



# Water Framework Directive programmes of measures: Lessons from the 1st planning cycle of a catchment in England

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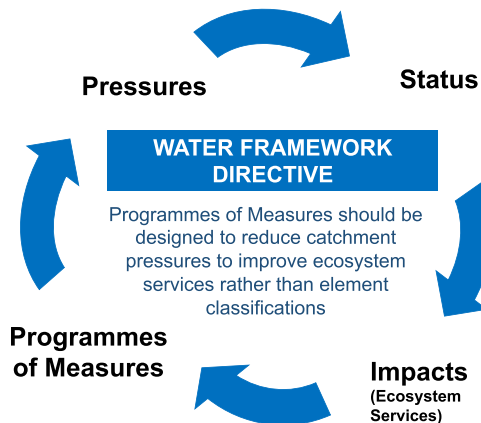
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## HIGHLIGHTS

- The way Cycle 1 PoMs were developed limited their potential to deliver good status
- Targeting classification elements is not the way to overall status improvements
- Sound assessment of pressures and impacts is key to developing effective measures
- PoMs should be developed to target catchment pressures to achieve good status
- Improving ES better than elements classifications when designing PoMs

## GRAPHICAL ABSTRACT



## ARTICLE INFO

### Article history:

Received 16 June 2018  
Received in revised form 30 January 2019  
Accepted 30 January 2019  
Available online 7 February 2019

Editor: Damia Barcelo

### Keywords:

Water policy  
Policy implementation  
Catchment management  
Systems thinking  
Ecosystem services

## ABSTRACT

The European Union's Water Framework Directive (WFD) required Member States to establish programmes of measures to achieve good water status formally by 2015, but on postponing the deadline by two six-year periods, by 2027 at the latest. With many Member States facing problems with developing such measures in the first planning cycle, and limited change in ecological status since the first river basin management plans were reported, we look at the implementation of the Directive in England, where only 17% of the surface water bodies were found at good status in 2015, a reduction of 4% since 2009. Using as a case study the Broadland Rivers catchment, we examine the measures taken for Cycle 1 and changes in the classifications of water body status, to investigate whether the way the measures were developed could have limited their potential to deliver WFD objectives. While the WFD was adopted to succeed and replace management practices targeting individually non-compliant element, findings indicate that little had changed in the way measures were developed. Although considerable progress has been made on the implementation of these measures, the limited progress in improving classifications demonstrates the limits of this approach and further makes the case for what the WFD was introduced for: the harmonised transposition of the Integrated River Basin Management paradigm, as the key for delivering good ecological status.

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## 1. Introduction

The Water Framework Directive (WFD), the European Union's (EU) flagship legislation on water protection, is widely acknowledged as the

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embodiment and vessel for the application of the Integrated River Basin Management (IRBM) paradigm (Bielsa and Cazarro, 2015). It was adopted to succeed and replace traditional management practices predicated upon the command and control paradigm, which looked at pressures in isolation and reduced environmental systems to their constituent elements when setting specific water objectives (European Commission, 2012). Adopting the river basin as the optimal management unit, in line with IRBM paradigm, the Directive 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). Careful observation, interrogation, interpretation, and monitoring is required to understand what is happening, and why, in the river basin system (Fryirs and Brierley, 2009), in order to take actions to improve its state. Under the WFD, River Basin Management Plans (RBMPs) had to be developed, and reviewed on a six-yearly basis, specifying the actions required within each river basin to reach “good status” objectives for water bodies.

Fundamental to RBMPs is evidence from analyses of the characteristics of the river basin, the impacts of human activity, and economic analysis of water use (European Commission, 2000). Understanding the relationship between environmental effects, their causes and measures taken (European Communities, 2003a), the WFD requires Programmes of Measures (PoMs) to be developed as responses to anthropogenic catchment pressures to improve ecosystem state (Voulvoulis et al., 2017). At the centre of each river basin management plan, these measures specify the management activities and strategies to be politically adopted to ensure protection and sustainable use of water. In designing the PoMs, the WFD article 11(1) requires Member States to take into account the previous planning steps. Indeed, the design of appropriate measures should be based on the analysis of the gap between water's current status and ‘good status’. This gap analysis is necessary to understand what needs to be done to achieve the objectives, how much time it will take, how much it will cost and to whom.

The 4th WFD implementation report published in 2015, reviewed progress with the River Basin Management Plans for the 1st planning cycle, and in 21 out of 27 Member States found no clear links between pressures and PoMs. In 23 out of 27 Member States, the gap analysis had not been effectively implemented for the development of appropriate and cost-effective measures (European Commission, 2015a). Member States were asked to step up their efforts to base their PoMs on a sound assessment of pressures and impacts on the aquatic ecosystem and on a reliable assessment of water status (European Commission, 2015a).

