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Man-made structures in the marine environment: A review of stakeholders' social and economic values and perceptions

Carmen E. Elrick-Barr[a,*], Johanna S. Zimmerhackel[b], Georgie Hill[c], Julian Clifton[a], Fran Ackermann[c], Michael Burton[b], Euan S. Harvey[d]

[a] School of Social Sciences, University of Western Australia, Perth, WA 6009, Australia
[b] School of Agriculture and Environment, University of Western Australia, Perth, WA 6009, Australia
[c] School of Management and Marketing, Curtin University, Perth, WA 6845, Australia
[d] School of Molecular and Life Sciences, Curtin University, Perth, WA 6845, Australia

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ABSTRACT

Man-made marine structures (MMS) are commonly used to describe any artificial structure in the marine environment, encompassing oil and gas infrastructure and pipelines, artificial reefs, jetties, piers and shipwrecks. MMS are increasingly proposed to address issues facing marine planners, including augmenting fish stocks through the creation of artificial reefs and the repurposing of redundant offshore oil and gas infrastructure ('rigs to reefs'). Marine spatial planning is a highly contested process, characterised by multiple stakeholders with often divergent priorities due to competing objectives and values. Understanding stakeholder perspectives in relation to MMS is therefore critical in formulating appropriate policies. This review presents the first systematic and comprehensive integration of information from academic journals and 'grey' literature relating to social and economic values and perceptions of MMS. The review identifies that, despite advocacy for research on social and economic values of MMS, there are significant gaps in knowledge, in particular relating to comparative assessments of stakeholder values across different types of MMS. Priority areas for future research are highlighted.

1. Introduction

The term 'man-made structures' (MMS) is commonly used to refer to any artificial structure in the coastal and marine environment, encompassing jetties, breakwaters, shipwrecks, aquaculture facilities, oil and gas infrastructure, pipelines, wind turbines and artificial reefs amongst others (Lemasson et al., 2021). The continued growth in the blue economy, most notably in the aquaculture and renewable energy sectors, is likely to increase the total spatial coverage of MMS from 32,000 km^2 in 2018, equivalent to 2.4% of the world's maritime exclusive economic zones, to 39,400 km^2 by 2028 (Bugnot et al., 2021).

The offshore wind sector has expanded dramatically in recent years, experiencing an annual growth rate of 24% from 2013 to 2019 with capacity totalling over 29 GW in 2019 (Global Wind Energy Council, 2020). Reflecting the universal need to meet greenhouse gas emission reduction targets, the widespread availability of cheap technology and the development of new concepts such as 'offshore energy islands', the total capacity of the offshore wind sector is expected to exceed 200 GW by 2030 (Global Wind Energy Council, 2020). Recent research indicates that the perceived urgency to develop offshore wind resources may lead to an imbalance in marine spatial planning processes, resulting in the exclusion of other users (Spijkerboer et al., 2020). This underlines the need to accommodate the interests of the wind energy sector alongside other users of marine space and to ensure that, wherever possible, multiple and sustainable usage is promoted.

Oil and gas infrastructure, including both pipelines and rigs, constitute a significant component of the total offshore construction footprint (Bugnot et al., 2021). This is of particular significance as, unlike most other types of offshore infrastructure, these installations have a limited lifespan, reflecting the availability and cost-effectiveness of hydrocarbon extraction and the conditions of the leases under which extraction is permitted. In addition, fluctuations in the price of oil and gas together with climate change policies may introduce additional incentives in the decision to retire or 'decommission' offshore production facilities. Decommissioning refers to the entirety of processes involved in capping wells and removing all pipelines and platform infrastructure. The financial implications of full infrastructure removal are considerable, with recent estimates indicating that the global cost of

* Corresponding author.
E-mail address: carmen.elrick-barr@uwa.edu.au (C.E. Elrick-Barr).

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decommissioning could reach $42 billion by 2024 (Rystad Energy, 2020). This issue is exacerbated by the worldwide lack of experience in the relatively new field of offshore decommissioning and the unique complexity of the task at each individual location (Parente et al., 2006).

Whilst the 1996 Protocol to the London Dumping Convention prohibits the dumping, abandonment or toppling of oil and gas infrastructure at sea for the sole purpose of disposal, it does allow for signatory parties to consider other decommissioning options that are not contrary to the aims of the Protocol (Techera and Chandler, 2015). Such options may range from leaving the entire structure in place, moving the structure to a new location, partial removal, toppling, or a combination of the above (Fowler et al., 2014). It is therefore not surprising that the oil and gas sector has been exploring cheaper options of in situ decommissioning, also referred to as 'reefing' or the 'rigs to reefs' alternative.

This terminology reflects the fact that artificial marine structures provide a hard substrate for rapid colonisation by invertebrates, allowing a complex habitat supporting various trophic levels to become established in less than 10 years (van Elden et al., 2019). Underwater surveys have recorded significantly higher fish abundance and diversity, including commercially valuable species, along pipelines and oil and gas infrastructure to depths of around 135 m (Bond et al., 2018; McLean et al., 2018). Moreover, recreational and commercial fishing is prohibited in the vicinity of offshore infrastructure in some countries such as the UK and Australia, leading to oil and gas platforms functioning as *de facto* fully protected marine reserves. A recent survey concluded that full removal of oil and gas platforms would reduce fish biomass at each site by at least 95%, as compared to a reduction of 10% associated with partial removal (Meyer-Gutbrod et al., 2020).

In situ options therefore reduce the financial costs of decommissioning which would be borne by governments and the private sector, whilst offering new opportunities to conserve marine habitats and species which would otherwise be destroyed through complete removal. These must be balanced with considerations of the potential for pollution arising from the leakage of contaminants from within the oil and gas materials structure and the potential further spread of invasive species found in association with oil and gas infrastructure (MacIntosh et al., 2021; Melbourne-Thomas et al., 2021). *In situ* decommissioning has only been pursued in a limited number of production areas, most notably the Gulf of Mexico where over 500 platforms have been converted to artificial reefs under the 1984 US Congress National Fishing Enhancement Act (Bureau of Safety and Environmental Enforcement, 2000). By contrast, the OSPAR regional convention which covers the North Sea production field requires full removal of redundant oil and gas infrastructure whilst also only permitting artificial reefs to be installed using new materials, reflecting a longstanding narrative against in situ decommissioning based around the Brent Spar experience in the North Sea in the mid 1990s (Jørgensen, 2012; Ounanian et al., 2020). Full removal of infrastructure is the default requirement in Australian waters under the Offshore Petroleum and Greenhouse Gas Storage Act 2006, although alternatives can be considered, provided they demonstrate equal or better environmental and safety outcomes (Department of Industry, Science, Energy and Resources, 2018).

