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Value of coastal habitats to commercial fisheries in Jersey, English Channel, and the role of marine protected areas

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Abstract

Fisheries are in decline worldwide, and Marine Protected Areas (MPAs) are being advocated as tools that can not only protect and restore biodiversity but also improve fisheries sustainability and protect fisher livelihoods. To understand the role of Marine Protected Areas (MPAs) in underpinning commercial fisheries, this study demonstrates the economic value of Jersey's benthic substrates (habitats) for five predominant species fished by Jersey and French vessels: *Homarus gammarus*, *Cancer pagurus*, *Maja brachydactyla*, *Pecten maximus* and *Buccinum undatum*. Value was apportioned between habitats that support these commercial species across their essential life history stages, and the proportional economic value that was protected from bottom-towed fishing within MPAs was analysed. Multiple habitats across Jersey's territorial waters contributed a total economic value of £14,664,729, with £4,127,999 protected within MPAs. Overall, subtidal sediment was the most valuable habitat to both Jersey (£2.12 million) and French (£2.47 million) fisheries but was also the least protected habitat from bottom-towed fishing (2.73%). Our findings support an ecosystem-based approach to fisheries management and emphasise the importance of considering species life histories, and their habitat requirements, in management plans.

KEYWORDS
ecosystem-based approach, life histories, marine, shared resource management, shellfish, valuation

1 | INTRODUCTION

Fisheries are a source of global food security, but many fish stocks have been overexploited (Steneck & Pauly, 2019). Corresponding habitat destruction caused by fishing gear has exacerbated global declines in ecosystem health, fish biomass and economic value (Steneck & Pauly, 2019; Sumaila et al., 2012). Humans and ecosystems are intrinsically linked, so effective management of ocean resources is essential to support human well-being (Millennium Ecosystem Assessment, 2005) and to achieve interlinked sustainability objectives defined in the United Nations Sustainable Development Goals (UN General Assembly, 2015). Processes of natural environments supporting human well-being have been described as ecosystem services, which are categorised into provisioning, regulating, cultural and supporting services (Millennium Ecosystem Assessment, 2005). To raise the profile of the importance of ecosystem services to human well-being, research programmes and projects have sought to value ecosystem services (Costanza et al., 2014; Millennium Ecosystem Assessment, 2005).

Traditionally, measurements of fisheries sustainability have focussed on population-based metrics, such as Maximum Sustainable Yield (Ulrich et al., 2017). However, these methods do not consider the wider ecosystem supporting the fishery. Many fish species rely on multiple habitats across their life cycle (Seitz et al., 2014). They specifically rely on "essential habitat" that is defined as waters and substrates needed for feeding, growth and reproduction of fish species throughout life (Rosenberg et al., 2000). Habitats in which adults are caught provide evidence of habitat use during adult stages, but habitats they rely on during spawning and juvenile stages are equally vital. Spawning areas are those where adults migrate to release eggs, and nursery areas support growth and survival of juveniles (Beck et al., 2001). Recently, habitat information has been incorporated into fisheries management (Brown et al., 2019) to move towards ecosystem-based fisheries management (Rosenberg & McLeod, 2005). Benthic habitats are particularly important for fisheries to provide shelter, foraging grounds and breeding grounds for species targeted by commercial fisheries (Howarth et al., 2011; Kritzer et al., 2016). Here, the term "habitat" refers to physical characteristics of benthic substrates that can be classified using the hierarchical European Nature Information System (EUNIS). Essential life history stages of fish species are supported by multiple dimensions of the marine environment (Elliott et al., 2017; Kritzer et al., 2016). Therefore, an understanding of species-habitat associations is central to identifying essential habitats that support life stages of exploited species and are, therefore, of high priority for management (Seitz et al., 2014).

Commercial fisheries do not operate in isolation of the wider ecosystem. Across the world, marine and coastal habitats are threatened by multiple anthropogenic impacts (Lotze et al., 2006), including fishing practices (Halpern et al., 2007). Bottom-towed fishing practices, such as trawling and scallop dredging, cause extensive damage to the seabed (Thrush & Dayton, 2002). This can create conflict with other fisheries targeting the same habitats through direct damage to target species (Beukers-Stewart & Beukers-Stewart, 2009) or indirectly through habitat degradation and disruption of trophic dynamics (Thrush & Dayton, 2002).

Marine Protected Areas (MPAs) and sustainable fisheries are intrinsically linked (Rees et al., 2020). MPAs are "clearly defined geographical space, recognised, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values" (Day et al., 2012). However, legal instruments available to fisheries managers (such as bylaws) that exclude specified fishing metiers from spatial areas are often employed to protect specific features within MPAs. Increasing evidence suggests that MPAs with fishery management measures to exclude bottom-towed gear can both protect and support the recovery of protected features (Solandt et al., 2020) and provide social and economic benefits (Rees et al., 2021a,b). Additionally, maintaining or improving the structural integrity of the seabed can enhance the ability of a system to support fishery species (Davies et al., 2021; Elliott et al., 2017; Howarth et al., 2011). At present, most fisheries bylaws to protect conservation features fall within national networks of MPAs that have limited potential to improve the sustainability of fisheries if habitats that are important to the survival of commercially targeted species fall outside of the MPA boundary of protection (Klein et al., 2015). Resource managers must now think beyond MPAs as the sole tool to underpin all demands of society from marine ecosystems and to move towards sustainable use of oceans for a wide range of societal benefits (Rees et al., 2020).

