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Marine Spatial Planning in a Climate of Uncertainty – An Irish Perspective

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Abstract: A €1.8bn 'blue economy' centred on shipping, commercial fishing, offshore energy extraction, and tourism, contributes approximately 1% toward Ireland's GDP. A suite of EU-level Directives, legislation, and national-level policies and strategies have been enacted to further expand upon this productivity while simultaneously reducing the risk of environmental damages. This paper examines the development and implementation of marine spatial planning in Ireland, and considers its functionality in the face of climate change impacts. Climate change will cause significant changes in the availability and reliable delivery of marine ecosystem services, particularly supporting and regulating services. It is important for policy makers and stakeholders to recognise the limits of planning when faced with the uncertain, complex nature of climate change. As such, marine spatial planning tools must be responsive, adaptive, and support larger responses that address the sources of climate change – greenhouse gas emissions – rather than responding to its impacts.

1. The Need for Marine Spatial Planning

1.1 Limits on Marine Natural Resource Exploitation

We are in an era of limited marine resources, unprecedented economic wealth from exploiting those resources, and historic changes to oceans once thought both inexhaustible and immune to human activities. The world's marine economy is valued at approximately €2.5tn per year, a testament to globalisation (WWF, 2015) and the rapidly growing demands of 8.2bn people, 40% of whom live within 100km of a coast (MA, 2005).

The global demand for seafood now exceeds 167m tonnes annually, with nearly 70% of production destined for direct human consumption (FAO, 2016). The world's commercial fisheries, 58% of which are considered to be fully fished while another 32% are classified as biologically unsustainable and overfished, land 94m tonnes. The remaining demand is being met through marine aquaculture, a €140bn industry. By 2050, the demand from an estimated 9.8bn people (UN, 2017) is expected to rise to nearly 200m tonnes, with aquaculture accounting for 71-117m tonnes of this production (Merino *et al.,* 2012).

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In the European Union, seafood imports are valued at €46bn, €22bn of which is produced outside the EU (FAO, 2016). Buoyed by low tariffs, relaxed import duties and low operating costs, EU demand for high-value products like Atlantic salmon is being met by extensive aquaculture operations in developing parts of the world (Barton and Fløysand, 2010). Farmed salmon, raised in the Pacific waters off Chile, are now brought to European markets at a lower cost than an equivalently sized, locally caught, native wild Atlantic salmon (Bjørndal, 2002; Lizuka and Katz, 2011; Asche *et al.,* 2015).

Global offshore oil and gas production produces 27m barrels annually, valued at €113bn (EIA, 2016). Technological advancements allow oil and gas exploration and extraction to proceed in ever more challenging environments. Offshore oil and gas rigs are operating or have been proposed for every ocean, including the Arctic (Harsem *et al.,* 2011) and Southern (MacDonald *et al.,* 1988; Ward, 1998). Wells operate in waters at least 2450m deep (Fahey, 2012). The limits of oil and gas exploration, as well as deep-sea mining (Halfar and Fujita, 2002), hinges not on the physical limits of the deep ocean or polar latitudes, but on market price (Arzeki *et al.,* 2017). Offshore wind energy, led by sectoral growth across Europe (12,631 MW capacity) is about to surpass 15,000 MW of capacity (GWEC, 2016). Additional emerging sectors include wave and tidal energy, although their contribution to energy production will likely remain comparatively small for the coming 30 years (Esteban and Leary, 2012). Recognising the opportunity, Ireland has made strides in renewable energy production. In 2012, nearly 20% of Irish energy demand was met by renewable sources, and Ireland is now halfway (SEAI, 2017) to meeting a 2020 target where 40% of energy consumption is met by renewable sources (DCENR, 2014).

Managing this resource base has been made more challenging by the scale of globalisation, which affects research, monitoring, policy development, and enforcement (Ostrom *et al.,* 1999; Berkes *et al.,* 2006; Pressey *et al.,* 2007; Aswani *et al.,* 2018). Further, determining sustainable exploitation levels for limited resources is no longer the sole concern of policy makers and managers. Spatial rights and competing sectors occupying the same space has emerged as an economic battleground. Conflicts over perceived rights to occupy a particular space while engaged in economic activity have flared up between sectors at every spatial scale, from the local to the global (Jones *et al.,* 2016; Moore *et al.,* 2017). Addressing these spatial conflicts has become the pressing issue for managing marine resources in the 21st century (Santos *et al.,* 2018). Failing to do so incurs not only economic costs, but also a range of damages to the environment and local communities dependent upon those resources for food, energy, livelihood, and identity (Douvere, 2008; Levine *et al.,* 2015).

1.2 Addressing Conflict over Shared Marine Spaces through Planning – The Irish Context

Ireland is actively working to strengthen its €1.8bn 'blue economy' through concerted growth across its shipping, commercial fishing, offshore energy extraction, and tourism sectors (Vega and Hynes, 2017). This economic activity currently contributes

approximately 1% toward Ireland's GDP, and the nation has set a target of doubling this contribution by 2030 (MCG, 2012), while surpassing €6.4bn in economic turnover by 2020. Such growth will further exacerbate inter-sectoral conflict over what has been shared marine space (Qiu and Jones, 2013), requiring new planning tools to better organise and utilise marine environments and the goods and services they provide.

One emerging policy and planning tool is Marine Spatial Planning, or MSP (Douvere, 2008; Pomeroy and Douvere, 2008; Flannery *et al.,* 2015). MSP is based upon the lessons and strengths of past management policy approaches that worked to secure economic productivity without jeopardising the functionality and health of the natural systems upon which they relied (IMP, 2012). MSP, however, is not conservation-orientated by default, even though it can include ecosystem-based management (EBM) and integrated management theory into the planning process (Douvere, 2008). As Qiu and Jones (2013, 183) write, 'MSP ultimately involves political processes that lead to the allocation of sea space to meet social, ecological and economic objectives. How sustainability is interpreted in such political processes thus has important implications for the outcomes of such processes.' Like any tool, MSP can be deployed at any particular scale, such as promoting Ireland's ongoing national efforts toward their 'blue economy' goals, and in doing so, neglect objectives outside national-level economic metrics. (Flannery and Ó Cinnéide, 2008; de Santo, 2011; Lester *et al.,* 2013). Therefore, it is imperative that MSP is provided with sufficiently robust tools to aid the planning process toward decisions that engage EBM theory, are socially inclusive and equitable, and balance the needs of economic sectors (Pinarbaşi *et al.,* 2017).

Planning and managing efforts are often restricted in their capabilities, bound on what is knowable and acceptable, and so encumbered with insufficient flexibility and capacity to address the uncertainty surrounding future conditions (Ludwig *et al.,* 1993). They can also be confounded by a lack of political will (Stead and Meijers, 2009), a governmental preference for incremental approaches (Jones *et al.*, 1997), and a fragmented governance structure which reinforces a sector-by-sector approach to planning (Kelly *et al.,* 2018). Ireland's recent record with managing its marine and coastal areas is uneven. Positive developments can be seen in initial efforts to meet EU commitments and implement MSP by 2021, although Ireland will need to be cognisant of potential shortcomings ahead of being brought online (Brennan *et al.,* 2014). Also, there are outstanding questions on how comprehensive public engagement and stakeholder involvement in the planning process should be (Gilliland and Laffoley, 2008; Flannery and Ó Cinnéide, 2008). Lastly, insufficient urgency toward identifying and addressing emerging issues regarding marine areas can hamper suitably scaled planning and management (Kelly *et al.,* 2018). Prominently, Ireland's Maritime Area and Foreshore (Amendment) Bill 2013, though drafted, remains stalled in debate. The Foreshore Bill seeks to streamline the development consent process for various activities along Ireland's coasts, and like other marine and coastal-focused statutes, how its implementation might affect national goals and strategies remain unknown (Kelly *et al.,* 2015).

