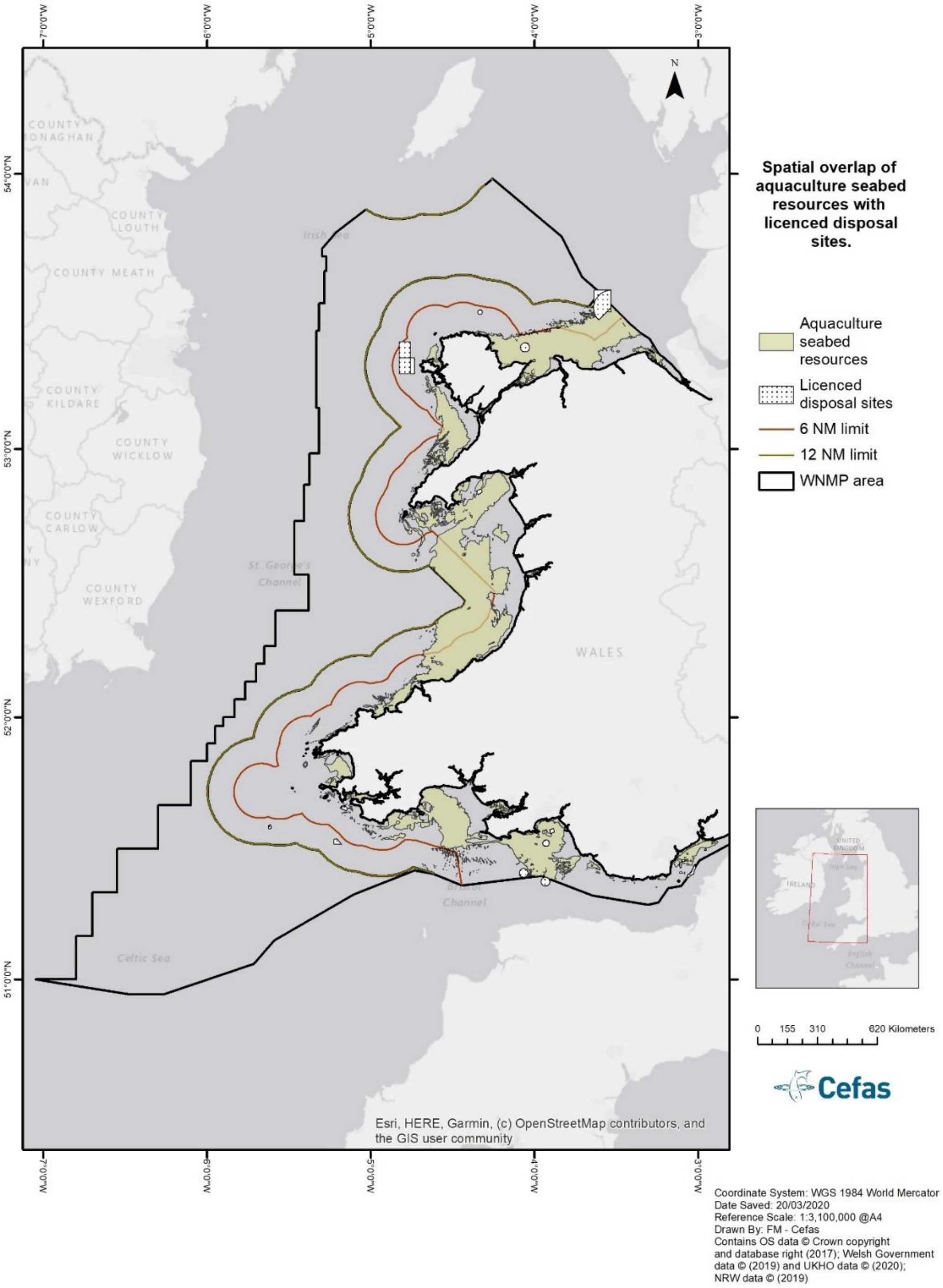

Figure 4.21: Spatial overlap of aquaculture seabed resources and licenced disposal sites.

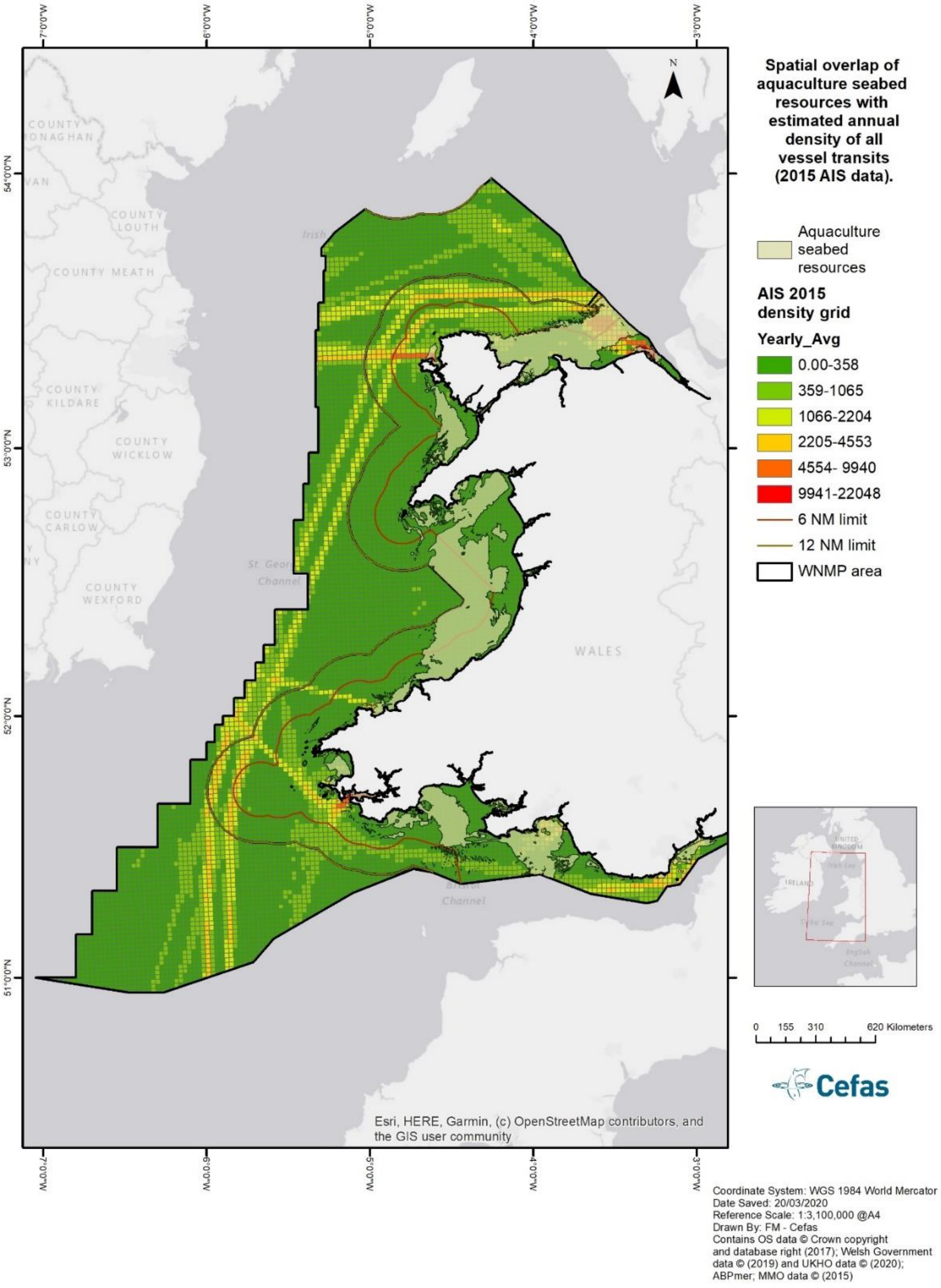

Figure 4.22: Spatial overlap of aquaculture seabed resources and shipping.
Shipping activity represented by estimated annual density of all vessel transits from Automatic Identification Systems data (2015).

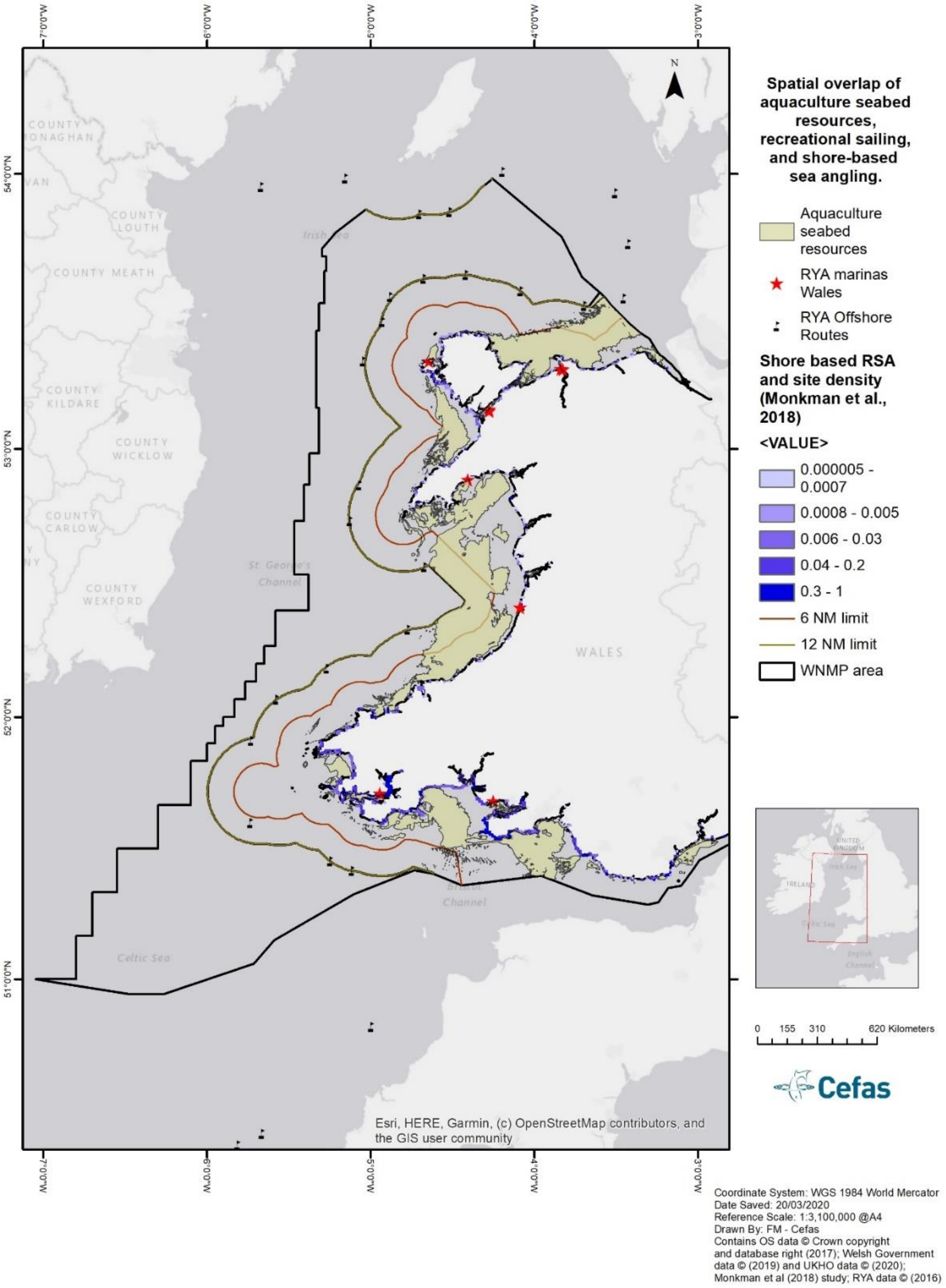

Figure 4.23: Spatial overlap of aquaculture seabed resources and recreational activities. Examples of sailing and shore locations for sea angling (source: Monkman et al., 2018).