In England, despite over 99% of the planned measures having been completed and with the cost of supplementary measures<sup>1</sup> for the 2010–2015 period representing over £90 million of Government funding, there was a decline in the proportion of water bodies that achieved good status or better. There was a 4% decline between 2009 (26%) and 2015 (22%), when 2015 classification results were compared with the monitoring standards and tools used in the 2009 classification baseline (Environment Agency, 2015). However, out of 34,320 monitored surface water elements in 2015, 2697 (7.8%) elements decreased, (38.4% of which moved from High to Good status), 27,481 elements (80.1%) maintained and 4142 (12.1%) elements improved their status, as reported by the Environment Agency (2015a). Similarly, at the EU level in 2015, the overall ecological status/potential of water bodies did not improve since the first RBMPs, with a reduction in the proportion of water bodies in good or better ecological status or potential for surface waters (rivers, lakes and transitional waters). Nonetheless,

50–70% of the classified water bodies had high or good status for several biological quality elements, while only 40% had good or high ecological status or potential, and only 38% good chemical status. For the physico-chemical and hydro-morphological quality elements, more than two thirds of the classified water bodies had at least good ecological status (European Environment Agency, 2018a).

Considering this in light of the issues with the development of PoMs reported earlier, and in view of the many member states evidently continuing with traditional water management approaches when implementing the WFD (Collins et al., 2012; Hering et al., 2010; Liefferink et al., 2011; Nielsen et al., 2013), we investigate whether the lack of improvements in water status could be down to the absence of appropriate measures developed in accordance with the WFD. The WFD requires the identification of significant pressures from point and diffuse sources of pollution, modifications of flow regimes through abstractions or regulation and morphological alterations, as well as any other pressures. ‘Significant’ means that the pressure contributes to an impact that may result in failing to meet the requirements of Article 4 (1) Environmental Objectives (i.e. of not having at least good status) (European Environment Agency, 2018b). Therefore, the identification of significant pressures and their resulting impacts (which in turn lead to reduced status) are critical to the successful development of PoMs. At the European level, a multitude of state-of-water assessments undertaken primarily focusing on the states and pressures of European waters were found to be too narrow in their scope, requiring a shift in focus towards management and measures (European Environment Agency, 2012a). The assessment of the 1st RBMPs by the EU had also shown that none of the 23 Member States assessed had undertaken source apportionment for all impacts and pressures (European Commission, 2015a). These have added to the considerable (and arguably quite justified) scepticism as to the extent to which the Directive has brought about real change from business as usual (Jager et al., 2016).

To investigate if the way PoMs were developed could have limited their potential to deliver WFD objectives, the Broadland Rivers catchment, one of the five study catchments of the EU GLOBAQUA project (Navarro-Ortega et al., 2015), was used as a case study. The catchment is part of the Anglian River Basin District, one of the eight River Basin Districts in England that showed an increase in the number of water bodies not achieving good ecological status between 2009 and the end of the 1st Cycle from 81% to 89% (European Environment Agency, 2018c). The estimated cost for implementing the basic measures for the same period was £114 million annually with an additional cost of £64 million for the supplementary measures (Environment Agency, 2009a), while only relatively small percentages of surface water bodies (11%) achieved good status in 2015. Furthermore, the Broadland Rivers catchment showed no improvements at the end of the 1st Cycle, with 96% of water bodies failing to achieve good ecological status. The number of water bodies classified as good and moderate declined, while the number of those classified as poor and bad gradually increased from 13 and 3 in 2009 to 32 and 4 at the end of 2014 respectively.

## 2. Materials and methods

### 2.1. Study area

The Broadland Rivers catchment is one of the eleven catchments in the Anglian River Basin District situated in the east of England (Fig. 1), and covers an area of 3181.47 km<sup>2</sup>. The largest settlements include the city of Norwich and the seaside towns of Great Yarmouth and Lowestoft. It includes the Broads Executive area, which due to its high density of protected sites has the equivalent management status to a national park (Environment Agency, 2014). There are 93 river water bodies (of which 55 are designated as heavily modified and three artificial), 18 lake water bodies (of which nine are designated as heavily modified and one artificial) and one groundwater body within the Broadland Rivers catchment (Environment Agency, 2009a).

<sup>1</sup> Programmes of measures consisted of compulsory basic measures, including some taken under several directives that pre-date the WFD and other WFD specific, such as controls on water abstraction, discharges, diffuse pollution or the physical alteration of water bodies; and supplementary measures, where those are required to achieve the environmental objectives (European Commission, 2015a).

