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Protecting and Restoring Biodiversity across the Freshwater, Coastal and Marine Realms: Is the existing EU policy framework fit for purpose?

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ABSTRACT

While some progress has been made, Europe is far from achieving its policy objective of healthy aquatic ecosystems. This paper presents an integrated assessment of how EU policies influence aquatic biodiversity, in order to determine how EU policies and laws contribute to achieving and/or hindering EU and international biodiversity targets. The paper also discusses whether European policy has a synergistic or conflicting mix of instruments to address the main problems facing aquatic biodiversity, and whether gaps in the existing policy framework exist. The integrated policy review assessment presented in this paper is based on the application of the drivers–pressures–state–impact–responses (DPSIR) framework to six known pressures on aquatic biodiversity, selected to provide a representative range: nitrogen pollution, species extraction, invasive alien species, water abstraction, alterations to morphology, and plastic waste. The DPSIR framework is used to characterize these pressures and how they are influenced by underpinning socio-economic drivers and major European policies. The conclusions highlight that the policy framework is most developed when it comes to defining environmental targets and sets a number of instruments to reduce pressures by encouraging the adoption of more resource-efficient practices, but it becomes less specific when tackling sectors (drivers) and supporting more environmental sound economic development. © 2017 The Authors. Environmental Policy and Governance published by ERP Environment and John Wiley & Sons Ltd

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Introduction

AQUATIC ECOSYSTEMS ARE INDISPENSABLE HABITAT FOR BIODIVERSITY, AS THEY COVER OVER 70% OF THE EARTH'S SURFACE AND AN even larger percentage of habitable space (Covich *et al.*, 2004). However, anthropogenic pressures and their direct and indirect ramifications have had, and continue to have, an extensive negative effect on freshwater, coastal (i.e. brackish transitional water and coastal areas) and (open) marine realms (Halpern *et al.*, 2015;

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Gari *et al.*, 2015; Vörösmarty *et al.*, 2010; Dudgeon *et al.*, 2006). As a result, aquatic biodiversity loss remains a global environmental issue that demands comprehensive political action. Within Europe, extensive policy measures and instruments have been implemented in response to the complex matter of aquatic biodiversity conservation. European directives and regulations in particular now are a major source of environmental policies transposed and implemented by the 27 EU member states.

Nature protection and conservation has achieved a prominent place in the European legislative framework. The main instruments of the EU's approach to halt the loss of biodiversity and degradation ecosystem services are connected to the EU 2020 Biodiversity Strategy. The EU Biodiversity Strategy coordinates with the international Convention on Biological Diversity and its Aichi Biodiversity Targets as well as the UN Sustainable Development Goals. In relation to the protection of aquatic biodiversity, the strategy specifically aims to ensure sustainable use of fisheries resources, to achieve the Marine Strategy Framework Directive objective of good environmental status (GES) by 2020, and to successfully combat invasive alien species (IASs). In addition, the Biodiversity Strategy targets to complete the establishment of Natura 2000 protected areas, which is a network of natural and semi-natural habitats protecting an array of valuable and threatened species and habitats within the EU.

The *Mid-term Review of the EU Biodiversity Strategy to 2020* recognizes partial improvement within the generated knowledge base, as well as the positive development of some policy frameworks in relation to the key targets set by the strategy. The review concludes that 'at the current rate of implementation, biodiversity loss and the degradation of ecosystem services will continue throughout the EU' (EC, 2015b). As of 2015, the EC additionally applies the *Better Regulation Agenda* to maximize synergies between EU policies and to reduce the regulatory burden between policies (EC, 2015c). However, even though the regulatory instruments are in place, the existing policy framework has not yet been successful in reversing the loss of aquatic biodiversity and ecosystem services (EEA, 2016; EC, 2015b).

The legislative framework in place to achieve the Biodiversity Strategy in aquatic ecosystems can be linked to a complex array of interlinked policies, of which the most far-reaching ones are the Birds and Habitats Directives (BHDs), Water Framework Directive (WFD) and Marine Strategic Framework Directive (MSFD). However, despite decades of EU policy implementation, neither aquatic biodiversity loss nor negative trends has halted yet.

A significant body of literature discusses the effectiveness of EU environmental policies. The implementation of the WFD has been reviewed through assessments led by European institutions (e.g. EC, 2012, 2015a; EEA, 2012) and research studies on its legal and policy principles (e.g. Josefsson and Baaner, 2011), monitoring and assessment approaches (e.g. Brack *et al.*, 2017; Bouleau and Pont, 2015; Solimini *et al.*, 2009), planning (e.g. Moss, 2004), public participation (e.g. Jager *et al.*, 2016) and implementation success (e.g. Voulvoulis *et al.*, 2017; Boeuf and Fritsch, 2016; Hering *et al.*, 2010). A similar level of attention has been given to the implementation of the BHDs (see, e.g., EEA, 2015b; Louette *et al.*, 2015; Milieu *et al.*, 2015; Kati *et al.*, 2014) and the MSFD (see, e.g., EEA, 2015c; Boyes and Elliott, 2014; Hendriksen *et al.*, 2014; Freire-Gibb *et al.*, 2013; Van Leeuwen *et al.*, 2012).