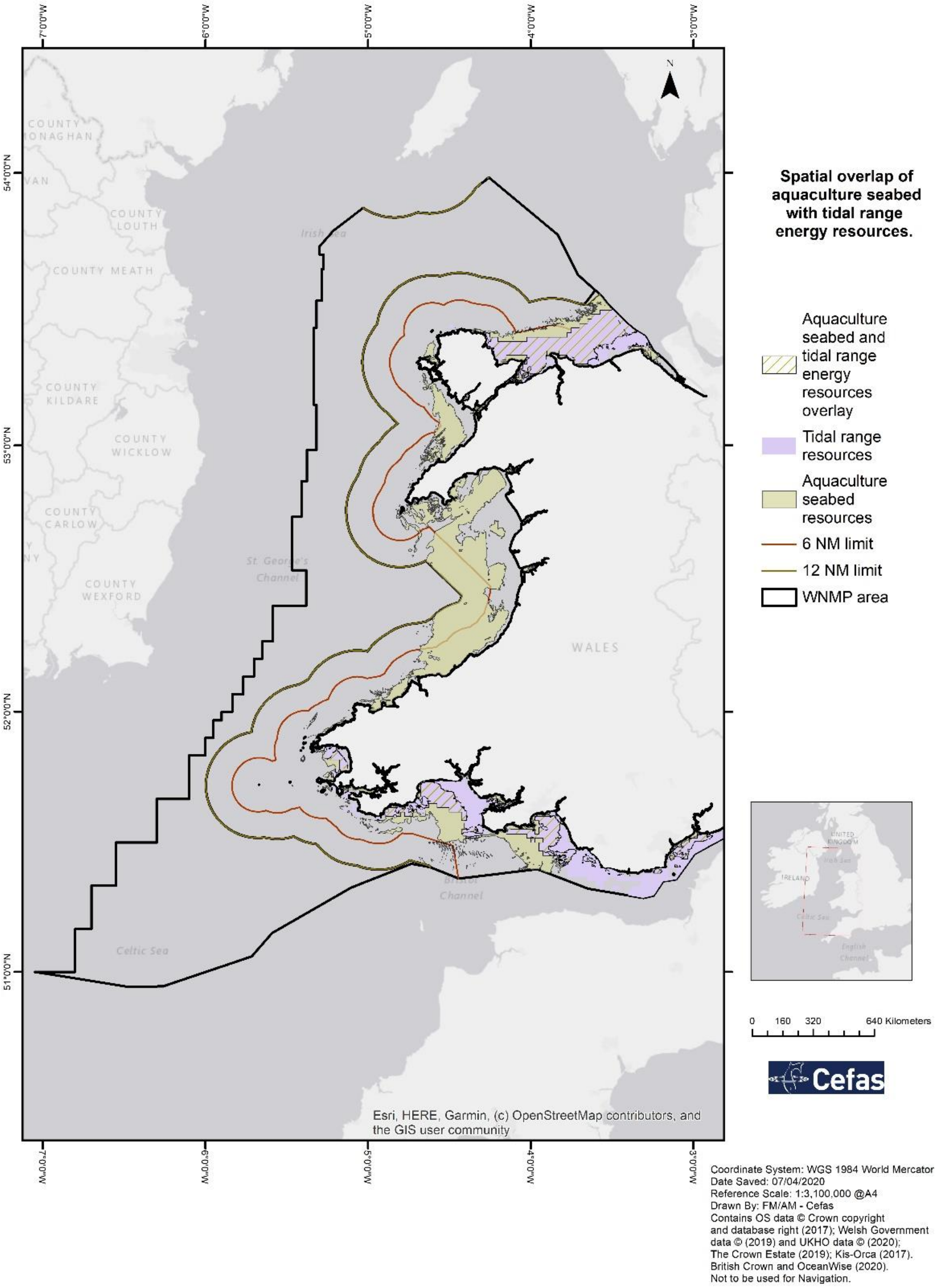

Figure 4.24: Spatial overlap of aquaculture seabed and tidal range energy resources.

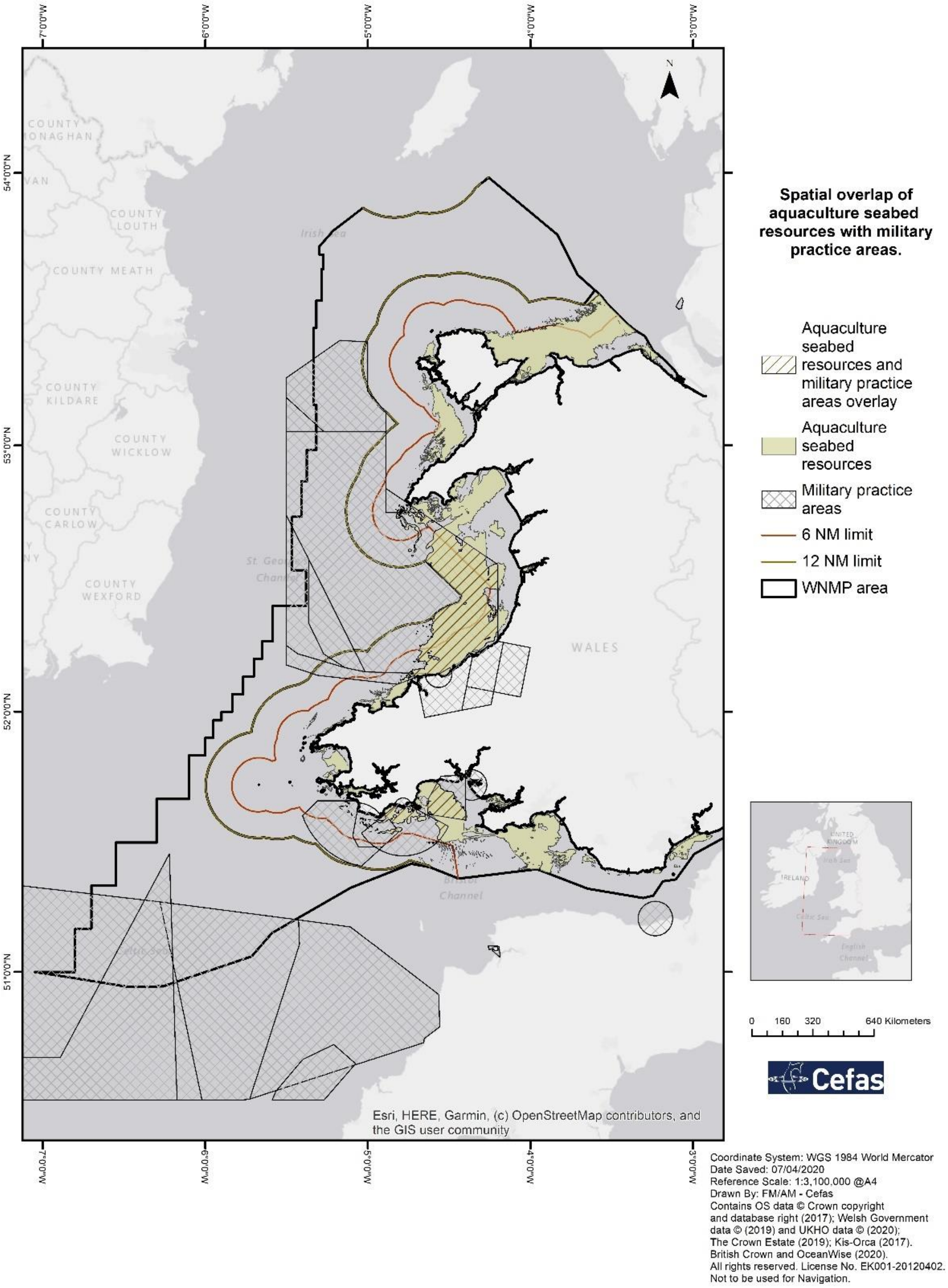

Figure 4.25: Spatial overlap of aquaculture seabed resources and military practice areas.

Table 4.4: Summary of seabed resource for shellfish aquaculture (bottom cultivation) and interaction with focal and other sectors.

Marine Plan Sector	Activity/Sector	Are the two activities likely to interact (possible, likely or unlikely)? If so, how interact?	Can the structures/activities physically co exist in space, recognising activities could occur in the same space yet at different times (possible, likely or unlikely)?
Marine minerals	Marine aggregates	**Possible** – Seabed aquaculture resources coincide with aggregate resources in several locations: north-east Anglesey, off North Wales, south Pembrokeshire, and Carmarthen and Swansea Bay.	**Unlikely** – Safety and operational reasons, areas of seabed cultivation spatially separate from aggregate extraction.
Energy	Wave energy	**Possible –** Seabed aquaculture resources and wave resources overlap off Pembrokeshire, and coastal sites in South Wales.	**Unlikely** – Safety and operational reasons, wave devices on the sea surface/water column spatially separate from seabed cultivation.
	Tidal stream (fixed and floating)	**Possible** – Seabed aquaculture resources and tidal stream resources overlap off the Llŷn Peninsula, Pembrokeshire, and coastal sites in South Wales.	**Unlikely** – Safety and operational reasons, tidal stream devices on the sea surface/water column or on the seabed, spatially separate from seabed cultivation.
	Tidal range **Refer to Figure 4.24 for the indicative sector interaction map.**	**Possible** – Seabed aquaculture resources and tidal range resources overlap off Anglesey and coastal sites in South Wales.	**Unlikely** – Safety and operational reasons, tidal range devices on the sea surface/water column or on the seabed, spatially separate from seabed cultivation.
	Wind turbines (fixed and floating) Offshore wind farms (fixed and floating)	**Possible** – Seabed aquaculture resources and wind energy resource overlap off North Wales, to the north-west of Anglesey, around the Llŷn Peninsula, within Cardigan Bay, off Pembrokeshire, as well as coastal sites in South Wales.	**Possible** – Currently only one example in Wales of co-location, involving a trial of mussel cultivation within North Hoyle OWF (Wales) in 2010. Future opportunity to potentially scale up shellfish cultivation within OWFs, particularly where operations are in more high energy environments and cost incentives to share infrastructure.
	Oil and Gas (incl. submarine pipelines and other infrastructure)	**Possible** – Seabed aquaculture resources coincide with oil and gas infrastructure and petroleum licensing blocks in off North Wales, in Liverpool Bay.	**Unlikely** – Safety and operational reasons, seabed cultivation is likely to be spatially separate from oil and gas structures atop the sea surface and pipelines/well heads etc on/along the seabed.

Marine Plan Sector	Activity/Sector	Are the two activities likely to interact (possible, likely or unlikely)? If so, how interact?	Can the structures/activities physically co exist in space, recognising activities could occur in the same space yet at different times (possible, likely or unlikely)?
	Miscellaneous (incl. overhead power lines, power station, substations)	**Unlikely** - Seabed cultivation of shellfish at sea and hence separate from coastal structures.	**Likely** – Maritime occurrence of shellfish aquaculture, whereas miscellaneous structures present at the coast or in the case of substations (e.g. for operational renewable developments), tend not to be sited directly in the middle of the shellfish bed/resource.
Aquaculture	Rope culture - shellfish	**Likely** – Seabed aquaculture resources and water column resources, suitable for rope-culture of bivalves, overlap in several locations. This includes off North Wales, north-west Anglesey, north coast the Llŷn Peninsula, and off Pembrokeshire.	**Possible** – Wave regime required for wave devices may not be suitable for shellfish rope cultivation, and there may be limited financial incentives for co-location. But in the future, there is potential for overlap should the rope cultivation and wave devices move offshore into more extreme, high energy conditions. Notably, potential for combining wave energy and seaweed aquaculture. Recognised by partnership of Wave Dragon, Seaweed Energy Solutions (SES) and BELLONA Foundation, which is seeking to progress combined project to commercialisation (also see Dalton et al., 2019).
	Rope culture - seaweed	**Likely** – Seabed aquaculture resources and water column resources, suitable for rope-culture of seaweed, overlap in several locations. This includes off south coast of the Llŷn Peninsula, within Carmarthen and Swansea Bay.	
	Trestle culture - shellfish	**Unlikely** – Where trestle cultivation is intertidal compared with subtidal cultivation of shellfish.	
Fisheries	Mobile mid-water gear **Refer to Figure 4.19 for the indicative sector interaction map.**	**Likely** – Fishing is a mobile activity and hence could overlap with seabed aquaculture resources and water column resources suitable for rope-culture of bivalves.	**Unlikely** – Safety and operational reasons, seabed aquaculture resources are likely to be kept spatially separate from grounds fished by mobile fishing gears
	Mobile bottom gear **Refer to Figure 4.19 for the indicative sector interaction map.**		
	Static gear (pots, lines, nets etc) **Refer to Figure 4.20 for the indicative sector interaction map.**	**Likely** – Fishing is a mobile activity and hence could overlap with seabed aquaculture resources and water column resources suitable for rope-culture of bivalves.	**Unlikely** – Safety and operational reasons, seabed aquaculture resources are likely to be kept spatially separate from grounds fished by static gear types. But potential for flexibility in the locations of gear deployment