In addition to food security, fisheries provide jobs and income, through direct market values at the point of landing. Economic valuation applied to ecological systems is proving to be a useful tool to progress debate and discussion as to costs and benefits of fisheries management and conservation (Ovando et al., 2016). The first-sale wet weight market values at the point of port landings have been used as an indicator of the value of fisheries to coastal communities (Jackson et al., 2015; Rees et al., 2021b). However, an ecosystem-based approach to marine management is increasingly recognised in both policy (e.g. Food and Agriculture Organization of the United Nations (Staples & Funge-Smith, 2009); and Marine Strategy Framework Directive (MSFD) (European Parliament and Council, 2008)) and practice (Marshall et al., 2019) as a tool to link essential habitats inside and outside MPAs.

Our objective was to determine whether coastal habitats supporting the economic value of key fisheries in Jersey and France were protected within existing MPAs. To achieve our objective, we assessed the availability of essential fish habitat that supports the supply of commercially important species, including adult, juvenile and spawning stages. Economic value (landings value [£]) was assumed to be supported equally by all habitats used by each species throughout its life cycle. This is a standard approach in economic and ecological valuation studies for which ecological evidence on the availability and suitability of habitats is insufficient (Jackson et al., 2015; Seitz et al., 2014). We also did not wish to highlight the economic value of fishing grounds (adult life history stages) over other areas important for the availability of species to the commercial market, as has been demonstrated previously (Calderwood et al., 2020; Kafas et al., 2017). The economic importance of habitats has been identified as a data-deficient area for the Government of Jersey Marine Resources team (Pers. comm. Government of Jersey Marine Resources) and management decisions for MPAs are currently focussed on protecting areas of high biodiversity or sensitive habitat but do not take habitat requirements of fishery species into account. An understanding of which habitats in Jersey contributed to the final economic value of a fishery, and whether these habitats are currently covered by spatial management measures that exclude bottom-towed fishing, can be used to better inform decisions in Marine Spatial Planning (MSP). We, therefore, hypothesised that, within the defined fishing area of Jersey's territorial waters, multiple habitats contributed to the final value of exploited species and the value safeguarded for each fishery species by the MPAs differed among habitats.

2 | MATERIALS AND METHODS

2.1 | Study area

Jersey is a self-governing dependency of the United Kingdom situated in the Normano-Breton Gulf off the west coast of Normandy. The marine territorial area (~2500 km^2) has a maximum depth of 50 m, with rocky reef, boulders, cobbles, gravel, sand and biogenic habitats, such as maerl and seagrass. The large tidal range Jersey (12.2 m) also creates a vast intertidal area. As an island community, Jersey depends on its marine estate, which supports tourism, recreational and commercial exploits, especially fisheries. Commercial catch comprises a mixture of shellfish and finfish, with 94% of commercial landings attributed to five shellfish species: lobster (*Homarus gammarus*); brown crab (*Cancer pagurus*); spider crab (*Maja brachydactyla*); scallop (*Pecten maximus*); and whelk (*Buccinum undatum*). Most commercial fishing by Jersey vessels for these five shellfish species (>90%) takes place within Jersey's territorial waters from a combination of static and bottom-towed fishing vessels, and SCUBA diving vessels. Landings Per Unit Effort (LPUE) declined locally for lobster since 2015 and brown crab since 2012, but increased for spider crab since 2013. LPUE declined slightly for whelk since 2016. Scallop LPUE declined for dredge fisheries since 2013 but increased for dive fisheries since 2015 (Marine Resources, 2019). With fisheries largely dependent on benthic species, management of benthic habitats is key to ensuring the sustainability of these stocks. While adult and larval stages of commercial species move across the boundary of Jersey's territorial waters, detailed spatial coverage of habitats outside of this area is currently unknown.

Jersey fishing vessels operate from a number of harbours and marinas across the island, with most landing their catch at St. Helier, although vessels are also permitted to land their catch in France. Historical fishing agreements between France and Jersey have resulted in shared fishing grounds defined in the Bay of Granville Treaty (Chambers et al., 2020), which grants access to both Jersey and French vessels in possession of a fishing permit (Figure 1). To protect areas of fragile habitat and high biodiversity within Jersey's territorial waters that are shared with France, two offshore MPAs were designated in 2017 (Chambers et al., 2020) to exclude the use of bottom-towed fishing gears (Figure 1), while static fishing is permitted. This, in addition to multiple coastal MPAs already in place within Jersey's exclusive fishing zone, resulted in 6.5% of Jersey's territorial waters protected from bottom-towed fishing. Currently, these are the only management measures specific to protecting benthic habitats within the Normano-Breton Gulf. Most of Jersey's fishing fleet comprises vessels under 12 metres and are, therefore, not required to have Vessel Monitoring Systems (VMS) that track their fishing positions. Instead, fishers are required to submit logbooks to report their catch and zones fished. Landing data are not attributable to MPAs because fishers are not required to report if they fished in the MPA and reporting zones are larger than the MPAs.

