Ecosystem Services 34 (2018) 126–135

Contents lists available at ScienceDirect

Ecosystem Services

journal homepage: www.elsevier.com/locate/ecoser

A participatory ecosystems services approach for pressure prioritisation in support of the Water Framework Directive

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ARTICLE INFO

Keywords:
Water policy
Integrated catchment management
Systems thinking
Stakeholders

ABSTRACT

The pressure and impact analysis is an important process in integrated river basin management and a key procedural element of the EU Water Framework Directive. It aims to inform both the assessment of water body status and the development of management responses. However, the Directive does not provide prescriptive guidance on how it should be carried out and during the 1st river basin cycle, its application proved to be a real challenge. Incorporating ecosystem services as indicators of impacts, a participatory framework for pressure prioritisation is presented here. While various methods exist for engaging stakeholders in river basin management, the framework allows for the ecosystem approach to be operationalised through a risk assessment perspective, in the context of the pressure impact analysis. Applying this to a case study in England, we demonstrate how a ranking of pressures can be delivered based on stakeholders' perception of how the delivery of ecosystem services is affected by each pressure and incorporating their value as indicator of the magnitude of the impact. This approach allows for a more systematic way to effectively prioritise significant pressures and therefore select appropriate programmes of measures in line with the Directive's integrated river basin management paradigm.

1. Introduction

The institutionalisation of the river basin scale for the spatial organisation of water management in the European Union Water Framework Directive (WFD) can be viewed as the point of departure for a new multi-scalar strategy by the European Commission and a key instrument for pursuing the WFD's environmental objectives of good ecological quality for surface waters (Hüesker and Moss, 2015). Acknowledging ecological variability and the socio-political differences between river basins, the Directive calls for a tailored approach to integrated water management from a river basin perspective (Giakoumis and Voulvoulis, 2018a). In practice, this requires a shift from having a single mandate for freshwater management across Europe to a more robust understanding of the essential features of river basins, as systems (Voulvoulis et al., 2017).

It is now well accepted that many (but not all) of the factors (pressures) influencing the ecological condition of waters come from the river basin. River basin management can be a difficult, multivariate problem involving multiple pressures, multiple ecological issues, and competing social priorities. Although there is considerable general knowledge regarding the cause-effect relationships between many of these pressures and the consequent ecological effects (Hart et al., 2006), the complexity of the river basin limits their potential to support decision-making. For this, the WFD treats the river basin as one interconnected system, with the development of management responses aimed towards improving water quality as a result of improving ecosystem health (system state). River basins are complex systems, and research demonstrates that they cannot be managed only in terms of cause and effect relationships (Everard and Powell, 2002; Liu et al., 2007; Pahl-Wostl, 2004). The most effective solutions require good understanding of the river basin, and usually emerge from understanding pressures through discussions within the wider community. Even in cases when the most important pressures are known, mechanisms to facilitate the development of effective management strategies and increase public support are missing. Risk-based approaches are increasingly being applied by river basin managers (Hart et al., 2006).

The pressures and impacts analysis is the most important step of the characterisation of river basins (Article 5) and fits in the broader context of the development of integrated river basin management plans as required by the WFD (European Commission, 2000). The process must consider how pressures would be likely to develop during a management cycle period in ways that would place water bodies at risk of failing to achieve good status if appropriate programmes of measures were not designed and implemented (European Communities, 2003). For this, the WFD requires Member States to use information collected

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https://doi.org/10.1016/j.ecoser.2018.10.007
Received 1 July 2018; Received in revised form 18 October 2018; Accepted 28 October 2018
Available online 09 November 2018

on the pressures to which water bodies are likely to be subject and on the characteristics of those water bodies, together with any other relevant information, including existing environmental monitoring data. This includes information on the type and magnitude of significant anthropogenic pressures, broadly categorised into: point sources of pollution; diffuse sources of pollution; effects of modifying the flow regime through abstraction or regulation; and morphological alterations. Any other pressures, i.e. those not falling within these categories, must also be identified. In addition, there is a requirement to consider land use patterns (e.g. urban, industrial, agricultural, forestry etc.), as these may be useful to indicate areas in which specific pressures are located. The results of the analyses should be used in targeting the monitoring programmes[1] required under Article 8, making the directive's objectives practicable[2] under Article 4 and designing targeted and proportionate measures to achieve the Directive's objectives, in accordance with Article 11 (European Communities, 2003).

In the implementation of the Directive by Member States, the pressure and impact analysis proved to be a challenge for water authorities, with the 4th WFD implementation report revealing problems in most States. In 21 of the 27 Member States there were no clear links between pressures and the programmes of measures, and in 23, the gap analysis had not been effectively implemented for the development of appropriate and cost-effective measures (European Commission, 2015). Often assuming a linear causality, incomplete pressure inventories and the absence of appropriate indicators for impacts, put in jeopardy the design of monitoring networks both in terms of identifying water bodies at risk and quality elements to be monitored for the classification of ecological and chemical status. When significant pressures were overlooked, there were monitoring implications, and as a result the assessment schemes were mainly focused on more traditional pressures (Hering et al., 2010). Similarly, measures were often designed to target elements for improving classification, targeting the symptoms rather than the pressures causing the gap to the achievement of objectives (Voulvoulis et al., 2017).

The Directive acknowledges that apart from the ecological domain, the aquatic system encompasses a social and economic domain, to which ecosystem health is conditional to, thus must be adequately integrated in the overall decision-making process (Vugteveen et al., 2006). The influence of pressures on ecosystem health could be investigated by incorporating societal needs and expectations when referring to a healthy ecosystem (Pollard and Huxham, 1998). In support of this, the WFD acknowledges the exploration of environmental benefits defined as welfare gains resulting from the improvements towards the desired good status (Martin-Ortega, 2012).

Incorporating ecosystem services, the benefits that people obtain from ecosystems (MEA, 2005) and the direct and indirect contributions of ecosystems to human well-being (TEEB, 2010), as indicators of impacts through a process of engaging with stakeholders (Article 14), the paper presents a risk-based approach for the pressure and impact analysis. In line with the ecosystem approach, a holistic and integrated management strategy that proactively defends and protects the overall health and functionality of the ecosystem as the source of water as well as a water user with specific requirements (Pollard and Toit, 2008), it proposes a framework for ranking pressures based on stakeholder understanding of human-nature interdependencies at the river basin level. Relating ecological status to the "capacity" of the freshwater system to deliver ecosystem services, freshwater experts and stakeholders are tasked to consider ways that the delivery of ecosystem services, can be affected by the various pressures that human activities pose, to prioritise these pressures as required by the Directive.