While present research offers a compelling basis in regards to the representation of aquatic biodiversity conservation within the EU policy framework, it largely focuses on assessing individual European environmental policies and on individual water realms (i.e. freshwater, coastal, marine). However, since legislative environmental measures have been developed individually with reference to scale and objectives, the result may reflect a patchwork of incoherent ambitions (O'Higgins, 2017). The recent review of eutrophication abatement policies (Ibisch *et al.*, 2017) illustrates well the difficulties of integrating environmental targets (e.g. on nutrient standards and pollution loads) and coordinating implementation of measures, and shows the need for additional integrative assessments across the freshwater, coastal and marine realms in order to identify opportunities to enhance policy implementation effectiveness and efficiency. Other studies call for integrated implementation of the policies in, e.g., the marine environment (Borja *et al.*, 2010).

Furthermore, a growing body of literature highlights the conflicts and trade-offs between biodiversity protection on the one hand and policies supporting economic growth and food security on the other (e.g. Gorenflo and Warner, 2016), such as the Common Agricultural Policy (CAP) (Leventon *et al.*, 2017; Vesterager *et al.*, 2016; Meyer *et al.*, 2014) and the Common Fisheries Policy (CFP) (Elliott, 2014; Khalilian *et al.*, 2010; Frost and Andersen, 2006). It is thus important to consider not only the multiple objectives set by environmental policies, but also the impact of sectoral, food security and growth policies on the protection of aquatic biodiversity.

This paper presents an integrated assessment of EU policies and their direct and indirect impact on aquatic biodiversity protection. It discusses whether the European policy framework in place has a synergistic or

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conflicting mix of instruments to address the main problems facing aquatic biodiversity, and whether significant gaps exist. Such overarching analysis can provide insights into the coherence of the EU policy framework and is relevant to a range of ongoing policy process including the fitness check of the BHDs and the upcoming one for the WFD.

The analysis focuses on EU level legislative texts and policies, and does not examine national or regional level implementation. It examines the general scope of relevant EU policies, the instruments they establish and whether these provide a comprehensive approach to tackle aquatic biodiversity loss. A large number of EU policies and laws potentially influence aquatic biodiversity (Figure 1). The main methodological challenge is thus to adequately represent the causal chain between EU environmental and sectoral policies and aquatic biodiversity, and to select a limited but representative set of issues affecting aquatic biodiversity across realms (freshwater, coastal, marine).

The research presented in this paper uses a well-established analytical DPSIR framework to structure the analysis of causal links between human activities, aquatic biodiversity and European policies. Subsequently, it applies the DPSIR to six known pressures to aquatic biodiversity, and draws observations on how European policies contribute to reducing human pressures on aquatic biodiversity, as well as how they may lead to an intensification of these pressures.

Finally, the paper discusses if and to what extent the EU policy framework sets a comprehensive approach to tackling aquatic biodiversity loss, and highlights current gaps. The paper concludes with the need to improve policy integration and environmental mainstreaming.

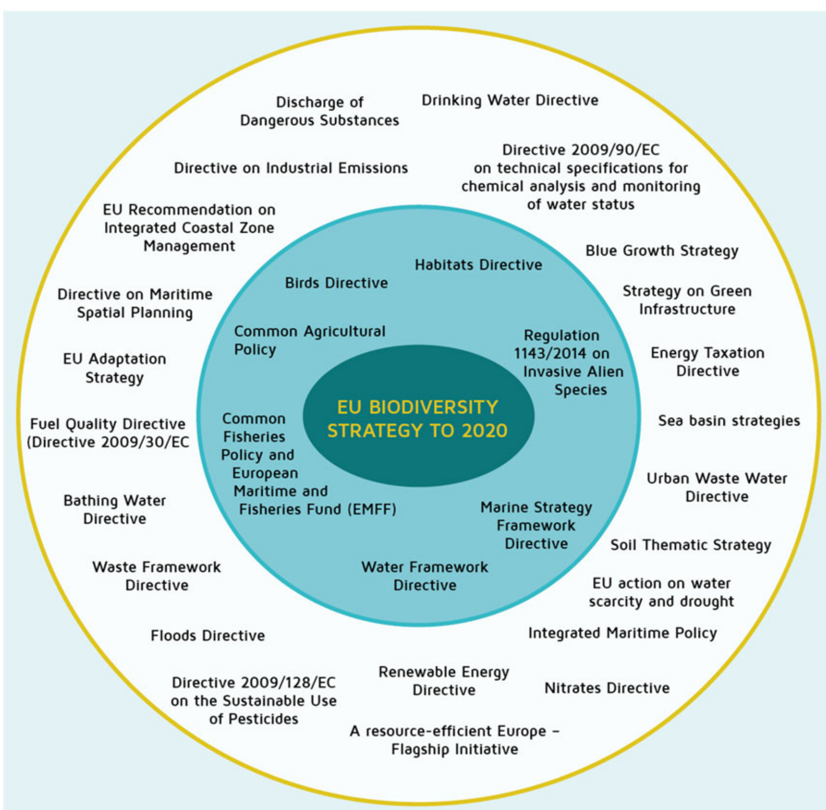

Figure 1. Key EU environmental and sectoral policies relevant to the achievement of EU Biodiversity Targets in aquatic realms. The inner circle represents policies deemed to have a significant impact on aquatic biodiversity either by contributing to its protection or by intensifying the pressures leading to biodiversity loss. The outer core is other relevant environmental and sectoral policies. [Colour figure can be viewed at wileyonlinelibrary.com]

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Methodology

The DPSIR framework is a causal framework used to describe interactions between society and the environment (EEA, 2010) and helps to disentangle the biophysical and social aspects of a system under study (Smeets and Weterings, 1999). Often used to analyse and assess the social and ecological problems of various environmental systems, it was adopted by the European Environment Agency (EEA) in the early 1990s and has been directly applied in the implementation process of the WFD and more recently the MSFD. The DPSIR framework was also used by the European working group MAES (Mapping and Assessment on Ecosystems and their Services) to support the implementation of the EU Biodiversity Strategy to 2020.