This is the central challenge: how to organise marine space in an equitable, democratic

fashion, for multiple users in such a manner as to meet a diversity of socioeconomic and environmental goals (Jones *et al.,* 2016). On its own, the necessary response is already full of complexity. Systems must be considered at multiple spatial and temporal scales (Worm *et al.,* 2006; Tittensor *et al.,* 2010). Economic sectors must be evaluated not only for their own production and impacts, but also for the direct and indirect ways their actions affect other sectors and the environment. Public support must be won and political will girded. Socioeconomic demands of today must be balanced against long-term ecological requirements (Santos *et al., in press*). The challenge becomes all the greater when attempting to incorporate plans that address climate change impacts.

2. Planning for Climate Change

2.1 The Governance of Ecosystem Services

For Ireland, the development of MSP stems from the Maritime Spatial Planning Directive (2014/89/EU), adopted by the European Union in 2014. The Directive views MSP as a 'cross-cutting policy tool enabling public authorities and stakeholders to apply a coordinated, integrated and trans-boundary [and] ecosystem-based approach' so as to promote 'the sustainable development and growth of the maritime and coastal economies and the sustainable use of marine and coastal resources'(Recital 3).

Structured as a coordinating statutory arm, the MSP Directive is meant to better link together legislation, policies, and strategies that are concerned with the development and use of Ireland's coastal and marine waters. Some, like the Common Fisheries Policy, are sector-focused and seek to improve the reliable delivery of some marketable good. Others, including the Marine Strategy Framework Directive (MSFD) and Water Framework Directive (WFD), are structured around ecosystem health and functionality targets (i.e. 'Good Environmental Status' in the MSFD and 'Good Ecological Status' in the WFD). Their guidance is preferential toward supporting and regulating services, rather than determining some rate of exploitation. As the MSFD notes (Article 3(5)), the Directive's goal is to support actions that lead to marine systems which 'provide ecologically diverse and dynamic oceans and seas which are clean, healthy and productive within their intrinsic conditions, and the use of the marine environment is at a level that is sustainable, thus safeguarding the potential for uses and activities by current and future generations' even if recognising that the 'determination of good environmental status may have to be adapted over time' because of climate change impacts (Recital 34). The following sections highlight the types of ecosystem services produced by the marine environment, as discussed more fully by Peterson and Lubchenco (1997) and Doney *et al.,* (2012), paying particular attention to the forecasted impacts from climate change around Ireland (Table 1).

Table 1

Marine Ecosystem Services	–	o	+	Impact Cause	References
Marine Supporting Services					
Biodiversity	–			1a,c,d,e; 2a,b,c; 3a,b,c,d,e	Cheung *et al.*, 2009
Ecosystem Resilience	–			1a,b,c,d,e; 2a,b,c; 3a,b,c,d,e	Beaugrand *et al.*, 2008
Habitat	–	o	+	1a,b,c,d,e; 2a,b,c; 3a,b,c,d,e	Birchenough *et al.*, 2015
Nutrient Cycling	–	o		1a,b,c; 2a,b,c; 3a,b,c,d,e	Wang *et al.*, 2018
Ocean Circulation	–			1a,b,c,d,e; 2a,b,c; 3a,b,c,d,e	Schmittner *et al.*, 2005
Primary Production	–	o		1a,b,c,d,e; 2a,b,c; 3a,b,c,d,e	Richardson and Schoeman, 2004
Marine Regulating Services					
Carbon Capture & Sequestration	–			1a,b,c,d,e; 2a,b,c; 3a,b,c,d,e	Beaumont *et al.*, 2014
Climate & Weather Regulation	–			1a,b,c,e; 2a,b,c; 3a,b,c,d,e	Marshall *et al.*, 2001
Disease Regulation	–	o		1a,c; 2a,b,c; 3a,b,c,d,e	Edwards *et al.*, 2006
Natural Hazard Regulation	–	o		1a,b,c,d,e; 3a,c,d,e	Devoy, 2008
Waste Absorption	–	o		1a,c; 2a,b,c; 3a,b,c,d,e	Levin and Le Bris, 2015
Marine Provisioning Services					
Food	–	o		1a,c,d; 2b,c; 3a,b,c,d,e	Cheung *et al.*, 2009
Genetic Resources	–	o		1a,c,d,e; 3a,b,c,d,e	Heath *et al.*, 2012
Oil, Gas and Mineral Extraction		o		1b,e; 3a,c,d,e	Burkett, 2012
Wave and Tidal Energy		o	+	1a,b,c,d,e; 3a,c,d,e	Debernard *et al.*, 2002
Wind and Solar Energy		o	+	1b,c,e; 3a,c,d,e	Debernard *et al.*, 2002
Marine Cultural Services					
Aesthetic Values	–			1b,d,e; 2b,c; 3a,c,d,e	Ellis *et al.*, 2007
Bequest Values	–			1a,b,c,d,e; 2a,b,c,d; 3a,b,c,d,e	Norton and Hynes, 2014
Recreational Values	–	o		1a,b,c,d,e; 3a,b,c,d,e	Cooper and Boyd, 2011
Spiritual Values	–	o		1b,c,d,e; 3a,b,c,d,e	Daniel *et al.*, 2012

1. **Physical Processes**
   a. Changes in current patterns
   b. Changes in weather patterns
   c. Changes in sea surface temperatures
   d. Sea-level rise
   e. Storm strength and frequency
2. **Biogeochemical Processes**
   a. Carbon availability
   b. Nutrient availability
   c. Oxygen availability
3. **Ecological Processes**
   a. Changes in biodiversity
   b. Changes in food web dynamics
   c. Changes in habitat range
   d. Changes in population range
   e. Changes in population vigour

2.2 Climate Change Impacts on Marine Supporting Services

Supporting services are responsible for all life on the planet, and, therefore, are necessary for other services to exist. Supporting services include nutrient cycling, ocean circulation, exchange, and transport, primary production, habitats and biodiversity, and ecosystem resilience. Proper stewardship and accounting for supporting services is the foundation for EBM (Qiu and Jones, 2013).

Under current trends, marine biodiversity (Cheung *et al.,* 2009; Bellard *et al.,* 2012), ecosystem resilience (Beaugrand *et al.,* 2008), and ocean circulation (Schmittner *et al.,* 2005) will be negatively affected in the northeast Atlantic. Biodiversity will be impacted by changes in ocean currents and sea temperatures, which will shift both habitat and species range poleward. Species and habitats at their most southerly extent will be replaced by more southerly, sub-tropical systems that are more tolerant of warm waters (Hiscock *et al.,* 2004). Changes in ocean currents will affect not just weather patterns, but also larval transport and settlement (Bell and Shaw, 2002). Coupled with warming surface waters, which speed the rate of larval development, larval transport is expected to be negatively impacted due to climate change, with implications for both population vigour, year-class survival (Hoegh-Guldberg and Bruno, 2010), and predator-prey dynamics throughout the marine food web (Durant *et al.,* 2007).

Environmental cycling of nutrients will also be affected by climate change (Wang *et al.,* 2018). There may be some moderation to the effect as there is a lack of consensus on how anthropogenic actions are affecting the marine nitrogen cycle (Landolfi *et al.,* 2017). By 2050, however, human activities will dominate the nitrogen budget, further raising the nitrogen load in coastal waters compared to the open ocean (Galloway *et al.,* 2004).

Climate change-related impacts on habitats extend beyond poleward shifts (Cheung *et al.,* 2009). The predicted sea level rise will increase the amount of available subtidal and intertidal habitats, although this does not mean that habitats will be free to expand vertically. Successfully establishing into new areas will be dependent on a host of other physical factors (Brooker *et al.,* 2007). It is expected that some habitats and populations will expand if proper substrates and slopes are available, while others will be limited in their ability to expand due to increased wave action or loss of suitable substrate (Hiscock *et al.,* 2004).

2.3 Climate Change Impacts on Marine Regulating Services

Regulating services perform essential maintenance to the marine environment as well as its associated natural and human systems. Oceans regulate climate (Marshall *et al.,* 2001; Beaugrand *et al.,* 2008; Levin and Le Bris, 2015), play an essential role in the carbon cycle (Wigley *et al.,* 1996; Feely *et al.,* 2009; Beaumont *et al.,* 2014), and store wastes (Levin and Le Bris, 2015). Natural coastal systems, such as dunes and barrier islands, protect lands from storm and wave damage (Devoy, 2008). Other regulating services include waste absorption and detoxification, and disease regulation.