2. Pressures assessment in the WFD

While it is clear from the WFD that *impacts* are the result of *pressures*, neither term is explicitly defined, nor the Directive provides a prescriptive guidance on how pressure assessment should be carried out (European Communities, 2003). Instead it offers a general approach conceptually based on the Drivers Pressure State Impact Response (DPSIR) framework (Borja et al., 2006). The anthropogenic activities that may have an environmental effect (e.g. agriculture, industry) are considered drivers and their direct effect (for example, an effect that causes a change in flow or a change in the water chemistry), pressures. The environmental effects of these pressures (e.g. fish killed, ecosystem modified) are the impacts. The assessment of whether a pressure on a water body is significant or not, must be based on knowledge about the pressures within each river basin area, together with some form of conceptual understanding of how the river basin system functions (e.g. water flow, chemical transfers, and biological functioning of the water body within the river basin system) (European Communities, 2003). Pressures and their interactions are context-specific, and prioritisation requires targeted and localised research to ensure that programmes of measures target the right pressures that are emerging from the landscape and human nature interdependences.

As with risk assessment, the process relies on investigating the likely presence and significance of a pressure linkage, the potential of a pressure affecting ecosystem state (European Communities, 2003). This source-pathway-receptor relationship (Fig. 1) is critical to the pressure assessment and requires an understanding of the river basin system and how it functions, partly enabled by the participatory nature of the WFD. Article 14 specifically requires public consultation in the production of River Basin Management Plans (RBMPs), to which the pressures and impacts analysis is a significant part (European Communities, 2003). Stakeholders can be a useful source of information and water agencies and authorities are required to make this process as transparent and opened to the public as possible. Their participation can help with data on characterisation, pressure identification and assessment as well as the assessment of environmental impacts needed for the pressures and impact analysis (European Communities, 2003). The *IMPRESS* guidance document highlights that the value of local knowledge and experience should not be underestimated or dismissed in favour of a more formal process imported from elsewhere (European Communities, 2003). Also, it provides guidance on "who needs to get involved" in the pressure impacts analysis process and on "how" they could be identified. Still, in the implementation so far, public participation on this process has been largely neglected, with many Member States following the "letter of the law" than its "spirit" (Ker Rault and Jeffrey, 2008).

Approaching the pressure and impact analysis from a risk assessment perspective, offers the opportunity to prioritise pressures by considering both the magnitude of the potential impact and the probability that this impact will occur. The risk arising from an anthropogenic activity in the river basin could therefore be estimated by multiplying the probability of the activity causing damage ("likelihood"), by the measure of the damage ("consequence") (Emanuelsson et al., 2014) or "impact" in the WFD context.

3. Ecosystem services and the WFD

Although ecosystem services are not mentioned in the WFD (Bouwma et al., 2017), the Directive is nonetheless ecosystem-focused and has the purpose of protecting future human uses of the environment when implemented in a social and economic context (Vlachopoulou et al., 2014). There is a clear connection between the WFD and both the delivery of ecosystem services and also principles of

[1] Provide suitable information for validating the analyses and assessing the effectiveness of the measures.

[2] Identify water bodies for which the application of heavily modified water body designations under Article 4.3, extensions to the timetable under Article 4.4, less stringent objectives under Article 4.5 or exceptions from the obligation to prevent deterioration in status under Articles 4.6 and 4.7 may be appropriate.

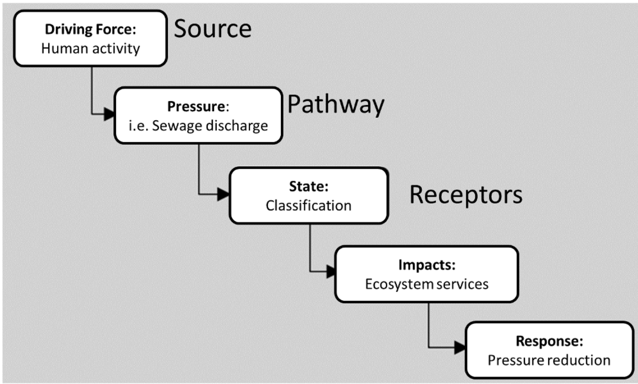


Fig. 1. The risk assessment components in relation to DPSIR framework (European Communities, 2003).

the ecosystem approach as outlined in the Convention on Biological Diversity (Voulvoulis, 2014). Legislative objectives towards sustaining the functional integrity of the freshwater ecosystems would increase their capacity to provide services and ensure social wellbeing (Chan et al., 2006). The "capacity" of a freshwater system to provide services is conditional to its structure and functioning which in the context of the WFD is reflected on ecological status, therefore "good status" can be seen as a prerequisite for ecosystem functions (Vlachopoulou et al., 2014). The development of RBMPs could benefit from the concept of ecosystem services, adopted to recognise the multi-functionality of the water system and account for the benefits people receive from nature, justifying the costs of protection and restoration (WFD programmes of measures). For the water bodies at risk of failing to achieve good ecological status, management responses should be in place for the improvement of the overall system's health by targeting the pressures and their drivers contributing to ecosystem dysfunction (Fig. 2). For example, improvements in ecological quality of rivers have been reported to lead to increases in the abundance of fish stocks (Hartje and Klaphake, 2006).

Although references to ecosystem services were generally absent in the first cycle of the RBMPs, they have started to appear in the second cycle (Grizzetti et al., 2016). The *Fitness Check* and the *Blueprint*, have already acknowledged the importance of actions for protecting ecosystems and delivering services in the context of sustainable water management and the need to integrate more the ecosystem services in RBMPs (European Commission, 2012a,b). Several studies have investigated the potential of implementing ecosystem services in the WFD context (Heink et al., 2016; Martin-Ortega, 2012; Pistocchi et al., 2017; Vlachopoulou et al., 2014), and a number of steps of particular relevance to the characterisation of river basins, the determination of cost effective measures and the cost recovery from water supply and wastewater services have already been identified (Sørensen et al., 2014).