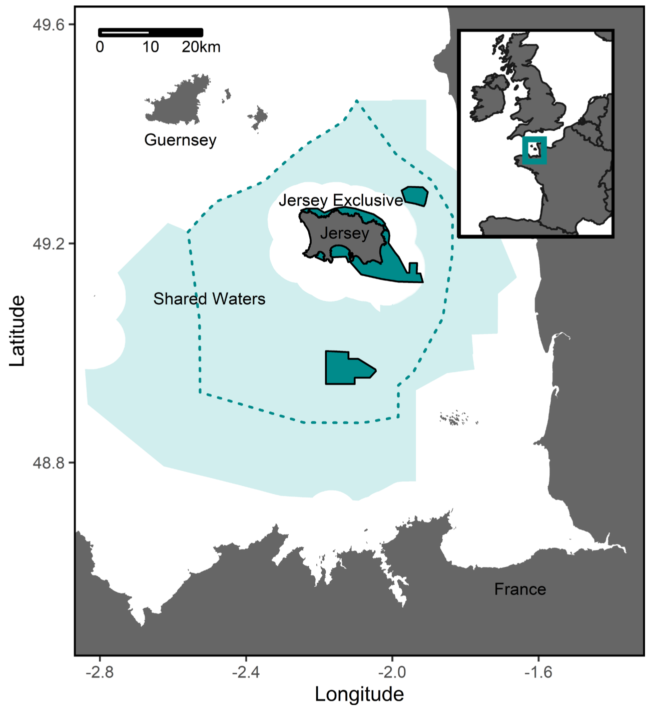

FIGURE 1 Location of Jersey within the Normano-Breton Gulf. Green filled polygons are areas which are protected from bottom-towed fishing gear. The light green shaded area shows the extent of the Bay of Granville, which is an area of shared access rights for both Jersey and French vessels. The dashed green line shows the international boundary between Jersey and France, everything within this boundary is Jersey's territorial waters

2.2 | Analytical approach

A novel social-ecological mixed methods approach was used to determine how marine habitats in Jersey contributed to value of commercial fisheries and the extent to which life history stages of key commercial species were protected by Marine Protected Areas. Previous studies focussed on the socio-economic impact of MPAs within a fisheries management context have assessed changes to fisher well-being (Rees et al., 2013), landings and spatial fishing effort (Moore et al., 2016; Rees et al., 2021b), and ecosystem service value (Hussain et al., 2010), or on singular habitats (Unsworth et al., 2010). The present study combines landings data, primary sales information, spatial habitat and MPA data and life history information to value multiple habitat types to assess the role of essential habitats, across a whole ecosystem, underpinning the economic value of fisheries.

2.3 | Commercial landings value

Commercial fishers in Jersey are required to submit logbooks, which state their catch in kilograms for every fishing trip. Data for trips between 2015 and 2018 were obtained from the Government of Jersey Marine Resources to calculate mean yearly landings for all commercial species and identify key fisheries. While commercial fishing activity can and does take place in shared waters, most landings into Jersey ports (~94%) are caught within the island's territorial waters (Pers. comm. Marine and Coastal Manager, Government of Jersey Marine Resources).

Data on primary fish sales in Jersey were based on quarterly buying prices (wet weight) from a local vendor (The Fresh Fish Co) between 2015 and 2018. Landing value (first-sale wet weight) in Jersey was calculated by multiplying the quarterly landing weight by the quarterly primary sale value. Quarterly values were summed for each year and then averaged across the 4 years to give a mean landings value (£) per year for each fishery.

French vessels target the same species in Jersey's territorial waters as Jersey vessels, so French landings were also quantified. Landings data between 2015 and 2018 for French vessels were supplied by the Government of Jersey Marine Resources in tonnes per year and value per year (€) based on information shared by a French research institution, IFREMER (The Institut Français de recherche pour l'exploitation de la mer). These data were filtered for the same key fisheries as Jersey and converted to kilograms. Values were converted (€ to £) using exchange rates from statista.com on 4 February 2021. From this, mean yearly landings values (£) were calculated. No other nationalities operate in Jersey's waters and landings calculated from Jersey and French vessels represent all landings from this area.

2.4 | Habitats and essential life history stages for commercial species value

Spatial habitat information was obtained from the Government of Jersey Marine Resources. This habitat information is a combination of modelled and surveyed data that represents best available evidence of the location of benthic habitats in Jersey's territorial waters (Pers. comm. Marine and Coastal Manager, Government of Jersey Marine Resources). Habitats were defined using the European Nature Information System (EUNIS) habitat classification system. The EUNIS classification system is a publicly accessible database that provides reference information for European habitats and is widely compatible with peer-reviewed literature, legislation and marine spatial planning across Europe (Davies et al., 2004). To establish how different shellfish species used habitats throughout their life history, a species-habitat matrix was created from literature compiled primarily through Google Scholar, using search terms that included each species name and known habitat types. Literature was searched using specific EUNIS habitat nomenclature and also broad habitat groups to account for lack of detail about species habitat use in the literature (Seitz et al., 2014). When information could not be found for certain life stages of a species, literature from laboratory studies or closely related species was used (e.g. Kamenos et al., 2004).

EUNIS habitat data for Jersey's territorial waters were grouped into categories (Table 1) to account for lack of available information on species habitat use in the literature (Seitz et al., 2014). Jersey's large intertidal area provides essential habitat for juvenile brown crab and lobster, and all habitats above the low-water mark were grouped into an intertidal habitat category. All rock and boulder categories below the low-water mark were grouped into subtidal hard substrate, and sedimentary habitats below the low-water mark were categorised into subtidal sediment. Seagrass and maerl were separated from subtidal sediment because they provide added structural complexity for distinct species assemblages (Howarth et al., 2011; Jackson et al., 2015).