Marine Plan Sector	Activity/Sector	Are the two activities likely to interact (possible, likely or unlikely)? If so, how interact?	Can the structures/activities physically co exist in space, recognising activities could occur in the same space yet at different times (possible, likely or unlikely)?
			to accommodate areas of bottom cultivation with future development.
	Hydraulic dredging	**Likely** – Fishing is a mobile activity and hence could overlap with seabed aquaculture resources and water column resources suitable for rope-culture of bivalves.	**Unlikely** – Safety and operational reasons, seabed aquaculture resources are likely to be kept spatially separate from hydraulic dredging areas.
	Rod and lining	**Likely** – Fishing is a mobile activity and hence could overlap with seabed aquaculture resources and water column resources suitable for rope-culture of bivalves.	**Unlikely** – Safety and operational reasons, rod and lining is unlikely to occur in locations of seabed aquaculture resources.
	Hand gathering	**Unlikely** – Where hand gathering is primarily intertidal compared with subtidal seabed cultivation of shellfish.	**Likely** – Spatial separation from subtidal shellfish cultivation at sea, and intertidal nature of hand gathering.
Ports and Shipping	Shipping - navigation routes **Refer to Figure 4.22 for the indicative sector interaction map.**	**Possible** – Seabed aquaculture resources coincide with vessel traffic routes including to/from Pembroke/Milford Haven, Pembrokeshire and Holyhead, Anglesey.	**Likely** – Seabed presence of shellfish and passage of vessels above or in nearby area, subject to harvesting vessels being able to access the cultivated area.
	Anchorage areas	**Possible** – Seabed aquaculture resources overlap with coastal anchorage sites off north-east Anglesey, south Pembrokeshire and Swansea Bay.	**Unlikely** – Designated shellfish beds unlikely to want damage or risk of damage from anchors, hence co-existence is considered unlikely.
Subsea cables	Cables and telecommunications	**Possible** – Seabed aquaculture resources coincide with submarine cabling into north/north-west Anglesey and into/from the Swansea coastline.	**Unlikely** – Safety and operational reasons, subtidal shellfish cultivation likely to be kept spatially separate from subsea cables. This would ensure accessibility to the infrastructure during operational and maintenance works.
Surface water and wastewater treatment and disposal	Intakes and outfalls, including licensed discharges	**Possible** – Seabed aquaculture resources coincide with coastal outfall pipes including from the coasts of Cardiff, Swansea, Pembrokeshire and North Wales.	**Unlikely** – Preference is to locate shellfish bottom cultivation away from sources of potential contamination, such as sewage outfalls.

Marine Plan Sector	Activity/Sector	Are the two activities likely to interact (possible, likely or unlikely)? If so, how interact?	Can the structures/activities physically co exist in space, recognising activities could occur in the same space yet at different times (possible, likely or unlikely)?
Dredging and Disposal	Designated disposal sites (Active) **Refer to Figure 4.21 for the indicative sector interaction map.**	**Possible** – Seabed aquaculture resources coincide to the north/north-west of Anglesey, Liverpool Bay and Swansea Bay, coincide with licensed disposal sites.	**Unlikely** – Preference is to locate shellfish bottom cultivation away from dredging and disposal sites, due to the potential for smothering and contamination.
Defences	Military exercise areas/ammunition disposal sites **Refer to Figure 4.25 for the indicative sector interaction map.**	**Possible** – Seabed aquaculture resources overlap with existing Military Practise Areas encompassing Cardigan Bay, around the Pembrokeshire coast, off Tenby and in Carmarthen Bay.	**Possible** – Potential for harvesting of bottom cultivated bivalves to occur within military practise areas unless they are subject to temporal restrictions during operational test and military training periods.
Tourism and Recreation	Recreational Sea Angling (RSA) **Refer to Figure 4.23 for the indicative sector interaction map.**	**Possible** – RSA undertaken from chartered vessels around seabed features/wrecks, and islands e.g. Skomer, likely to overlap seabed aquaculture resources.	**Likely -** RSA notably from boats or from shore, could occur near to subtidal shellfish beds.
	RYA marinas and sailing routes **Refer to Figure 4.23 for the indicative sector interaction map.**	**Possible** – Possible that sailing routes pass by or through areas of seabed aquaculture resources.	**Likely** - Supporting vessels for shellfish harvesting may utilise existing navigational routes.
	Water sports (e.g. surfing, kite surfing, diving, rafting)	**Possible** – Possible use of the sea surface or water column for water sports, in proximity to potential aquaculture (bottom culture) resource. Notably, diving sites around Grassholm and Skokholm islands.	**Likely** – Water sports could occur in waters around and above subtidal shellfish beds, subject to access for harvesting vessels and placement of markers.
	Shore based activity (e.g. coasteering, hiking, dog walking, kites)	**Unlikely** – Shore-based activities not likely to occur within subtidal seabed areas of seabed aquaculture resources.	**Likely** – Spatial separation from subtidal shellfish cultivation at sea and activities on/by the shore. Harvesting vessel and marker buoys possibly visible from shore if operations are inshore.
	Wildlife watching - shore based		**Likely** – Spatial separation from finfish aquaculture at sea and activities on/by the shore.

Marine Plan Sector	Activity/Sector	Are the two activities likely to interact (possible, likely or unlikely)? If so, how interact?	Can the structures/activities physically co exist in space, recognising activities could occur in the same space yet at different times (possible, likely or unlikely)?
	Wildlife watching - boat based	**Possible** – Seabed aquaculture resources and potential for overlap with boat-based tourism. Such as in proximity to islands that are wildlife hotspots e.g. Grassholm and Skokholm.	**Likely** – Wildlife tourism could occur in waters around and above subtidal shellfish beds, subject to access for harvesting vessels and placement of markers.

4.4.2 Water column resource

In general, the aquaculture water column resources covers an area of ca. 7,545 km^2, of which ca. 37.4% (ca. 2,824 km^2) overlaps with marine aggregate resources 6.2% (ca. 466 km^2) with tidal stream energy resources, ca. 7.3% (ca. 552 km^2) with wave energy resources and 46.5% (ca. 3,512 km^2) with seabed column aquaculture resources.

4.4.2.1 Water column resource: rope-based aquaculture

A summary of interaction appraisal for water column resources (rope-based aquaculture) and other sectors is shown in Table 4.5.

As mentioned in section 3.1.1 and section 3.1.2, there is unlikely to be spatial co-existence between rope-based aquaculture and marine aggregates and tidal stream. Although the timing/sequencing of the sectors could influence the interaction. There is also unlikely to be a spatial co-existence with other sectors, including surface water and wastewater treatment and disposal, dredging and disposal as well as military defence.

However, spatial and temporal management could be applied to sequence the activities of each sector. Such future planning would benefit from dialogue between the respective sectors and their associated regulators. Having these resource overlaps mapped and considering the interactions (Table 4.5.) will help to target this dialogue on forward-looking, proactive and spatial planning.

As referenced in section 3.2.12 and in Table 4.2, there is potential for spatial co-existence of rope-based aquaculture and offshore wind energy and wave energy (Figure 4.26) as well as tidal range energy (Figure 4.27). Likewise, there is the potential for co-existence between seabed cultivation and rope-based aquaculture.

Potential co-existence exits for several, other sectors including fisheries, shipping (Figure 4.28), subsea cables (Figure 4.29), and tourism and recreation (Figure 4.30), in locations around the Wales marine plan area. Overall, this could mean an opportunity for maximising spatial co-existence between these sectors and future planning would benefit from dialogue between the respective sectors and their associated regulators.

New development of aquaculture in Cardigan Bay, around the Pembrokeshire coast, off Tenby and in Carmarthen Bay (Figure 4.31) would need the permission of the Ministry of Defence due to potentially creating navigational hazards for military practices.

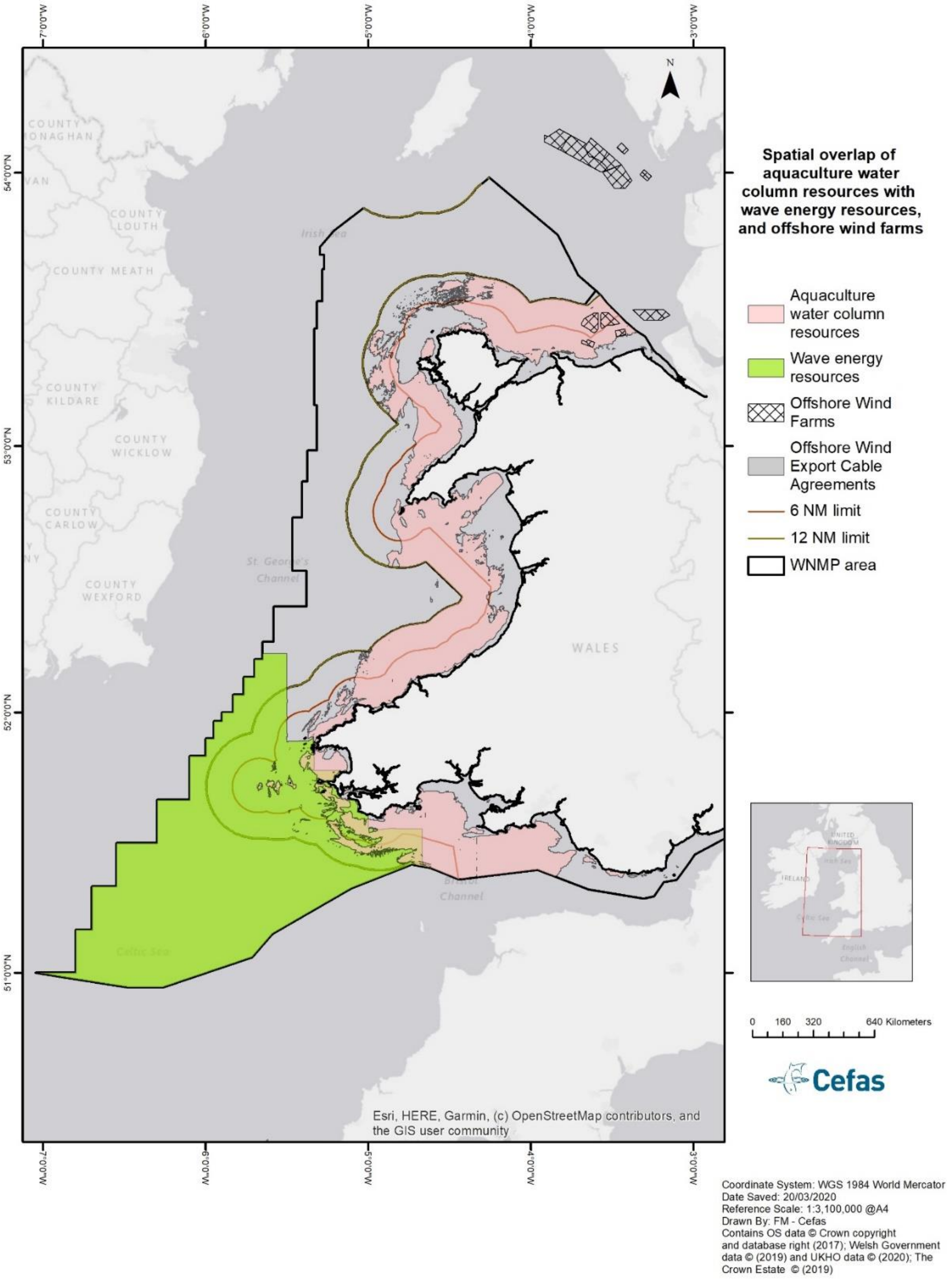

Figure 4.26: Spatial overlap of aquaculture water column resources, wave energy resources and offshore wind farms (as of 2017).