## The Broadland Rivers catchment

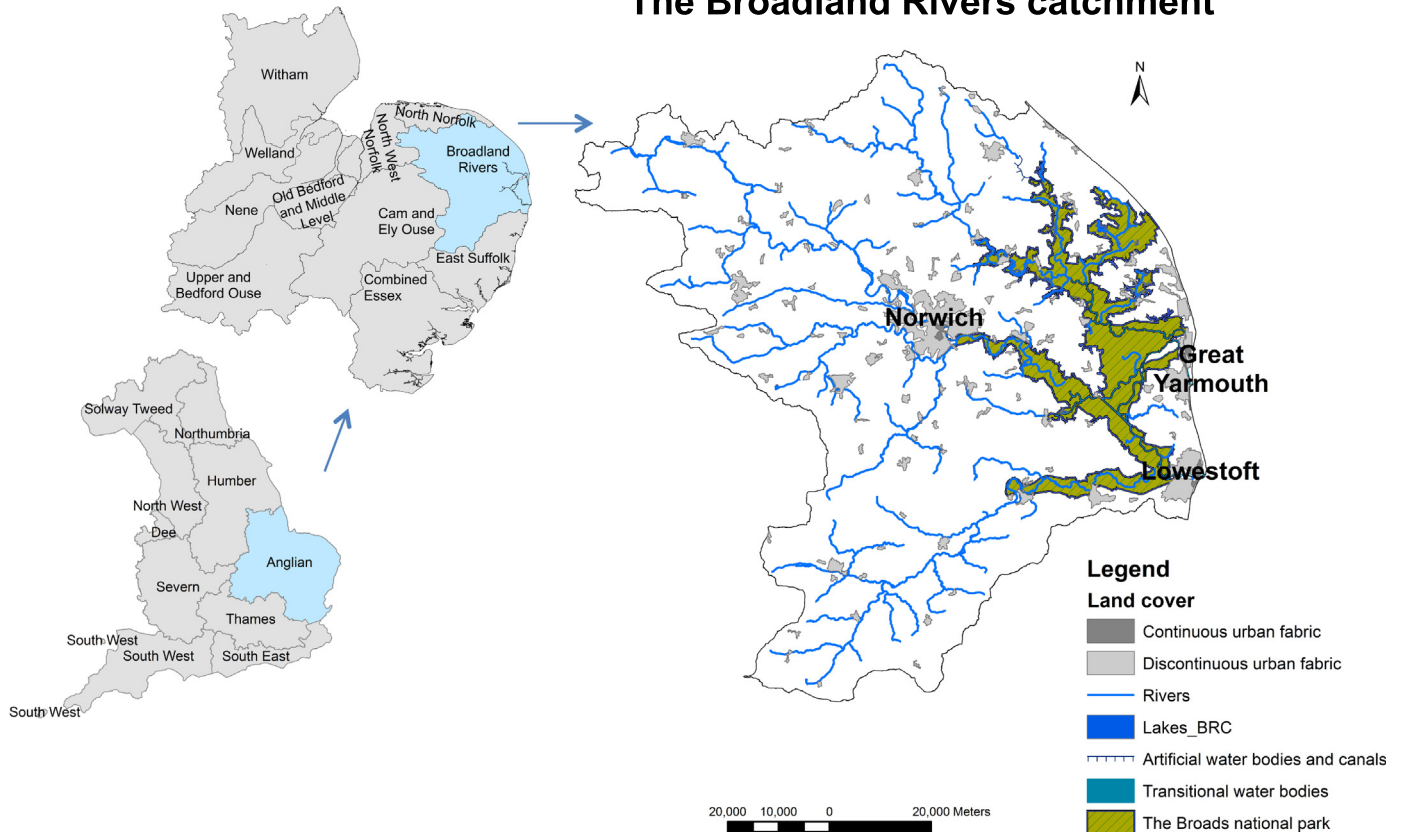


Fig. 1. The Broadland Rivers catchment. Location of the catchment, water body types and The Broads national park.

Eighty-seven per cent of the catchment area is covered by agricultural land, predominately non-irrigated arable land and pastures (European Environment Agency, 2012b). The artificial areas account for 7.56% of the catchment, comprising mainly urban areas but also including parks, industrial, commercial and transport units, mines and dump and construction sites. The remaining area (3.92%) is covered by forest and natural land of which 99% is wetlands and 0.66% is surface water bodies (Fig. 2).

The population of the catchment is approximately 850,000 permanent residents. Agriculture represents the main economic sector and corresponds to 8500 jobs in the wider Broadland area (Environment Agency, 2014). The farming industry generates more than £150 million per year for the regional economy. Diffuse pollution mainly from agricultural sources has been the largest pressure category existing in the Broadland Rivers catchment, with mixed agricultural land, arable fields and livestock farming (pigs, dairy and beef cattle) being the most important sources (DEFRA, 2011). Other diffuse sources are run-off from roads, drainage from houses, commercial areas but also individual small-scale sewage discharges. The area is also a thriving tourist destination, with 7.4 million visitors supporting more than 6000 jobs, spending £469M in The Broads in 2011 (Environment Agency, 2014). Sewage discharges including phosphates from urban wastewater treatment plants have been another key pressure for the catchment's water bodies. There are 30 urban wastewater treatment plants operating in the catchment; 22 equipped only with secondary treatment and eight with tertiary treatment as well (Environment Agency, 2012). More than half of the case study's surface water bodies (68 out of the 111) are artificial or heavily modified. Physical modification has been a critical pressure and has been mainly related to land drainage activities (including operational management and water level management). Other important physical modification pressures have been related to benefits such as recreation, flood protection management and improved

navigation but have also posed barriers to fish migration. Pressures such as abstraction and other artificial flow regulation problems in surface and ground water bodies have also been important (Environment Agency, 2009b). The catchment area is considered water-stressed, receiving an annual average rainfall of less than 700 mm, and under stress in meeting water supply demands for agriculture, potable supply and wildlife needs (Environment Agency, 2014). Many of the catchment's towns and cities have been expanding, adding extra pressures on water resources (Broadland Catchment Partnership, 2014). In addition, several invasive species such as floating pennywort and North American signal crayfish have been found in Broadland Rivers catchment freshwater systems (Environment Agency, 2009b).

### 2.2. Data analysis

A review of the measures developed as part of the 1st Cycle's RBMP for the catchment (Environment Agency, 2010) was undertaken (Supplementary Table S1). The measures were analysed in terms of the "mechanisms" i.e. policy, legal and financial tools employed to bring about the actions on ground (Environment Agency, 2009c), their apportionment to sectors, whether they were basic or supplementary and the year they were planned to become operational.