2.5 | Apportioning commercial fisheries values to essential life history

To estimate the annual value to commercial fisheries linked to Jersey's habitats, and the proportion of value protected from physical impacts from bottom-towed fishing gear, fishery species landing values were apportioned to habitats used by each life stage. This was achieved for all landings, regardless of catch method. Habitat information was available for a 250-m resolution, which provided areas of habitat across Jersey's territorial waters and within MPAs (Figure 2). For each commercial species, landings value was spread equally across multiple habitats used by each life stage. Values were divided equally among habitats used by a species that were assumed to contribute to their ability to reach the adult stage and therefore their economic value. This was calculated separately for Jersey and French landing values. The value of benthic habitat safeguarded through the exclusion of bottom-towed fishing gear was calculated by multiplying the proportion of each habitat within MPAs by the total value of the habitat.

TABLE 1 Habitat table detailing the EUNIS code habitats in Jersey waters that have been grouped together and a description of their defining features

Habitat type	EUNIS codes	Description
Intertidal sand and rock	A1, A2	All hard and soft substrates in the intertidal zone
Subtidal hard substrate	A3.12, A3.214, A4.13	Bedrock and boulders below the low-water mark
Subtidal sediment	A5.133, A5.135, A5.137, A5.141, A5.142, A5.145, A5.231, A5.431, A5.451	Coarse and mixed sediments below the low-water mark
Maerl beds	A5.51	Coralline red algae
Seagrass meadows	A5.53	*Zostera marina* and *Zostera noltei*

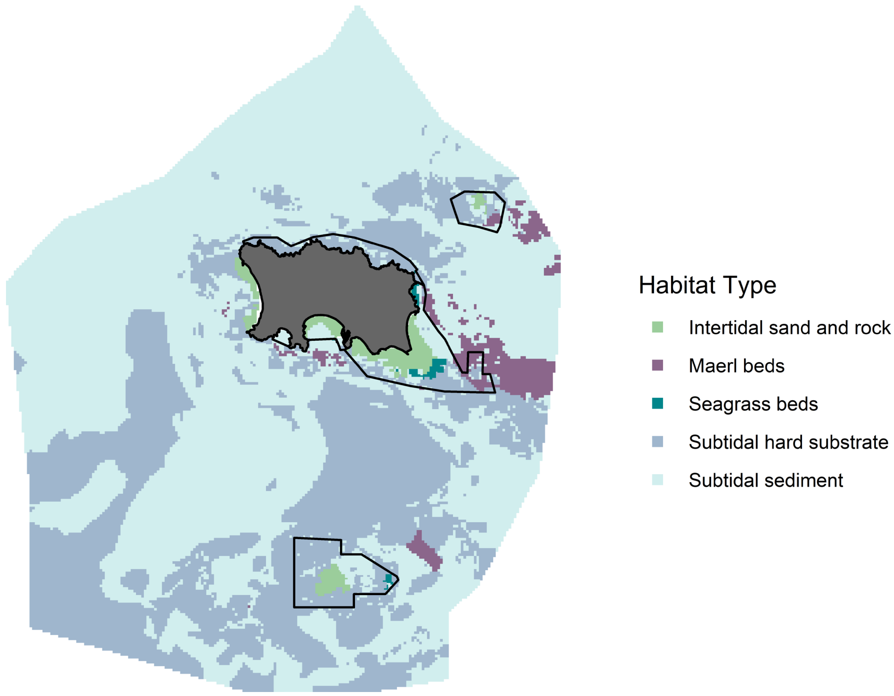

FIGURE 2 Spatial distribution of five habitat types in Jersey's territorial waters. Jersey is shown as a filled grey polygon, and MPAs are outlined by transparent polygons

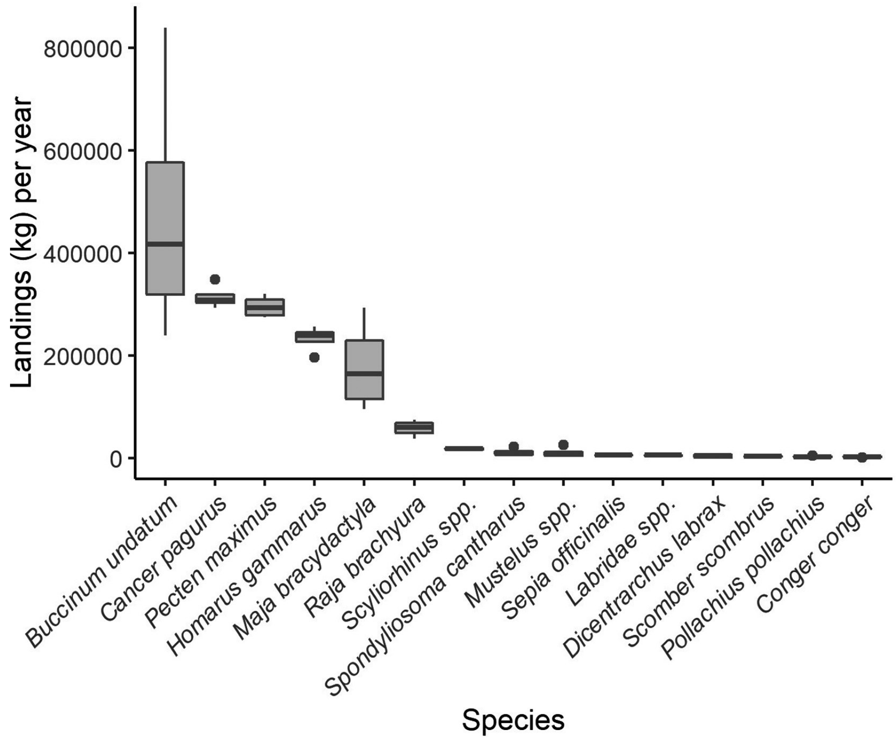

FIGURE 3 Commercial landings (kg) in Jersey from Jersey vessels between 2015 and 2018 showing the top 15 species that contribute to 99% of landings by weight. The remaining 1% of commercial landings consists of 36 species. Outliers are shown by filled circles