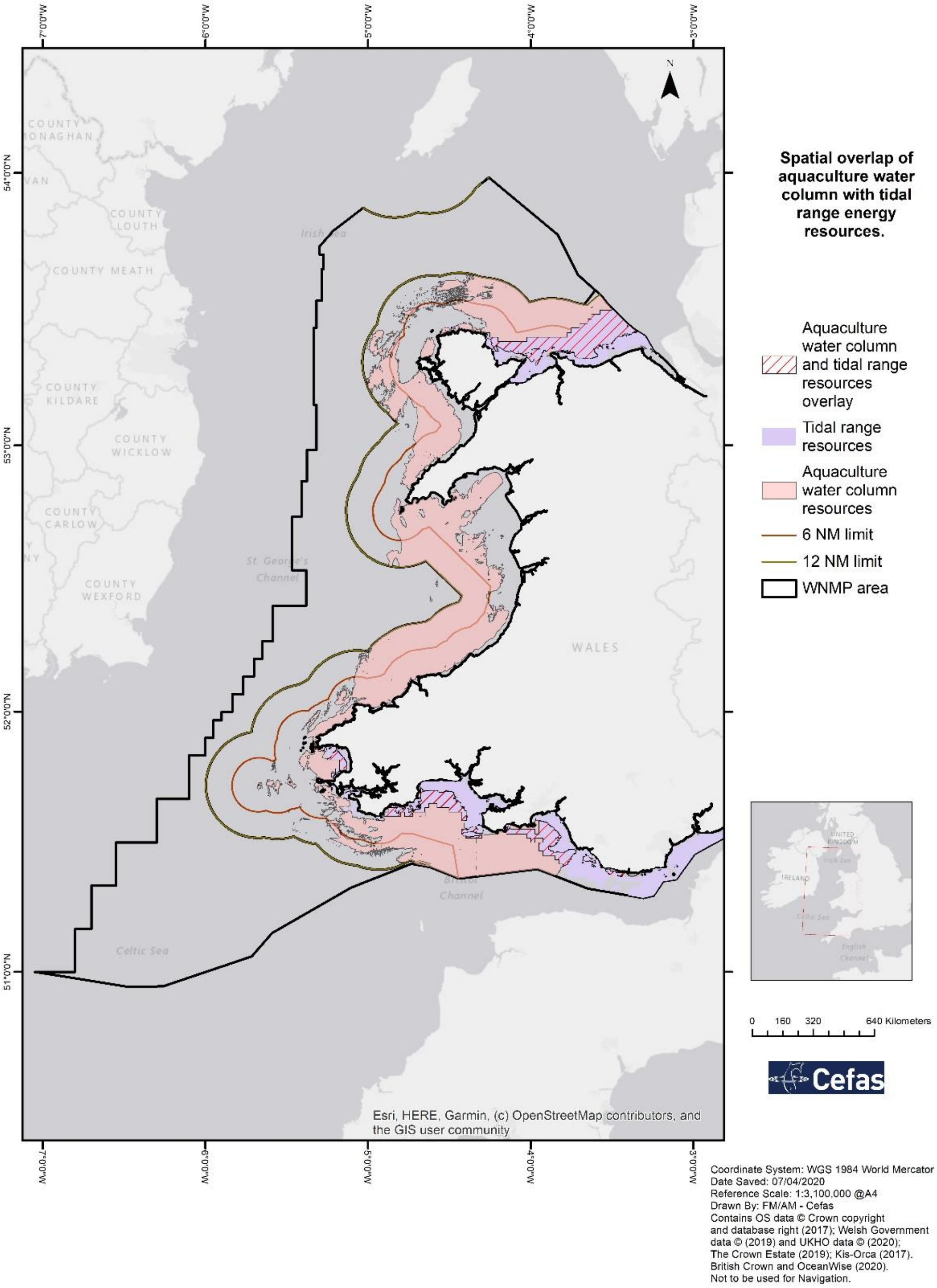

Figure 4.27: Spatial overlap of aquaculture water column with tidal range energy resources.

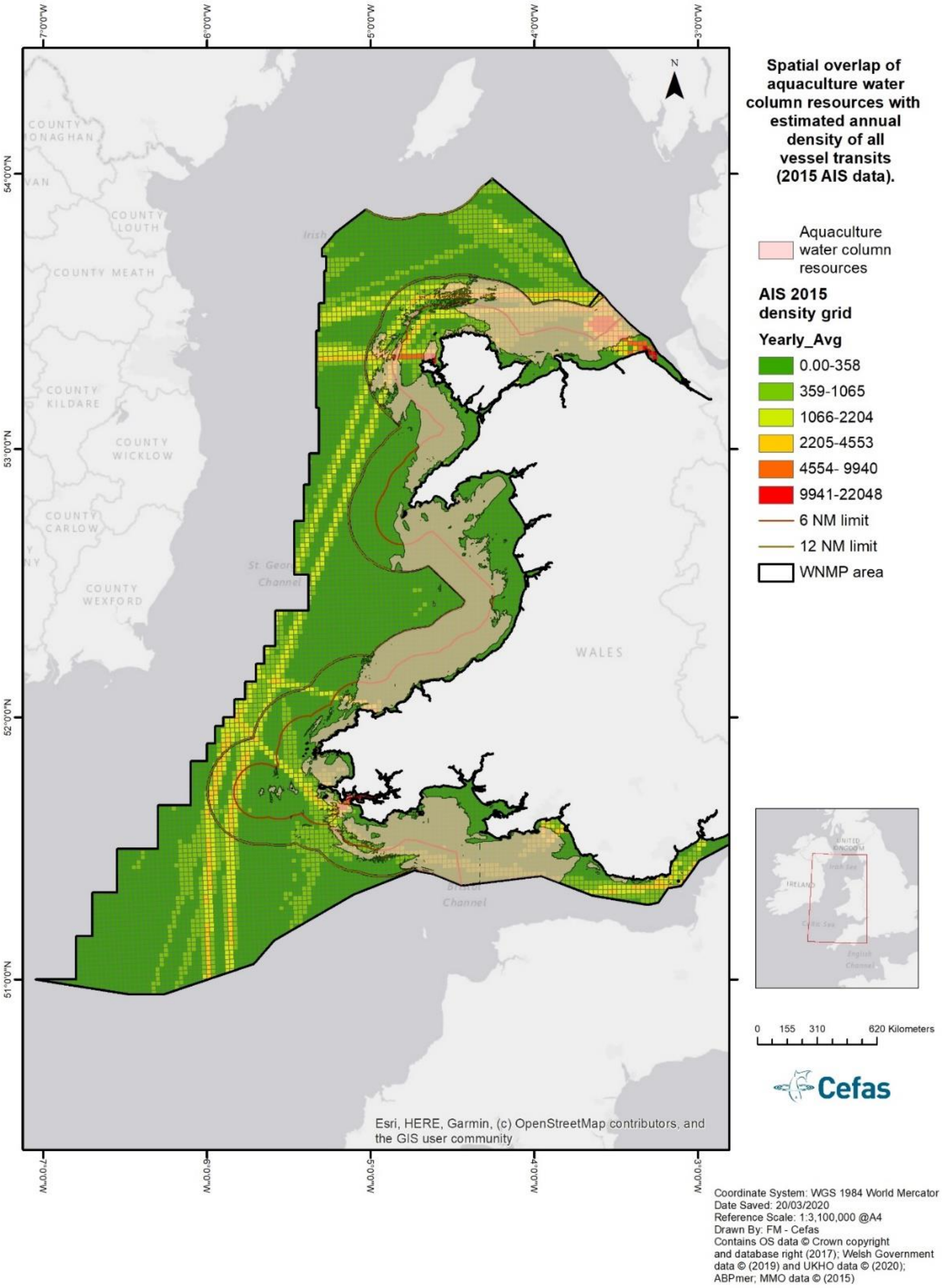

Figure 4.28: Spatial overlap of aquaculture water column resources and shipping. Shipping activity represented by estimated annual density of all vessel transits from Automatic Identification Systems data (2015).

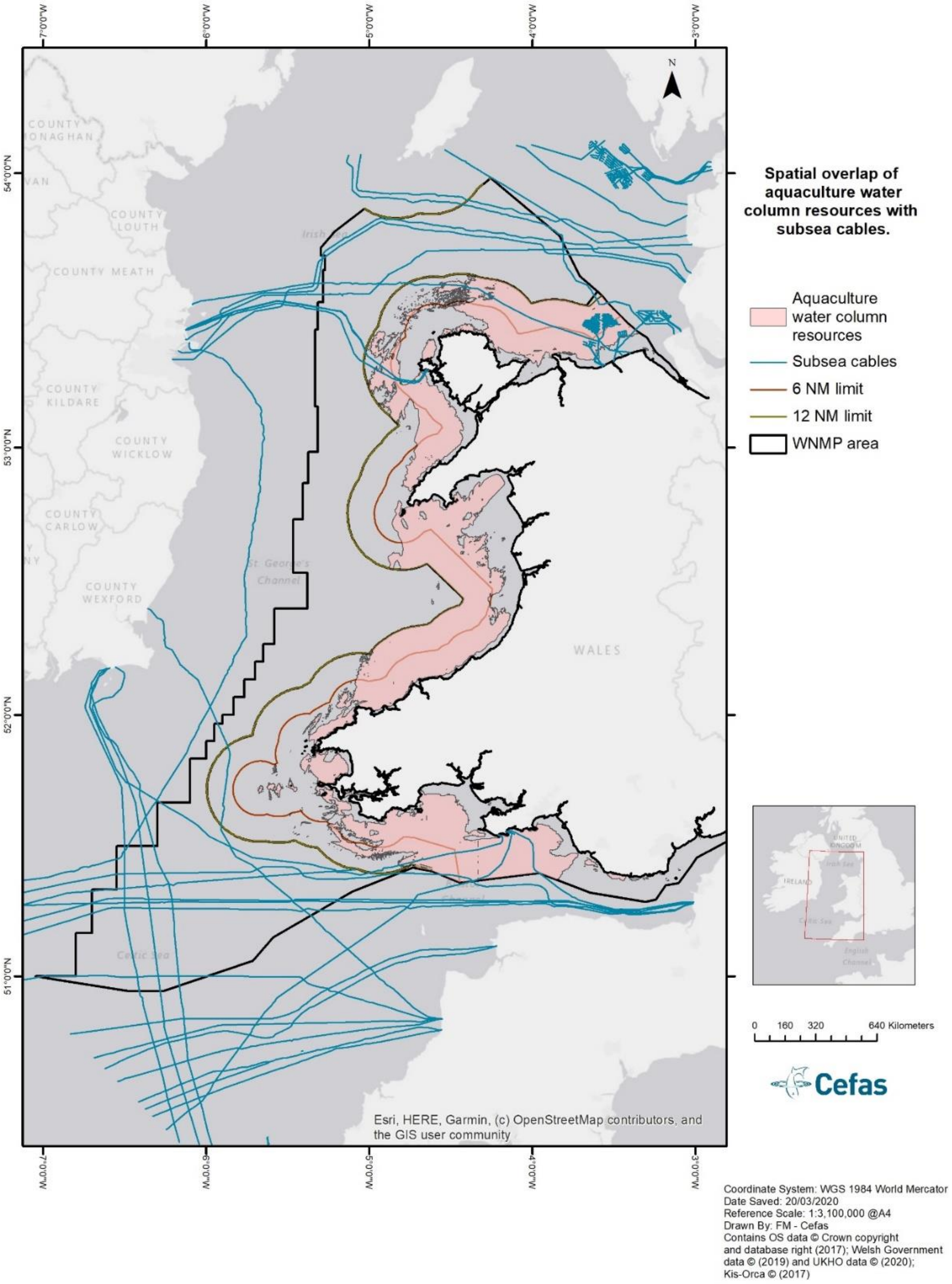

Figure 4.29: Spatial overlap of aquaculture water column resources and subsea cabling.