Under forecasted future conditions, most regulating services provided by Ireland's marine environment are likely to become degraded (Table 1). Carbon sequestration rates are being slowed by a steadily acidifying ocean (Feely *et al.,* 2009; Levin and Le Bris, 2015), a consequence of atmospheric CO_2 concentrations that have now passed 400 parts per million (ppm) and may exceed 550 ppm by 2050 (IPCC, 2001). This affects the ability of carbon to be transformed into calcium carbonate by calcifying marine organisms. Work by McNeil and Matear (2008) suggests that the limits for calcification in polar and sub-polar waters may be reached at 450 ppm. Climate change is also likely to bring more frequent and intense storm systems toward Ireland, particularly in the wintertime (Wang *et al.,* 2008). An increase in marine disease prevalence is likely from warmer surface waters, and already stressed marine populations and habitats (Edwards *et al.,* 2006; Hoegh-Guldberg and Bruno, 2010).

2.4 Climate Change Impacts on Marine Provisioning Services

Provisioning services provide tangible goods from the marine environment, captured for the continued benefit of human systems. Well-known provisioning services include fisheries and aquaculture, as well as oil, gas and mineral resources. Renewable energy sources (i.e., wind, wave, tidal) are non-extractive, and represent an emerging area of provisioning services made possible by technological advancements. Finally, oceans harbour immense genetic resources that are sought after and utilised in emerging fields such as blue biotechnology.

Effects of climate change are expected to harm marine populations and their genetic pool (Bellard *et al.,* 2012; Heath *et al.,* 2012), including those targeted by fisheries (Cheung *et al.,* 2012). Some of these losses may be offset by habitat expansion of sub-tropical and mid-latitude pelagic species (Blanchard *et al.,* 2012; Birchenough *et al.,* 2015), although not enough to offset losses elsewhere or meet future demand (Merino *et al.,* 2012). Aquaculture operations are at risk from climate change-related impacts through disease and parasite outbreaks (Abolofia *et al.,* 2017), as well as storm-related damage (Thorstad *et al.,* 2008). Oil, gas, and mineral extraction in offshore areas face similar increased risks to storms (Burkett, 2012). Conversely, an increase in storm frequency and strength may provide opportunities for the expansion of renewable offshore energy like wind and wave (Debernard *et al.,* 2002), although development locations proposed today may not be well suited as wind and current patterns change toward 2050, or once low-priority fishing grounds become more intensively targeted as habitats shift and productivity increases.

2.5 Climate Change Impacts on Marine Cultural Services

Finally, cultural services include intangible benefits enjoyed by individuals and communities. Some cultural services, such as coastal and marine recreation, including tourism, are widely enjoyed and considered to be economically valuable, non-extractive resources. These areas also provide deep yet intangible benefits through community identity, spiritual and religious linkages, and as a place for education and introspection.

The aesthetic beauty of these coasts and waters can be treasured, as well as their promise of enjoyment (Barry *et al.,* 2011) and use in the future (MacLeod *et al.,* 2002). Where popular coastal areas are threatened by climate change impacts (Devoy, 2008), loss of cultural services through declines in tourism are likely to occur (Cooper and Boyd, 2011). Physical structures like seawalls and offshore wind turbines help mitigate effects of greenhouse gas emissions and climate change-strengthened natural hazards, yet may also negatively impact aesthetics (Ellis *et al.,* 2007; Jin *et al.,* 2015). Continued degradation of coastal and marine systems will also lower bequest values (Norton and Hynes, 2014), as future generations are bestowed a less resilient and less functional system.

There remains some questions about the full impact of climate change on cultural services (Hamilton *et al.,* 2005). Some cultural services are replaceable, as tourists simply opt for an alternate destination (Hamilton and Tol, 2007). Similarly, recreational opportunities may be replaced as individuals switch from one pursuit to another. As a result, a disparity may exist between the health and functionality of coastal and marine systems and its value for tourism and recreation. Spiritual and religious services are also unlikely to be particularly affected by climate change if the memory of a place and its meaningfulness is sufficient (Daniel *et al.,* 2012).

3. Accounting for Climate Change in MSP

The impacts from climate change on marine environments, and the ecosystem services they provide, will be widespread (Hiscock *et al.,* 2004; Harley *et al.,* 2006; Cheung *et al.,* 2009; Callaway *et al.,* 2012). Climate change has captured the attention of policy makers since the 1992 Rio Conference, which resulted in the UN Framework Convention on Climate Change (UNFCCC, 1992). Through Article 4(1)(d), the UNFCCC commits parties to 'promote sustainable management, and promote and cooperate in the conservation and enhancement, as appropriate, of sinks and reservoirs of all greenhouse gases' including coastal and marine systems. Concern over climate change impacts to these systems is highlighted by various national and EU-level regulations (*see Appendix*).

The MSP Directive was transposed into Irish law (S.I. No. 352/2016, since revoked and replaced) by the Planning and Development (Amended) Act (Act No. 16 of 2018, Part 5). Thus authorised, efforts are underway to prepare, approve and submit a national plan to the European Commission by a March 31, 2021 deadline (DHPLG, 2017). A national MSP, which must be reviewed and updated every six years while supporting goals established by the National Planning Framework – Project Ireland 2040, is meant to provide an overarching, coordinated planning framework (Recital 15) that will help Ireland achieve public policy goals set out by the Habitats (92/43/EEC), Water Framework (2000/60/EC), Strategic Environmental Assessment (2001/42/EC), Marine Strategy Framework (2008/56/EC), Renewable Energy (2009/28/EC), and amended Birds (2009/147/EC) Directives, in addition to the Common Fisheries Policy (2371/2002; 1380/2013), Integrated Maritime Policies (COM(2007) 575;

COM(2012) 491), and Europe Smart, Sustainable Growth Strategy (COM(2010) 2020), EU Biodiversity Strategy 2020 (COM(2011) 244, and Adaptation to Climate Change (COM(2013) 216) Communications. The MSP Directive is not meant to impose additional obligations to Member States in how they may choose to pursue sectoral policies (Recital 9), but contribute to existing policies through spatial planning that 'promote sustainable development and identify the utilisation of the maritime space for different sea uses as well as manage spatial uses and conflicts in marine areas' while 'taking into consideration long-term changes due to climate change' (Recital 19).

As there are little explicit statements on the matter of climate change by several of the above listed items (*see Appendix*), there is a question on how well MSP can coordinate Ireland's actions for safeguarding its coastal and marine systems, in line with Recital 15 of the MSP Directive. Ireland's principal response to climate change impacts is through the Climate Action and Low Carbon Development Act (Act No. 46 of 2015), which carries no reflexive considerations on coastal or marine systems, or planning their development and use. These considerations are covered instead through the Act's related mechanisms, National Mitigation Plans (NMPs) and National Adaptation Frameworks (NAFs). NMPs 'must specify the policy measures that Government consider are required to manage greenhouse gas emissions and the removal of emissions at a level that is appropriate for furthering the national transition objective' (DCCAE, 2017, 8). In a complementary fashion to NMPs, NAFs establish 'the national strategy for the application of adaptation measures in different sectors and by local authorities in their administrative areas in order to reduce the vulnerability of the State to the negative effects of climate change and to avail of any positive effects that may occur' (DCCAE, 2018, 9). Both are instrumental policy tools as Ireland pursues the National Transition Objective toward a low carbon, climate resilient and environmentally sustainable economy through an 80% reduction in carbon dioxide emissions (compared to 1990 levels). Of the two, NAFs will likely contribute more fully to MSP actions regarding climate change.