Public views, including personal values arising from the use or existence of offshore artificial structures, and perceptions of the issues and opportunities associated with their presence in the marine environment, clearly play an integral role in determining the success or failure of marine planning. It is therefore essential to understand the nature and drivers of social and economic values and perceptions held by stakeholders with reference to MMS for the development of evidence-based management policies. This paper contributes to this objective through providing the first systematic review of academic and grey literature relating to public social and economic values associated with MMS. We show that, despite the relative dearth of primary data, some consistent values can be identified but there remains considerable progress to be made in key areas in order that management of MMS reflects stakeholder needs in the broader marine spatial planning context.

2. Literature review

2.1. Methodology

A review of academic and grey literature exploring the topic of socioeconomic values and man-made marine structures was conducted between June and September 2019. Web of Science, Scopus and Google Scholar databases were searched using synonyms for 'economic value', 'social value', 'man-made marine structure', 'structure user' and 'structure objectives'. These terms were based on existing literature and recommendations from technical experts.

The academic and grey literature search returned a total of 689 articles. All articles' abstracts were then screened to include only those papers published in English from reputable academic, government or professional organisations with a clear focus on social or economic values of MMS and whose full texts could be accessed via the authors' institutions. This yielded a total of 104 papers, 75 of which related to social values and 29 dealing with economic values. These were then searched for additional references which met the screening criteria above, resulting in 123 papers examining social values and 35 focusing on economic values. All of these were subjected to a full text analysis to identify papers which provided detailed information relating to social or economic values which could be attributed to a user group and/or MMS type. A final suite of 31 articles addressing social values and 34 addressing economic values were identified (Fig. 1). All economic values papers were from the academic literature, with the grey literature providing five of the social values papers. Full details of the above methodology and a summary of all papers in the final suite are provided in the Supplementary material.

The 31 papers detailing social values of MMS were analysed to extract information on the country and year of study; MMS types; stakeholder groups; methods of stakeholder engagement; methods of social value assessment; and findings in relation to social value by stakeholder groups. The concept of social value is diffuse and context-specific, with many different approaches adopted to characterise and measure the values held by stakeholder groups. Thus, research themes covered within the social literature were identified via an inductive approach, listing the social value research question of each paper, and collating into research themes. Three core themes were identified, and sub-themes were also constructed, where relevant, to capture further variation in research focus.

The 34 articles examining economic values of MMS were analysed to identify the country and year of study; MMS type; the measured value type(s); valuation method(s); valuation context or question; and willingness-to-pay estimate. All value estimates were converted to 2019 USD values using the Consumer Price Index for the relevant countries (World Bank, 2019) and an online currency converter (www.xe.com).

3. Social values

3.1. Geographic scope, structure types and stakeholder groups

Of the 31 papers on social values of MMS identified through the review, 17 were published since 2015. The geographic focus of the research was predominantly Australia, the United States, and the United Kingdom (19 studies). Other papers covered Brazil, France, Israel, Norway, the Philippines and Portugal or were global in their extent. Artificial reefs were the predominant MMS in almost half of all the papers whilst either recreational or commercial fishers were the target stakeholder group in over half of all papers reviewed.

3.2. Themes in social values and perceptions

Three dominant research themes were identified in the social values

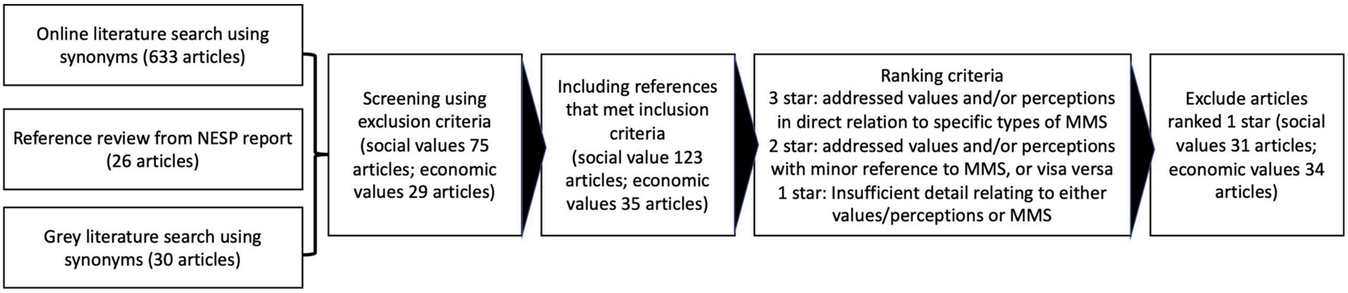

Fig. 1. Literature review process.

literature, namely: a) stakeholder use and satisfaction with MMS; b) social values associated with MMS; and c) stakeholder perceptions of MMS. In addition, three sub-themes were identified within both the 'social values' and 'stakeholder perceptions' themes. Further details of these themes and their occurrence across the literature is provided in the Supplementary materials.