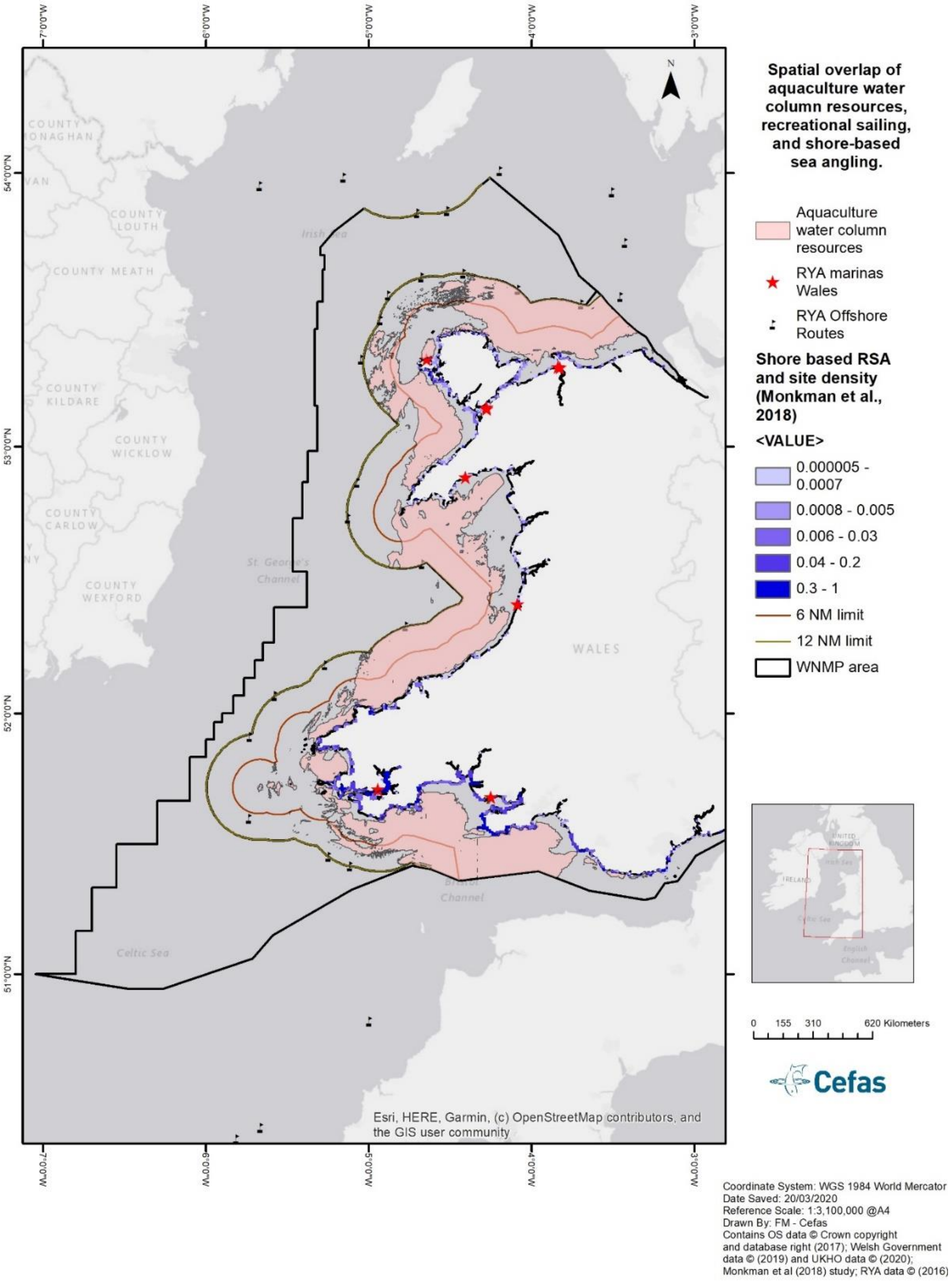

Figure 4.30: Spatial overlap of aquaculture water column resources and recreational activities. Examples of sailing and shore locations for recreational sea angling (source: Monkman et al., 2018).

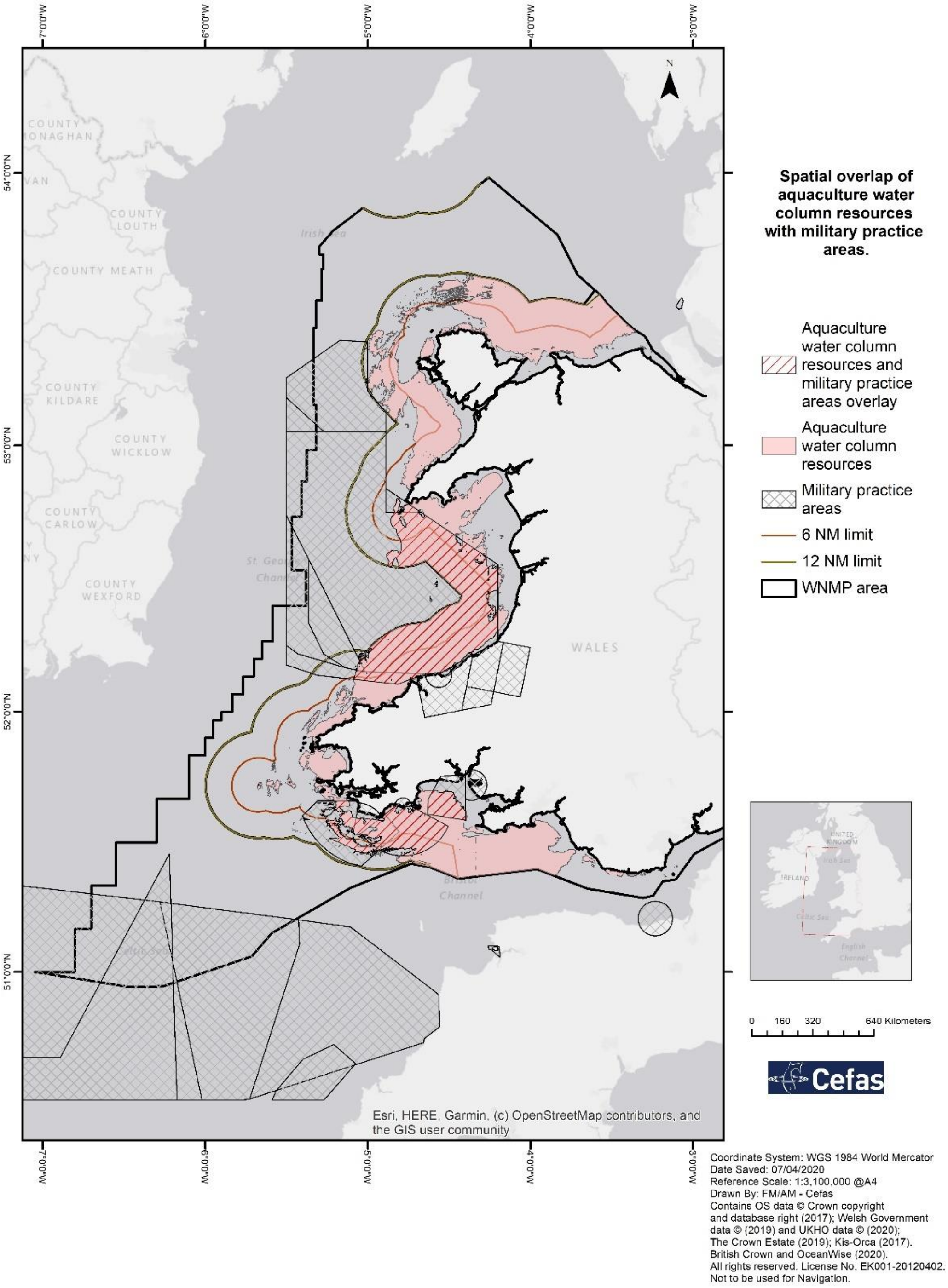

Figure 4.31: Spatial overlap of aquaculture water column resources and military practice areas.

Table 4.5: Summary of water column resource and rope-based aquaculture (shellfish and seaweed) and interaction with focal and other sectors.

Marine Plan Sector	Activity/Sector	Are the two activities likely to interact (possible, likely or unlikely)? If so, how interact?	Can the structures/activities physically co exist in space, recognising activities could occur in the same space yet at different times (possible, likely or unlikely)?
Marine minerals	Marine aggregates	**Possible** – Water column aquaculture resources (rope-based aquaculture), coincide with aggregate resources in several locations: north-east Anglesey, off North Wales, south Pembrokeshire, and Carmarthen and Swansea Bay.	**Unlikely** – Safety and operational reasons, aggregate extraction spatially separate from rope cultivation in the water column.
Energy	Wave energy **Refer to Figure 4.26 for the indicative sector interaction map.**	**Possible** – Water column aquaculture resources (rope-based aquaculture), coincide with wave energy resources off Pembrokeshire.	**Possible** – No known examples in Wales at present, of integrated aquaculture (finfish and shellfish/macroalgae). However, a potential co-location opportunity for the future.
	Tidal stream (fixed and floating)	**Possible** – Water column aquaculture resources (rope-based aquaculture), coincide with tidal stream resources off the Llŷn Peninsula, Pembrokeshire, and coastal sites in South Wales.	**Possible** – No known examples in Wales at present, of integrated aquaculture (finfish and shellfish/macroalgae) and tidal stream. However, a potential co-location opportunity for the future.
	Tidal range **Refer to Figure 4.27 for the indicative sector interaction map.**	**Possible** – Water column aquaculture resources (rope-based aquaculture), coincide with tidal stream resources off Anglesey and coastal sites in South Wales.	**Possible** – No known examples in Wales at present, of integrated aquaculture (finfish and shellfish/macroalgae) and tidal range. However, a potential co-location opportunity for the future.
	Wind turbines (fixed and floating) Offshore wind farms (fixed and floating) **Refer to Figure 4.26 for the indicative sector interaction map.**	**Possible** – Water column aquaculture resources (rope-based aquaculture), coincide with wind energy resource off North Wales, to the north-west of Anglesey, around the Llŷn Peninsula, within Cardigan Bay, off Pembrokeshire, as well as coastal sites in South Wales.	**Possible** – No known examples in Wales at present, of integrated aquaculture (finfish and shellfish/macroalgae). However, a potential co-location opportunity for the future.
	Oil and Gas (incl. submarine pipelines and other infrastructure)	**Likely** – Water column aquaculture resources (rope-based aquaculture), coincide with oil and gas infrastructure and petroleum licensing blocks in off North Wales, in Liverpool Bay.	**Unlikely** – Safety and operational reasons, rope-based cultivation is likely to be spatially separate from oil and gas structures atop the sea surface and pipelines/well heads etc on/along the seabed.

Marine Plan Sector	Activity/Sector	Are the two activities likely to interact (possible, likely or unlikely)? If so, how interact?	Can the structures/activities physically co exist in space, recognising activities could occur in the same space yet at different times (possible, likely or unlikely)?
	Miscellaneous (incl. overhead power lines, power station, substations)	**Unlikely** – Water column aquaculture resources (rope-based aquaculture), in coastal waters or further offshore and hence separate from coastal structures.	**Likely** – Maritime occurrence of shellfish aquaculture, whereas miscellaneous structures present at the coast or in the case of substations (e.g. for operational renewable developments), tend not to be sited directly in the middle of the shellfish bed/resource.
Aquaculture	Cage culture – finfish	**Possible** – Water column aquaculture resources (rope-based aquaculture) and for caged finfish aquaculture, likely to insert in locations, including off North Wales, north-west Anglesey, north coast the Llŷn Peninsula, and off Pembrokeshire.	**Possible** – No known examples in Wales at present, of integrated aquaculture (finfish and shellfish/macroalgae). However, a potential co-location opportunity for the future.
	Bottom culture – shellfish	**Possible** – Water column aquaculture resources (rope-based aquaculture) and seabed aquaculture resources overlap in several locations. This includes off south coast of the Llŷn Peninsula, within Carmarthen and Swansea Bay.	
	Trestle culture - shellfish	**Unlikely** – Where trestle cultivation is intertidal compared with subtidal rope cultivation of shellfish and algae.	
Fisheries	Mobile mid-water gear	**Likely** – Fishing is a mobile activity and hence could overlap with water column aquaculture resources (rope-based aquaculture) and for caged finfish aquaculture.	**Possible** – Safety and operational reasons, water column aquaculture resources (rope-based aquaculture) likely to be spatially separate from grounds fished by mobile fishing gears. Likely that there could be flexibility in the activity location to meet requirements of mobile gear deployment and fished areas.
	Mobile bottom gear		
	Static gear (pots, lines, nets etc)	**Likely** – Fishing is a mobile activity and hence could overlap with water column aquaculture resources (rope-based aquaculture) and for caged finfish aquaculture.	**Possible** –Safety and operational reasons, water column aquaculture resources (rope-based aquaculture) likely to be spatially separate from grounds fished by static gear types. It is likely, however, that there could be flexibility in the activity location to meet requirements of static gear deployment and fished areas.
	Hydraulic dredging	**Likely** – Fishing is a mobile activity and hence could overlap with water column aquaculture	**Possible** – Safety and operational reasons, water column aquaculture resources (rope-based aquaculture) likely to be

Marine Plan Sector	Activity/Sector	Are the two activities likely to interact (possible, likely or unlikely)? If so, how interact?	Can the structures/activities physically co exist in space, recognising activities could occur in the same space yet at different times (possible, likely or unlikely)?
		resources (rope-based aquaculture) and for caged finfish aquaculture.	spatially separate from hydraulic dredging areas. It is likely, however, that there could be flexibility in the activity location relative to dredging locations.
	Rod and lining	**Likely** – Fishing is a mobile activity and hence could overlap with water column aquaculture resources (rope-based aquaculture) and for caged finfish aquaculture.	**Possible** – Safety and operational reasons, rod and lining is unlikely to overlap with water column aquaculture resources (rope-based aquaculture). It is likely, however, that there could be flexibility in the activity location relative to lining locations.
	Hand gathering	**Unlikely** – Where hand gathering is primarily intertidal compared with subtidal rope-cultivation of seaweed and bivalves.	**Likely** – Spatial separation from typically subtidal cultivation at sea, and intertidal nature of hand gathering.
Ports and Shipping	Shipping - navigation routes **Refer to Figure 4.28 for the indicative sector interaction map.**	**Likely** – Water column aquaculture resources (rope-based aquaculture) overlap with vessel traffic routes including to/from Pembroke/Milford Haven, Pembrokeshire and Holyhead, Anglesey.	**Likely** – Rope cultivation with surface markers and associated infrastructure, would be present in the water column and near the sea surface. This is likely to preclude vessels directly passing through the licenced cultivation area, although access around the harvested area could remain accessible. Likely that there could be flexibility in the activity location to meet requirements of navigational routes and port activity.
	Anchorage areas	**Likely** – Water column aquaculture resources (rope-based aquaculture) overlap with coastal anchorage sites off north-east Anglesey, south Pembrokeshire and Swansea Bay.	**Unlikely** – Avoidance of anchoring among rope cultivation and infrastructure, and potential negative impacts.
Subsea cables	Cables and telecommunications **Refer to Figure 4.29 for the indicative sector interaction map.**	**Likely** – Water column aquaculture resources (rope-based aquaculture) overlap with submarine cabling into north/north-west Anglesey and into/from the Swansea coastline.	**Likely** – Safety and operational reasons, rope-based cultivation could occur in water column above cables, though agreements needed between operators for accessibility to the infrastructure during operational and maintenance works.
Surface water and wastewater treatment and disposal	Intakes and outfalls, including licensed discharges	**Likely** – Water column aquaculture resources (rope-based aquaculture) overlap with coastal outfall pipes including from the coasts of Cardiff, Swansea, Pembrokeshire and North Wales.	**Unlikely** – Preference is to locate rope-based cultivation of shellfish and macroalgae away from sources of potential contamination, such as sewage outfalls.