In essence, the integration of ecosystem services assessments in the WFD implementation could be seen as an evolutionary step for the Directive to achieve its vision on sustainability and communicating management objectives in relation to societal welfare (Dufour and Piégay, 2009; Everard, 2011; Hartje and Klaphake, 2006; Spray and Blackstock, 2013). Ecosystem services meet the criteria of being adequate human–environmental system indicators as they are policy-relevant representations of the system's state (Kandziora et al., 2013) and they embrace the ecological, biophysical and socio-economic aspects necessary to evaluate the sustainability of human-coupled ecosystems (Lu et al., 2015). Although the benefits from combining ecosystem services and risk assessment frameworks in support of river basin management have been acknowledged (Brauman et al., 2014), such approaches have yet to be developed.

4. A participatory ecosystems services framework for ranking pressures

A conceptual framework for prioritising pressures based on their potential to affect ecological status (causing the gap to the achievement of objectives) using ecosystem services as indicators of impact that can be delivered through stakeholder engagement is presented here (Fig. 3). It requires stakeholders to see the river basin as a system of human-nature interdependencies, with their effects driving ecosystem health. Human activities taking place in the river basin that could be acting as sources of degradation (pressures) of system state need to be identified first (Supplementary Table S1). It is also important that stakeholders understand and appreciate the ecosystem services delivered by the river basin, setting objectives for the system state that could deliver them

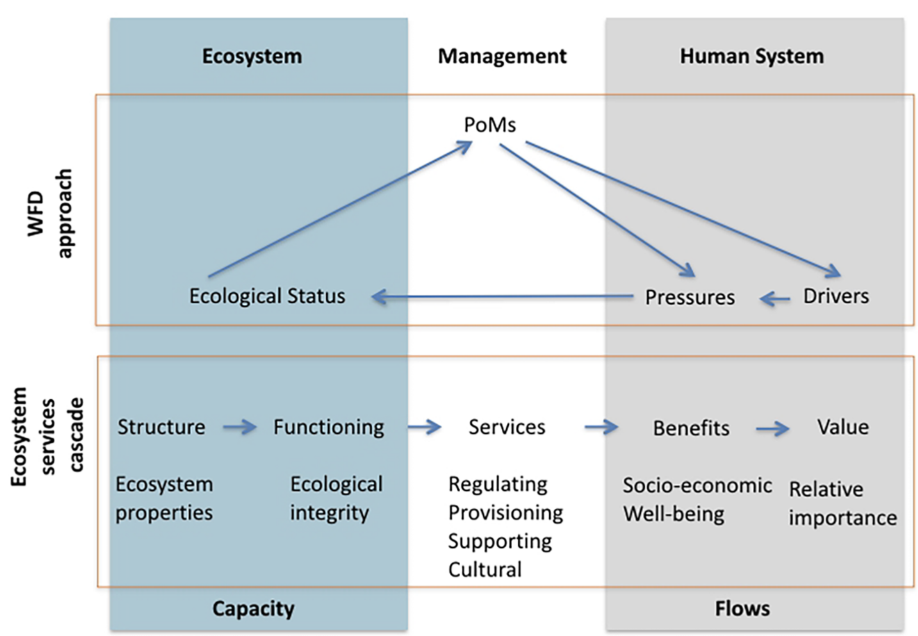


Fig. 2. Ecosystem services as parts of the Water Framework Directive (WFD) approach for the management of socio-ecological systems, following the ecosystem services cascade.

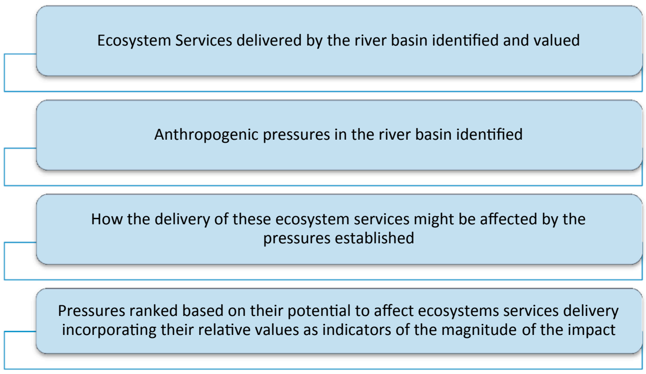


Fig. 3. A participatory ecosystems services framework for pressure prioritisation in support of the WFD.

Table 1
A broad list of ecosystem services[4] based on Millennium Ecosystem Assessment (MEA, 2005), for stakeholders to select those of relevance and supplement them as necessary.

ECOSYSTEM SERVICES		
Provisioning	Regulating	Cultural
Food	Climate regulation	Spiritual and religious
Fresh water	Disease regulation	Recreation and ecotourism
Fuel wood	Water regulation	Aesthetic
Fibre	Water purification	Inspirational
Bio-chemicals		Educational
Genetic resources		Sense of place
		Cultural heritage

[4] In the context of environmental valuation, the classification of ES into intermediate processes, final services and benefits addresses the problem of double counting the values of ES (Fisher et al., 2009; Fu et al., 2011; McVittie et al., 2015).

when this is not the case (Table 1). This can be based on ecosystem services assessments (physical or economic flows) potentially already undertaken in the river basin or participative ecosystem service valuation workshops where stakeholders derive the relative importance of ecosystem services using data from existing valuation studies or qualitatively rank them based on their preferences (Salgado et al., 2009). A ranking of pressures can then be delivered based on stakeholders' perception of how the delivery of ecosystem services is affected by each pressure at the river basin and incorporating the relative value of these services as indicators of the magnitude of the impact. Participants are encouraged to look at the river basin as a system and consider how the ability of the system to deliver ecosystem services ("what they value") is affected by pressures ("what stakeholders do").