A literature review was carried out to identify existing definitions of DPSIR and how relevant they were to support the analysis of European policy responses to aquatic biodiversity loss (Elliott *et al.*, 2017; Patrício *et al.*, 2016; Anzaldúa *et al.*, 2016; Gari *et al.*, 2015; Hering *et al.*, 2015; Haines-Young and Potschin, 2013; Maes *et al.*, 2013; CIS, 2011; Fisher *et al.*, 2009). Based on existing definitions and because of a need for consistency across freshwater, coastal and marine realms, a set of definitions was developed for the purpose of the policy analysis. The definitions presented in Table 1 acknowledge these multiple understandings while maintaining a close link to the definition used by the EEA. Within this framework, aquatic biodiversity loss is the related impact, while potential policy responses can be mapped against drivers, pressures and state, highlighting positive and negative interaction with biodiversity protection of aquatic ecosystems along the causal links.

To limit the scope of the analysis, the DPSIR framework was applied to a selected number of 'pressures', which have a significant impact on biodiversity loss, and represent a diverse range of threats to aquatic realms. A consolidated list of pressures was prepared based on a review of studies that have identified and evaluated key threats to freshwater biodiversity (Gorenflo and Warner, 2016; Vörösmarty *et al.*, 2010; Dudgeon *et al.*, 2006; Gleick *et al.*, 2001) and coastal and marine biodiversity (Halpern *et al.*, 2015; Knights *et al.*, 2015; Pauly, 2011; Costello *et al.*, 2010). In addition, policy relevant assessments, which contain information on threats to aquatic biodiversity (EEA, 2015a, 2015b, 2015c, 2012), were used.

Pressures were then classified into one of the three following general pressure categories (hydro-morphological, pollution and biological pressures). Two pressures per broader category were selected in order to illustrate (1) major environmental issues and (2) a good range of policy challenges as examples across the freshwater, coastal and marine continuum. For the purposes of the policy review analysis, the list focused on single pressures driven by human activities, and other compounding factors, such as climate change, are considered through their impact on these

Driver	A human activity, in particular production and consumption processes, that may produce an environmental effect (i.e. a pressure) on the ecosystem. Production or consumption processes are structured according to economic sectors (e.g. agriculture, energy, industry, transport, households). For an industrial sector a driving force could be the need to be profitable and to produce at low costs, while for a nation a driving force could be the need to keep unemployment levels low. Drivers are also influenced by the regulatory and market conditions in which they operate.
Pressures	Mechanisms through which a driver has an effect on the environment. Pressures can be of a physical, chemical or biological nature, and include for example the extraction of water or aquatic species, emissions of chemicals, waste, radiation or noise, or the introduction of invasive alien species.
State	The environmental condition of an ecosystem as described by its physical, chemical and biological parameters. Physical parameters encompass the quantity and quality of physical phenomena (e.g. temperature). Chemical parameters encompass the quantity and quality of chemicals (e.g. nitrogen concentration). Biological parameters encompass the conditions at the ecosystem, habitat, species, community or genetic levels (e.g. fish stocks).
Impact	The effect of a change in the physical, chemical and biological parameters on ecosystem structures and functions, and the provision of ecosystem services (Impact I), as well as on human well-being (Impact II). In other words changes in the state may have environmental 'impacts' on the functioning of ecosystems, on their life-supporting abilities, and ultimately on human health and on the economic and social performance of society.
Responses	The measures taken to address drivers, reduce pressures, improve the state of the ecosystem under study or reduce impacts (e.g. implementing innovative water treatment systems).

Table 1. Consolidated definition of the DPSIR framework for freshwater, coastal and marine aquatic realms. Based on the work of Anzaldúa *et al*. (2016), Gari *et al*. (2015), Haines-Young and Potschin (2013), Maes *et al*. (2013), CIS (2011) and Fisher *et al*. (2009)

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pressures. The six selected pressures are presented in Table 2 together with their link to biodiversity loss, related drivers and their significance and trend.

A template was designed to apply the DPSIR framework for each of these six selected pressures and determine the relevant information linked to the selected pressures and the existing EU policy framework. The template included in particular (1) a description of the pressure and the linked state, so as to characterize the environmental condition of freshwater, coastal and marine waters, with a focus on those parameters that are affected by the identified pressures, (2) a description of the drivers leading to the pressure, including an assessment of their significance to the European economy and future trends so as to evaluate the likely evolution of driving forces leading to an increase or reduction of the pressure, and (3) a description of the relevant European environmental and sectoral policies and how they influence the pressure, drivers and linked state.

Relevant European policy instruments were selected by examining their direct and indirect relationship to the list of selected pressures and identified drivers and state indicator linked to each pressure. At the level of pressures, for example, policies were selected based on their influence on the direct or indirect effect of a driver on aquatic ecosystems (e.g. emissions of pollutants, alterations to flow or morphology). This includes, for example, end-of-pipe pollution measures (e.g. requirements for building wastewater treatment plants). At the level of drivers, policies influencing human activities and uses that induce pressures on aquatic environments were identified. This includes, for example, subsidies for intensive or organic farming. At the level of state, policies were identified based on whether they established relevant standards and targets on the environmental condition of an aquatic ecosystem as described by its physical, chemical and biological parameters, or aimed to directly restore these environmental conditions (e.g. restoration of habitat).