Ireland's National Planning Framework, published in February 2018, establishes policy objectives related to climate change impacts to coastal areas through 2040. The framework sets to 'ensure that Ireland's coastal resource is managed to sustain its physical character and environmental quality' (National Objective 41a) while also advancing adaptation strategies to reduce the impact of sea level rise, coastal flooding, and erosion (National Objective 41b). Objective 5 in the National Biodiversity Action Plan 2017-2021 recognises the potential positive contribution of MSP for conserving and restoring marine biodiversity and ecosystem services through an improved capacity to identify and protect threatened habitats and species. MSP, through the MSP Directive and subsequent legislation, policies, and strategies is envisaged as the coordinating arm of these efforts, providing an integrated decision-making framework that 'focuses on a specific area, considers economic, environmental and social issues, encompasses all sectors, and is forward-looking with a clearly set out vision, objectives and policies' (DHPLG, 2017, 6).

3.1 Reaching What MSP Can Provide

As Table 1 shows, the cumulative impacts of a changing climate will be largely negative for Ireland's marine ecosystem services. Some, like increased coastal damage and shoreline erosion from winter storms, will be potentially catastrophic (Devoy, 2008). Governance and policy responses like NMPs and NAFs expressly centred on coastal and marine concerns will be important elements in producing a coordinated response. Yet, how much protection can they provide? At what point should the discussion on climate mitigation end, and turn instead to climate adaptation (Adger, 2001; Creighton *et al.,* 2016)?

Many provisioning services underway both in Ireland's nearshore and offshore environments will continue to remain active toward 2050, leading to a potential risk of increased spatial conflict between sectors (Norton *et al.,* 2014) at the same time that the full effects of climate change are being felt (Cheung *et al.,* 2009, 2012; Hoegh-Guldberg and Bruno, 2010; Johnson *et al.,* 2018). Though there are legitimate concerns that MSP represents just the next round of drawing 'lines on maps' (Crowder and Norse, 2008, 773), reducing conflict over shared space is essential if environmental and socioeconomic objectives are to be met (DHPLG, 2017, 2018). MSP can be utilised to plan for 'shifting lines' as migratory fish pathways and ecosystem boundaries become affected by a changing climate. Such ecosystem boundaries may begin to overlap with static boundaries like those of oil, gas, and mineral deposits or potential offshore wind energy sites, leading to a reappraisal of how best to address emerging conflict in spaces where none had existed before (Katsanevakis *et al.,* 2011; Magris *et al.,* 2014). Although schools of fish or habitats are unlikely to recognise politically drawn borders, with sufficient precaution to account for historical and likely future range or movement, MSP can weight decisions on how space is shared to reduce conflict (White *et al.,* 2012) while also introducing adaptations toward climate change impacts. Such adaptability more fully incorporates EBM approaches by extending efforts beyond the conservation of provisioning services and toward a fuller consideration of regulating and supporting services.

There remains the concern on how well mitigation plans and adaptation frameworks can inform planning when predicting the full scale of climate change impacts continues to carry uncertainty (Ludwig *et al.,* 1993; Adger *et al.,* 2005; Keenlyside *et al.,* 2008; Cheung *et al.,* 2009; Hoegh-Guldberg and Bruno, 2010; Gallagher *et al.,* 2016). There is a concern that piecemeal, incremental approaches have not been effective responses to climate change (Coglianese and d'Ambrosio, 2008; van Asselt, 2014) or marine resource management (Murawski, 2007). At the same time, developing a transformational policy pathway requires anticipatory action that may not be politically viable (Murawski, 2007; Eriksen *et al.,* 2015; Gillard *et al.,* 2016). MSP represents such a new course of action, and its ultimate contribution to Ireland meeting future targets will depend on how closely it is implemented compared to how it is envisaged, and whether it can comprehensively coordinate necessary, timely responses to the various environmental and socioeconomic pressures marine systems will face.

3.2 Reaching What MSP Cannot Provide

Climate change is driven by the release of greenhouse gases into the atmosphere, often far from the oceans in question. MSP is ultimately concerned with the organised planning and use of marine and coastal systems. Securing provisioning and cultural services while conserving regulating and supporting services is the central objective for MSP. Climate change will affect the delivery of these services, yet in terms of limiting these impacts by mitigating emissions by 80% by 2050, MSP serves only a supporting role for legislation and national greenhouse gas mitigation policies. MSP decisions can support NMPs by favouring renewable energy development or limiting offshore oil and gas production. Yet a far broader public policy response will be necessary to address Ireland's out-sized contribution to greenhouse gas emissions (EPA, 2018) and difficulty in making progress toward the National Transition Objective (Climate Change Advisory Council, 2018). At a minimum, respecting the limits of MSP lets policy makers and sectors prepare better through NMPs and NAFs, rather than assuming that MSP is some panacea for addressing climate change impacts on marine and coastal systems.

Like any public policy mechanism, MSP will encounter difficulties that challenge its capabilities and hamper its contributions toward reaching planning objectives. MSP-aligned policies and strategies require support and compliance, and must be reviewed for purpose. Sectoral interests will continue to dominate, given their relative priority in economic decision-making. In turn, there is a chance that planning will prioritise production from provisioning services while neglecting to consider regulating and supporting services beyond aspirational language (Curtin and Prellezo, 2010), favouring short-term growth of the blue economy while passing on the societal and environmental implications of such development onto future generations (Lester *et al.,* 2013; Qiu and Jones, 2013). Such a potentiality would place any aforementioned plan in direct odds with Article 3(5) 'Good Environmental Status' conditions defined by the MSFD. Therefore, regulatory and enforcement coherence is an essential contribution if MSP is structured to be an overarching, coordinating framework for the sustainable development and use of Ireland's marine environment. Currently, this coordination is not fully comprehensive nor aligned across legislation, policies, and strategies concerned with Ireland's coastal and marine areas, their development, use, and ultimately stewardship.

Given that impacts associated with climate change are likely to exacerbate damages to marine ecosystem services, properly incorporating climate change as a consideration in MSP will be challenging. Warming oceans, changing currents, ocean acidification, the uncoupling of crucial ecological processes necessary for primary production and the maintenance of the marine food web will transfer and transform marine ecosystem services (Santos *et al., in press*), complicating efforts to account for 'shifting lines'. Therefore, planning must be responsive and adaptive as the ocean changes. Lines must be ready to be redrawn, and that means that new seeds of conflict are likely to sprout. The ocean is a vast, complicated system whose functions and characteristics remain only partially understood. Its uncertain nature will be further heightened by climate forcing and feedback systems brought to ferocious life by climate change (Walther *et al.,* 2002; Payne *et al.,* 2016).

4. Conclusion

Ireland's marine systems are stressed by a number of interacting pressures, many caused or exacerbated by climate change. Local economic pursuits and expansion, increasing demand for its resources, newly emerging impacts, poor land-use practices that damage the land-sea interface and coastal zone, and disconnected, delayed policy structures that do not provide for a fully deliberative, inclusive governance system (Flannery and Ó Cinnéide, 2008) each contribute negatively to the health and productivity of the marine environment. MSP can improve regulatory coordination, thus helping to promote EBM goals while supporting growth of the €1.8bn 'blue economy' (Vega and Hynes, 2017). Such coordination ultimately safeguards the foundation of the marine ecosystem services Ireland enjoys for health and wealth. As such, coordinating regulatory efforts by providing a cohesive and integrated plan is the best contribution to the much larger work underway to address climate change through mitigation and adaptation efforts. To do this, policy makers, sector representatives, stakeholders, and the public must work together. Regulatory tools and incentives can be shaped through deliberations to realise policy goals. The tools must be adaptable and incentives inclusionary, rather than favouring one interest over another. The interest must be the collective enjoyment, enhancement, and, ultimately successful stewardship of the marine system. Only in this way can its ecosystem services be reliably delivered.

Ireland must collectively realise that oceans and coasts are changing. Decisions must be made about how much change can be mitigated, and how much cannot. Resilience will require a precautionary policy of both climate mitigation and adaptation. Embracing responsiveness and adaptiveness in planning will lessen the pains of both.

References

Abolofia, J., Asche, F. and Wilen, J.E., 2017. The cost of lice: quantifying the impacts of parasitic sea lice on farmed salmon. Marine Resource Economics 32: 329-349.