Stakeholder engagement has been at the core of the Water Governance Principles formulated by the Organisation for Economic Co-operation and Development in 2015 and has become a central requirement for water-related projects in many different contexts (Wehn et al., 2017). There is no "one-size-fits-all" approach to involving stakeholders in delivering the participatory framework presented here, but a number of important factors including the problem, the stakeholders, geography, schedules and time frames, and agency's organisational capacity should be considered (Prell et al., 2007; Reed et al., 2009), and a number of principles (Areizaga et al., 2012; Withycombe Keeler et al., 2015) and best practices (Pomeroy and Douvere, 2008) are also available. For example, depending on the number of participants, stakeholders could be separated into small groups to create the conditions for meaningful and productive discourse (Webler et al., 1995), knowledge exchange and joined understanding of problems within the system of interest (river basin). River basin partnerships offer the natural management structures to facilitate this approach, and in Europe, they are often already in place to deliver the participatory requirements of the WFD. Still, the framework could be adopted to any participatory arrangements in place or planned for to address the individual needs of a basin.

5. Application to a catchment in England

To demonstrate how the framework could be operationalised for prioritising pressures in the context of existing decision-making structures, the Broadland Rivers catchment (Fig. 4) was selected as a case study and the associated Partnership Steering group as the forum for its application. The group, comprising of members of the Broads Authority, the Environment Agency, National Farmers Union, water industries (Anglian Water, Essex and Suffolk Water), Water Management Alliance, National Trust, The Rivers Trust, Natural England, Norfolk County Council, Country Land and Business Association, University of East Anglia, The River Waveney Trust, Norfolk Wildlife Trust, Suffolk Wildlife Trust and River Society for the Protection of Birds, has been the official stakeholder group for the WFD implementation in the region and the consultation body for the development of RBMPs.

At a workshop organised during a Broadland Catchment Partnership Steering group meeting, the thirty-three members that participated discussed the potential of integrating ecosystem services in the development of the next catchment management plan, while randomly organised into four groups. Using a generic list of human activities (Supplementary Table S1), considered as part of the pressures and impacts assessment (European Communities, 2003), stakeholders were encouraged to discuss how activities present in their catchment act as pressures ensuring that all representative activities and associated pressures were being considered. They also discussed and confirmed the ecosystem services provided by their catchment. Out of a broad list of final services (Table 1) they selected those of relevance to their catchment or supplemented them accordingly if necessary. Through an active discussion in their groups, participants were able to agree and report on how the delivery of the ecosystem services they identified and valued, can be affected by the pressures from the human activities they identified in the catchment.

6. Results

Twenty activities acting as pressures to the Broadland Rivers catchment were identified during the workshop (Table 2). The participants selected pressures from all source categories, most from diffuse sources (of agricultural and urban origin) and point sources of pollution from a variety of industrial activities.

A total of 37 services were identified and their relative values (Table 3) were derived during an earlier participative ecosystem service valuation workshop, based on a dynamic sequence of group and individual activities[3]. The number of important services was almost equally distributed between the three categories (14 provisioning, 11 regulating and 12 cultural services).

In their groups, participants identified which pressures could be affecting the delivery of each ecosystem service in their catchment, and the results are summarised in Fig. 5 as diagrams of interconnections between ecosystem services on the left (codes from Table 3) and pressures by human activities (codes from Table 2), for each of the four groups (see also data in Supplementary Tables S2–S5). Variation between the four groups was observed. Group 2 demonstrated a much denser conceptual diagram with 118 links, while groups 1, 3 and 4 had 37, 64 and 26 links respectively (Fig. 5). In Group 1, 51% of the links corresponded to provisioning services, 27% to regulating and 22% to cultural. In Group 2, the provisioning account for 46% of the links while

[3] Methodology and results of ecosystem services co-definition and participative valuation workshop are described on GLOBAQUA (2018).

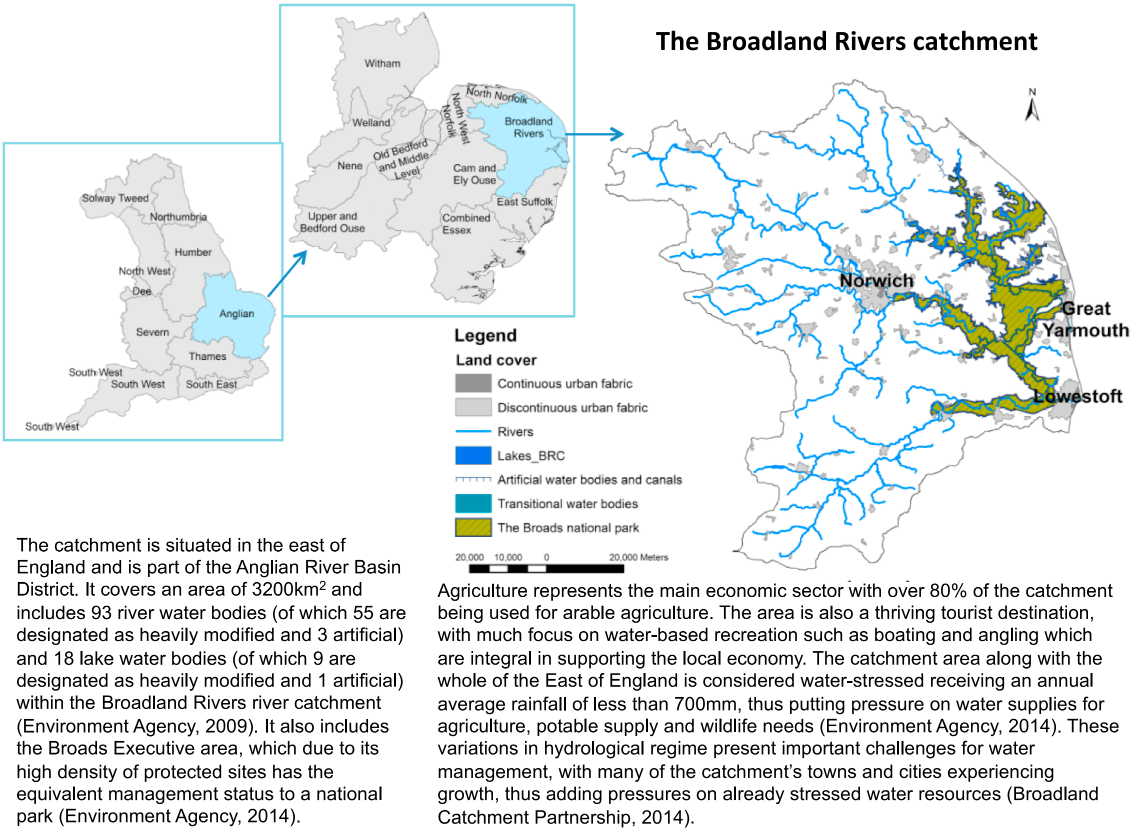


Fig. 4. The Broadland Rivers catchment. (See above-mentioned references for further information.)