The aim of operational monitoring is to establish the status of those water bodies identified as being at risk of failing their environmental objectives and to assess any changes in their status from the PoMs (European Communities, 2003b). Therefore, changes in the overall status of water bodies between 2009 and the end of 2014 were investigated as indicative of the effectiveness of the measures. A qualitative summary of the overall WFD status classifications for the Broadland Rivers catchment's 111 surface water bodies over the 1st implementation cycle as baseline conditions was based on data for 2009 provided by the Environment Agency (Environment Agency, 2018). The analysis

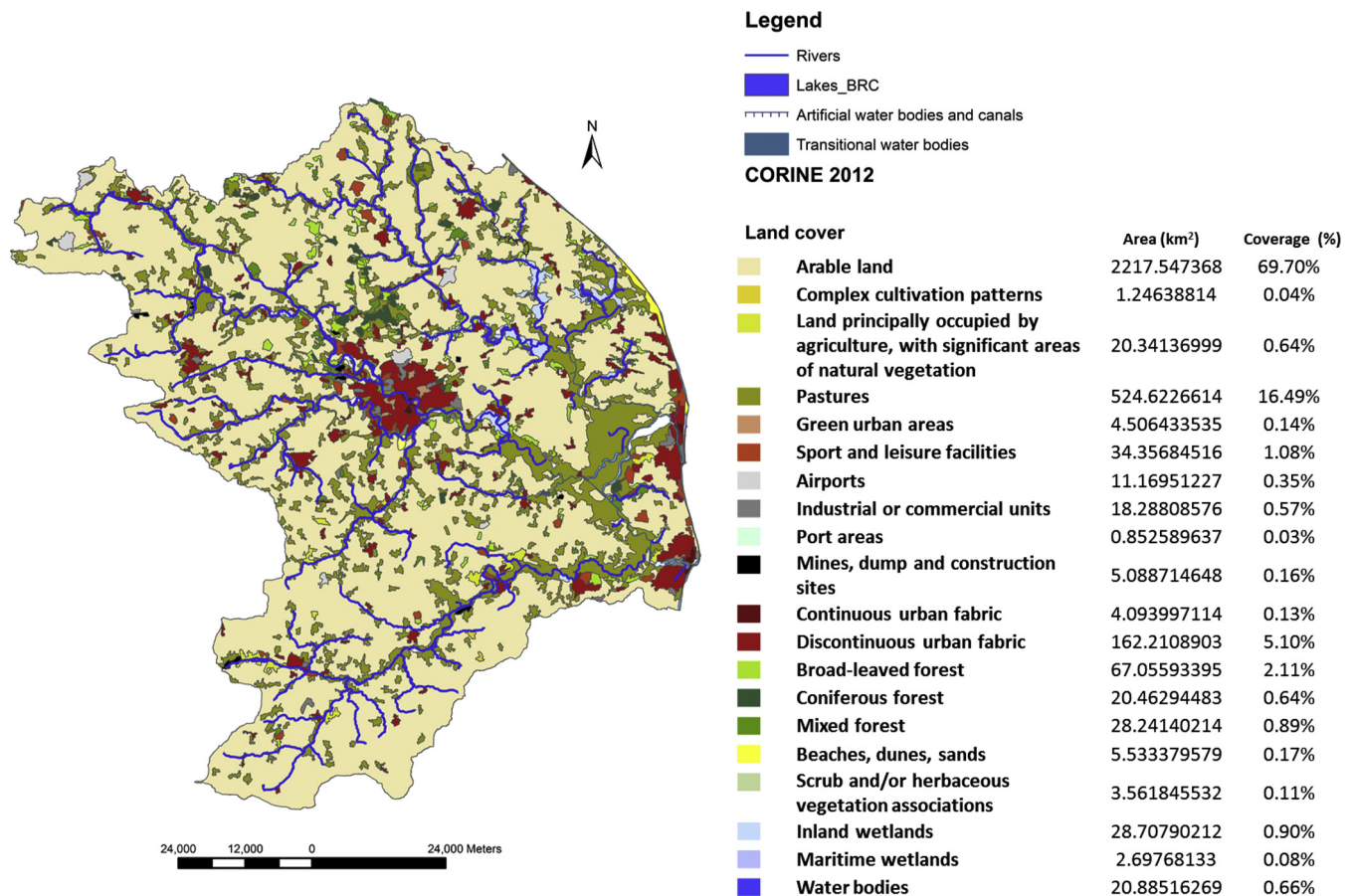


Fig. 2. Land use and coverage in the Broadland Rivers catchment.

employed Environment Agency (2015b) reports with national survey data collected up to the end of 2014 using the water body network, standards and classification tools used in 2009.

### 3. Results

#### 3.1. The programme of measures

A total of 84 (51 basic and 33 supplementary) measures were selected during the 1st implementation cycle (Supplementary Table S1) for the Broadland Rivers catchment. Ranging from hard regulation to softer approaches (Fig. 3), more than half (48) of the measures were *Legislative*, 38 of which used *Environmental permits and statutory requirements*. The vast majority of the remaining measures (32 out of the 36 measures), were locally derived, developed with liaison panels (Environment Agency, 2009c). Most measures from this category (17 in total) were based on *education & targeted information* measures, followed by local *direct actions* and *cooperative agreements* (Fig. 3).