Adger, W.N., 2001. Scales of governance and environmental justice for adaptation and mitigation of climate change. *Journal of International Development* 13: 921-931.

Adger, W.N., Arnell, N.W. and Tompkins, E.L., 2005. Successful adaptation to climate change across scales. *Global Environmental Change* 15: 77-86.

Arzeki, R., Jakab, Z., Laxton, D., Matsumoto, A., Nurbekyan, A., Wang, H. and Yao, J., 2017. Oil prices and the global economy. *IMF Working Paper*, WP/17/15. International Monetary Fund, Washington.

Asche, F., Dahl, R.E. and Steen, M., 2015. Price volatility in seafood markets: farmed vs. wild fish. *Aquaculture Economics and Management* 19: 316-335.

Aswani, S., Basurto, X., Ferse, S. and Glaser, M., 2018. Marine resource management and conservation in the Anthropocene. *Environmental Conservation* 45: 192-202.

Barry, L., van Rensburg, T.M. and Hynes, S., 2011. Improving the recreational value of Ireland's coastal resources: a contingent behavioural application. *Marine Policy* 35: 764-771.

Barton, J.R. and Fløysand, A., 2010. The political ecology of Chilean salmon aquaculture, 1982-2010: a trajectory from economic development to global sustainability. *Global Environmental Change* 20: 739-752.

Beaugrand, G., Edwards, M., Brander, K., Luczak, C. and Ibanez, F., 2008. Causes and projections of abrupt climate-driven ecosystem shifts in the North Atlantic. *Ecology Letters* 1157-1168.

Beaumont, N.J., Jones, L., Garbutt, A., Hansom, J.D. and Toberman, M., 2014. The value of carbon sequestration and storage in coastal habitats. *Estuarine, Coastal and Shelf Science* 137: 32-40.

Bell, J.J. and Shaw, C., 2002. Lough Hyne: a marine biodiversity hotspot? In: J.D. Nunn, (Ed), *Marine Biodiversity in Ireland and Adjacent Waters*. Belfast: Ulster Museum, 35-43.

Bellard, C., Bertelsmeier, C., Leadley, P., Thuiller, W. and Courchamp, F., 2012. Impacts of climate change on the future of biodiversity. *Ecology Letters* 15: 365-377.

Berkes, F., Hughes, T.P., Steneck, R.S., Wilson, J.A., Bellwood, D.R., Crona, B., Folke, C., Gunderson, L.H., Leslie, H.M., Norberg, J., Nyström, M., Olsson, P., Österblom, **H., Scheffer, M. and Worm, B., 2006.** Globalization, roving bandits, and marine resources. *Science* 311: 1557-1558.

Birchenough, S.N.R., Reiss, H., Degraer, S., Mieszkowska, N., Borja, A., Buhl-Mortense, L., Braeckman, U., Craeymeersch, J., de Mesel, I., Kerckhof, F., Kröncke, I., Parra, S., Rabaut, M., Schröder, A., van Colen, C., van Hoey, G., Vincx M. and Wätjen, K., 2015. Climate change and marine benthos: a review of existing research and future directions in the North Atlantic. *WIREs Climate Change* 6: 203-223.

Bjørndal, T., 2002. The competitiveness of the Chilean salmon aquaculture industry. *Aquaculture Economics and Management* 6: 97-116.

Blanchard, J.L., Jennings, S., Holmes, R., Harle, J., Merino, G., Allen, J.I., Holt, J., Dulvy, N.K. and Barange, M., 2012. Potential consequences of climate change for primary production and fish production in large marine ecosystems. *Philosophical Transactions of the Royal Society B* 5: 2979-2989.

Brennan, J., Fitzsimmons, C., Gray, T. and Raggatt, L., 2014. EU marine strategy framework directive (MSFD) and marine spatial planning (MSP): which is the more dominant and practicable contributor to maritime policy in the UK? *Marine Policy* 43: 359-366.

Brooker, R.W., Travis, J.M.J., Clark, E.J. and Dytham, C., 2007. Modelling species' range shifts in a changing climate: the impacts of biotic interactions, dispersal distance and the rate of climate change. *Journal of Theoretical Biology* 245: 59-65.

Burkett, V., 2012. Global climate change implications for coastal and offshore oil and gas development. *Energy Policy* 39: 7719-7725.

Callaway, R., Shinn, A.P., Grenfell, S.E., Bron, J.E., Burnell, G., Cook, E.J., Crumlish, M., Culloty, S., Davidson, K., Ellis, R.P., Flynn, K.J., Fox, C., Green, D.M., Hays, G.C., Hughes, A.D., Johnston, E., Lowe, C.D., Lupatsch, I., Malham, S., Mendzil, A.F., Nickell, T., Pickerell, T., Rowley, A.F., Stanley, M.S., Tocher, D.R., Turnbull, J.F., Webb, G., Wootton, E. and Shields, R.J., 2012. Review of climate change impacts on marine aquaculture in the UK and Ireland. *Aquatic Conservation* 22: 389-421.

Cheung, W.W.L., Lam, V.W.Y., Sarmiento, J.L., Kearney, K., Watson, R. and Pauly, D., 2009. Projecting global marine biodiversity impacts under climate change scenarios. *Fish and Fisheries* 10: 235-251.

Cheung, W.W.L., Pinnegar, J., Merino, G., Jones, M. and Barange, M., 2012. Review of climate change impacts on marine fisheries in the UK and Ireland. *Aquatic Conservation: Marine and Freshwater Ecosystems* 22: 368-388.

Climate Change Advisory Council, 2018. Annual Review 2018. Climate Change Advisory Council, Dublin.

Coglianese, C. and d'Ambrosio, J., 2008. Policymaking under pressure: the perils of incremental responses to climate change. *Connecticut Law Review* 40: 1411-1429.

Cooper, J.A.G. and Boyd, S.W., 2011. Climate change and coastal tourism in Ireland. In: A.W. Jones and M.R. Phillips (Eds) *Disappearing Destinations: Climate Change and Future Challenges for Coastal Tourism.* Cambridge: CABI, 125-143.

Creighton, C., Hobday, A.J., Lockwood, M. and Pecl, G.T., 2016. Adapting management of marine environments to a changing climate: a checklist to guide reform and assess progress. *Ecosystems* 19: 187-219.

Crowder, L. and Norse, E., 2008. Essential ecological insights for marine ecosystem-based management and marine spatial planning. *Marine Policy* 32: 772-778.

Curtin, R. and Prellezo, R., 2010. Understanding marine ecosystem based management: a literature review. *Marine Policy* 34: 821-830.

Daniel, T.C., Muhar, A., Arnberger, A., Aznar, O., Boyd, J.W., Chan, K.M.A., Costanza, R., Elmqvist, T., Flint, C.G., Gobster, P.H., Grêt-Regamey, A., Lave, R., Muhar, S., Penker, M., Ribe, R.G., Schauppenlehner, T., Sikor, T., Soloviy, I., Spierenburg, M., Taczanowska, K., Tam, J. and von der Dunk, A., 2012. Contributions of cultural services to the ecosystem services agenda. *PNAS* 109: 8812-8819.

DCCAE, 2017. National Mitigation Plan. Department of Communications, Climate Action and Environment [DCCAE].

DCCAE, 2018. National Adaptation Framework: Planning for a Climate Resilient Ireland. Department of Communications, Climate Action and Environment [DCCAE].

DCENR, 2014. Offshore Renewable Energy Development Plan. Department of Communications, Energy and Natural Resources [DCENR; now DCCAE].

Debernard, J., Saetra, Ø. and Røed, l.P., 2002. Future wind, wave and storm surge climate in the northern Atlantic Ocean. *Climate Research* 23: 39-49.

de Santo, E.M., 2011. Environmental justice implications of maritime spatial planning in the European Union. *Marine Policy* 35: 34-38.

Devoy, R.J.N., 2008. Coastal vulnerability and the implications of sea-level rise for Ireland. *Journal of Coastal Research* 24: 325-341.