3 | RESULTS

3.1 | Identifying commercially important species to Jersey fisheries

Most of the Jersey fisheries harvest depended on shellfish (Figure 3), with ~1.5 million kg (94%) of landings per year attributed to five shellfish species: Lobster, *Homarus gammarus*; Brown crab, *Cancer pagurus*; Spider crab, *Maja squinado*; Scallop, *Pecten maximus*; and Whelk, *Buccinum undatum*. All other species (n = 46) accounted for only ~140,000 kg (6%) of landings, much of which was incidental catch, such as catsharks (*Scyliorhinus* spp.), a bycatch of netting and potting fisheries. Individually, these species did not influence overall fisheries value and were excluded from further analysis.

3.2 | Commercial landings value

The combined value of shellfish landings from Jersey and French vessels operating in Jersey's territorial waters had an average annual value of £14,664,729 ± £969,105 per year in primary sales (wet weight), with £7,521,275 ± £1,366,282 attributed to landings from Jersey vessels. Jersey obtained most of its value from lobster (£4.1 million per year), whereas France obtained most of its value from scallop (£1.9 million per year), spider crab (£2 million per year) and whelk (£2.4 million per year) (Figure 4). Scallop and whelk contributed less to Jersey fisheries than France fisheries (Figure 4). Brown crab and lobster contributed relatively low values to overall France fishery (Figure 3). Jersey scallop landings were higher from dredging than diving (Figure 3).

3.3 | Habitat value and value protected

Habitat use varied among species, and all habitat types were used by multiple species (Table 2). Maerl was a foraging habitat for all species, except lobster, and was also a nursery and spawning habitat for scallop. Scallops used maerl and subtidal sediment at all three life stages. Seagrass was used as a foraging habitat by all three species, but was not known to be used by the two mollusc species. Intertidal sand and rock was a nursery habitat for brown crab and lobster. Subtidal hard substrate was a foraging and nursery ground for all three crustacean species, and a spawning ground for whelk. Subtidal sediment was a foraging ground for all species, but only a nursery ground for lobster and whelk and a spawning ground for brown crab. Of the five species, crustaceans used more habitat types than molluscs (Table 2). Brown crab was particularly ubiquitous in habitat use, while scallops only used two habitat types. All species use more habitat types for foraging than for nursery or spawning.

Value differed among habitats, between nations and among species (Figure 5). Subtidal sediment had the highest economic value to both nations because it was the only habitat used by all species

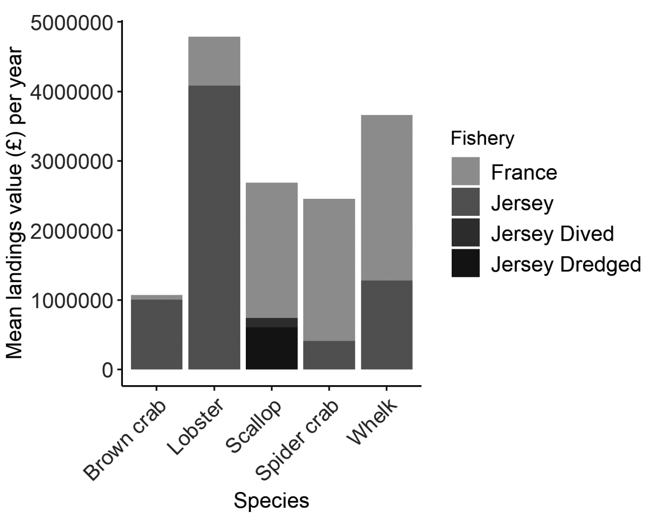

FIGURE 4 Mean landings (£) per year (2015–2018) for each five predominant fishery species (brown crab, lobster, scallop, spider crab and whelk) and nation (light grey: France, dark grey: Jersey) from jerseys territorial waters. Scallop landings in Jersey have been split into dived and dredged

(Figure 5). The second most valuable habitat for Jersey's commercial fisheries was subtidal hard substrate, whereas for France it was maerl. Maerl beds were of greater value to French fisheries than Jersey fisheries because scallop and whelk were exploited more by vessels from France (Figure 5). Seagrass and intertidal habitats were of greater value to Jersey than France because lobster was associated with these habitats at adulthood (Figure 5, Table 3).

Several habitats of high value to both Jersey and French fisheries were largely unprotected by MPAs (Figure 6), with a total economic value of £4,127,999 protected annually between the two nations (Table 3). Cumulatively, subtidal sediment was the most valuable habitat to both nations (£2.12 million to Jersey and £2.47 million to France annually), but was also the least protected habitat (Figure 6), with just 2.73% within MPAs (Table 3). The value of protected maerl (14.78%) and subtidal hard substrate (8.91%) was similarly low. Consequently, because scallop and whelk used habitats with greater coverage outside of MPAs, habitats supporting French fisheries were less protected than Jersey fisheries. A substantial economic value of seagrass (97.04%) and intertidal rock (88.49%) was protected within MPAs, although these two habitats contributed less to the economic value of fisheries from both nations (Figure 6, Table 3).