In terms of the time frame for implementation, 19 measures were implemented in 2009, 13 of which were supplementary and six basic. Six were to be implemented between 2010 and 2011 and 38 in 2012. Interestingly, ten basic measures were planned to become operational at the end of the planning cycle and not by 2012 as required by Article 11.7 of the WFD. These measures were related to levels of nutrients in waste water effluent discharges (Supplementary Table S1: Measures 7, 17, 18, 19 and 21), the “Improvement of water company assets” (Supplementary Table S1: Measures 4 and 39) and the “Modification of abstraction licence to ensure no adverse effect on integrity of Natura

2000 sites” (Supplementary Table S1: Measures 70, 71 and 72). The implementation of these interventions during the 1st Cycle is important because they represent the minimum requirements<sup>2</sup> for compliance with the WFD, but also to monitor their effectiveness in addressing pressures in accordance with the adaptive management approach championed by the Directive. Additionally, for other 11 basic measures there was no specific timetable, seven of which were “Schemes to improve discharges” of phosphates (Supplementary Table S1: Measures 5, 8, 9, 10, 11, 12 and 13), one on ammonia (Supplementary Table S1: Measure 20) and three on “treatment of pollutants discharged to groundwater” (Supplementary Table S1: Measure 23, 24 and 27).

In general, measures were mainly found to target the point source pressures coming from the urban wastewater system’s continuous discharges to receiving waters but not intermittent discharges (i.e. combined sewer overflows). Unsewered domestic point source pollution has only been targeted by one measure via provision of information and through educational campaigns to package treatment plant owners (Supplementary Table S1: Measure 37). Only one measure was shown

<sup>2</sup> Basic measures are the minimum requirements to be included in the PoMs (European Commission, 2015a) consisting of:

A) measures associated with the implementation of other Community legislation for the protection of waters (referred to in WFD Article 11(3)a and Annex VI, for example, measures to achieve compliance with the objectives of the Nitrates and Urban Waste Water Treatment Directives) and

B) other WFD-specific basic measures (WFD Articles 11(3) paragraphs b to l) that are required to achieve the environmental objectives. These WFD-specific basic measures are largely administrative and regulatory instruments such as permit regimes, general binding rules, etc. These instruments should enable the authorities to exert control over all activities that can have a significant impact on water bodies and therefore potentially hinder the achievement of the environmental objectives. (European Commission, 2015a).