DHPLG, 2017. Towards a marine spatial plan for Ireland. Department of Housing, Planning and Local Government [DHPLG].

DHPLG, 2018. National Marine Planning Framework Baseline Report. Department of Housing, Planning and Local Government [DHPLG].

Doney, S.C., Ruckelshaus, M., Duffy, J.E., Barry, J.P., Chan, F., English, C.A., Galindo, H.M., Grebmeier, J.M., Hollowed, A.B., Knowlton, N., Polovina, J., Rabalais, N.N., Sydeman, W.J. and Talley, L.D., 2012. Climate change impacts on marine ecosystems. *Annual Review of Marine Science* 4: 11-37.

Douvere, F., 2008. The importance of marine spatial planning in advancing ecosystem-based sea use management. *Marine Policy* 32: 762-771.

Durant, J.M., Hjermann, D.Ø., Ottersen, G. and Stenseth, N.C., 2007. Climate and the match or mismatch between predator requirements and resource availability. *Climate Research* 33: 271-283.

Edwards, M., Johns, D.G., Leterme, S.C., Svendsen, E. and Richardson, A.J., 2006. Regional climate change and harmful algal blooms in the northeast Atlantic. *Limnology and Oceanography* 51: 820-829.

EIA, 2016. Global oil production statistics: 2015. US Energy Information Administration [EIA].

Ellis, G., Barry, J. and Robinson, C., 2007. Many ways to say 'no', different ways to say 'yes': applying Q-Methodology to understand public acceptance of wind farm proposals. *Journal of Environmental Planning and Management* 50: 517-551.

EPA, 2018. Ireland's greenhouse gas emissions projections 2017-2035. Environmental Protection Agency (EPA) Ireland.

Eriksen, S.H., Nightingale, A.J. and Eakin, H., 2015. Reframing adaptation: the political nature of climate change adaptation. *Global Environmental Change* 35: 523-533.

Esteban, M. and Leary, D., 2012. Current developments and future prospects of offshore wind and ocean energy. *Applied Energy* 90: 128-136.

Fahey, J., 2012. Deep Gulf drilling thrives 18 mos. After BP spill. *Japan Times*. 4 January 2012, 11.

FAO, 2016. The state of world fisheries and aquaculture. Food and Agriculture Organization of the United Nations, Rome.

Feely, R.A., Doney, S.C. and Cooley, S.R., 2009. Ocean acidification: present conditions and future changes in a high-CO_2 world. *Oceanography* 22: 36-47.

Flannery, W. and Ó Cinnéide, M., 2008. Marine spatial planning from the perspective of a small seaside community in Ireland. *Marine Policy* 32: 980-987.

Flannery, W., O'Hagan, A.M., O'Mahony, C., Ritchie, H. and Twomey, S., 2015. Evaluating conditions for transboundary Marine Spatial Planning: challenges and opportunities on the island of Ireland. *Marine Policy* 51: 86-95.

Gallagher, S., Gleeson, E., Tiron, R., McGrath, R. and Dias, F., 2016. Wave climate projections for Ireland for the end of the 21st century including analysis of EC-Earth winds over the North Atlantic Ocean. *International Journal of Climatology* 36: 4592-4607.

Galloway, J.N., Dentener, F.J., Capone, D.G., Boyer, E.W., Howarth, R.W., Seitzinger, S.P., Asner, G.P., Cleveland, C.C., Green, P.A., Holland, E.A., Karl, D.M., Michaels, A.F., Porter, J.H., Townsend, A.R. and Vöosmarty, C.J., 2004. Nitrogen cycles: past, present and future. *Biogeochemistry* 70: 153-226.

Gillard, R., Gouldson, A., Paavola, J. and van Alstine, J., 2016. Transformational responses to climate change: beyond a systems perspective of social change in mitigation and adaptation. *WIRES Climate Change* 7: 251-265.

Gilliland, P.M. and Laffoley, D., 2008. Key elements and steps in the process of developing ecosystem-based marine spatial planning. *Marine Policy* 32: 787-796.

GWEC, 2016. Global wind 2015 report. Global Wind Energy Council, Brussels.

Halfar, J. and Fujita, R.M., 2002. Precautionary management of deep-sea mining. *Marine Policy* 26: 103-106.

Harley, C.D.G., Hughes, A.R., Hultgren, K.M., Miner, B.G., Sorte, C.J.B., Thornber, C.S., Rodriguez, L.F., Tomansek, L. and Williams, S.L., 2006. The impacts of climate change in coastal marine systems. *Ecology Letters* 9: 228-241.

Hamilton, J.M. and Tol, R.S.J., 2007. The impact of climate change on tourism in Germany, the UK and Ireland: a simulation study. *Regional Environmental Change* 7: 161-172.

Hamilton, J.M., Maddison, D.J. and Tol, R.S.J., 2005. Climate change and international tourism: a simulation study. *Global Environmental Change* 15: 253-266.

Harsem, Ø., Eide, A. and Heen, K., 2011. Factors influencing future oil and gas prospects in the Arctic. *Energy Policy* 39: 8037-8045.

Heath, M.R., Neat, F.C., Pinnegar, J.K., Reid, D.G., Sims, D.W. and Wright, P.J., 2012. Review of climate change impacts on marine fish and shellfish around the UK and Ireland. *Aquatic Conservation* 22: 337-367.

Hiscock, K., Southward, A., Tittley, I. and Hawkins, S., 2004. Effects of changing temperature on benthic marine life in Britain and Ireland. *Aquatic Conservation: Marine and Freshwater Ecosystems* 14: 333-362.

Hoegh-Guldberg, O. and Bruno, J.F., 2010. The impact of climate change on the world's marine ecosystems. *Science* 328: 1523-1528.

IMP, 2012. Progress of the EU's Integrated Maritime Policy [IMP]. Report from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. COM(2012) 491, Directorate-General for Maritime Affairs and Fisheries, European Commission.

IPCC, 2001. Climate change 2001: impacts, adaptation, and vulnerability. *Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC)*. Cambridge: Cambridge University Press.

Jin, D., Hoagland, P., Au, D.K. and Qiu, J., 2015. Shoreline change, seawalls, and coastal property values. *Ocean and Coastal Management* 114: 185-193.

Johnson, D., Ferreira, M.A. and Kenchington, E., 2018. Climate change is likely to severely limit the effectiveness of deep-sea ABMTs in the North Atlantic. *Marine Policy* 87: 111-122.

Jones, B.D., True, J.L. and Baumgartner, F.R., 1997. Does incrementalism stem from political consensus or from institutional gridlock? *American Journal of Political Science* 41: 1319-1339.

Jones, P.J.S., Lieberknecht, L.M. and Qiu, W., 2016. Marine spatial planning in reality: introduction to case studies and discussion of findings. *Marine Policy* 71: 256-264.

Katsanevakis, S., Stelzenmüller, V., South, A., Sørensen, T.K., Jones, P.J.S., Kerr, S., Badalamenti, F., Anagnostou, C., Breen, P., Chust, G., D'Anna, G., Duijn, M., Filatova, T., Fiorentino, F., Hulsman, H., Johnson, K., Karageorgis, A.P., Kröncke, I., Mirto, S., Pipitone, C., Portelli, S., Qiu, W., Reiss, H., Sakellariou, D., Salomidi, M., van Hoof, L., Vassilopoulou, V., Vega Fernández, T., Vöge, S., Weber, A., Zenetos, A. and ter Hofstede, R., 2011. Ecosystem-based marine spatial management: review of concepts, policies, tools, and critical issues. *Ocean and Coastal Management* 54: 807-802.

Keenlyside, N.S., Latif, M., Jungclaus, J., Kornblueh, L. and Roeckner, E., 2008. Advancing decadal-scale climate prediction in the North Atlantic sector. *Nature* 453: 84-88.

Kelly, C., Ellis, G. and Flannery, W., 2015. Working paper II: Policy review and matrix of regulatory compliance. IMMERSE Project, Queen's University Belfast, 58 pp.