Table 2
List of river basin sources of pressures selected by the stakeholders as part of the participatory process.

Source	Code	Source within the source type
Diffuse		
Urban drainage (including runoff)	D1.2	Urban areas (including sewer networks)
	D1.3	Airports
	D1.4	Trunk roads
	D1.5	Railway tracks and facilities
Agriculture (diffuse)	D2.2	Crops, with intensive nutrient or pesticide usage or long bare soil periods
	D2.3	Over grazing- leading to erosion
Other diffuse	D4.2	Atmospheric deposition
	D4.4	Shipping/navigation
Point source		
Waste water Industry	P1.1	Municipal waste water primarily domestic
	P2.5	Iron and steel
	P2.14	Other manufacturing processes
Mining	P3.4	Peat extraction
Waste management	P6.1	Operating landfill site
Aquaculture	P7.1	Land based fish farming/watercress/ aquaculture
Abstraction		
Reduction in flow	A1.2	Abstractions for potable supply
	A1.5	Abstractions by hydro-energy
Morphological		
River management	M2.3	Agricultural enhancement
Other anthropogenic		
	O1.5	Recreation (including fishing/angling)
	O1.9	Climate change

the rest is shared equally in the other two categories. Similarly, in Group 4 the provisioning account for 46% of the links but the cultural come second with 31%. In Group 3 the percentages among the categories are almost equal.

The four most important pressures were found to be common between all groups and perceived to affect different baskets of services; hence there is mixture of both common and unique links present at each pressure in different groups. For example, the pressure 'Crops with intensive nutrient or pesticide' (D2.2) is linked with services P6, P5, P8, P9, R1 and R2 in all groups but pressure's impacts on services are either common in 3 or 2 groups or unique to only one group (Fig. 5 and Supplementary Table S6).

Incorporating the value of the ecosystem services affected by each pressure, a ranking of pressures was derived for each group (Table 5 and Supplementary Tables S7–S10). While we propose a standardisation formula in Supplementary Table S11 that can be used to derive the overall final ranking of pressures, it is worth noting that in this case the top pressures were similar across the groups (Table 4). 'Crops with intensive nutrient or pesticide' (D2.2), 'Agricultural enhancement' (M2.3), 'Urban areas including their sewer networks' (D1.2) and 'Abstractions for potable supply' (A1.2) were the same in all four groups but one.

With the values of the ecosystems services affected being the same across the groups, we also investigated how sensitive the final ranking would be if different values were used. Using data from an ecosystem services evaluation undertaken in the catchment in 2013 (White et al., 2015), calculated values were used instead of the scores given by the stakeholders to derive a new pressure ranking. Using the values of the seven ecosystem services (Table 5), included in the evaluation (out of the 37 services identified by the stakeholders), the ranking of pressures when considering these pressures was shown to follow similar trends (Fig. 6). Both datasets are provided in the Supplementary Tables S12 and S13.

Table 3
The list of ecosystem services identified during the workshop and their scores (relative values). The different types of services are categorised into provisioning (P), regulating (R), cultural (C).

Ecosystem service types	Score	Ecosystem service types	Score
P1: Intensive farming (cereals, veg, sugar beet, peas, maize)	3.7	R5: Air quality (woodland)	4.17
P2: Intensive farming (poultry, pigs)	3.25	R6: Pollination	4.65
P3: Grazing marsh	4.55	R7: Natural water purification	4.6
P4: Wild food (venison)	2.7	R8: Riparian shading buffer strip	4
P5: Water quality drinking water	4.91	R9: Drought protection	4.75
P6: Water for industry	4.37	R10: Pollutant sequestration	4
P7: Water for irrigation	4.3	R11: Pest control (beetle bank)	4
P8: Water for Breweries	3.6	C1: Health and wellbeing	4.5
P9: Arable ponds (wildlife)	4.47	C2: Tourism coasting holidays	4.3
P10: Reed and sedge	4.6	C3: Local recreation (angling, bird watching, boating)	4.7
P11: Timber (fuel wood), coppice	3.75	C4: Archaeology (built buried)	4.3
P12: Wind energy, solar energy, biomass	3.7	C5: Spiritual wellbeing	3.8
P13: Hydropower	2.7	C6: Education and research	4.5
P14: Fertilizers	2.6	C7: Social cohesion	4.25
R1: Natural hazards regulation (flooding)	4.6	C8: Arts	4.08
R2: Soil erosion	4.4	C9: Walking, cycling	4.26
R3: Attenuation of sea level change	4.55	C10: Sense of place, uniqueness	4.8
R4: Carbon sequestration	4.55	C11: Landscape beauty: Big skies, wilderness, tranquillity	4.8
		C12: Dark skies	3.64