3.2.1. *Use and satisfaction*

The predominant focus in this collection of papers was on recreational divers' use of artificial reefs, with a particular focus on the relationships between divers' background (e.g. dive experience) and site satisfaction (e.g. natural versus artificial reefs or habitat preferences). Most papers dealt with case studies from the United States and neighbouring countries together with Israel and France (Murray and Betz, 1994; Ditton et al., 2002; Stolk et al., 2007; Shani et al., 2012; Kirkbride-Smith et al., 2013; Tessier et al., 2015; Belhassen et al., 2017; ten Brink and Dalton, 2018; Montes et al., 2019). The studies indicated that artificial reefs were favoured over natural reefs owing to the relative ease of access, although levels of satisfaction with artificial reefs were found to decline with diver experience (Belhassen et al., 2017). Recreational divers valued subjective elements associated with artificial reefs such as the opportunity to witness the range of underwater biodiversity, gain a different experience and take photographs (Ditton et al., 2002; Kirkbride-Smith et al., 2013). Shipwrecks were the preferred type of artificial reef, followed by oil and gas infrastructure (Murray and Betz, 1994; Ditton et al., 2002; Kirkbride-Smith et al., 2013). Overcrowding was the main source of dissatisfaction, with some respondents indicating that zoning was needed to reduce conflict between recreational divers and recreational fishers (Ditton et al., 2002). Access was particularly noted as impacting recreational fishers' experience around a wind farm, relating to loss of access during construction and difficulties in navigation following construction (ten Brink and Dalton, 2018).

3.2.2. *Social values of MMS*

Despite the limited number of papers in this category, a range of types of MMS were covered, including artificial reefs, natural reefs, sea walls, offshore wind farms and oil and gas infrastructure. Furthermore, these articles encompassed data from a broad range of stakeholder groups (recreational and commercial fishers, divers, tourism sector representatives, environmental groups and various government institutions). Study sites were predominantly from the global North, including the United States, the United Kingdom, Australia and Portugal.

Three sub-themes within this category were identified. A focus on social wellbeing, which integrates both material and non-material outcomes associated with MMS, was explored in four papers (Ramos et al., 2007; Morris et al., 2016; Barclay et al., 2017; Voyer et al., 2017). Another sub-theme examined the interests of different stakeholder groups and how these interests supported or hindered the implementation of offshore MMS (Schroeder and Love, 2004; Ramos et al., 2011). A third sub-theme focused on values derived from the asset or resource more broadly (Pike et al., 2010; Evans et al., 2017).

Due to the variety of MMS and stakeholder groups involved, trends in social values by stakeholder group or structure type could not be identified from the literature captured in the review. The reported social values, do however, indicate stakeholder values are likely contingent on MMS structure type. For example, divers valued the diversity of species associated with artificial reefs (Ramos et al., 2007) whilst recreational fishers' values were affected by the presence or absence of commercial fishers on natural reefs (Barclay et al., 2017). Sea defences were valued according to net overall benefits in terms of economic cost and ecological impacts (Evans et al., 2017). Furthermore, stakeholder groups' values may be influenced by less tangible factors than structure type, as demonstrated by Voyer et al. (2017) in their finding that the presence of a commercial fishing industry was positively associated with tourists' experience of a location. Access was again identified as a key factor influencing values relating to decommissioning of oil and gas infrastructure (Schroeder and Love, 2004).

3.2.3. *Social perceptions of MMS*

As outlined above, the values held by individuals shape their expressions of opinion or 'perceptions' in relation to external objects. Perceptions in relation to MMS are thus informed by individual values but may be easier to identify and quantify than values, and consequently recurred far more frequently in the literature review. Most studies related to perceptions of either artificial reefs or offshore wind farms, with many studies focusing on multiple stakeholders. Again, the research was conducted in a limited number of countries including the United States, Australia, and the United Kingdom.

Three sub-themes were identified within this theme. The first involved a focus on perceived benefits, conflicts, and awareness of MMS in general (Murray and Betz, 1994; Ditton et al., 2002; Ramos et al., 2007; Shani et al., 2012; Hooper et al., 2015, 2017; Tessier et al., 2015; Andriesse, 2018; ten Brink and Dalton, 2018; Kienker et al., 2018; Lima et al., 2018). The second sub-theme examined issues of resource access to an MMS site and its surrounding habitat (Sutton and Bushnell, 2007; Ammar et al., 2009; Hooper et al., 2015; Kruse et al., 2015). The final sub-theme involved the identification of priority issues or threats associated with MMS (Cripps and Aable, 2002; Leeworthy et al., 2004; WAFIC, 2017; Shaw et al., 2018).

It was apparent amongst many of these papers that the majority of stakeholders were aware of the biodiversity benefits associated with the presence of MMS. However, Ramos et al. (2007) noted that scientists tended to be more optimistic about these benefits than other user groups. Commercial fishers in particular voiced concerns relating to access, damage to fishing gear and resulting compensation associated with MMS, with most favouring full removal of offshore oil and gas infrastructure (Hooper et al., 2015; Kruse et al., 2015). Ramos et al. (2011) also noted that positive user experiences shaped divers' perceptions of artificial reefs.

3.3. *Summary*

The concept of 'wellbeing' is receiving increased attention as a means of exploring what is valued by society, encompassing material (for example income, wealth, livelihoods), subjective (satisfaction, hopes, fears) and relational (networks, identities and influence) dimensions (White, 2010). This has been elaborated on by Weeratunge et al. (2014) to produce a model of social wellbeing which superimposes these three dimensions on micro (individual), meso (community/region) and macro (socio-ecological system) scales. We utilised this framework to depict the range of social values identified through the literature review with respect to MMS to provide a framework for future analysis of social values, as depicted in Fig. 2. Thus, at the macro scale, we locate values associated with satisfaction with the policy environment and ecosystem health benefits of MMS in the relational and subjective categories respectively. Material values associated with tourism and employment benefits of MMS are situated at the meso scale, along with subjective values involving inter-generational benefits and the ecological connectivity of MMS structures and relational values linked to cultural benefits of MMS, and conflict or co-operation over their usage. At the micro scale, individuals hold a wider range of values associated with MMS, with a noticeable leaning towards subjective values including personal experience, memories, satisfaction, and associations of identity with MMS. Rights of access, quantity of fishing catch and personal income are micro-level material values that stakeholders associate with MMS. Finally, there is evidence that MMS hold micro-level relational values through acting as a foci for social interaction.