Marine Plan Sector	Activity/Sector	Are the two activities likely to interact (possible, likely or unlikely)? If so, how interact?	Can the structures/activities physically co exist in space, recognising activities could occur in the same space yet at different times (possible, likely or unlikely)?
Dredging and Disposal	Designated disposal sites (Active)	**Likely** - Water column aquaculture resources (rope-based aquaculture) overlap with licenced disposal sites. Including to the north/north-west of Anglesey, Liverpool Bay and Swansea Bay.	**Unlikely** – Preference is to locate rope-based cultivation of shellfish and macroalgae away from dredging and disposal sites, due to the potential for smothering and contamination.
Defences	Military exercise areas/ammunition disposal sites **Refer to Figure 4.31 for the indicative sector interaction map.**	**Likely** – Water column aquaculture resources (rope-based aquaculture) overlap with Military Practise Areas encompassing Cardigan Bay, around the Pembrokeshire coast, off Tenby and in Carmarthen Bay.	**Possible** – Potential for rope-based aquaculture to occur within military practise areas unless they are subject to temporal restrictions during operational test and military training periods. Future development for rope-based aquaculture where fixed infrastructure to be used, would need to be in dialogue with the MoD.
Tourism and Recreation	Recreational Sea Angling (RSA) **Refer to Figure 4.30 for the indicative sector interaction map.**	**Possible** –RSA undertaken from chartered vessels around seabed features/wrecks, and islands e.g. Skomer. Potential to overlap with water column aquaculture resources (rope-based aquaculture).	**Possible** – RSA from boats could occur in waters around the cultivation area, subject to access for harvesting vessels and placement of markers.
	RYA marinas and sailing routes **Refer to Figure 4.30 for the indicative sector interaction map.**	**Possible** – Water column aquaculture resources (rope-based aquaculture) overlap with sailing routes.	**Possible** – Sailing could occur in waters around the cultivation area, subject to access for harvesting vessels and placement of markers.
	Water sports (e.g. surfing, kite surfing, diving, rafting)	**Possible** – Water column aquaculture resources (rope-based aquaculture) and potential to overlap with water sports atop the sea or through the water column e.g. recreational scuba diving. Notably, diving sites around Grassholm and Skokholm islands.	**Possible** – Water sports could occur in waters around and above subtidal shellfish beds, subject to access for harvesting vessels and placement of markers.
	Shore based activity (e.g. coasteering, hiking, dog walking, kites)	**Unlikely** – Water column aquaculture resources (rope-based aquaculture) at sea compared with shore/coastal location of activities.	**Possible** – Spatial separation from subtidal cultivation at sea and activities on/by the shore. Harvesting vessel and marker buoys possibly visible from shore if operations are inshore.
	Wildlife watching - shore based		**Possible** – Spatial separation of water column aquaculture resource (rope-based aquaculture) at sea and activities on/by the shore.

Marine Plan Sector	Activity/Sector	Are the two activities likely to interact (possible, likely or unlikely)? If so, how interact?	Can the structures/activities physically co exist in space, recognising activities could occur in the same space yet at different times (possible, likely or unlikely)?
	Wildlife watching - boat based	**Possible** – Water column aquaculture resources (rope-based aquaculture) and potential for overlap with boat-based tourism. Such as in proximity to islands that are wildlife hotspots e.g. Grassholm and Skokholm.	**Possible** – Wildlife tourism could occur in waters around the cultivation area, subject to access for harvesting vessels and placement of markers.

4.4.2.2 Water column resource: finfish aquaculture

A summary of interaction appraisal for water column resources (finfish aquaculture) and other sectors is shown in Table 4.6.

Water column aquaculture (finfish) is unlikely to spatially co-exist with marine aggregate resources, tidal stream resources, and seabed and water column aquaculture resources. This is considering safety and operational restrictions and consenting basis, applicable to combining the activities in space. There is also unlikely to be a spatial co-existence with other sectors, including surface water and wastewater treatment and disposal, dredging and disposal, tidal range energy as well as defence.

Spatial and temporal management could be applied to sequence the activities of each of the sectors. Such future planning would benefit from dialogue between the respective sectors and their associated regulators. Having these resource overlaps mapped and considering the interactions (Table 4.6) will help to target this dialogue on forward-looking, proactive and spatial planning.

Table 4.6: Summary of water column resources and finfish aquaculture interaction with focal and other sectors.

Marine Plan Sector	Activity/Sector	Are the two activities likely to interact (possible, likely or unlikely)? If so, how interact?	Can the structures/activities physically co exist in space, recognising activities could occur in the same space yet at different times (possible, likely or unlikely)?
Marine minerals	Marine aggregates	**Possible** – Water column aquaculture resources (finfish cultivation), overlaps with aggregate resources in several areas: north coast and south-west of Anglesey, south Pembrokeshire, and Carmarthen and Swansea Bay.	**Unlikely** – Safety and operational reasons, aggregate extraction spatially separated from finfish cages in the water column.
Energy	Wave energy	**Possible** – Water column aquaculture resources (finfish cultivation) and overlap with wave energy resources off Pembrokeshire.	**Unlikely** – Safety and operational reasons, wave devices on the sea surface/water column and finfish cages in the water column are likely to be spatially separate.
	Tidal stream (fixed and floating)	**Possible** – Water column aquaculture resources (finfish cultivation) and overlap with tidal stream resources off Anglesey, the Llŷn Peninsula, Pembrokeshire, and coastal sites in South Wales.	**Unlikely** – Safety and operational reasons, tidal stream devices on the sea surface/water column or on the seabed, and finfish cages in the water column, are likely to be spatially separate.
	Tidal range	**Possible** – Water column aquaculture resources (finfish cultivation) and overlap with tidal range resources off Anglesey.	**Unlikely** – Safety and operational reasons, tidal range devices on the sea surface/water column or on the seabed, and finfish cages in the water column, are likely to be spatially separate.
	Wind turbines (fixed and floating) Offshore wind farms (fixed and floating)	**Possible** – Water column aquaculture resources (finfish cultivation) and overlap with wind energy resource off North Wales, to the west of Anglesey, around the Llŷn Peninsula, within Cardigan Bay, off Pembrokeshire, and coastal sites in South Wales.	**Possible** –Currently for safety and operational reasons, finfish cages in the water column, kept spatially separate from fixed/floating turbines (and turbines together in a wind farm) and wind farms. But in the future, it could be conceivable to co-locate wave devices and wind farms, particularly where operations are in more high energy environments and cost incentives to share infrastructure[9].
	Oil and Gas (incl. submarine pipelines and other infrastructure)	**Likely** – Water column aquaculture resources (finfish cultivation), coincide with oil and gas infrastructure and petroleum licensing blocks in Liverpool Bay, off the west coast of Anglesey, and off Pembrokeshire, located in the Outer Bristol Channel.	**Unlikely** - Safety and operational reasons, finfish cages in the water column are likely to be spatially separate from oil and gas structures atop the sea surface and pipelines/well heads etc on/along the seabed.
	Miscellaneous (incl. overhead power lines, power station, substations)	**Unlikely** – Water column aquaculture resources (finfish cultivation) separate from coastal-based infrastructure like power stations.	**Likely** – Maritime occurrence of shellfish aquaculture, whereas miscellaneous structures present at the coast or in the case of substations (e.g. for operational renewable

Marine Plan Sector	Activity/Sector	Are the two activities likely to interact (possible, likely or unlikely)? If so, how interact?	Can the structures/activities physically co exist in space, recognising activities could occur in the same space yet at different times (possible, likely or unlikely)?
			developments), tend not to be sited directly in the middle of the shellfish bed/resource.
Aquaculture	Bottom culture - shellfish	**Possible** – Water column aquaculture resources (finfish cultivation) and seabed aquaculture overlap off North Wales, north-west Anglesey, north coast of the coast of Llŷn Peninsula, as well as Carmarthen and Swansea Bays.	**Possible** – No known examples in Wales at present, of integrated aquaculture (finfish and shellfish/macroalgae). However, a potential co-location opportunity for the future.
	Rope culture - shellfish	**Possible** – Water column aquaculture resources for finfish cultivation and for rope cultivation intersect off North Wales, north-west Anglesey, north coast the Llŷn Peninsula, and off Pembrokeshire.	
	Rope culture - seaweed	**Possible** – Water column aquaculture resources for finfish cultivation and for rope cultivation, intersect off the south coast of the Llŷn Peninsula, within Carmarthen and Swansea Bay.	
	Trestle culture - shellfish	**Unlikely** – Where trestle cultivation is intertidal compared with subtidal resources for finfish cultivation.	
Fisheries	Mobile mid-water gear Mobile bottom gear	**Likely** – Fishing is a mobile activity and hence could overlap with water column aquaculture resources (finfish cultivation).	**Possible** – Safety and operational reasons, water column aquaculture resources (finfish cultivation) likely to be spatially separate from grounds fished by mobile fishing gears. Likely that there could be flexibility in the activity location to meet requirements of mobile gear deployment and fished areas.
	Static gear (pots, lines, nets etc)	**Likely** – Fishing is a mobile activity and hence could overlap with water column aquaculture resources (finfish cultivation).	**Possible** –Safety and operational reasons, water column aquaculture resources (finfish cultivation) likely to be spatially separate from grounds fished by static gear types. It is likely, however, that there could be flexibility in the activity location to meet requirements of static gear deployment and fished areas.
	Hydraulic dredging	**Likely** – Fishing is a mobile activity and hence could overlap with water column aquaculture resources (finfish cultivation).	**Possible** – Safety and operational reasons, water column aquaculture resources (finfish cultivation) likely to be spatially separate from hydraulic dredging areas. It is likely,