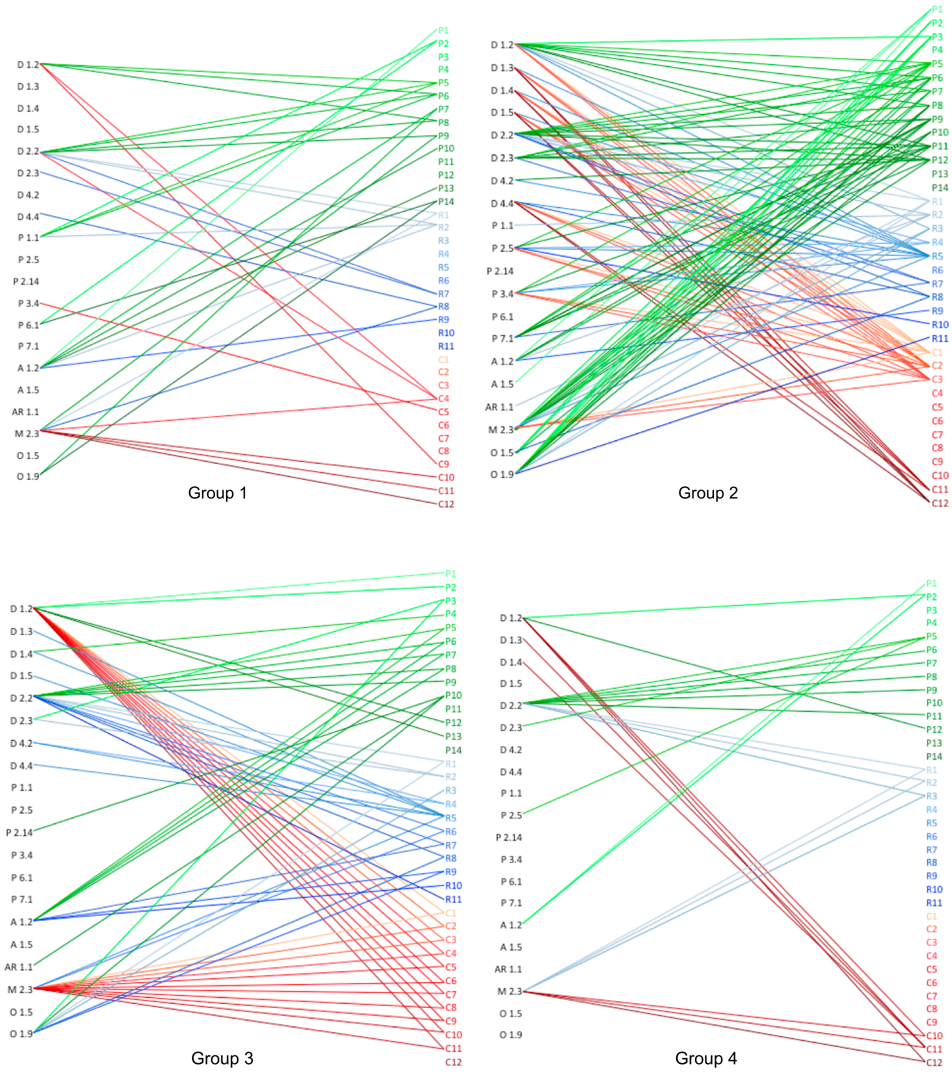
7. Discussion

Pressure prioritisation is particularly important to the selection of programme of measures, the actions we take to manage these pressures in order to improve ecological status and the delivery of ecosystem services. Looking at the pressure and impact analysis from a risk assessment perspective, offers the opportunity to rank pressures based on how the delivery of ecosystem services is affected by each pressure and incorporating the value of ecosystem services as indicator of the magnitude of the impact. Fundamental to this approach is the assumption that there is a clear link between ecological quality (and status) and the delivery of ecosystem services (Vlachopoulou et al., 2014). Human activity impairs the flow of many services because of escalating human impacts on ecosystems (pressures in the WFD) reducing their capacity to provide the services necessary for an acceptable level of human wellbeing. The use of ecosystem services in river basin management planning provides a framework for assessing multiple pressures and their potential to reduce the capacity of the ecosystem to supply services in order to select appropriate management responses. The approach presented in this paper demonstrates how the ecosystem services approach can be operationalised and mainstreamed in the context of pressure impact analysis, offering an opportunity for adopting systemic thinking in the implementation of the WFD.

The WFD requires in depth understanding of catchments and management that is aligning human-nature interdependencies with the goal of improving the system as a whole, under an ecological vision that considers human activities as a source of disturbance and water quality degradation (Voulvoulis et al., 2017) and as a result requires programme of measures taken to manage anthropogenic pressures in order to improve ecosystem health (European Commission, 2000). Considering that for the case study these were identified and documented in the 2009 RBMPs (Environment Agency, 2010; Supplementary Table S14), measures attributed to various sectors (Fig. 7) were compared to the ranking of pressures from this study. Most of these measures (43%) focused on 'water industry' and more specifically in relation to "Improvement of water company assets", and also "schemes to improve discharges…to remove more phosphorus than required by the Urban Waste Water Treatment Directive" (See supplementary Table S14). However, in this study the point pressure 'Municipal waste water primarily domestic' (P1.1) was ranked relatively low (12th out of 20), and the diffuse pressure 'Urban areas including their sewer networks' (D1.2) ranked among the highest (3rd out of 20). The sector 'agriculture and rural land management' accounted for 18% of the measures targeting both diffuse pressures 'Crops with intensive nutrient or pesticide' (D2.2) and morphological pressures 'Agricultural enhancement' (M2.3) that were ranked here first and second respectively (Fig. 7). With the latter being a critical pressure about 70% of the measures related to 'Angling and Conservation Activities' were designed to address physical modification (Fig. 7). The pressure 'Shipping/navigation' (D4.4) was ranked ninth, and accounts the 8% of measures, while pressure Trunk roads (D1.4) ranked eighth, accounted for an 8% of the measures. Despite the pressure 'Climate change' (O 1.9) was ranked fifth in this study, only one measure made a reference to it in the context of a 'Lake Restoration Strategy' (reference ID AN0279) (Environment Agency, 2009) belonging to the 'Angling and Conservation Activities'. These findings potentially indicate that the measures implemented have not accounted for all significant pressures, demonstrating the added value of incorporating multiple perspectives and stakeholder based conceptual models when assessing pressure significance in line with previous studies (Connell, 2010; Hart et al., 2006).

The pressure prioritisation framework presented here addresses some of the current problems with the implementation of the pressure analysis, which often involves several technical considerations (Giakoumis and Voulvoulis, 2018b) that might not be transparent to the public and could result to stakeholder alienation. In order to address the complex nature of catchments, the framework facilitates understanding of how the river basin functions, using conceptual human-nature interdependencies to inform management decisions. The participatory nature of the proposed approach emphasises the need to integrate different forms of information, one that incorporates multiple stakeholder perspectives to strengthen the evidence-base to support the decisions for implementing the WFD and the development of measures. This strategy facilitates constructive dialogue between the participants and enhances the process by which sharing knowledge and reaching a consensus within groups could provide data that represent the shared appreciation of the reality of the participants which could overcome data availability issues often compromising the pressure assessments (Barceló and Petrovic, 2011).