4. Economic values

The literature search identified 34 studies that quantified the economic value that MMS provide to stakeholders such as divers, recreational and commercial fisheries, the general public, and other user groups. These papers date back to 1973 and exhibit a gradual increase in publication frequency over time, with 15% published in the last five years. The most common structure types investigated were purpose built artificial reefs (18 studies) and shipwrecks (15 studies). We also found six studies on offshore oil and gas platforms and one on offshore wind turbines. While the literature includes economic valuation studies from all over the world, half of these studies were conducted on field sites in the USA. All 34 articles quantified direct use values (19 extractive use values and 17 non-extractive use values), whilst non-use values were assessed by only two studies. None of the studies estimated indirect use values, even where the context of the studies could be relevant e.g. coastal protection.

4.1. Direct use values

MMS have been found to generate direct use values in terms of business revenues from extractive uses such as commercial fishing (Brock, 1994; Vivekanandan et al., 2009; Islam et al., 2014) and recreational fishing (Buchanan, 1973; Milon, 1988; Morgan et al., 2018; Brandini, 2014). For example, Buchanan (1973) estimated that an artificial reef in South Carolina, USA caused an increase of 10% in the gross economic contribution of marine recreational fishing in the region. In the Gulf of Mexico, a significant part of the commercial harvest of snappers originates from oil and gas platforms (Bull and Love, 2019). Moreover, Kolian et al. (2018) estimated that in the Gulf of Mexico, a sustainable harvest of aquarium fish could yield approximately USD 1.4 million per oil and gas platform per year. They also point out that there is an unknown value in novel pharmaceutical and/or nutritional products that could be sourced from marine invertebrates that grow on oil and gas platforms. However, (Islam et al., 2014) found that benefits from artificial reefs in Malaysia, including oil and gas structures, were unequally distributed among artisanal fishers and suggest that sustainable fisheries management within the artificial reef development should ensure economic benefits for the local fishing communities.

MMS also provide business revenues through non-extractive uses

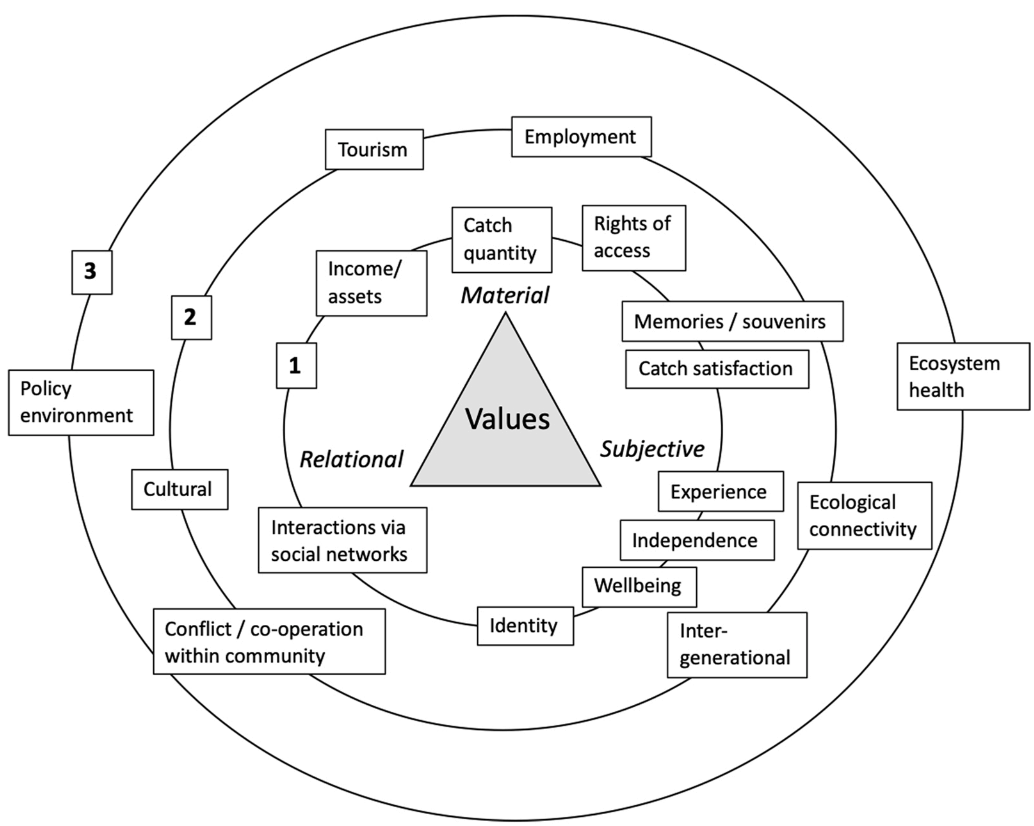

Fig. 2. Model of social values of MMS derived from the literature. 1 = micro (local) scale, 2 = meso (regional) scale, 3 = macro (national/global) scale. Adapted from Weeratunge et al. (2014).

such as scuba diving (Ditton et al., 2002; Dowling and Nichol, 2001; Leeworthy et al., 2006). For example, Dowling and Nichol (2001) analysed the expenditures from dive tourists that visit the HMAS Swan shipwreck in Western Australia and estimated the annual economic impact to be USD 1.39 million. Johns et al. (2001) estimated that shipwrecks in Southeast Florida provide 26,800 jobs for the tourism industry and are generating USD 2.4 billion of revenue annually. A similar study from Bell et al. (1998) showed that artificial reefs in Northwest Florida have an annual impact of USD 415 million annually and provide 8100 jobs for the dive tourism industry. Hiett and Milon (2002) found that recreational fishing and diving associated with oil and gas facilities in the Gulf of Mexico not only generated USD 324.6 million in annual economic revenues, but also provided employment for approximately 5560 full time equivalents. Both fishing charter and dive tour operators considered the presence of oil and gas structures to be very important to their businesses.

Two articles compared economic values of commercial fishing opposed to recreational and/or tourism activities on shipwrecks (Brock, 1994; Crabbe and Mcclanahan, 2006). Both studies found that the revenues generated from recreation and tourism greatly exceed those from commercial fishing.

4.2. Non-market direct use values

In addition to business revenues, MMS can provide economic benefits in terms of increased user satisfaction (consumer surplus). Mcgurrin and Fedler (1989) found that the increase in catchability and/or catch rate around oil and gas platforms in the USA improves satisfaction of recreational fishers which translated into fishers on oil and gas platforms being willing to pay more (USD 19.38) than non-platform fishers (USD 10.00) for another artificial reef site.