The policy review work focused on EU legally binding instruments, including regulations, directives and decisions. Where directly relevant to the protection of EU aquatic biodiversity, some non-binding EU instruments, such as communications, recommendations and opinions, were also considered as well as other official documentation (e.g. implementation reports, guidance documents, fitness checks, EEA reporting and statistical reports). They were identified initially through a web-search on the EU Commission website and communications with relevant Commission staff and experts (e.g. consultants, researchers). Filled templates are available online (AQUACROSS, 2017).

Results

Key Policies Contributing to the Protection of Aquatic Biodiversity

Table 3 presents an overview of European policies contributing to the protection of aquatic biodiversity, and the drivers and pressures potentially tackled by the policy. The supplementary material provides more information on the specific policy instrument established by each directive and policy.

A number of instruments cross-cut all selected pressures implicitly. The overarching document governing environmental policy in the Union is the EU Environment Action Programme to 2020 (see Table 3), which sets the general objective to ensure protection, conservation and enhancement of the EU's natural capital, including aquatic ecosystems. It also specifically targets combating IASs and actively calls for more cost-effective, sustainable and resource-efficient approaches to manage the nutrient cycle, in particular regarding the efficient use of fertilizers. The LIFE programme 2014–2020 (see Table 3), with a budget of 3.4 billion EUR (EC, 2017a), is the main financial instrument to support projects that help reach EU environmental and climate objectives. Specific support is expressed for the conservation of the marine environment, the preparation of river basin management plans (RBMPs) and the efficient use of water resources.

The most relevant overarching policies are the BHDs, WFD and MSFD, which all set more specific objectives and targets relevant for the protection of aquatic biodiversity. The BHDs aim for good conservation status for designated species and habitats, and require the establishment of Special Areas for Conservation and Special Protection Areas (i.e. the Natura 2000 network). The BHDs require species to be appropriately managed across their whole natural range in the EU. They also allow the application, within and near protected areas, of more stringent restrictions to human activities to avoid their degradation.

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Pressure	Link to biodiversity loss	Drivers	Trend
Nitrogen pollution	An enrichment of nitrogen contributes to plant growth, changes in nutrient cycling, uncontrolled growth of algae, eutrophication, acidification, an increase of organic matter settlement, stimulation of cyanobacteria blooms, oxygen depletion and benthic mortality.	agriculture urban areas water utilities aquaculture energy transport industry waste sector tourism	Reduction in nitrogen concentration in European waters has undergone a positive trend over the last 30 years. However, most monitoring stations still show unchanged concentrations between 1985 and 2010 (EEA, 2012). In freshwaters, enough nitrogen still remains to lead to the loss of biodiversity (Carstensen *et al*., 2014).
Extraction of species	Active removal of living organisms and genetic resources from the ecosystem and disruption of aquatic habitat through overfishing, bottom trawling, mechanical seaweed harvesting affects population abundance and the related food web in highly unpredictable ways.	fishing agriculture industry	In 2007, 94% of assessed fish stocks in the EU North-East Atlantic Ocean and the Baltic Sea were fished above maximum sustainable yield rates. Promising trends have been observed since then (EEA, 2015a), but the level of knowledge on species extraction is still very limited, making it impossible to assess change over time.
Water abstraction	Over-abstraction leads to reduced river flows, lower lake and groundwater levels, and drying up of wetlands, influencing natural flow regimes. Changes in flow features can alter responses of ecosystems and their function.	agriculture urban areas water utilities energy transport industry tourism	Over-abstraction of water is a major pressure on Europe's freshwater. It is especially severe in the Mediterranean, with agriculture being the main consumer (EEA, 2012).
Invasive alien species	IASs can introduce competition, predation and transmission of diseases between alien and native species. IASs are prominent in aquatic ecosystems with high levels of connectivity with other ecosystems, high human frequency and high levels of disturbance.	aquaculture transport	Europe's seas harbour around 1 400 IASs, 80% of which have been introduced since 1950 (EEA, 2015a). The Mediterranean is the European sea with the largest number of IASs, with over one-fifth (21%) of all threatened and near threatened freshwater fish species currently being threatened by IASs (IUCN, 2014).
Morphological alterations	Alterations to morphology are linked to a range of pressures on aquatic ecosystems such as constructions, channelization, straightening, deepening or dredging, and mineral extraction. This leads to habitat destruction, migration and depletion of spawning gravels.	agriculture urban areas water utilities aquaculture energy transport industry tourism	Historically, European rivers have undergone significant modifications associated with the expansion and intensification of agriculture, industrial revolutions and economic growth. While the rate of morphological alterations has probably reduced, it is not established whether trends have reversed or will in the future.
Plastic waste	Plastic waste causes entanglement in floating debris or ingestion of microplastic particles, which can attract toxic chemical pollutants. Plastics can also be responsible for IASs through transportation of organisms and the creation of novel habitat.	urban areas fishing aquaculture transport industry waste sector tourism	The amount of plastic waste generated has dramatically increased in the 20th century and is pervasive to all water realms (Eurostat, 2016). Hi-tech product waste contains complex materials, including plastics, precious metals and hazardous materials, that are difficult to deal with (EC, 2010).