The concept of ecosystem services facilitates a more comprehensive communication of the objectives of the WFD and their environmental and socio-economic outcomes (benefits), and has the potential to promote policy acceptance and commitment to policy decisions (Howarth, 2009). It also allows for promoting actions that deliver multiple ecosystem service outcomes for the advantage of all service's beneficiaries, optimised for multiple benefits (Everard and McInnes, 2013). This approach could also enable stakeholders identify the most vulnerable



D1.2 (Urban areas, including sewer networks), **D1.3** (Airports), **D1.4** (Trunk roads), **D1.5** (Railway tracks and facilities), **D2.2** (Crops, with intensive nutrient or pesticide usage or long bare soil periods), **D2.3** (Over grazing-leading to erosion), **D4.2** (Atmospheric deposition), **D4.4** (Shipping/ navigation), **P1.1** (Municipal waste water primarily domestic), **P2.5** (Iron and steel), **P2.14** (Other manufacturing processes), **P3.4** (Peat extraction), **P6.1** (Operating landfill site), **P7.1** (Land based fish farming / watercress / aquaculture), **A1.2** (Abstractions for potable supply), **A1.5** (Abstractions by hydro-energy), **AR1.1** (Groundwater recharge), **M2.3** (Agricultural enhancement), **O1.5** (Recreation), **O1.9** (Climate change).

P1 (Intensive farming), **P2** (Intensive farming), **P3** (Grazing marsh), **P4** (Wild food), **P5** (Water quality drinking water), **P6** (Water for industry), **P7** (Water for irrigation), **P8** (Water for Breweries), **P9** (Arable ponds), **P10** (Reed and sedge), **P11** (Timber), **P12** (Wind energy, solar energy, biomass), **P13** (Hydropower), **P14** (Fertilizers), **R1** (Natural hazards regulation), **R2** (Soil erosion), **R3** (Attenuation of sea level change), **R4** (Carbon sequestration), **R5** (Air quality), **R6** (Pollination), **R7** (Natural water purification), **R8** (Riparian shading buffer strip), **R9** (Drought protection), **R10** (Pollutant sequestration), **R11** (Pest control), **C1** (Health and wellbeing), **C2** (Tourism coasting holidays), **C3** (Local recreation), **C4** (Archaeology), **C5** (Spiritual wellbeing), **C6** (Education and research), **C7** (Social cohesion), **C8** (Arts), **C9** (Walking, cycling), **C10** (Sense of place, uniqueness), **C11** (Landscape beauty), **C12** (Dark skies).

Fig. 5. Constructed diagrams presenting stakeholders' perception on the interconnections between catchment pressures on the left and ecosystem services on the right for the Broadland Rivers case study for each Group. The lines in green, blue and red represent the provisioning, the regulating and the cultural service categories respectively. The different hues represent different types of services.

ecosystem services (Fig. 8) as a means for developing measures that tackle pressures towards targets for the delivery of such services. With the development of such consensus, decision making is better informed and programmes of measures as risk management solutions can be more readily accepted (Quevauviller, 2009).

River basin management is a social and scientific process, and in fact, the WFD calls for the developing of socio-ecological tools and frameworks for complex problem-solving (Martin-Ortega, 2012). The participatory framework for pressure prioritisation presented here aims to facilitate the adoption of the systemic thinking required for integrated river basin management (Voulvoulis, 2012). Systems knowledge relates to an understanding of social and ecological system functioning, including social–ecological interactions as well as the current and potential future flows of services from those interactions (Abson et al., 2014). Considering ecosystem services through a participatory approach, the framework allows for different disciplines and lay knowledge in the river basin management process. Ensuring that stakeholders are well informed and can actively contribute to problem solving can lead to greater stakeholder confidence and better outcomes being reached (Collins et al., 2012). With the participants varying from policymakers and scientists to representatives of local stakeholders groups, the ecosystem services concept and terminology satisfied the information requirements of each one of them and enabled them to develop shared mental models (Jones et al., 2011). This approach is also supported by recent examples of applying system tools in integrated coastal management (Sanò et al., 2014; Sanò and Medina, 2012) and in assimilating different value dimensions of ecosystem services (Lopes and Videira, 2017). These studies however have only focused on one perspective, where one category of variables (either anthropogenic activities or ecosystem service alone) and based on

Table 4
Pressure rankings from the four groups of participants and overall derived ranking for all participants. The order of each pressure is in brackets (highlighted in blue the top four pressures).

Code	Pressure Type	Ranks of pressures and order: Group 1	Group 2	Group 3	Group 4	Overall rank and order
D1.2	Urban areas (including sewer networks)	21.44 (4th)	56 (2nd)	61.64 (1st)	20.19 (3rd)	1.623 (3rd)
D1.3	Airports	0 (11th)	26.11 (8th)	4.17 (10th)	4.8 (6th)	-0.295 (10th)
D1.4	Trunk roads	0 (11th)	26.11 (8th)	6.87 (8th)	4.8 (6th)	-0.262 (8th)
D1.5	Railway tracks and facilities	0 (11th)	26.11 (8th)	4.17 (10th)	0 (7th)	-0.408 (13th)
D2.2	Crops, with intensive nutrient or pesticide usage or long bare soil periods	35.25 (1st)	51.25 (3rd)	52.45 (3rd)	38.95 (1st)	2.192 (1st)
D2.3	Over grazing- leading to erosion	4.6 (8th)	25.8 (9th)	8.95 (6th)	4.91 (5th)	-0.138 (6th)
D4.2	Atmospheric deposition	0 (11th)	7.87 (12th)	8.72 (7th)	0 (7th)	-0.590 (16th)
D4.4	Shipping/ navigation	4 (9th)	30.11 (7th)	4.17 (10th)	0 (7th)	-0.268 (9th)
P1.1	Municipal waste water primarily domestic	16.93 (5th)	4.4 (13th)	0 (11th)	0 (7th)	-0.370 (12th)
P2.5	Iron and steel	0 (11th)	34.88 (5th)	0 (11th)	4.91 (5th)	-0.229 (7th)
P2.14	Other manufacturing processes	0 (11th)	0 (15th)	4.6 (9th)	0 (7th)	-0.742 (19th)
P3.4	Peat extraction	3.8 (10th)	30.88 (6th)	0 (11th)	0 (7th)	-0.313 (11th)
P6.1	Operating landfill site	5.85 (7th)	0 (15th)	0 (11th)	0 (7th)	-0.670 (17th)
P7.1	Land based fish farming / watercress / aquaculture	0 (11th)	25.8 (9th)	0 (11th)	0 (7th)	-0.462 (14th)
A1.2	Abstractions for potable supply	24.45 (3rd)	21.92 (10th)	30.53 (4th)	6.95 (4th)	0.557 (4th)
A1.5	Abstractions by hydro-energy	0 (11th)	3.7 (14th)	0 (11th)	0 (7th)	-0.750 (20th)
AR1.1	Groundwater recharge	0 (11th)	4.4 (13th)	4.6 (9th)	0 (7th)	-0.685 (18th)
M2.3	Agricultural enhancement	30.61 (2nd)	65.07 (1st)	57.85 (2nd)	26.79 (2nd)	2.050 (2nd)
O1.5	Recreation (including fishing/angling)	0 (11th)	16.27 (11th)	0 (11th)	0 (7th)	-0.586 (15th)
O1.9	Climate change	6.9 (6th)	50.9 (4th)	27.05 (5th)	0 (7th)	0.344 (5th)