Users also can value how MMS alleviate user pressure on natural reefs. For example, Hannak et al. (2011) found less experienced snorkellers (who are more likely to damage reefs) were willing to pay for a snorkel trail built to prevent tourists from trampling on and harming natural reefs. Moreover, the siting of artificial reefs can allow for safer conditions than on some natural sites. Christie (2009) assessed the economic value associated with safer swimming conditions and found that members of a community in Wales held significant values for a multipurpose reef which would provide such conditions. Likewise, Taiwan residents were willing to pay about USD 13 per recreational fishing and diving trip for access to an artificial reef zone that provides safer conditions than surrounding areas (Chen et al., 2013).

4.3. Comparison of values for MMS and natural marine habitat

Nine studies compared economic values related to MMS with those from non-MMS sites, six of which recorded higher economic values on MMS than on adjacent areas (Johns et al., 2001, Vivekanandan et al., 2006, Whitmarsh et al., 2008, Oh et al., 2008, Kasim et al., 2013, Kirkbride-Smith et al., 2016). Notably, Kasim et al. (2013) found that the revenues of commercial fishers in India were over twice as high on artificial reefs compared to non-artificial reef areas, whilst Johns et al. (2001) observed that recreational divers in South-East Florida were willing to pay over twice as much to protect natural reefs (USD 229.3 million/year) than to protect a shipwreck (USD 85.1 million/year). However, Huth et al. (2015) found that dive tourists in Florida had a higher willingness to pay for a dive trip to a shipwreck (USD 368) than to natural reefs (USD 300), whilst Islam et al. (2014) found that the monthly fishing income from artisanal fishers on an artificial reef in Malaysia was lower than on adjacent natural reefs.

4.4. Non-use values

MMS can enhance marine habitat and therefore improve the biodiversity and/or abundance of marine life on and around them. People who value these natural benefits can be willing to pay for maintaining artificial structures, even when they do not use them. Börger et al. (2015) estimated the willingness to pay of residents in Ireland for an increase in biodiversity on an offshore wind farm. They found people were willing to pay GBP 7.25 and GBP 14.83 per person for an increase of ten and 30 species around the wind farm respectively. Hicks et al. (2004) found a positive attitude towards oyster reef restoration programs in the USA and estimated that residents were willing to pay USD 86.68 per year to fund oyster reef programs although they may not necessarily use these reefs.

4.5. Summary

It is evident that studies of the economic value of MMS have been focused on shipwrecks and artificial reefs in the Global North and have prioritised direct use values. These have shown that economic benefits accrue to both extractive and non-extractive users. Whilst the magnitude of these varies significantly across case study sites, there exists evidence that recreational fishing and tourism are associated with higher revenues from MMS. There remains very little knowledge concerning non-use values, despite the wide range of ecosystem services associated with MMS (Ramos et al., 2021).

5. Discussion

Values and perceptions are informed by the perceived and actual benefits, risks and opportunities associated with MMS, which may be a combination of social (material, relational and subjective) and economic (use value, non-use value). The literature review first and foremost demonstrated that there are very few examples of research that attempt to measure both social and economic values of MMS, despite the long-established interlinkages between these (Cohen, 1987). The only paper found in this review to attempt such an integrated approach focused on one stakeholder group and one type of MMS (Ramos et al., 2007). It is evident that future research should adopt approaches which bridge this gap to better understand the drivers of public acceptance of MMS.

There are clear gaps in the coverage of both MMS and stakeholder groups which are highlighted by this review. Artificial reefs were the predominant MMS structure and recreational fishers and divers were the most common stakeholder group across the social and economic values literature. Whilst the latter may reflect direct use patterns, other stakeholder groups may hold contrasting values and perceptions, particularly the conservation community, that were rarely reflected in the literature. Furthermore, the focus on artificial reefs neglects the other types of MMS, particularly offshore wind farms which are projected to account for the majority of growth in MMS coverage into the future (Bugnot et al., 2021). There is a pressing need to understand stakeholder views on the options for decommissioning oil and gas infrastructure, which is under-represented in the literature, along with those associated with new forms of MMS involving eco-engineering of existing coastal infrastructure (O'Shaughnessy et al., 2020).

There is an evident lack of understanding of the nature and extent of heterogeneity of stakeholder views within groups. Some studies imply this, with a recognition of factors such as personal experience influencing diver satisfaction, but there are no systematic treatments of how and why and to what extent views may differ within stakeholder groups in the MMS literature. Such an approach would facilitate policy through identifying the drivers behind acceptance or rejection of MMS within key stakeholder groups. In relation to this, there were no studies exploring how or why views and perceptions may change over time in relation to MMS. As the footprint of MMS in the nearshore zone increases, it is essential to understand how this cumulative process affects changes in individual values and perceptions associated with man-made marine infrastructure.

Finally, this review has demonstrated the overwhelming focus on the

Global North in relation to social and economic values of MMS. This demonstrates a lack of knowledge regarding stakeholders more commonly found in the Global South such as artisanal fishers, whilst also precluding an understanding as to how Indigenous groups in both developed and developing countries perceive and value offshore marine structures.

6. Conclusion

Whilst humans have modified coastlines for thousands of years, the spread of artificial construction offshore to exploit energy and mineral resources and construct telecommunications networks has developed rapidly in the past few decades. The unintended consequences of offshore construction include a variety of ecosystem services and associated socio-economic benefits through habitat creation which potentially accrue to a wide range of stakeholders. This presents new areas of potential conflict in marine spatial planning, extending into disputed issues of legal liability for offshore construction and raising questions over established principles and norms relating to artificial marine structures. Understanding the social and economic values and perceptions of stakeholders with regards to offshore marine structures is therefore essential to guide policy-makers.