Kelly, C., Ellis, G. and Flannery, W., 2018. Exploring transition pathways as an alternative approach for the integrated management of Irish estuaries and coasts. In: C.P. Heidkamp and J. Morrissey (Eds), *Towards Coastal Resilience and Sustainability*. London: Routledge, 81-102.

Landolfi, A., Somes, C.J., Koeve, W., Zamora, L.M. and Oschlies, A., 2017. Oceanic nitrogen cycling and N_2O flux perturbations in the Anthropocene. *Global Biogeochemical Cycles* 31: 1236-1255.

Lester, S.E., Costello, C., Halpern, B.S., Gaines, S.D., White, C. and Barth, J.A., 2013. Evaluating tradeoffs among ecosystem services to inform marine spatial planning. *Marine Policy* 38: 80-89.

Levin, L.A. and Le Bris, N., 2015. The deep ocean under climate change. *Science* 350: 766-768.

Levine, A.S., Richmond, L. and Lopez-Carr, D., 2015. Marine resource management: culture, livelihoods, and governance. *Applied Geography* 59: 56-59.

Lizuka, M. and Katz, J., 2011. Nature resource industries, 'tragedy of the commons' and the case of Chilean salmon farming. *Institutions and Economies* 3: 259-286.

Ludwig, D., Hilborn, R. and Walters, C., 1993. Uncertainty, resource exploitation, and conservation: lessons from history. *Ecological Applications* 3: 548-549.

MA, 2005. *Ecosystems and Human Well-being: Current State and Trends Assessment.* Millennium Ecosystem Assessment (MA), Washington: Island Press.

MacDonald, D.I.M., Barker, P.F., Garrett, S.W., Ineson, J.R., Pirrie, D., Storey, B.C., Whitman, A.G., Kinghorn, R.R.F. and Marshall, J.E.A., 1988. A preliminary assessment of the hydrocarbon potential of the Larsen Basin, Antarctica. *Marine and Petroleum Geology* 5: 34-53.

MacLeod, M., da Silva, C.P. and Cooper, J.A.G., 2002. A comparative study of the perception and value of beaches in rural Ireland and Portugal: implications for coastal zone management. *Journal of Coastal Research* 18: 14-24.

Magris, R.A., Pressey, R.L., Weeks, R. and Ban, N.C., 2014. Integrating connectivity and climate change intro marine conservation planning. *Conservation Biology* 170: 207-221.

Marshall, J., Kushnir, Y., Battisti, D., Chang, P., Czaja, A., Dickson, R., Hurrell, J., McCartney, M., Saravan, R. and Visbeck, M., 2001. North Atlantic climate variability: phenomena, impacts and mechanisms. *International Journal of Climatology* 21: 1863-1898.

MCG, 2012. *Harnessing Our Ocean Wealth – An Integrated Marine Plan for Ireland Roadmap: New Ways, New Approaches, New Thinking.* Government of Ireland Marine Coordination Group [MCG], Dublin.

McNeil, B.I. and Matear, R.J., 2008. Southern Ocean acidification: a tipping point at 450-ppm atmospheric CO_2. *PNAS* 105: 18860-18864.

Merino, G., Barange, M., Blanchard, J.L., Harle, J., Holmes, R., Allen, I., Allison, E.H., Badjeck, M.C., Dulvy, N.K., Holt, J., Jennings, S., Mullon, C. and Rodwell, L.D., 2012. Can marine fisheries and aquaculture meet fish demand from a growing human population in a changing climate? *Global Environmental Change* 22: 795-806.

Moore, S.A., Brown, G., Kobryn, H. and Strickland-Munro, J., 2017. Identifying conflict potential in a coastal and marine environment using participatory mapping. *Journal of Environmental Management* 197: 706-718.

Murawski, S.A., 2007. Ten myths concerning ecosystem approaches to marine resource management. *Marine Policy* 31: 681-690.

Norton, C., Barnes, J., O'Broin, D., Flannery, W., Adamson, C. and Berne, S., 2014. Towards an integrated policy framework for maritime spatial planning in Ireland: recommendations for preparing maritime spatial planning in Ireland. Report No. 174. EPA Research Programme 2014-2020, Environmental Protection Agency of Ireland.

Norton, D. and Hynes, S., 2014. Valuing the non-market benefits arising from the implementation of the EU Marine Strategy Framework Directive. *Ecosystem Services* 10: 84-96.

Ostrom, E., Burger, J., Field, C.B., Norgaard, R.B. and Policansky, D., 1999. Revisiting the commons: local lessons, global challenges. *Science* 284: 278-282.

Payne, M.R., Barange, M., Cheung, W.W.L., MacKenzie, B.R., Batchelder, H.P., Cormon, X., Eddy, T.D., Fernandes, J.A., Hollowed, A.B., Jones, M.C., Link, J.S., Neubauer, P., Ortiz, I., Queirós, A.M. and Paula, J.R., 2016. Uncertainties in projective climate-change impacts in marine environments. *ICES Journal of Marine Science* 73: 1272-1282.

Peterson, C.H. and Lubchenco, J., 1997. Marine ecosystem services. In: G.C. Daily, (Ed), *Nature's Services: Societal Dependence on Natural Ecosystems.* Washington: Island Press, 177-194.

Pinarbaşi, K., Galparsoro, I., Borja, Á., **Stelzenmüller, V., Ehler, C.N. and Gimpel, A., 2017.** Decision support tools in marine spatial planning: present applications, gaps and future perspectives. *Marine Policy* 83: 83-91.

Pomeroy, R. and Douvere, F., 2008. The engagement of stakeholders in the marine spatial planning process. *Marine Policy* 32: 816-822.

Pressey, R.L., Cabeza, M., Watts, M.E., Cowling, R.M. and Wilson, K.A., 2007. Conservation planning in a changing world. *Trends in Ecology and Evolution* 22: 583-592.

Qiu, W. and Jones, P.S.J., 2013. The emerging policy landscape for marine spatial planning in Europe. *Marine Policy* 39: 182-190.

Richardson, A.J. and Schoeman, D.S., 2004. Climate impacts on plankton ecosystems in the northeast Atlantic. *Science* 305: 1609-1612.

Santos, C.F., Agardy, T., Andrade, F., Crowder, L.B., Ehler, C.N. and Orbach, M.K., *In Press*. Major challenges in developing marine spatial planning. *Marine Policy*.

Schmittner, A., Latif, M. and Schneider, B., 2005. Model projections of the North Atlantic thermohaline circulation for the 21st century assessed by observations. *Geophysical Research Letters* 32: e4.

SEAI, 2017. Energy in Ireland 1990-2016: 2017 Report. Sustainable Energy Authority of Ireland [SEAI].

Stead, D. and Meijers, E., 2009. Spatial planning and policy integration: concepts, facilitators and inhibitors. *Planning Theory and Practice* 10: 317-322.

Thorstad, E.B., Fleming, I.A., McGinnity, P., Soto, D., Wennevik, V. and Whoriskey, F., 2008. Incidence and impacts of escaped farmed Atlantic salmon Salmo salar in nature. NINA Special Report 36. Tungasletta, Norway: Norwegian Institute for Nature Research, 110pp.

Tittensor, D.P., Mora, C., Jetz, W., Lotze, H.K., Ricard, D., van den Berghe, E. and Worm, B., 2010. Global patterns and predictors of marine biodiversity across taxa. *Nature* 466: 1098-1101.

UN, 2017. 2017 Revision of World Population Prospects. United Nations (UN) Population Division, Department of Economic and Social Affairs, New York.

UNFCCC, 1992. United Nations Framework Convention on Climate Change. United Nations, New York.

van Asselt, H., 2014. Between the devil and the deep blue sea: enhancing flexibility in international climate change law. *Netherlands Yearbook of International Law* 45: 255-286.

Vega, A. and Hynes, S., 2017. *Ireland's Ocean Economy*. Socio-Economic Marine Research Unit, Whitaker Institute of Innovation and Societal Change, NUI Galway, Ireland.