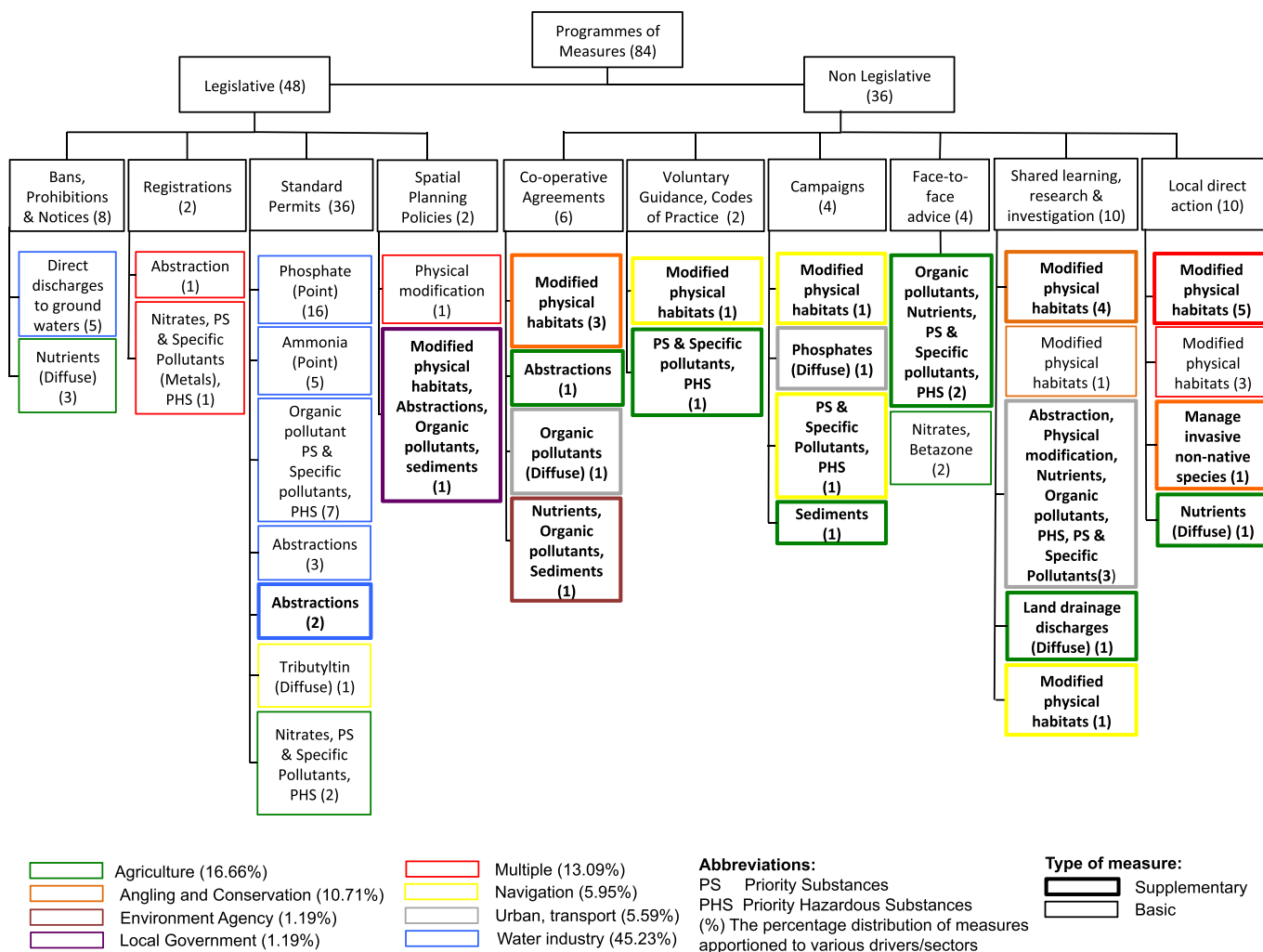


Fig. 3. The 84 measures selected during the 1st implementation cycle for the Broadland Rivers catchment, presented in terms of their type, mechanisms and sectors targeted.

to target industrial discharges by implementing a new regulatory approach (via Environmental Permitting Regulations) (Supplementary Table S1: Measure 47). With regard to invasive species, there has been a locally derived measure targeting pennywort control on River Waveney and the Rockland Broads (Supplementary Table S1: Measure 75), however, its eradication was not achieved due to inherent difficulties dealing with the species (Broads Authority, 2015). Other species such as the North American signal crayfish have not been targeted by measures. Measures delivered through a number of collaborative partnerships within the Broadland Rivers catchment show important steps towards the catchment-based approach requirements (DEFRA, 2014). However, planned improvements of river habitats on Waveney, Upper Bure and Wensum were “not delivered due to lack of funding and appropriate consents” (Broads Authority, 2015).

A number of measures that called for a partnership to “identify core areas for biodiversity” (Supplementary Table S1: Measure 76) or Task and Finish groups and expert panels (Supplementary Table S1: Measures 61 and 65) do not directly manage pressures, but instead call for research that will support management. Twelve measures were investigatory (Supplementary Table S1: Measures 1, 35, 40, 41, 45, 49, 57, 68, 69, 82, 83 and 84) aiming to develop better understanding of the catchment’s pressures and their impacts. For example, one measure referred to mapping of land drainage discharges (Supplementary Table S1: Measure 45) to better assess their impact on water quality and good ecological status. While this

understanding is critical to the development of PoMs, it should have been delivered earlier to allow for measures that are more targeted and focused towards pressures.

In addition, other measures (Supplementary Table S1: Measures 16, 17, 18, 19, 20, 21, 35, 38, 55, 64 and 77) were rather generic lacking essential detail regarding how they were going to achieve pressure reductions and status improvements. For example, one measure referred to the development of a proposed Ecotown, stating only that its implementation should cause no deterioration in the catchment. Similarly, another measure required “All consent processes need to be” WFD-proof “i.e. ensure that all WFD issues are taken properly into account”. With regard to climate change, one measure (Supplementary Table S1: Measure 79) has been applied to lake water bodies only. Overall, a climate change impact sensitivity analysis or “climate check” in support of “selecting actions that are effective, sustainable and cost efficient under changing conditions” required further consideration in the RBMP.

### 3.2. How the PoMs were developed

In the RBMP published in 2009 (Environment Agency, 2009a) it is clear that the PoMs had been based on the 2009 classification and the reasons for not achieving good status that were as identified by Environment Agency staff using monitoring data, their knowledge and their experience of individual water bodies. The approach taken in developing the

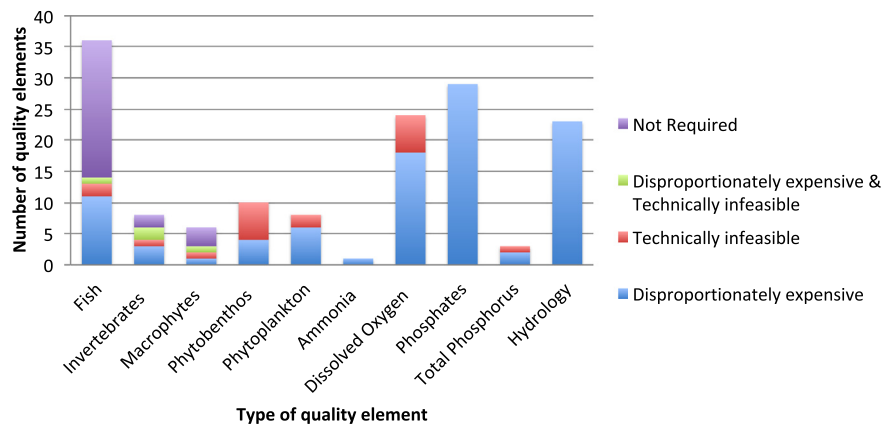


Fig. 4. The justifications in the 2009 RBMP for not targeting selected elements (Environment Agency, 2009d).

measures, aimed to improve classification elements and as stated in the RBMP “Even if good status is not completely achieved, the actions will also lead to improvements to the key elements impacted”. The status of each of the classification elements for 2015 (Environment Agency, 2009d) was also predicted as a result of implementing the proposed measures, indicating the focus on elements (and reasons for failure) rather than catchment pressures. In the cases where the elements were not expected to achieve good status, the reasons for these were reported as either down to technical infeasibility<sup>3</sup> or disproportionate costs<sup>4</sup> or due to natural conditions<sup>5</sup> (Fig. 4). Thirteen water bodies were expected to achieve good overall status/potential by 2015, representing 1% more than 2009 for rivers and 11% for lakes. However, 25% of river water bodies and 56% of lakes were expected to improve classification for at least one element (Table 1).