Most subtidal hard substrate and subtidal sediment were not protected within MPAs, although these two habitats had a greater total area within Jersey's territorial waters (Table 3). The value of each fishery species protected within MPAs from bottom-towed fishing gear differed depending on the area of their associated habitats within MPAs (Table 3). The value of lobster fisheries was most protected within MPAs (49.29%), followed by brown crab fisheries (42.38%), due to the association of these two species with seagrass and intertidal habitat that was mostly within MPAs. Scallop (8.75%) and whelk (8.8%) fisheries were protected similarly low (Table 3) because of their association with fewer habitats, most of which fell outside MPA boundaries (Table. 2, Figure 5).

4 | DISCUSSION

Our objective was to determine whether coastal habitats supporting the economic value of key fisheries in Jersey and France were appropriately protected within MPAs. Previous efforts to value the marine environment have focussed on single habitats (Jackson et al., 2015) or fishing grounds (Bastardie et al., 2010), and studies of multiple habitats have not done so in monetary terms (Kritzer et al., 2016; Seitz et al., 2014). Here, we used a method in which life history information was used to better understand how the economic value of fisheries was related to broad habitats by analysing the market value of species according to habitats necessary to reach commercial size (adult). Species studied herein used multiple habitats, as in other studies (Kritzer et al., 2016; Seitz et al., 2014), thereby highlighting the need for an ecosystem-based approach to estimate overall value of fishery resources. As markets change, landing values will also change to reflect demand. Therefore, habitat value is not fixed so our results only provide a snapshot of the current habitat value.

TABLE 2 Literature summary of the top five predominant commercial shellfish species (lobster, brown crab, spider crab, scallop and whelk) habitat use as spawning areas (S), nursery areas (N) and feeding areas (F). Full references are listed in supplementary material (Table S1)

Species	Intertidal sand and rock	Subtidal hard substrate	Subtidal sediment	Maerl	Seagrass
Lobster (*Homarus gammarus*)	N	N,F	N,F		F
Brown crab (*Cancer pagurus*)	N	N,F	F,S	F	F
Spider crab (*Maja brachydactyla*)		N,F	F	F	F
Scallop (*Pecten maximus*)			S,N,F	S,N,F	
Whelk (*Buccinum undatum*)		S	N,F	F	

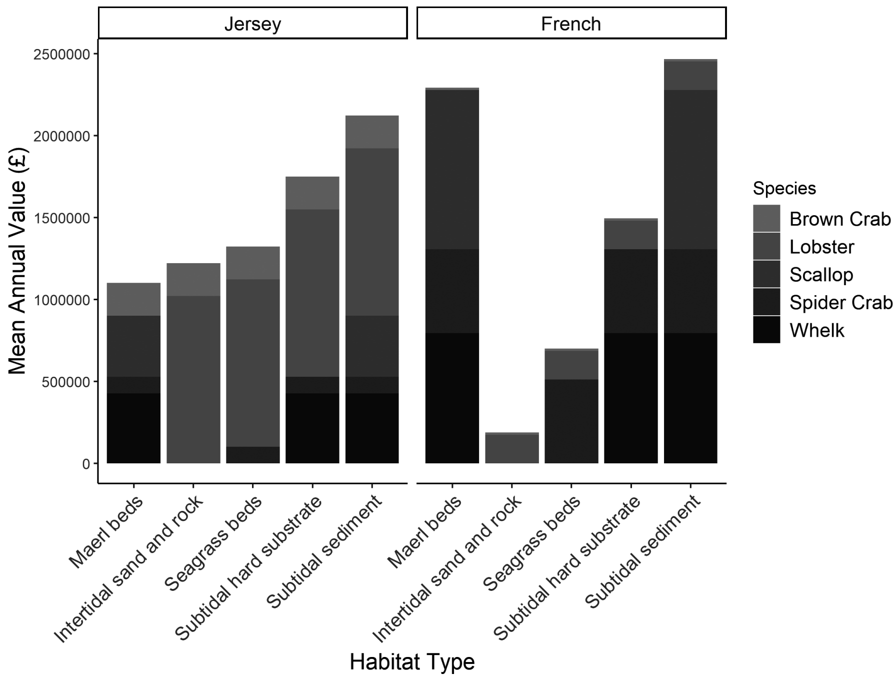

FIGURE 5 Contribution of each of the five predominant fishery species (lobster, brown crab, spider crab, scallop and whelk) to the value (£) of each habitat type for each nation (Jersey and France)

Habitat value varied among species and between France and Jersey fisheries, although subtidal sediments were the most valuable to both nations. Soft sediments have previously been identified to support the greatest range of species because more species were able to utilise it (Kritzer et al., 2016). Similarly, we found that subtidal sediments, the most prevalent habitat, supported all five of the most predominant commercial species and were, therefore, also worth the greatest value to fisheries as a whole. Importantly, subtidal habitat supported all five commercial species through adulthood but only a fraction of the area of subtidal sediment (and therefore value) was currently protected from destructive fishing practices, primarily scallop dredging. With no clearly defined thresholds for what may be considered “acceptable” impact on sediment habitats (Hooper et al., 2017), benefits of multiple sectors of an industry must be balanced to ensure activities of one sector do not risk sustainability of another.