This review has identified social and economic values, placed social values within the social-wellbeing framework, and identified significant gaps in research, including an absence of integrated social and economic research, and a paucity of multi-stakeholder and multi-structure assessments. The findings provide a foundation to explore the socio-economic values of MMS, through for example, applying the model of social values in future research (see Fig. 1). Expanding the present focus from individual resources and users towards social and economic assessments that capture multiple structures and user groups, including those in the Global South, will provide a more accurate representation of the current situation. Such information will build a greater understanding of the social and economic consequences arising from the increasing prevalence of offshore marine structures.

Declaration of Competing 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.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.envsci.2021.12.006.

References

Ammar, M.S.A., 2009. Coral reef restoration and artificial reef management, future and economic. Open Environ. Eng. J. 2 (1), 37–49.
Andriesse, E., 2018. Persistent fishing amidst depletion, environmental and socio-economic vulnerability in Iloilo Province, the Philippines. Ocean Coast. Manag. 157, 130–137.
Barclay, K., Voyer, M., Mazur, N., Payne, A.M., Mauli, S., Kinch, J., Fabinyi, M., Smith, G., 2017. The importance of qualitative social research for effective fisheries management. Fish. Res. 186, 426–438.
Belhassen, Y., Rousseau, M., Tynyakov, J., Shashar, N., 2017. Evaluating the attractiveness and effectiveness of artificial coral reefs as a recreational ecosystem service. J. Environ. Manag. 203 (1), 448–456.
Bell, F.W., Bonn, M.A., Leeworthy, V.R., 1998. Economic Impact and Importance of Artificial Reefs in Northwest Florida. Office of Fisheries Management and Assistance Service, Florida Department of Environmental Administration, Tallahassee, FL.
Bond, T., Partridge, J.C., Taylor, M.D., Langlois, T.J., Malseed, B.E., Smith, L.D., McLean, D.L., 2018. Fish associated with a subsea pipeline and adjacent seafloor of the North West Shelf of Western Australia. Mar. Environ. Res. 141, 53–65.
Börger, T., Hooper, T.L., Austen, M.C., 2015. Valuation of ecological and amenity impacts of an offshore windfarm as a factor in marine planning. Environ. Sci. Policy 54, 126133.
Brandini, F., 2014. Marine biodiversity and sustainability of fishing resources in Brazil: a case study of the coast of Paraná state. Reg. Environ. Chang. 14, 2127–2137.
Brock, R.E., 1994. Beyond fisheries enhancement: artificial reefs and ecotourism. Bull. Mar. Sci. 22 (2–3), 1181–1188 (8).
Buchanan, C.C., 1973. Effects of an artificial habitat on the marine sport fishery and economy of Murrells Inlet, South Carolina. MFR 1002.
Bugnot, A.B., Mayer-Pinto, M., Airoldi, L., Heery, E.C., Johnston, E.L., Critchley, L.P., Strain, E.M.A., Morris, R.L., Loke, L.H.L., Bishop, M.J., Sheehan, E.V., Coleman, R.A., Dafforn, K.A., 2021. Current and projected global extent of marine built structures. Nat. Sustain. 4, 33–41.
Bureau of Safety and Environmental Enforcement, 2000. Rigs to Reefs. Available at: ⟨https://www.bsee.gov/what-we-do/environmental-compliance/environmental-programs/rigs-to-reefs⟩.
Bull, A.S., Love, M.S., 2019. Worldwide oil and gas platform decommissioning: a review of practices and reefing options. Ocean Coast. Manag. 168, 274–306. https://doi.org/10.1016/j.ocecoaman.2018.10.024.
Chen, J.L., Chuang, C.T., Jan, R.Q., Liu, L.C., Jan, M.S., 2013. Recreational benefits of ecosystem services on and around artificial reefs: a case study in Penghu, Taiwan. Ocean Coast. Manag. 85, 58–64.
Christie, M., 2009. An economic assessment of the amenity benefits associated with alternative coastal defence options. Reef J. 1, 247–266.
Cohen, R.L., 1987. Distributive justice: theory and research. Soc. Justice Res. 1, 19–40.
Crabbe, M., Mcclanahan, T.R., 2006. A biosocioeconomic evaluation of shipwrecks used for fishery and dive tourism enhancement in Kenya. West. Indian Ocean J. Mar. Sci. 5, 35–54.
Cripps, S.J., Aable, J.P., 2002. Environmental and socio-economic impact assessment of Ekoreef, a multiple platform rigs-to-reef development. J. Mar. Sci. 59, 300–308.
Department of Industry, Science, Energy and Resources, 2018. Offshore Petroleum Decommissioning Guidelines. Available at: ⟨https://www.nopta.gov.au/_documents/guidelines/decommissioning-guideline.pdf⟩.
Ditton, R.B., Osburn, H.R., Baker, T.L., Thailing, C.E., 2002. Demographics, attitudes, and reef management practices of sport divers in offshore Texas waters. ICES J. Mar. Sci. 59, 186–191.
Dowling, R.K., Nichol, J., 2001. The HMAS Swan artificial dive reef. Ann. Tour. Res. 28, 226–229.
Evans, A.J., Garrod, B., Firth, L.B., Hawkins, S.J., Morris-Webb, E.S., Goudge, H., Moore, P.J., 2017. Stakeholder priorities for multi-functional coastal defence developments and steps to effective implementation. Mar. Policy 75, 143–155.
Fowler, A.M., Macreadie, P.I., Jones, D.O.B., Booth, D.J., 2014. A multi-criteria decision approach to decommissioning of offshore oil and gas infrastructure. Ocean Coast. Manag. 87, 20–29.
Global Wind Energy Council, 2020. Global Offshore Wind Report (2020). Global Wind Energy Council, Brussels.
Hannak, J.S., Kompatscher, S., Stachowitsch, M., Herler, J., 2011. Snorkelling and trampling in shallow-water fringing reefs: risk assessment and proposed management strategy. J. Environ. Manag. 92, 2723–2733.
Hicks, R.L., Haab, T.C., Lipton, D., 2004. The Economic Benefits of Oyster Reef Restoration in the Chesapeake Bay. Final Report: Chesapeake Bay Foundation.
Hiett, R., Milon, J.W., 2002. Economic Impact of Recreational Fishing and Diving Associated with Offshore Oil and Gas Structures in the Gulf of Mexico. DOI Minerals Management Service Document. DOI Minerals Management Service.
Hooper, T., Ashley, M., Austen, M., 2015. Perceptions of fishers and developers on the co-location of offshore wind farms and decapod fisheries in the UK. Mar. Policy 61, 16–22.
Hooper, T., Hattam, C., Austen, M., 2017. Recreational use of offshore wind farms: experiences and opinions of sea anglers in the UK. Mar. Policy 78, 55–60.
Huth, W., Morgan, O., Hindsley, P., 2015. Artificial reef attributes and the relationship with natural reefs: evidence from the Florida keys. J. Ocean Coast. Econ. 40, 2–2426.
Islam, G.M.N., Noh, K.M., Sidique, S.F., Noh, A.F.M., 2014. Economic impact of artificial reefs: a case study of small scale fishers in Terengganu, Peninsular Malaysia. Fish. Res. 151, 122–129.
Johns, G.M., Leeworthy, V.R., Bell, F.W., Bonn, M.A., 2001. Socio-Economic Study of Reefs in South-East Florida – Final Report. Hazen and Sawyer Environmental Engineers and Scientists.
Jørgensen, D., 2012. OSPAR's exclusion of rigs-to-reefs in the North Sea. Ocean Coast. Manag. 58, 57–61.
Kasim, H.M., Rao, G.S., Rajagopalan, M., Vivekanandan, E., Mohanraj, G., Kandasami, D., Muthiah, P., Jagdis, I., Gopakumar, G., Mohan, S., 2013. Economic performance of artificial reefs deployed along Tamil Nadu coast, South India. Indian J. Fish. 60, 18.
Kienker, S.E., Coleman, R.A., Morris, R.L., Steinberg, P., Bollard, B., Jarvis, R., Strain, E. M.A., 2018. Bringing harbours alive: Assessing the importance of eco-engineered coastal infrastructure for different stakeholders and cities. Mar. Policy 94, 238–246.
Kirkbride-Smith, A.E., Wheeler, P.M., Johnson, M.L., 2013. The relationship between diver experience levels and perceptions of attractiveness of artificial reefs – examination of a potential management tool. PLoS ONE 8, 7.
Kirkbride-Smith, A.E., Wheeler, P.M., Johnson, M.L., 2016. Artificial reefs and marine protected areas: a study in willingness to pay to access Folkestone Marine Reserve, Barbados, West Indies. PeerJ 4, e2175.