Table 2. Selected pressures, underpinning drivers and trend

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Policy Instruments	Drivers targeted											Pressures potentially tackled					
	Agriculture	Urban Areas	Water Utility	Fishing	Aquaculture	Energy	Transport	Industry	Waste sector	Tourism	Species trade	Nitrogen Pollution	Species Extraction	Water Abstraction	Invasive Alien Species	Alterations to Morphology	Plastic Waste
Decision (1386/2013/EU) Environment Action Programme to 2020	■	□	■	■	■	■	■	■	■	■		✔	✔	✔	✔	✔	✔
Regulation (1293/2013) Programme for Environment and Climate	■	□	■	■	■	■	■	■	■	■		✔	✔	✔	✔	✔	✔
Environmental impact assessment (2011/92/EU) Directive	□	□	□	□	□	□	□	□	□	□		✔	✔	✔	✔	✔	✔
Strategic environmental assessment (2001/42/EC) Directive	□	□	□	□	□	□	□	□	□	□		✔	✔	✔	✔	✔	✔
Habitats Directive (92/43/EEC)	□	□	□	□	□	□	□	□	□	□	□	✔	✔	✔	✔	✔	✔
Birds Directive (2009/147/EC)	■	■	■	■	■	■	■	■	■	■	□	✔	✔	✔	✔	✔	✔
Regulation (2014/1143) on invasive alien species					■		■			■	■				✔		
Water Framework Directive (2000/60/EC)	■	■	■	■	■	■	■	■	■	■	■	✔	✔	✔	✔	✔	✔
Nitrates Directive (91/676/EEC)	□											✔					
Urban Waste Water Treatment Directive (91/271/EEC)		□	□					□		■		✔					✔
Regulation (1306/2013) on the Common Agricultural Policy	□											✔		✔		✔	
Regulation (1305/2013) Agricultural Fund for Rural Development	□											✔		✔		✔	
Regulation (1255/2011) on Integrated Maritime Policy				□	□	□	□	□		■			✔			✔	✔
Regulation (508/2014) European Maritime and Fisheries Fund				□	□	□	□			■		✔	✔		✔	✔	✔
Regulation (380/2013) on the Common Fisheries Policy				□	□								✔				
Marine Strategy Framework Directive (2008/56/EC)		■	■	□	□	□	□	□		□		✔	✔	✔	✔	✔	✔
Directive (2014/89/EU) maritime spatial planning		□		□	□	□	□	□		□		✔	✔	✔	✔	✔	
Waste Framework Directive (2008/98/EC)								■	■								✔
Packaging and Packaging Waste Directive (94/62/EC)								■	■								✔

■ = The respective driver is explicitly mentioned in the text of the directive or regulation
□ = The policy has the potential to address the respective driver

Table 3. Some key European policies contributing to reducing aquatic biodiversity loss

The ecological status of the WFD describes the extent to which biological and physico-chemical quality elements differ compared to their reference (or high status) conditions as a result of human activity. Management measures are required when pressures resulting from human activities affect quality elements to the extent that the water body is classified as less than ‘good status’ or is at risk of deterioration, i.e. an RBMP must be developed that tackles significant drivers and pressures.

The environmental status of the MSFD refers to 11 descriptors. Management measures are to be identified and taken in order to achieve or maintain GES. Member states must develop marine strategies and a programme of measures to reach GES. Furthermore, the MSFD requires the establishment of marine protected areas, coherent with the BHDs, in which more stringent measures are to be adopted.

More specific policies were found for each of the six pressures. Regarding nitrogen pollution, the Urban Waste Water Treatment Directive (91/271/EEC) and the Nitrates Directive (91/676/EEC) set target values for the eutrophic state of freshwater and coastal waters, and additionally promote measures to reduce nitrogen emissions from the domestic, industrial and agricultural sectors. Nitrogen pollution is also tackled through other legislation such as air quality protection seeking to reduce NO_x emissions (see Table 3) through emission controls and the promotion of best available techniques (see supplementary material).

In terms of species extraction, the Common Fisheries Policies (CFP) promotes measures to catch fish at maximum sustainable yield to ensure food security. It requires the adoption of multi-species plans that contain conservation measures with quantifiable targets to restore and maintain fish stocks at levels capable of producing maximum sustainable yield. It includes measures to reduce pressures from fishing activities in marine waters, for example by increasing selectivity and reducing unwanted catches, and by controlling the capacity of the fishing fleet. Some of these measures can be financially supported by the European Maritime and Fisheries Fund (EMFF).

Water abstraction should be considered in the WFD through maintenance of ecological flows (CIS, 2015) and reaching good quantitative status in groundwater bodies. The principle of recovery of the costs of water services (Art. 9), including environmental and resource costs, should be implemented via water pricing to provide incentives for users to use water resources more efficiently. Emphasis is put on water reuse and groundwater recharge.

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Regarding IASs, the BHDs place restrictions on the deliberate introduction of IASs into the wild, while Directive 29/2000 and Regulation 1143/2014 (see Table 4 later) foresee three types of intervention: prevention, early detection and rapid eradication, and management.

The WFD establishes a specific management regime for water bodies most affected by morphological alterations through their designation as Heavily Modified Water Bodies. The EC Note (2011) *Towards Better Environmental Options for Flood Risk Management* encourages the adoption of less intrusive flood risk protection measures such as Natural Water Retention Measures and Green Infrastructure (EC, 2013a).

Regarding plastic waste, the Waste Framework Directive (2008/98/EC) sets the basic concepts and definitions related to waste management, while the Packaging and Packaging Waste Directive (94/62/EC) requires preventive measures by public and privately led programmes, and packaging reuse systems for the reduction of the impact of packaging and packaging waste on the environment. There are further directives and policies in place that indirectly limit and eliminate plastic waste, along with other legislative elements, such as Descriptor 10 of the MSFD specific for marine litter.