Species move among habitats during their life cycle (Seitz et al., 2014) and, therefore, their economic value depends on multiple habitats. Protection from activities that cause impact to structure and function of habitats that are essential in supporting the life stages of commercial species is fundamental to maintaining the economic value of fisheries. This raises several points for discussion with regard to a more integrated approach to fisheries management, whereby multiple habitats are protected from impacts of bottom-towed fishing to maintain habitat connectivity for all life stages. While every habitat type in Jersey was represented within MPAs, the degree to which each habitat type was protected varied: for example, 97% of seagrass but only 3% of subtidal sediment was protected. Specific habitats may be limiting for species that are not able to substitute one habitat for another in certain life stages (Wahle & Steneck, 1991). If, for example, seagrass habitat was lost, some species may not be able to use adjacent habitats as substitutes, as in intertidal boulder fields (Chapman, 2012). In contrast, survival may be lower if substituted habitats are of lower quality than original habitat (Godet et al., 2018). We found that seagrass had a combined value of £2 million annually to both Jersey and French fisheries so loss of seagrass habitat could result in substantial economic costs to fisheries if species are not able to survive on nearby habitat. Additionally, associated changes to the food web through loss of habitat could negatively affect many species or communities (Komyakova et al., 2019).

Nursery habitats support high densities of juveniles (Beck et al., 2001) that may be a demographic bottleneck for many species

TABLE 3 Total area of habitat types within Jersey's territorial waters, the area (km^2) contained within MPAs, the total annual value (£) and value protected (both £ and %) within MPAs for Jersey and French fisheries

Habitat type	Total area (km^2)	Area inside MPA (km^2)	Jersey total value (£)	French total value (£)	Jersey value (£) protected	French value (£) protected	Value (%) protected
Intertidal sand and rock	29.10	25.75	1,222,024	188,721	1,082,739	167,211	88.49
Maerl	56.70	8.38	1,101,490	2,291,821	162,734	338,593	14.78
Seagrass	4.06	3.94	1,324,117	701,075	1,283,375	679,504	97.04
Subtidal hard substrate	806.00	71.81	1,750,998	1,494,921	155,961	133,152	8.91
Subtidal sediment	1440.00	39.25	2,122,646	2,466,915	57,687	67,043	2.73
Habitat total			7,521,275	7,143,454	2,742,496	1,385,503	–
Species							
Brown crab	–	–	1,004,335	68,138	425,685	28,880	42.38
Lobster	–	–	4,084,626	700,375	2,013,209	345,197	49.29
Scallop	–	–	743,297	1,943,987	65,007	170,018	8.75
Spider crab	–	–	408,376	2,049,415	125,904	631,843	30.83
Whelk	–	–	1,280,641	2,381,539	112,691	209,565	8.80
Species total	–	–	7,521,275	7,143,454	2,742,496	1,385,503	–

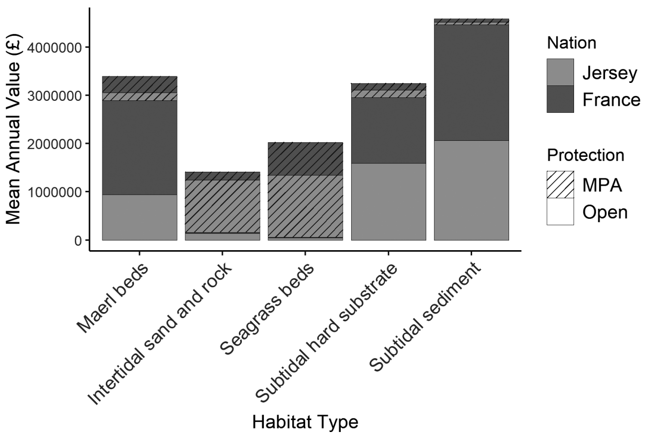

FIGURE 6 Mean annual value (£) per habitat type for each nation (Jersey and France). Hatched areas show the value protected within the MPAs, and non-hatched areas show the value in areas open to bottom-towed fishing (open)

(Nagelkerken et al., 2015). Soft sediments are important nursery habitats, especially in the Mid-Atlantic and North Atlantic (Kritzer et al., 2016), for commercially important species (Seitz et al., 2014). Subtidal sediment was the only habitat used by all five species studied here and was also a habitat primarily targeted by bottom-towed fishing gear due to France's resource demand for scallop (*P. maximus*). This habitat was of more value to lobster fisheries than scallop fisheries, and dredging for scallops may negatively affect the lobster fishery by reducing nursery habitat quality (Thrush & Dayton, 2002) and thereby reducing value of the fishery. Subtidal sediment makes up the vast majority of Jersey's subtidal area, so future discussion is needed to further spatial management of the scallop fleet, guidance for which may be sought through the development of indicators of Good Environmental Status for seabed integrity within the European Union's MSFD (European Parliament and Council, 2008). To achieve an ecosystem-based approach to fisheries management in Jersey, commercial needs of the scallop fleet must be balanced with long-term sustainability of the lobster fishery, which may require that some areas of subtidal sediment are protected to maintain integrity of the seabed and improve connectivity between life stages of lobster. With no thresholds for the minimum area of a habitat that is needed for essential life history of commercial species, a precautionary approach is advised to sustain the value of this high-value habitat for both nations.