Table 5
The list of ecosystem services and their values from White et al., 2015 and their equivalents as identified during the workshop.

Service Type	Value (£)	Equivalent service
Timber	23,975	P11: Timber (fuel wood), coppice
Livestock	83,160	P2: Intensive farming (poultry, pigs)
Crops	220,393	P1: Intensive farming
Climate regulation	1,108,920	R4: Carbon sequestration
Drinking water	2,939,062	P5: Water quality drinking water
Air quality	7,360,000	R5: Air quality (woodland)
Recreation	16,103,031	C3: Local recreation (angling, bird watching, boating)

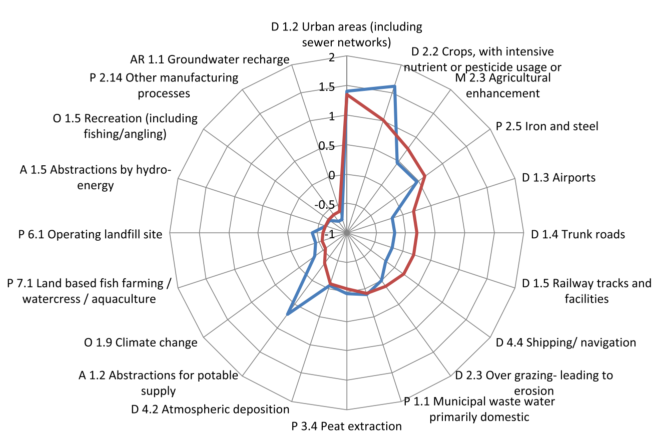


Fig. 6. Pressure prioritisation from this study compared to one derived when considering the ecosystem services and their values from White et al., 2015.

causal matrices with identical variables on the vertical and horizontal axes.

The pictorial representation of the participants' data offers visualisation of the links between services and activities as a means to make the participants aware of the complexities behind river basin management. The variation between the mental models of the four groups (Fig. 5) could be due to different factors. Variation between stakeholders on their understanding on how the system works and their views on the prioritisation of services will influence the data. However other factors will add noise to the data, such as: potentially the lack of time to answer the questionnaire, or even difficulties with understanding the questions or the terms used in the questionnaire. Conceptualising river basins as complex systems could further engage stakeholders in discussions about river basin problems. This could offer them the opportunity to reconsider the issues and change their understandings and ideas about the water bodies they represent and to increase their actions towards more sustainable ways (Collins et al., 2007; Steyaert and Ollivier, 2007).

The participatory ecosystems services framework for pressure prioritisation presented here has also an "awareness-raising role" (Potschin-Young et al., 2016) as it could also improve river basin

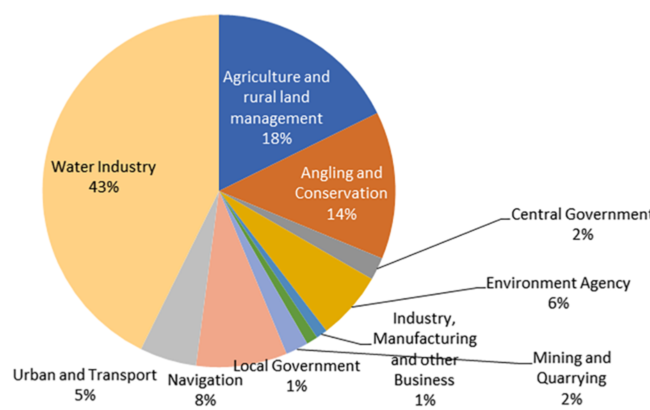


Fig. 7. Percentage of measures attributed to sectors in the 2009 RBMPs of the Broadland Rivers catchment.

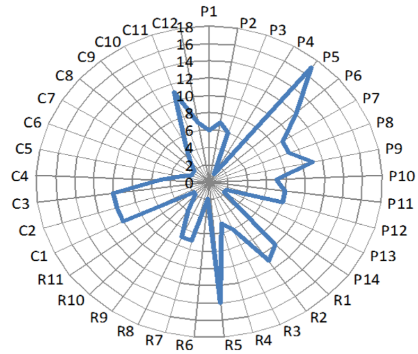


Fig. 8. Vulnerability of the ecosystem services provided by the catchment based on the number of links with pressures as identified by stakeholders.

understanding of managers, experts and stakeholders, a benefit of significant value alone. The round table discussions helped participants to gain a better understanding of the dynamics and relationships within the catchment and see activities and environmental impacts from a "human-in-ecosystem perspective" (Tippett et al., 2005). This in turn leads to greatest benefit of the approach, which is the communication of water body status improvements as yields in services flows and understanding of management responses addressing significant pressures as the way towards higher ecological gains at the basin scale. It also has the potential to create the conditions of a real change in the way the actors see themselves in relation to their environment since during this process they realise the multiple roles each of them has in society.

Acknowledgements

This work has received funding from the European Union's Seventh Programme for research, technological development, and demonstration under grant agreement no. 603629-ENV-2013-6.2.1-Globaqua and the NERC funded project A Novel Framework for Predicting Emerging Chemical Stressor Impacts in Complex Ecosystems, NERC Reference: NE/S000348/1. The Authors would like to thank the Broads Authority for the support in organising and facilitating the workshop and the Broadland Catchment Partnership steering group for their participation.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ecoser.2018.10.007.

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