Overall, the six pressures are well tackled by the reviewed policies through instruments such as pollutant emission control, adoption of best available technologies, water efficiency and groundwater recharge. Cross-cutting objectives and targets on the state of the aquatic environment are established by the BHDs, WFD and MSFD, while a range of thematic policies set out more specific targets for nitrogen, species extraction and IASs.

While few policies appear to place strong control on sectors (drivers), the establishment of strict licensing schemes regulating water uses for pollutant emissions or abstraction can indirectly encourage alternative production systems or development paths if the authorization is not expected to be provided. In a similar way, controls on fishing capacity and fleet, the control on new modifications to freshwater and coastal water bodies, or the licensing of new chemicals can reduce fishing, morphological and pollution emission pressures.

Key Policies Contributing to the Intensification of Pressures on Aquatic Biodiversity

Table 4 presents a variety of EU policies which can lead to aquatic biodiversity loss by supporting the development of particular economic sectors.

Sectoral Policies	Promoted Drivers											Key Pressures					
	Agriculture	Urban Areas	Water Utilities	Fishing	Aquaculture	Energy	Transport	Industry	Waste sector	Tourism	Species Trade	Nitrogen Pollution	Species Extraction	Water Abstraction	Invasive Alien Species	Alterations to Morphology	Plastic Waste
Regulation (508/2014) on the European Maritime and Fisheries Fund				[Direct support]	[Direct support]			[Direct support]				✔	✔		✔	✔	✔
Regulation (380/2013) on the Common Fisheries Policy				[Direct support]	[Direct support]							✔	✔		✔	✔	✔
Communication (COM (2004) 254 final/2) Innovation in the Blue Economy	[Promotion]				[Promotion]							✔	✔				
Regulation (1307/2013) establishing rules for direct payments to farmers under support schemes	[Direct support]											✔		✔		✔	
Regulation (1305/2013) for European Agricultural Fund for Rural Development	[Direct support]											✔		✔		✔	
Regulation (1300/2013) on Cohesion Fund						[Direct support]	[Direct support]					✔			✔	✔	✔
Regulation (1301/2013) on Regional Development Funds		[Direct support]	[Direct support]			[Direct support]	[Direct support]	[Direct support]		[Direct support]		✔		✔		✔	✔
Directive (2009/28/EC) on the promotion of the use of energy from renewable resources	[Encouraging]					[Encouraging]						✔		✔		✔	
Communication (COM/2014/014 final) Towards an Industrial Renaissance			[Direct support]			[Encouraging]		[Promotion]						✔			✔
Communication (COM/2010/0352 final) Europe, the world's No. 1 tourist destination										[Encouraging]				✔			✔
Communication (COM (2004) 453 final) on Short Sea Shipping			[Encouraging]				[Encouraging]					✔			✔	✔	
White paper (COM (2011) 144 final) Roadmap to a Single European Transport Area			[Encouraging]				[Encouraging]								✔		✔
Fuel Quality Directive (2009/30/EC)	[Promotion]											✔					

Legend:
- [Direct support] = Direct support (funding mechanisms) that increase threats to aquatic biodiversity;
- [Encouraging] = Encouraging a change of sectoral practices that leads to increase the threat;
- [Promotion] = Promotion of the threat through new practices by changing the regulatory landscape
- (empty) = Not applicable

Table 4. Some key European policies potentially leading to aquatic biodiversity loss

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The Common Agricultural Policy (CAP) aims to ensure a stable supply of affordable food, to enable farmers to make a 'reasonable living' and to address climate change and sustainable management of natural resources. The CAP presents a budget of around 290 billion EUR between 2014 and 2020 (EC, 2017b). The CAP supports agricultural production in several regions across Europe and, therefore, can indirectly contribute to intensifying agricultural pressures such as nitrogen emissions, water abstraction and alterations to morphology (Leventon *et al.*, 2017). Direct payments are however now decoupled from production, which reduces the incentive to intensify production. In addition, cross-compliance with environmental protection policies promotes good farm management practices.

Through the EAFRD, member states must also prepare Rural Development Programmes (RDPs) that outline activities for strengthening the competitiveness, social cohesion and environmental performance of agriculture and the rural economy. With an EU budget of close to 100 billion EUR between 2014 and 2020, RDPs are further co-financed by member states and significant flexibility is available to member states to select their funding priorities (EC, 2017b). This mechanism can contribute to maintaining (intensive) agriculture by encouraging investments and strengthening of the agricultural sector. However, RDPs are an important source of funding for restoring the water environment and reducing agricultural pressures, including those from nitrogen pollution, water abstraction and morphological changes (Rouillard *et al.*, 2017).

The EMFF promotes the development of fisheries and maritime activities, and the strengthening of their competitiveness, to safeguard rural coastal communities and promote their economies and job creation. With a budget of 6.4 billion EUR, it provides financial support for the CFP and co-finances projects, along with national funding (EC, 2015d). In both regulations, aquaculture and commercial fisheries are the major activities targeted through this funding mechanism, although emphasis is given to the need for promoting more sustainable practices. While the regulations may have positive effects in terms of some pressures to aquatic ecosystems, the EMFF financial support to the fisheries sector can contribute to promotion of species extraction and pressures from IASs (Pauly, 2011; Munro and Sumalia, 2002). At the same time, the Marine Spatial Planning Directive (2014/89/EU) aims to promote growth in the wide range of economic operations active in Europe's seas (e.g. offshore windfarms, aquaculture, tourism) while managing the associated competition for space and minimizing pressures in coherence with MSFD objectives (Boyes *et al.*, 2016; EC, 2013b).