Economic values apportioned to habitats differed between nations, because French fishers exploited the same species differently than Jersey fishers, and therefore the value protected within MPAs differed between nations. For example, maerl was of greater value to French fisheries due to higher levels of exploitation of scallops. Notably, maerl was also one of the least protected habitats via MPAs that exclude bottom trawling. Scallops prefer structurally complex habitats (Howarth et al., 2011; Kamenos et al., 2004), and large areas of maerl provide this structural complexity that favours scallop spat settlement (Hall-Spencer et al., 2010). Maerl habitats were largely unprotected from bottom-towed fishing gear but were also economically valuable to multiple fisheries. The use of MPAs to restrict bottom-towed fishing gear could improve the sustainability of scallop fisheries by protecting the integrity of maerl habitat. Scallops are broadcast spawners whose fertilisation success is increased at higher population density (Vause et al., 2007), and protecting areas of seabed that support dense aggregations of scallops will result in increased spawning and improved recruitment to areas within and beyond protected areas (Beukers-Stewart & Beukers-Stewart, 2009).

Species living in areas affected by bottom-towed fishing exhibit increased scavenging behaviour (Shephard et al., 2014), and the population of necrophagus whelks may benefit from the availability of dredge-damaged prey. In terms of landings weight, whelk is the largest fishery in Jersey, but due to its low market value this species is currently not as valuable (£1.3 million per year) as lobster (£4 million per year). Whelk has been fished in Jersey's waters by both French and Jersey vessels for decades, but expanded since 2018 (Marine Resources, 2019) in response to increased market demand through exports. This highlights the importance of considering the economic value of species in the socio-economic management of marine resources in a discussion on whether an emergent fishery is benefitting from a degraded ecosystem, as has been seen in the Firth of Clyde where overexploitation of benthic fish through bottom trawling resulted in a collapse of fisheries until only the Norway lobster (*Nephrops norvegicus)* and scallop (*Pecten maximus*) fisheries remained (Thurstan & Roberts, 2010).

Effectiveness of governance and enforcement will affect the success of an MPA (Bennett & Dearden, 2014). Differing fishery regulations, such as quotas and closed seasons, complicate management of shared resources, whereas clear simple measures that cover a seascape, such as a MPA, allow for more efficient and accurate enforcement (Chambers et al., 2020). As all of the key commercial species in Jersey are benthic, they are strongly associated with seabed habitats and, therefore, there is much to be gained from spatial management that protects this seabed. While reliance on certain species differs between Jersey and France due to differing markets, both nationalities depend on species that are using multiple habitats and, therefore, both nationalities will benefit from having areas of mixed habitats protected from bottom-towed fishing gear. This potential fishery benefit has been shown in Lyme Bay, where commercially exploited species increased in abundance following the removal of bottom-towed fishing pressure from a mosaic of habitats (Davies et al., 2021). When economic values and livelihoods become part of the discussion with regard to MPAs, motivations for protecting benthic habitats become more tangible as a fisheries benefit. MPAs will consequently gain commercial support from those most likely to benefit from management that ensures sustainability (Rees et al., 2021a,b).

Our research considered habitat use across a species' life history but not the relative importance of one habitat over another or temporal variability of habitat use. Species we studied were a subset of those found in Jersey's waters and were chosen based on their direct importance and value to commercial fisheries. Inclusion of other species may change the value of habitats but would not diminish the key finding that multiple habitats contribute to fisheries value. Jersey's marine estate will also support other industries that depend on a healthy functioning ecosystem, such as recreational fishing, diving and tourism. For example, seagrass had a higher direct value to recreational fishing than commercial fishing in the Mediterranean (Jackson et al., 2015). The vast intertidal area in Jersey supports several aquaculture concessions, further adding to economic value of this habitat. Other, less tangible, ecosystem services and benefits derive from marine ecosystems, such as regulation of climate and water quality, educational and cultural values, all of which feed into human well-being (Costanza et al., 2014; Millennium Ecosystem Assessment, 2005). The value of these ecosystem services needs to be considered, in addition to the value that habitats provide to fisheries, especially if considering the case of allowing bottom-towed fishing, which is known to alter the functional diversity and ecological processes of benthic communities (Tillin et al., 2006). Information relating to the condition of habitats and timescales for recovery is sparse due to the widespread use of bottom-towed fishing that results in a lack of unimpacted areas to use as a baseline (Jackson et al., 2011). Long-term MPAs provide an estimate of recovery time, but few prohibit bottom-towed fishing throughout their boundary (Davies et al., 2021). Further, accurate spatial information on fishing effort is lacking to develop proxy (pressure based) indicators of habitat condition (Rees et al., 2022). This information, in addition to an improved understanding of species-habitat associations, is a key next step to better inform MPA management to support fishery species.

5 | CONCLUSION

Marine ecosystems are a source of income for coastal communities, and the value of a fishery is not simply attributed to fishing grounds but is dispersed across a mosaic of habitats. Our study demonstrated the value of coastal habitats in Jersey to commercial fisheries and the importance of protecting multiple habitats to improve life stage connectivity and support fishery yield. The ability of a species to switch to a different habitat, if their primary habitat is degraded or lost, is not well understood, and indirect use of habitats needs to be considered to fully understand interactions between habitats and species survival, such as habitats that support prey of target species, which may not be used by the target species itself. Further research on habitat associations, in addition to incorporating habitat condition into assessments, is needed to advance this field of research. Fisheries and conservation can be integrated into an ecosystem-based approach to management that focusses on broader marine seascapes, not just single habitats, to maximise habitat connectivity. These results should be applied to conservation and management to support long-term commercial interests and sustainability of a broad range of ecosystem services, which underpin human well-being. Where shared waters are concerned, management decisions that benefit multiple nations can be difficult, especially when demands for fishery species differ. MPAs will protect habitats that contribute to fisheries value of multiple nations and by understanding how habitats contribute to individual fisheries MPA spatial coverage can be tailored to maximise economic value.

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CONFLICT OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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