Walther, G.R., Post, E., Convey, P., Menzel, A., Parmesan, C., Beebee, T.J.C., Fromentin, J.M., Hoegh-Guldberg, O. and Bairlein, F., 2002. Ecological responses to recent climate change. *Nature* 416: 389-395.

Wang, S., McGrath, R., Hanafin, J., Lynch, P., Semmler, T. and Nolan, P., 2008. The impact of climate change on storm surges over Irish waters. *Ocean Modelling* 25: 83-94.

Wang, X.T., Cohen, A.L., Luu, V., Ren, H., Su, Z., Haug, G.H. and Sigman, D.M., 2018. Natural forcing of the North Atlantic nitrogen cycle in the Anthropocene. *PNAS* 2018: e201801049.

Ward, J.J., 1998. Black gold in a white wilderness – Antarctic oil: the past, present, and potential of a region in need of sovereign environmental stewardship. *Journal of Land Use and Environmental Law* 13: 363-397.

White, C., Halpern, B.S. and Kappel, C.V., 2012. Ecosystem tradeoff analysis reveals the value of marine spatial planning for multiple ocean uses. *PNAS* 2012: e201114215.

Wigley, T.M.L., Richels, R. and Edmonds, J.A., 1996. Economic and environmental choices in the stabilization of atmospheric CO_2 concentrations. *Nature* 379: 240-243.

Worm, B., Barbier, E.B., Beaumont, N., Duffy J.E., Folke, C., Halpern, B.S., Jackson, J.B.C., Lotze, H.K., Micheli, F., Palumbi, S.R., Sala, E., Selkoe, K.A., Stachowicz, J.J. and Watson, R., 2006. Impacts of biodiversity loss on ocean ecosystem services. *Science* 314: 787-790.

WWF, 2015. Reviving the Oceans Economy: The Case for Action – 2015. World Wildlife Fund (WWF), Washington.

Appendix

EU Directives and Regulations

Maritime Spatial Planning (2014/89/EU)

Article 5(2): *Through their maritime spatial plans, Member States shall aim to contribute to the sustainable development of energy sectors at sea, of maritime transport, and of the fisheries and aquaculture sectors, and to the preservation, protection and improvement of the environment, including resilience to climate change impacts. In addition, Member States may pursue other objectives such as the promotion of sustainable tourism and the sustainable extraction of raw materials.*

Common Fisheries Policy (1380/2013)

No Statement on Climate Change, Impacts, or Planning

Environmental Impact Assessment (2011/92/EU; 2014/52/EU)

Article 3(1)(a-e): *The environmental impact assessment shall identify, describe and assess in an appropriate manner, the direct and indirect effects of a project on: (a) population and human health, (b) biodiversity, with particular attention to species and habitats protected under Directive 92/43/EC and Directive 2009/147/EC, (c) land, soil, water, air and climate, (d) material assets, cultural heritage and the landscape, (e) the interaction between the factors referred to in points (a) to (d).*

Annex III (1)(f) Characteristics of Projects: *the risk of major accidents and/or disasters which are relevant to the project concerned, including those caused by climate change, in accordance with scientific knowledge.*

Annex IV (4) Information for the Environmental Impact Assessment Report: *A description of the factors specified in Article 3(1) likely to be significantly affected by the project… climate (for example greenhouse gas emissions, impacts relevant to adaptation).*

Annex IV (5)(f) Information for the Environmental Impact Assessment Report: *The impact of the project on climate (for example, the nature and magnitude of greenhouse gas emissions) and the vulnerability of the project to climate change.*

Conservation of Wild Birds (2009/147/EC)

No Statement on Climate Change, Impacts, or Planning

Marine Strategy Framework (2008/56/EC)

Article 3(5)(a): *'Good Environmental Status' means the environmental status of marine waters where these provide ecologically diverse and dynamic oceans and seas which are clean, healthy and productive within their intrinsic conditions, and the use of the marine environment is at a level that is*

sustainable, thus safeguarding the potential for uses and activities by current and future generations, i.e.: (a) the structure, functions and processes of the constituent marine ecosystems, together with the associated physiographic, geographic, geological and climatic factors, allow those ecosystems to function fully and to maintain their resilience to human-induced environmental change. Marine species and habitats are protected, human-induced decline of biodiversity is prevented and diverse biological components function in balance.

Public Access to Environmental Information (2003/4/EC)

No Statement on Climate Change, Impacts, or Planning

Strategic Environmental Assessment (2001/42/EC)

No Statement on Climate Change, Impacts, or Planning

Water Framework (2000/60/EC)

No Statement on Climate Change, Impacts, or Planning

Habitats (92/43/EEC)

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Irish Legislation, Policies, and Strategies

Planning and Development (Amendment) Act No. 16 of 2018

Part 2, Section 10(2)(n)*: A development plan shall include objectives for climate change. (As Amending Act No.30 of 2000, and referencing 2014/52/EU EIA reporting requirements).*

Part 5, Marine Spatial Plans – Section 69(2)(a-d)*: The objectives of the marine spatial plan shall be: (a) to analyse and organise activities in the maritime area for the purpose of achieving ecological, economic and social priorities, (b) to establish a national strategy for Government in relation to the strategic planning and sustainable development in the maritime area, (c) to apply an ecosystem based approach for the purpose of supporting proper planning and sustainable development in the maritime area, and (d) to encourage the colocation of relevant activities and developments in the maritime area.*

National Planning Framework 2018 – Project Ireland 2040

Integrated Land and Maritime Planning National Objectives 41a-b*: Ensure that Ireland's coastal resource is managed to sustain its physical character and environmental quality. In line with the collective aims of national policy regarding climate adaptation, to address the effects of sea level changes and coastal flooding and erosion and to support the implementation of adaptation responses in vulnerable areas.*

National Adaptation Framework 2018

Sectoral Adaptation Planning (p.69)*: Departments should also cooperate in other adaptation-relevant areas that may not come under their direct remit but that may, nonetheless, require their input and advice. This is particularly relevant in areas such as flood risk management, critical infrastructure, marine and coastal issues and emergency planning.*

National Mitigation Plan 2017

National Planning Framework (p.29)*: A strong spatial plan will also help to prioritise the development of crucial infrastructure such as public transport that can deliver optimum national benefits in relation to the national transition objective for 2050. The integration of climate change adaptation and mitigation considerations into development plans will also help to sustain the momentum for addressing climate change that currently exists within the Local Government sector.*

National Biodiversity Action Plan 2017 – 2021

Objective 1 – Mainstream biodiversity into decision-making across all sectors*: The development of a sectoral adaptation plan for Biodiversity in line with the Climate Action and Low Carbon Development Act 2015 will address the requirements necessary to improve the resilience of biodiversity to climate change.*

Objective 5 – Conserve and restore biodiversity and ecosystem services in the marine environment*: The development and implementation of effective Marine Spatial Planning for Ireland's coastal zone and EEZ waters will assist in the identification and improved protection of threatened habitats and species in accordance with the EU Maritime Spatial Planning Directive (2014/89/EU) and MSFD.*

Statutory Instrument No. 352 of 2016 – EU (Framework for MSP) Regulations 2016 (since revoked and replaced by Planning and Development (Amendment) Act 2018)

Statutory Instrument No. 544 of 2014 – EU EIA and Appropriate Assessment (Foreshore) Regulations

No Statement on Climate Change, Impacts, or Planning

Foreshore Acts No. 12 of 1933 Revised 2011, Proposed Amendment Bill 2013

No Statement on Climate Change, Impacts, or Planning

Harnessing Our Ocean Wealth, Marine Coordination Group 2012

Goal 2 – Healthy Ecosystems*: Our goal is to protect, preserve and, where possible, restore our rich biological diversity and ecosystems. We need to proactively manage our living and non-living resources in harmony with those ecosystems, so that they continue to provide essential monetary and non-monetary goods and services (e.g. food, climate, health and well-being). Protection of our marine ecosystems and compliance with environmental legislation are essential components of our ecologically sustainable future and need to be seen as an essential enabler for a thriving maritime economy.*

Statutory Instrument No. 600 of 2001 – Planning and Development Regulations

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