Kolian, S.R., Sammarco, P.W., Porter, S.A., 2018. Use of retired oil and gas platforms for fisheries in the Gulf of Mexico. Environ. Syst. Decis. 38, 501–507.
Kruse, S.A., Bernstein, B., Scholz, A.J., 2015. Considerations in evaluating potential socioeconomic impacts of offshore platform decommissioning in California. Integr. Environ. Assess. Manag. 11 (4), 572–583.
Leeworthy, V.R., Maher, T., Stone, E.A., 2006. Can artificial reefs alter user pressure on adjacent natural reefs? Bull. Mar. Sci. 78 (1), 29–38.
Leeworthy, Wiley, Hospital, 2004. Importance-Satisfaction Ratings Five-year Comparison, SPA & ER Use, and Socioeconomic and Ecological Monitoring Comparison of Results 1995–96 to 2000–01. National Oceanic and Atmospheric Administration. Available online from: ⟨https://nmssanctuaries.blob.core.windows.net/sanctuaries-prod/media/archive/science/socioeconomic/floridakeys/pdfs/impsat.pdf⟩.
Lemasson, A.J., Knights, A.M., Thompson, M., Lessin, G., Beaumont, N., Pascoe, C., Queirós, A.M., McNeill, L., Schratzberger, M., Somerfield, P.J., 2021. Evidence for the effects of decommissioning man-made structures on marine ecosystems globally: a systematic map protocol. Environ. Evid. 10, 4.
Lima, J.S., Zappes, C.A., Di Beneditto, A.P.M., Zalmon, I.R., 2018. Artisanal fisheries and artificial reefs on the southeast coast of Brazil: Contributions to research and management. Ocean Coast. Manag. 163, 372–382.
MacIntosh, A., Dafforn, K., Penrose, B., Charlton, A., Cresswell, T., 2021. Ecotoxicological effects of decommissioning offshore petroleum infrastructure: a systematic review. Crit. Rev. Environ. Sci. Technol. 1–39.
Mcgurrin, J.M., Fedler, A.J., 1989. Tenneco II artificial reef project: an evaluation of rigs-to-reefs fisheries development. Bull. Mar. Sci. 44, 777–781.
McLean, D.L., Taylor, M.D., Partridge, J.C., Gibbons, B., Langlois, T.J., Malseed, B.E., Smith, L.D., Bond, T., 2018. Fish and habitats on wellhead infrastructure on the north west shelf of Western Australia. Cont. Shelf Res. 164, 10–27.
Melbourne-Thomas, J., Hayes, K.R., Hobday, A.J., Little, L.R., Strzelecki, J., Thomson, D. P., van Putten, I., Hook, S.E., 2021. Decommissioning research needs for offshore oil and gas infrastructure in Australia. Front. Mar. Sci. 8, 1007.
Meyer-Gutbrod, E.L., Love, M.S., Schroeder, D.M., Claisse, J.T., Kui, L., Miller, R.J., 2020. Forecasting the legacy of offshore oil and gas platforms on fish community structure and productivity. Ecol. Appl. 30 (8), e02185.
Milon, J.W., 1988. A nested demand shares model of artificial marine habitat choice by sport anglers. Mar. Resour. Econ. 5, 191–213.
Montes, N., Sidman, C., Lorenzen, K., Tamura, M., Ishida, M., 2019. Influence of fish aggregating devices on the livelihood assets of artisanal fishers in the Caribbean. Ocean Coast. Manag. 179, 104823.
Morgan, O.A., Huth, W.L., Hindsley, P., 2018. Examining the perceptions and effects of survey consequentiality across population subgroups. J. Benefit-Cost. Anal. 9, 305–322.
Morris, R.L., Deavin, G., Donald, S.H., Coleman, R.A., 2016. Eco-engineering in urbanised coastal systems: consideration of social values. Ecol. Manag. Restor. 17 (1), 33–39, 2016.
Murray, J.D., Betz, C.J., 1994. User views of artificial reef management in the southeastern US. Bull. Mar. Sci. 55, 970–981.
O'Shaughnessy, K.A., Hawkins, S.J., Evans, A.J., Hanley, M.E., Lunt, P., Thompson, R.C., Francis, R.A., Hoggart, S.P.G., Moore, P.J., Iglesias, G., Simmonds, D., Ducker, J., Firth, L.B., 2020. Design catalogue for eco-engineering of coastal artificial structures: a multifunctional approach for stakeholders and end-users. Urban Ecosyst. 23, 431–443.
Oh, C.-O., Ditton, R.B., Stoll, J.R., 2008. The economic value of scuba-diving use of natural and artificial reef habitats. Soc. Nat. Resour. 21, 455–468.
Ounanian, K., van Tatenhove, J.P.M., Ramírez-Monsalve, P., 2020. Midnight at the oasis: does restoration change the rigs-to-reefs debate in the North Sea? J. Environ. Policy Plan. 22 (2), 211–225.
Parente, V., Ferreira, D., dos Santos, E.M., Luczynski, E., 2006. Offshore decommissioning issues: deductibility and transferability. Energy Policy 34 (15), 1992–2001.