The EU regional funds, in the form of the Cohesion Fund and European Regional Development Fund, amount to about 350 billion EUR of the EU budget, and support a range of productive and infrastructure investments across the European Union to reduce inequalities in economic development between regions (EC, 2015e). Explicit support is given to the promotion of energy derived from renewable sources, particularly biofuels. Regional funds can thus potentially indirectly lead to an intensification of a range of pressures including nitrogen emissions, water abstraction and morphological alterations.

Directive 2009/28/EC on the promotion of the use of energy from renewable resources requires adoption of national renewable energy action plans, setting targets for the share of energy from renewable sources. More hydropower installations might for example be built as a response to this measure, leading to alterations to the morphology of water bodies (ETC/ICM, 2012). As member states are likely to increase bio-energy crops to meet targets, and bio-energy crops require more nutrients and water for their growth, it is possible that the directive is leading to increased emissions of nitrogen and larger water abstractions.

Other EU policies that support drivers worth highlighting can be found in the fields of, e.g., industry (e.g. Communication *Towards an Industrial Renaissance*), tourism (e.g. Communication *Europe, the World's No 1 Tourist Destination*) and transport (e.g. White Paper on a *Roadmap to a Single European Transport Area*) (see Table 4). These policies encourage economic development with limited control as to what type of development is envisaged, except general calls for sustainable development, resource efficiency, innovation investment and new technologies.

Discussion

The integrated assessment of how EU policies influence aquatic biodiversity has offered insights into where strengths, weaknesses and opportunities lie (Table 5). The main environmental directives provide an implicit scope for a large range of action at the levels of state, pressures and drivers. In addition to these more transversal

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Threat	Strength	Weaknesses/challenges	Opportunities
Nitrogen pollution	an extensive policy framework that tackles the threat along the whole DPS, including major drivers clear set of measures on pressures	major incentives supporting key drivers (agriculture) and a policy framework that mainly set specific instruments to reduce the threat at the level of state and pressures	strengthen mainstreaming on key drivers (e.g. reduced support to intensive agriculture)
Extraction of species	an extensive policy framework that tackles the threat along the whole DPS, including fishing and aquaculture clear set of instruments on pressures	an emphasis on production and supporting the fishing and aquaculture sector with weak requirements for sustainable production	strengthen mainstreaming on key drivers (e.g. reduced support to intensive fishing practices)
Water abstraction	some policy support for reducing pressures (e.g. increasing water efficiency) with range of funding instruments available for multiple drivers (mainly urban and industry)	major incentives to increase overall water use across a range of drivers. Limited range of instruments on state (e.g. water quantity) and unclear instruments to tackle drivers (e.g. promote less water intensive economic activities)	strengthen instruments acting on state (e.g. application of ecological flows); strengthen mainstreaming on key drivers (e.g. reduced support to irrigated agriculture); develop instruments on drivers (e.g. better control between economic development e.g. tourism and available resources)
Alien invasive species	an extensive policy framework that regulates the introduction of species (pressures) and trade (driver)	few instruments on how to deal with the threat at the level of state (e.g. how to restore natural conditions) and on key drivers (e.g. transport)	strengthen instruments on specific drivers (e.g. reducing impact of transport)
Alteration to morphology	a policy framework that provides a good level of control on new development (pressures)	lack of strong policy support to do restoration and deal with past alterations (e.g. restoring state) lack of strong instruments on current drivers (e.g. transport, energy) to tackle new alterations	strengthen mainstreaming on key drivers (e.g. licensing of modifications) develop instruments for restoration of state (e.g. river restoration)
Plastic waste	a nascent policy framework that provides some control on the emissions of litter (pressures)	lack of instruments to tackle existing litter and pollutants in water (e.g. no target in WFD) and need to strengthen instruments on drivers (e.g. support for alternative material)	strengthen instruments acting on state (e.g. establishing targets for safe plastic concentration in water, removal of plastic waste) strengthen instruments on specific drivers (e.g. plastic industry)

Table 5. Overview of key strengths, weaknesses and opportunities to strengthen the European policy framework for the protection of aquatic biodiversity

instruments, distinct regulations or policy instruments help tackle each pressure more specifically. However, the analysis also reveals that substantial policy gaps remain in addressing the selected pressures sufficiently, but ensuring that conflicting policy objectives between environmental protection and economic growth are reconciled.

The case of nitrogen pollution illustrates well the limitations of the current European policy framework. While policy instruments such as the Urban Waste Water Treatment Directive and the Nitrates Directive offer a comprehensive basis for combating nitrogen pollution across all aquatic realms (e.g. discharge authorization, collection and treatment, codes of good practice), they set, together with a host of other environmental directives and regulations

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(e.g. WFD, Bathing Water Directive), an array of overlapping policy objectives, standards and measures, which make implementation more complex (Ibisch *et al.*, 2017). Furthermore, despite extensive action, most European coastal waters still carry nitrogen loads resulting in eutrophication, which indicates that current policy efforts remain insufficient (EEA, 2015a, 2015b). Some policies may even increase nitrogen pollution in aquatic ecosystems by promoting the maintenance or expansion of agriculture, transport, aquaculture and other drivers of nitrogen pollution. The CAP in particular has been shown to support intensive farming and maintain the viability of agricultural practices in several regions (Vesterager *et al.*, 2016) and cross-compliance requirements within the CAP are currently not implemented sufficiently to ensure that nitrogen pressures from farming reach a sustainable level (European Court of Auditors, 2014; Meyer *et al.*, 2014).