### 3.3. Evaluating the effectiveness of the measures

The effectiveness of measures was examined by comparing the classifications at the end of 2014 to the 2009 baseline conditions. In 2009, 102 out of the 111 of the catchment's water bodies were classified as below good status, with 86 classified as moderate, 13 as poor and three as bad (Fig. 5A). Out of the 865 WFD classification quality elements monitored, 624 (72%) were classified as good or high while 241 (28%) were moderate or lower. However, over 62% of the biological quality elements (117 in total) were classified as moderate or lower, in contrast to the supporting ones that overall were associated with good or high status (Fig. 5B). From the physico-chemical supporting elements, the total phosphorus (measured in lakes), the phosphates (measured in rivers) and dissolved oxygen were found to fail in 69%, 47% and 31% respectively of the water bodies being measured. With regard to the hydro-morphological supporting quality elements, morphology scored good or high in all water bodies assessed, while hydrology was not found to support good status in 23% of the water bodies' monitored (Fig. 5B).

At the end of 2014, only three water bodies had good overall status, 71 moderate, 32 poor, four bad while one was not assigned a status class (Fig. 6A). Out of the 909 quality element classification results, 590 (65%) were classified as good or high, while 319 (35%)

were moderate or less.<sup>6</sup> However, over 70% of the biological quality elements (141 in total) were classified moderate or less, in contrast to the supporting ones that failed in 25% (178 in total) (Fig. 6B). Apart from invertebrates, which failed less than 22% of the times being classified, the other biological quality elements failed on average 87% of the times. Similar to 2009 classification results, from the physico-chemical supporting elements, the total phosphorus (measured in lakes), the phosphates (measured in rivers) and dissolved oxygen were found to fail in 76%, 44% and 37% of the water bodies being classified respectively. With regard to the hydro-morphological supporting quality elements, morphology was found to support good or high status in all natural water bodies being assessed, while hydrology found not to support good status in the 21% of the water bodies' monitored (Fig. 6B).

Although considerable progress was made with the implementation of the measures selected in the catchment, only five water bodies improved their classification between 2009 and 2014 and without reaching good status (Fig. 7). On the contrary, the overall status of 30 water bodies actually declined. Seventy-five water bodies did not change classification status, most of them (87%) retaining the same classification for the entire period (Fig. 7B).

Comparing classification results between 2009 and the end of the cycle with those expected when the PoMs were selected, it is clear that this approach has not delivered, not only for the overall status of the corresponding water bodies, but even for the classification elements targeted by measures. For example, out of the 34 quality elements expected to improve at least by one class in response to measures (Environment Agency, 2009d), 20 failed to do so, remaining in the same class or even deteriorating (Supplementary Tables S3, S4 & S5).

Evaluating the effectiveness of phosphate-specific measures (Fig. 8A), at the end of 2014 out of the 16 water bodies that these measures were applied, only one (GB105034055881) improved its overall classification and without the element phosphate improving, indicating that PoMs did not target the appropriate catchment pressures (Fig. 9). This is also evident in the case of the five water bodies that deteriorated, as three of them actually improved for phosphate (GB105034045720,

<sup>3</sup> When the pressure is suspected but attributed to a low level of confidence regarding the identification process or understanding their effects.

<sup>4</sup> When site-specific actions that may be deemed expensive due to the lack of evidence or that actions for improvement were happening but the extent of improvement was uncertain.

<sup>5</sup> Not required measures (morphology-sensitive) stands for cases where morphology-sensitive biological elements are predicted to be at less than good status in 2015.

<sup>6</sup> The number of quality elements monitored for the classification of ecological status increased from 865 in 2009 to 909 in 2014. The type of elements used in the classifications in most water bodies in 2014 was also different from the ones reported in 2009, as indicated from the increased number of water bodies monitored for biological quality elements (Fig. 6). In 2014, 67 water bodies were monitored for more biological elements. In 2009, 39 out of the 111 water bodies were assigned an overall status class without having classification results for any of the biological quality elements, while in 2014, were decreased to 19 out of the 110 that were assigned an overall status. This includes the mitigation measures assessment as classification element (corresponding to 68 water bodies). Although not a WFD quality element, they are used as a policy indicator showing the level of implementation of measures for the heavily modified and artificial water bodies.

**Table 1**  
Status objectives for rivers and lakes in the Broadland Rivers catchment from the 2009 RBMP (Environment Agency, 2009a).