Marine Plan Sector	Activity/Sector	Are the two activities likely to interact (possible, likely or unlikely)? If so, how interact?	Can the structures/activities physically co exist in space, recognising activities could occur in the same space yet at different times (possible, likely or unlikely)?
			however, that there could be flexibility in the activity location relative to dredging locations.
	Rod and lining	**Likely** – Fishing is a mobile activity and hence could overlap with water column aquaculture resources (finfish cultivation).	**Possible** – Safety and operational reasons, water column aquaculture resources (finfish cultivation) likely to be spatially separate from rod and lining areas. But likely that there could be flexibility in the activity location relative to lining.
	Hand gathering	**Unlikely** – Where hand gathering is conducted in the intertidal zone compared with subtidal resources for finfish cultivation.	**Unlikely** – Spatial separation from finfish aquaculture e.g. pens and associated anchors/lines at sea, and intertidal nature of hand gathering.
Ports and Shipping	Shipping - navigation routes	**Likely** – Water column aquaculture resources (finfish cultivation) overlap with several vessel traffic routes, including to/from Pembroke/Milford Haven, Pembrokeshire and Holyhead, Anglesey.	**Likely** - Finfish aquaculture e.g. pens and associated anchors/lines at sea, usually spatially separate from shipping traffic and designated anchorages.
	Anchorage areas	**Likely** – Water column aquaculture resources (finfish cultivation) overlap with coastal anchorage sites off north-east Anglesey and Swansea Bay.	**Unlikely** – Where anchorage areas are already present before finfish pens, the potential for co-location on operational and safety grounds is limited.
Subsea cables	Cables and telecommunications	**Likely** – Water column aquaculture resources (finfish cultivation) overlap with submarine cables into north/north-west Anglesey, Swansea coast as well as routes into the Inner Bristol Channel.	**Likely** – Pens for fish in the water column could co-occur over seabed with buried subsea cables.
Surface water and wastewater treatment and disposal	Intakes and outfalls, including licensed discharges	**Possible** – Water column aquaculture resources (finfish cultivation) coincide with coastal outfall pipes including from the coasts of Swansea, Pembrokeshire and North Wales.	**Unlikely** – Finfish aquaculture e.g. pens and associated anchors/lines usually locations away sources of potential contamination, such as outfalls.
Dredging and Disposal	Designated disposal sites (Active)	**Likely** – Water column aquaculture resources (finfish cultivation) overlap with licensed disposal sites to the north/north-west of Anglesey, Liverpool Bay and Swansea Bay.	**Unlikely** – Safety and operational reasons, finfish aquaculture e.g. pens and associated anchors/lines, likely to be kept spatially separate from designated disposal sites.
Defences	Military exercise areas/ammunition disposal sites	**Likely** – Water column aquaculture resources (finfish cultivation) coincide with Military Practise Areas encompassing Cardigan Bay, around the	**Unlikely** – Safety and operational reasons, finfish aquaculture e.g. pens and associated anchors/lines, likely to be kept spatially separate from military defence areas. Future development for finfish aquaculture where fixed

Marine Plan Sector	Activity/Sector	Are the two activities likely to interact (possible, likely or unlikely)? If so, how interact?	Can the structures/activities physically co exist in space, recognising activities could occur in the same space yet at different times (possible, likely or unlikely)?
		Pembrokeshire coast, off Tenby and in Carmarthen Bay.	infrastructure to be used, would need to be in dialogue with the MoD.
Tourism and Recreation	Recreational Sea Angling (RSA)	**Possible** –RSA undertaken from chartered vessels around seabed features/wrecks, and islands e.g. Skomer. Potential to overlap with water column aquaculture resources (finfish cultivation).	**Possible** – Boat-based RSA in proximity to the cages, though not directly in the cage 'footprint'.
	RYA marinas and sailing routes	**Possible** – Water column aquaculture resources (finfish cultivation) likely to overlap with sailing routes.	**Possible**- Supporting vessels for tidal stream operations, may utilise existing navigational routes to access devices. However, navigational measures and best practise measures would limit close spatial co-existence, mainly on safety grounds.
	Water sports (e.g. surfing, kite surfing, diving, rafting)	**Possible** – Water column aquaculture resources (finfish cultivation) and potential to overlap with water sports atop the sea or through the water column e.g. recreational scuba diving. Notably, diving sites around Grassholm and Skokholm islands.	**Unlikely** – Safety and operational reasons, finfish aquaculture sites separate spatially from water sports.
	Shore based activity (e.g. coasteering, hiking, dog walking, kites)	**Unlikely** – Shore-based activities compared with subtidal nature of water column aquaculture resources (finfish cultivation).	**Unlikely** – Spatial separation from finfish aquaculture at sea and activities on/by the shore.
	Wildlife watching - shore based		**Unlikely** – Spatial separation from finfish aquaculture at sea and activities on/by the shore. Vessels and surface buoys may be visible if cages inshore.
	Wildlife watching - boat based	**Possible** – Water column aquaculture resources (finfish cultivation) and potential for overlap with boat-based tourism. Such as in proximity to islands that are wildlife hotspots e.g. Grassholm and Skokholm.	**Possible** – Wildlife tourism could occur in waters around the cultivation area, subject to access for harvesting vessels and placement of markers.

5 Plan, policy and legislative considerations

5.1 Additional UK Plan and policy considerations

Considerations include policies in existing Marine Plans like the Integrated Marine Plan for Ireland and marine policies/objectives set by the Isle of Man Government. There are also future Marine Plans for areas bordering the WNMP where cross-boundary considerations may apply, for instance, the south-west and north-west England Marine Plans and The Republic of Ireland Marine Planning Framework.

Policy considerations include the Marine Policy Statement, and sector specific National Policy Statements.

5.2 National Development Framework and Regional and Local Plans

Relevant terrestrial plans/frameworks at a national, regional and local level have been identified, in view of potential links and relevance to the focal sectors e.g. jobs that could exist on land because of the focal activity.

5.2.1 National Development Framework 2020-2040[30]

The draft National Development Framework (NDF)[28] applies to all of Wales and the Strategic and Local Development Plans must support the implementation of the NDF. The draft NDF contains several objectives of relevance to the focal sectors including climate change, decarbonisation and energy, natural resources, economic prosperity and regeneration. Potential NDF policies with relevance to the focal sectors have been identified and summarised in Table 5.1.

Table 5.1: National Development Framework policies and descriptions with potential relevance to focal sectors, under the WNMP[28].

Policy	Description from NDF 2020 2040
Policy 8 – Strategic framework for biodiversity enhancement and ecosystem resilience	*"opportunities where strategic green infrastructure could be maximised as part of development proposals, requiring the use of nature based solutions as a key mechanism for securing sustainable growth, ecological connectivity, social equality and public well-being."*
Policy 13 – Other Renewable Energy Developments	Reference to Policy 11 for Wind and Solar Energy Outside of Priority Areas *"Outside of the Priority Areas for Solar and Wind, planning applications for large scale wind and solar development must demonstrate the proposal is acceptable, in accordance with the criteria below.*

[30] Source: https://gov.wales/sites/default/files/consultations/2019-08/Draft%20National%20Development%20Framework.pdf [Last access 06/04/2020]. This version is still in draft / consultation form and is the most up-to-date consultation draft of the NDF. It is, however, liable to change as the final version has not yet been adopted.

Policy	Description from NDF 2020 2040
	Planning applications must demonstrate how local social, economic and environmental benefits have been maximised and that there are no unacceptable adverse *effects on, or due to, the following:* • *landscape and visual impacts;* • *cumulative impacts;* • *the setting of National Parks and Areas of Outstanding Natural Beauty;* • *visual dominance, shadow flicker, reflected light or noise impacts;* • *electromagnetic disturbance to existing communications systems; and* • *the following identified protected assets:* - *archaeological, architectural or historic assets;* - *nature conservation sites and species;* - *natural resources or reserves.*"
Policy 17 – Wrexham and Deeside **(linkage to North Wales Strategic Development Plan)**	*"The Welsh Government supports Wrexham and Deeside as the primary focus for regional growth and investment. Wrexham and Deeside's role within the North region and the wider cross-border areas of Cheshire West and Chester and Liverpool City Region should be maintained and enhanced."*
Policy 18 – North Wales Coastal Settlements	*"The Welsh Government supports the built up coastal arc from Caernarfon to Deeside as the focus for managed growth, reflecting this area's important sub-regional role supporting the primary growth area of Wrexham and Deeside.* *Strategic and Local Development Plans across the region should recognise the role of this corridor as a focus for housing, employment and key services."*
Policy 20 – Port of Holyhead	*"The Welsh Government will work with port operators, local authorities and investors to support the development of the port and facilitate new investment in order to ensure that its strategic gateway role is maintained and enhanced. Investment to improve the port's capacity to accommodate cruise ships is supported…"*
Policy 23 – Swansea Bay and Llanelli	*"Swansea Bay and Llanelli will be the main focus for regional scale growth and investment.* *Regional and local development plans should recognise Swansea Bay and Llanelli as the focus for strategic growth; essential services and facilities;*

Policy	Description from NDF 2020 2040
	transport and digital infrastructure; and consider how they can support and benefit from their strategic regional role."
Policy 24 – Regional Centres **(linkage to Mid and West Wales Strategic Development Plan)**	"*…Carmarthen, Llandrindod Wells, Newtown, Aberystwyth and the four Haven Towns will be the focus for managed growth, reflecting their important sub-regional functions.* *Regional and local development plans should recognise the roles of these settlements as being a focus for housing, employment and key services within their wider areas and consider how they continue as a focal point for sub-regional growth*."
Policy 28 – Newport **(linkage to South East Wales Strategic Development Plan)**	"*The Welsh Government supports Newport as the focus for regional growth and investment…the strategic emphasis should be focussed on achieving growth in the city.* *Strategic and Local Development Plans across the region should recognise Newport as a focus for strategic housing and economic growth; essential services and facilities; transport and digital infrastructure; and consider how they can support and benefit from Newport's increased strategic regional role. Development in the wider region should be carefully managed to support Newport's growth and to provide a focus for regional planning*."

5.2.2 Wales Strategic Development Plans

Strategic Development Plans (SDPs) are applicable at regionals/sub-regional level and existing SDPs are for the following regions in Wales:

- South East Wales (Local Authority Areas of Cardiff, Newport, Monmouthshire, Bridgend, Vale of Glamorgan, RCT, Merthyr Tydfil, Torfaen, Blaenau Gwent and Caerphilly).
- South West and Mid Wales (LA areas of Powys, Carmarthenshire, Ceredigion, Pembrokeshire, Swansea, Neath Port Talbot).
- North Wales (LA areas of Gwynedd, Anglesey, Conwy, Flintshire, Wrexham and Denbighshire).

5.2.3 Wales Local Development Plans

Local Development Plans (LDPs) are prepared by each Local Authorities. Where LDP are available online, these have been reviewed and LDP policies with relevance to the (maritime) focal sectors, subsequently identified (Table 5.2). The LDP with a link to the WNMP focal sectors appears to be for counties situated on the coast and those with a link to maritime sectors/activities e.g. Swansea and aggregate wharves.

The types of relevant policies identified from the LDP are those for renewable energy and low carbon energy, where in the marine environment these are Energy – Low Carbon: Wave energy.

Tidal stream (fixed and floating) and Offshore Wind Energy (Table 5.2). There are LDP policies about safeguarding (terrestrial) aggregate resources and sustainable mineral resources e.g. Cardiff Council LDP (Table 5.2). These are considered to be relevant where marine minerals supplement terrestrial sources, such as for the construction industry.

There are relevant LDP policies about shipping freight, (associated with shipping activity), harbours/ports and associated access channels e.g. Cardiff LDP (Table 5.2). These have been identified given the socio-economic importance of shipping and coastal infrastructure e.g. ports which support and enable operations (marine and ashore) associated with the focal sector and non-focal sectors/activities.

Policies about managing water quality such discharges from land to coastal waters (e.g. Swansea Council LDP, Table 5.2), are considered relevant. This is given the importance of water quality for sectors like fisheries, aquaculture and recreational activities.

Table 5.2: Examples of Local Development Plan policies with potential relevance to focal sectors, under the Welsh National Marine Plan

Local Authority	Local Development Plan and relevant policies
Cardiff Council	Local Development Plan 2006-2026[31] <u>Policies of relevance:</u> EN12: Renewable energy and low carbon technologies M6: Sand wharf protection areas M7: Safeguarding of sand and gravel resources
Ceredigion County Council	Local Development Plan 2007-2022[32] <u>Policies of relevance:</u> Policy LU25: Renewable Energy Generation Policy LU27: Sustainable Supply of Mineral Resources
Gwynedd Council **Isle of Anglesey County Council**	Anglesey and Gwynedd Joint Local Development Plan 2011 – 2026[33] <u>Policies of relevance:</u> Strategic policy PS 7: renewable energy technology, with reference to marine energy sources including wind and tidal stream energy.

[31] Source: https://www.cardiff.gov.uk/ENG/resident/Planning/Local-Development-Plan/Documents/Final%20Adopted%20Local%20Development%20Plan%20English.pdf [Last access: 06/04/2020].

[32] Source: https://www.ceredigion.gov.uk/media/6223/ceredigion-local-development-plan-ldp-volume-1-strategy-and-policies-english.pdf [Last access: 06/04/2020].

[33] Source: https://www.gwynedd.llyw.cymru/en/Council/Documents---Council/Strategies-and-policies/Environment-and-planning/Planning-policy/Anglesey-and-Gwynedd-Joint-Local-Development-Plan-Written-Statement.pdf [Last access: 06/04/2020].