Conflicting policy objectives can also be illustrated in the marine realm. Commercial fishing is responsible for exploitative extraction of aquatic species through intensive fishing methods such as trawling, which subsequently impacts food-web dynamics, stock resilience and overall stock levels (EEA, 2015a). Some policies, including the CFP and the EMFF, can contribute to an increase in fishing and aquaculture activities. Although instruments to manage extractive pressures are proposed (such as the multi-species plan), a strong emphasis remains on blue growth objectives. The CFP has been especially criticized for its lack of transparency, as it inhibits the cooperation between science and policy, sets excessive quotas and enables payment of direct and indirect subsidies to fisheries (Khalilian *et al.*, 2010; Da Rocha *et al.*, 2012; Daw and Gray, 2006). While signs of improvement are present, the level of knowledge on species extraction is still very limited, making a compelling assessment difficult over time (EEA, 2015a).

Several EU directives and regulations aim to tackle pressure from IASs by regulating the deliberate introduction of species in Europe. Nevertheless, IASs are being introduced into Europe's seas with increasing regularity, in part due to the non-deliberate introduction through trade and species migration associated with climate change (EEA, 2015a; IUCN, 2014). Sectoral policies promoting growth in trade and the transport sector are likely to increase IAS pressure on aquatic ecosystems (see also Keller *et al.*, 2011). In addition, defining targets (state) on IASs (e.g. which species to include or not) remains a challenging task in part due to a lack of understanding on the impacts (see Davis *et al.*, 2011) of IASs and the multiplicity of criteria used to integrate species on the list of union concern (Briggs, 2017).

Plastic waste pollution is targeted by nascent explicit EU policy framework in part through the control on emissions of litter and through the promotion of the circular economy and alternative material production. However, there is a lack of instruments to tackle existing litter and pollutants within aquatic realms (Rochman *et al.*, 2013). It can also be argued that EU strategies supporting the expansion of, for example, industrial activities and tourism (two major drivers of plastic pollution) based on current production and consumption practices will ultimately contribute to enhancement of plastic waste pollution.

The assessment presented in this paper reveals that few EU policy instruments address specifically pressures from alterations to morphology and water abstraction. Instead, cross-cutting environmental policies such as the WFD and MSFD may implicitly require improvement actions (e.g. wetland restoration) or controls on developments altering morphological conditions or impacting abstraction levels to achieve their objectives. Specifically on water abstraction, there are explicit requirements in EU policy for promoting water efficiency in the domestic and agriculture sectors (e.g. resource efficient Europe, WFD water pricing, RDP subsidies). However, without further attempts at decoupling economic development from water consumption or infrastructure development, sectoral growth in, e.g., the agriculture, energy and transport sectors is likely to intensify abstraction pressures and alterations to the morphological condition of water bodies.

The analysis has identified that several directives and regulations in place support the European economy without establishing sufficient requirements to decouple food security and economic growth from environmental damage. Thus, some of these may contradict and even reverse the efforts of environmental policies to decrease trends in aquatic biodiversity loss (Gasparatos *et al.* 2017). There are also significant disparities between the budget dedicated to environmental protection and sectoral funding (O'Higgins, 2017), with for example 3.4 billion EUR dedicated to LIFE 2014–2020 compared with 290 billion EUR for the CAP and 350 billion EU for regional funds. EU funding instruments such as the CAP have nevertheless started to decouple payments from production objectives and to financially support more environmentally friendly investments and practices through mechanisms such as the RDPs. Such reforms are warranted to ensure that future EU policies contribute more effectively to the protection of aquatic biodiversity.

Conclusion

This research provides a first comprehensive, high level analysis of EU policies relevant for the protection of aquatic biodiversity across the freshwater, coastal and marine realms. This paper has utilized the DPSIR framework to audit direct and indirect biodiversity-related EU policies and their impact on aquatic biodiversity conservation and loss. The analysis shows that the policy framework is most developed when it comes to defining environmental targets (level of state) and sets a number of instruments to reduce pressures by encouraging the adoption of more resource-efficient practices, but it becomes less specific when tackling sectors (drivers) and supporting more environmental sound economic development.

The paper indicates that several sectoral policies of the EU that support economic expansion can lead to the intensification of pressures on aquatic biodiversity, hence reversing the efforts of environmental policies and amplifying drivers. Thus, the EU policy landscape has a mixed effect in its efforts to reduce aquatic biodiversity loss. To tackle this issue and strengthen the European policy framework, there is clearly scope to mainstream further policy actions for biodiversity protection in sectoral policies, by considering how seeking food security, economic growth and competition policies impacts aquatic biodiversity, and aim to 'uncouple' growth and resource use.

Overall, the results presented in this paper show the need for greater coherence between the large number of environmental and sectoral EU policies in order to prevent biodiversity loss and maximize the provision of multiple ecosystem services from aquatic ecosystems. To achieve greater coherence and more integrative policy implementation, future research should test management concepts that that offer an explicit consideration and management of the trade-offs between multiple societal and policy objectives. Promising ones include the ecosystem services approach, which has received a significant level of attention in recent years, and ecosystem-based management, which is now being applied in marine policy.

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Supporting information

Additional Supporting Information may be found online in the supporting information tab for this article.

Data S1. Supplementary material
Policy instruments set out by European policies contributing to the protection of aquatic biodiversity

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