Pike, K., Johnson, D., Fletcher, S., Wright, P., Lee, B., 2010. Social value of marine and coastal protected areas in England and Wales. Coast. Manag. 38 (4), 412–432.
Ramos, J., Santos, M., Whitmarsh, D., Monteiro, C., 2011. Stakeholder analysis in the Portuguese artificial reef context: winners and losers. Braz. J. Oceanogr. 59, 133–143.
Ramos, J., Tuaty-Guerra, M., Almeida, M., Raposo, A.C., Gaudêncio, M.J., Silva, A.D., Rodrigues, N., Leandro, S.M., Caetano, M., 2021. An artificial reef at the edge of the deep: an interdisciplinary case study. Ocean Coast. Manag. 201, 105729.
Ramos, Jorge, Santos, Miguel N., Whitmarsh, David, Monteiro, Carlos C., 2007. Stakeholder perceptions regarding the environmental and socio-economic impacts of the Algarve artificial reefs. Hydrobiologia 580, 181–191.
Rystad Energy, 2020. ⟨https://www.rystadenergy.com/newsevents/news/press-releases/global-oil-gas-decommissioning-costs-to-total-$42-billion-through-2024-dominated-by-uk-north-sea⟩.
Schroeder, D.M., Love, M.S., 2004. Ecological and political issues surrounding decommissioning of offshore oil facilities in the Southern California Bight. Ocean Coast. Manag. 47, 21–48.
Shani, A., Polak, O., Shashar, N., 2012. Artificial reefs and mass marine ecotourism. Tour. Geogr. 14 (3), 361–382.
Shaw, J.L., Seares, P., Newman, S.J., 2018. Decommissioning Offshore Infrastructure: A Review of Stakeholder Views and Science Priorities, Available online from: ⟨http://www.marinescienceblueprint.org.au/⟩.
Spijkerboer, R.C., Zuidema, C., Busscher, T., Arts, J., 2020. The performance of marine spatial planning in coordinating offshore wind energy with other sea-uses: the case of the Dutch North Sea. Mar. Policy 115, 103860.
Stolk, P., Markwell, K., Jenkins, J.M., 2007. Artificial reefs as recreational scuba diving resources: a critical review of research. J. Sustain. Tour. 15 (4), 331–350.
Sutton, S.G., Bushnell, S.L., 2007. Socio-economic aspects of artificial reefs: considerations for the Great Barrier Reef Marine Park. Ocean Coast. Manag. 50 (10), 829–846.
Techera, E., Chandler, J., 2015. Offshore installations, decommissioning and artificial reefs: do current legal frameworks best serve the marine environment? Mar. Policy 59, 53–60.
ten Brink, T.S., Dalton, T., 2018. Perceptions of commercial and recreational fishers on the potential ecological impacts of the Block Island Wind Farm (US). Front. Mar. Sci. 5, 439.
Tessier, A., Francour, P., Charbonnel, E., Dalias, N., Bodilis, P., Seaman, W., Lenfant, P., 2015. Assessment of French artificial reefs: due to limitations of research, trends may be misleading. Hydrobiologia 753, 1–29.
van Elden, S., Meeuwig, J., Hobbs, R.J., Hemmi, J.M., 2019. Offshore oil and gas platforms as novel ecosystems: a global perspective. Front. Mar. Sci. 6, 548.
Vivekanandan, E., Venkatesan, S., Mohanraj, G., 2009. Service provided by artificial reef off Chennai. Indian J. Fish. 53, 67–75.
Voyer, M., Barclay, K., McIlgorm, A., Mazur, N., 2017. Connections or conflict? A social and economic analysis of the interconnections between the professional fishing industry, recreational fishing and marine tourism in coastal communities in NSW, Australia. Mar. Policy 76, 114–121.
WAFIC, 2017. Thevenard Offshore Platform Retirement Commercial Fishing Sector Stakeholder Consultation – WAFIC Report. Available from: ⟨https://www.wafic.org.au/offshore-stakeholder-consultation-environment-plans-nopsema-update-commercial-fishers/⟩.
Weeratunge, N., Béné, C., Siriwardane, R., Charles, A., Johnson, D., Allison, E.H., Nayak, P.K., Badjeck, M.C., 2014. Small-scale fisheries through the wellbeing lens. Fish Fish. 15 (2), 255–279.
White, S.C., 2010. Analysing wellbeing: a framework for development practice. Dev. Pract. 20, 158–172.
Whitmarsh, D., Santos, M.N., Ramos, J., Monteiro, C.C., 2008. Marine habitat modification through artificial reefs off the Algarve (southern Portugal): an economic analysis of the fisheries and the prospects for management. Ocean Coast. Manag. 51, 463–468.
World Bank, 2019. Inflation Calculator. ⟨https://data.worldbank.org/indicator/FP.CPI.TOTL.ZG⟩.