Local Authority	Local Development Plan and relevant policies
	STRATEGIC POLICY PS 22: Minerals and reference to "*Protect maritime wharf and railhead facilities as a means of encouraging sustainable transport of aggregates*."
Neath Port Talbot County Borough Council	Local Development Plan 2011-2026[34] <u>Policies of relevance:</u> Policy EN 1: The Undeveloped Coast and reference to "*The management and/or maintenance of shipping channels/port access and other associated infrastructure*." SP18: Renewable & Low Carbon Energy Policy TR 4: Safeguarding Freight Facilities Including: *TR4/1 Port Talbot Tidal Harbour* *TR4/2 Port Talbot Docks* *TR4/3 Existing & Potential Wharves* *TR4/4 Existing Rail Connections & Sidings*
Pembrokeshire County Council	Local Development Plan 2013-2021[35] <u>Policies of relevance:</u> GN.4 Resource Efficiency and Renewable and Low-carbon Energy Proposals SP 6 Minerals and referencing "*Safeguarding the landfall locations for marine dredged sand and gravel*."
Swansea Council	Local Development Plan 2010-2025[36] <u>Policies of relevance:</u> EU 1: Renewable and low carbon energy developments ER 1: Climate Change and reference to "*Promoting energy and resource efficiency and increasing the supply of renewable and low carbon energy.*" RP 11: Sustainable development of mineral resources and reference to "*Wharves in Swansea Docks used for the unloading of marine dredged sand and gravel will be safeguarded*." RP 3: Water pollution and the protection of water resources, and reference to "*Development proposals that would have a significant adverse impact on biodiversity, fisheries, public access or water related recreation use of water resources, will not be permitted*."

[34] Source: https://www.npt.gov.uk/media/7321/ldp_written_statement_jan16.pdf [Last access: 06/04/2020].
[35] Source: https://www.pembrokeshire.gov.uk/adopted-local-development-plan [Last access: 06/04/2020].
[36] Source: https://www.swansea.gov.uk/article/30232/Core-documents---Submitted-LDP-Docs-LDP [Last access: 06/04/2020].

6 Summary and Recommendations

The increasing demand and competition for marine space requires a sound approach for the optimal management of the marine and coastal environment. The approach needs to address the multiple, cumulative and potentially conflicting uses of the sea whilst promoting the effective protection of natural resources (OECD, 2016).

It is suggested that, although there are challenges to understand and develop the marine spatial planning process, co-existence and co-location are choices which deserve greater consideration from Welsh marine planners and stakeholders, whose goal is to minimise conflicts and maximise benefits between different sea users (Kyvelou and Ierapetritis, 2019).

The Welsh National Marine Plan (WNMP) defines the long-term vision for the sustainable development of the Welsh seas, which underpin the well-being of coastal regions and the wider Welsh population. The WMNP vision will be achieved "*through an integrated, evidenced and plan-led approach that respects established uses and interests whilst securing benefits from new opportunities, recognising the importance of our heritage, ecosystem resilience, the value of biodiversity and imperative to tackle climate change*" (Welsh Government, 2019, p. 1).

The WNMP is anchored into the Well-being of Future Generations (Wales) Act (WFGA) 2015 and Environmental (Wales) Act 2016. These legislative measures stress the sustainable current and future use of the marine resources as well as the consideration of co-existence of maritime activity, when and where feasible. However, the sustainability appraisal of the WNMP found several negative impacts regarding the promotion of the sectors: marine aggregates, energy - oil and gas, and energy – low carbon. Co-existence may offset the footprint of these sector and, therefore, enables early measure to counterbalance any potential negative environmental or social, culture impacts of developing these sectors. The sustainability appraisal recommends careful appraisal of the blue growth goal to achieve well-being goals. This report contributes to this appraisal and seeks to give more information, from a socio-economic perspective, on potential co-existence but also spatial and temporal conflicts between sectors.

To this end, the objectives of this report was to compile and synthesise evidence regarding sector-sector interactions - focal marine sectors and other marine activities – drawing on evidence from the Welsh marine area or from UK and international examples where Welsh specific data were lacking. This is to promote a better and clearer understanding of interaction opportunities and constraints within the SRA. We focused on the socio-cultural and economic factors impacting interaction between activities/uses of the marine space. The report is complemented by an overview of plans and polices at national, regional and local scales in Wales and elsewhere in the UK.

Primary evidence on sector-sector interactions are limited and dominated by consideration of **co-location** of **aquaculture** and **offshore renewables** (mostly offshore wind farms) in the UK and other Northern European countries, such as Germany, from both the industrial and academic perspective. This is demonstrated by more socio-economic available evidence of the impact of co-locating these two sectors presented in this report. On one hand, this is likely due to the expansion of the renewable energy sector. But on the other hand, it may be due to the potential for increasing seafood production to reduce pressure on the fish stocks.

Similarly, co-existence between the **marine aggregate** sector and other important activities for coastal communities (e.g. fisheries and tourism) has received more attention. This is partially a result of research targeting the marine aggregate industry, which has been subsidised between 2002 and 2011 through the Marine Aggregate Levy Sustainability Fund (MALSF). The outputs of the research undertaken over this decade have provided valuable inputs to the wider marine science, that underpins the planning and management of multiple activities taking place in the marine environment round the UK.

As a result of the evidence review the following recommendations are made. These have been divided in general recommendations and sector-sector interaction specific ones.

General recommendations include:

- More evidence targeting specifically the socio-cultural impacts of co-existence and co-location of marine activities is required. An interdisciplinary, bottom-up approach should be adopted. As such, stakeholder representatives from the private sector representing various Welsh marine industries and marine groups, public authorities and researchers should be involved at the early stages of the marine/coastal development proposal and throughout the spatial planning process.

- We suggest the adoption of the definition of Social Impact Assessment (SIA) provided by (Vanclay, 2003, p. 5) which states that SIA *"includes the processes of analysing, monitoring and managing the intended and unintended social consequences, both positive and negative, of planned interventions (policies, programs, plans, projects) and any social change processes invoked by those interventions"*. The social assessment plays an important role in understanding the interdependence between the marine environment and coastal communities and how the impacts distribute differently amongst different groups in society. It is also a tool to collect information about relevant social factors which will complement the environmental and social domains in order to inform planning and management decisions (Voyer et al., 2012).

- Good governance is indispensable in complex decision-making when assessing development options for marine sectors. It is also a key factor to enable adequate management of social, economic and ecological systems which incorporate human well-being. Planning should happen through a collaborative process where all relevant stakeholders with competing or common interests, are engaged. This is to identify strategic options, assess opportunities and risks and thus improving the design and administration of plans (Blau and Green, 2015; Partidario and Gomes, 2013). Moreover, a collaborative approach is likely to result in higher levels of compliance and wider social cohesion (Blau and Green, 2015).

- Equally, methods for evaluating the economic benefits and trade-offs of multiple seas uses should be defined. There is complexity associated with valuing ecosystem goods and benefits, and there are uncertainties with the lack of market prices for certain goods and benefits provided by nature. The economic appraisal was determined as best oriented towards economic efficiency and the management of sustainable economic growth, stemming from the combination and integration of activities developing or occurring in a specific area (Eggenberger and Partidário, 2000). Economic valuation is a crucial mechanism to unveil the total economic value of final goods and benefits (also called "ecosystem services") supplied by the marine and coastal environments, and inform policy choices and business decisions (Bateman et al., 2014; Turner et al., 2014). There are already methods available to quantify the value of ecosystem goods and services (e.g. water quality, healthy climate) (Partidario and Gomes, 2013; Turner et al., 2014).

- Ultimately, a flexible framework should be adopted for the integrated evaluation of environmental, social and economic impacts of sector-sector interactions. This could assist Welsh policy makers in planning for the use and management of coastal and marine resources to reflect the local context and needs.

Sector-sector interaction specific recommendations include:

- Much of the work undertaken to investigate opportunities for co-existence or co-location of offshore infrastructures (aquaculture farms and low carbon energy arrays), seems to prioritise technological and environmental factors and issues. Whereas research should be developed further to address social acceptance and spatial distribution of the users of the coastal areas where the infrastructures are planned to be located, together with associated potential impacts as well as economic viability of multiple uses of the same marine space.

- It would be useful to develop a context-specific framework, to provide guidance about the licensing process and safety regulations. This could also delineate minimum technical requirements and financial pathways (e.g. incentives, insurance coverage) for the co-location of aquaculture and low carbon energy installations. This type of framework should adopt a consultative process with representatives from the private sector (marine industries and groups) as well as public authorities and researchers. Engaging stakeholders is essential from the early stages of the planning process to develop a new project, a new strategy or action plan. Hence, an interdisciplinary bottom-up approach should be adopted.

- Displacement of activities (e.g. fisheries, recreational activities) resulting from interacting sectors can be a concern. This issue could be addressed through innovative, cooperative and coordinated ways between the parties involved, facilitated by strong stakeholder engagement. An example of cooperation between the fishing industry and the marine aggregate sector is provided in section 3.2.4.

- Building on existing examples of positive interaction between aquaculture and tourism in southern European countries (section 3.2.15), in depth research is needed to investigate how aquaculture and tourism can positively interact. For instance, interaction that promotes education and/or recreational activities, and associated societal and economic benefits.

7 References

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Appendix 1: Marine Plan Activity/Sectors

Marine Plan Sector	Activity/Sector category
Marine aggregates	Aggregate extraction
Energy	Wave
	Tidal stream (fixed and floating)
	Tidal range energy (tidal lagoons)
	Wind turbines (fixed and floating)
	Offshore wind Farms (fixed and floating)
	Oil and Gas (incl. submarine pipelines and other infrastructure)
	Miscellaneous (incl. overhead power lines, power station, substations)
Aquaculture **Resources in the mapping (Section 4) distinguish seabed resources, bottom cultivation of shellfish, and water column resources e.g. rope cultivation of shellfish.**	Bottom culture - shellfish
	Cage culture - finfish
	Rope culture - shellfish
	Rope culture - seaweed
	Trestle culture - shellfish
Fisheries	Mobile mid-water gear
	Mobile bottom gear
	Static gear (pots, lines, nets etc)
	Hydraulic dredging
	Rod and lining and hand gathering
Ports and Shipping	Shipping - navigation routes
	Anchorage areas
Cables and telecommunications	Subsea cables
Surface water and wastewater treatment and disposal	Intakes and outfalls, including licensed discharges
Dredging and Disposal	Designated disposal sites, and licensed maintenance/capital dredging
Defence	Military practise/operation areas; areas of intense aerial activity
Tourism and Recreation	Recreational Sea Angling
	Royal Yachting Association marinas and sailing routes
	Water sports (e.g. surfing, kite surfing, diving, rafting)
	Shore based activity (e.g. coasteering, hiking, dog walking, kites)
	Wildlife watching - shore based
	Wildlife watching - boat based

Appendix 2: Mapping data layers summary

Data layer	Data type (Points, Polygon, Polyline, Gridded)	Data source
Marine aggregate resources	Polygons	Key Resource Areas (KRA) identified by The Crown Estate (2014), cited in Welsh Government (2019).
Tidal stream resources	Polygons	Key Resource Areas (KRA) identified by The Crown Estate (2014), cited in Welsh Government (2019).
Tidal range resources	Polygons	Key Resource Areas (KRA) identified by The Crown Estate (2014). Includes data from ABPmer (2008), cited in Welsh Government (2019).
Wave energy resources	Polygons	Key Resource Areas (KRA) identified by The Crown Estate (2014). Includes data from ABPmer (2008), cited in Welsh Government (2019).
Seabed aquaculture resources	Polygons	Welsh Government (2015a).
Water column aquaculture resources	Polygons	
Offshore wind farms (Leasing rounds 1, 2 and 3 plus round 1 and 2 extensions **available for 2017**)	Polygons	The Crown Estate (2019).
Offshore wind export cable agreements	Polyline	The Crown Estate (2017).
Subsea cabling	Polyline	KIS-ORCA (2017).
Fishing activity data - Fishing activity for UK vessels 15m and over in 2016	Polygon & points	MMO (2016).
Vessel transits – Automatic Identification System (AIS) data	Density layer based on points	ABPmer and MMO (2015).
Licensed disposal sites	Polygons	Natural Resources Wales (2019)
Sea angling locations	Points and polygons	Monkman et al. (2018).
RYA marinas	Points	RYA (2016).
RYA offshore sailing routes	Points	RYA (2016).
Defence – Military Practise Areas	Polygons	British Crown and OceanWise (2020) License No. EK001-20120402.

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Head office
Pakefield Road
Lowestoft
Suffolk
NR33 0HT
Tel: +44 (0) 1502 56 2244
Fax: +44 (0) 1502 51 3865

Weymouth office
Barrack Road
The Nothe
Weymouth
DT4 8UB
Tel: +44 (0) 1305 206600
Fax: +44 (0) 1305 206601

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