Water body type	Rivers		Lakes	
	2009	2015	2009	2015
At good ecological status or potential	8%	9%	17%	28%
At good status overall (chemical and ecological)	8%	9%	11%	28%
Improving for one or more element		25%		56%

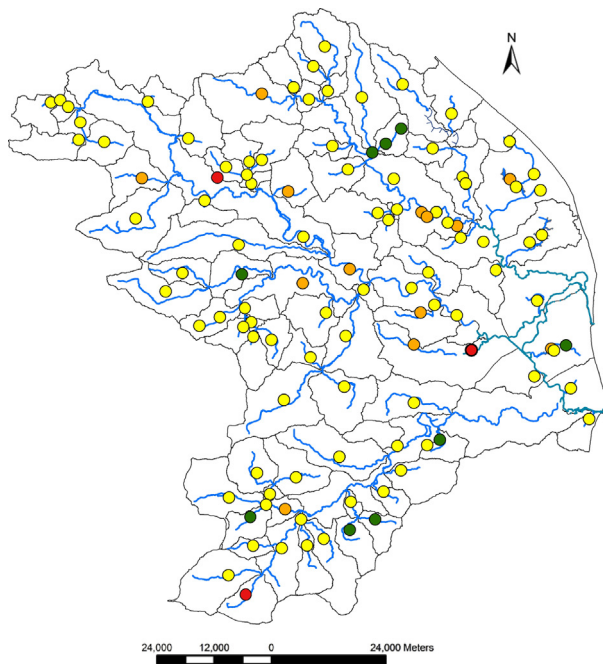
GB105034045900, GB105034051220), one retained its classification (GB105034045880), while the one in which phosphate also deteriorated (GB105034045660), this was not the reason for the deterioration in overall status. Ten water bodies maintained their overall status, of which seven also maintained their classification result for phosphate (but only in two, GB105034051000 and GB105034051130, did the classification of the element match the overall status), two deteriorated for phosphate (GB105034051120, GB105034051190) and one improved for phosphate (GB105034051230) confirming that the PoMs did not target the catchment pressure responsible.

Looking at all water bodies where phosphates or total phosphorus were monitored (93 out of 111), in those that phosphates remained the same (61 in total), 40 water bodies maintained their overall status, while 18 deteriorated (Supplementary Tables S3, S4 and S5). In those where phosphates improved (17 in total), overall status improved only in two (GB105034045650, GB105034051070) but deteriorated in eight and remained the same in seven, indicating again that PoMS did not target the appropriate catchment pressures (Supplementary Tables S3, S4 and S5). In the fifteen water bodies that phosphate

deteriorated, only two deteriorated in overall status, with only one because of phosphate alone (GB105034045860). Even this was not targeted by phosphate-specific measures, further indicating the limitations of this approach.

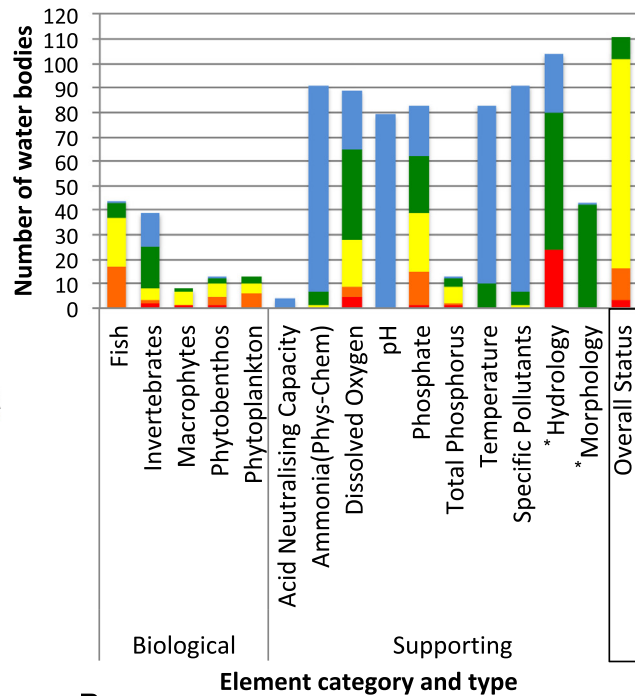
Similarly, looking into the 17 water bodies where fish passages were selected as measures, none of these water bodies achieved good status in 2014. Out of these, only one water body improved its overall status, with two deteriorating and 14 remaining the same (as in 2009). In the one, which improved (GB105034055881), the element fish had improved also, but fish was not the critical element (Fig. 10). Two water bodies deteriorated, one of which deteriorated also for fish. In this case (GB105034045720) fish seems to be the critical element behind the deterioration, potentially indicating that PoMs have not been effective even in improving the elements they targeted. In the 14 water bodies that maintained their overall status, four improved (GB105034050930, GB105034051000, GB105034051100, GB105034055882) one deteriorated (GB105034051020) and nine retained the same classification for fish. In five of these nine water bodies (GB105034045710, GB105034045730, GB105034045780, GB105034050970, GB105034051210), fish was not the critical element, indicating further that selected PoMs have not targeted the pressures responsible for the water body state. In the remaining four water bodies (GB105034050900, GB105034055660, GB105034055690, GB105034055730), fish proved to be the critical element, indicating that PoMs selected have not even managed to deliver the element classifications they were selected for.

Looking at all water bodies where fish was monitored (44 out of 111), in those that fish retained the same classification (21 in total), 17 water bodies maintained their overall status while three deteriorated (Supplementary Tables S3, S4 and S5). From the water bodies where



**A**

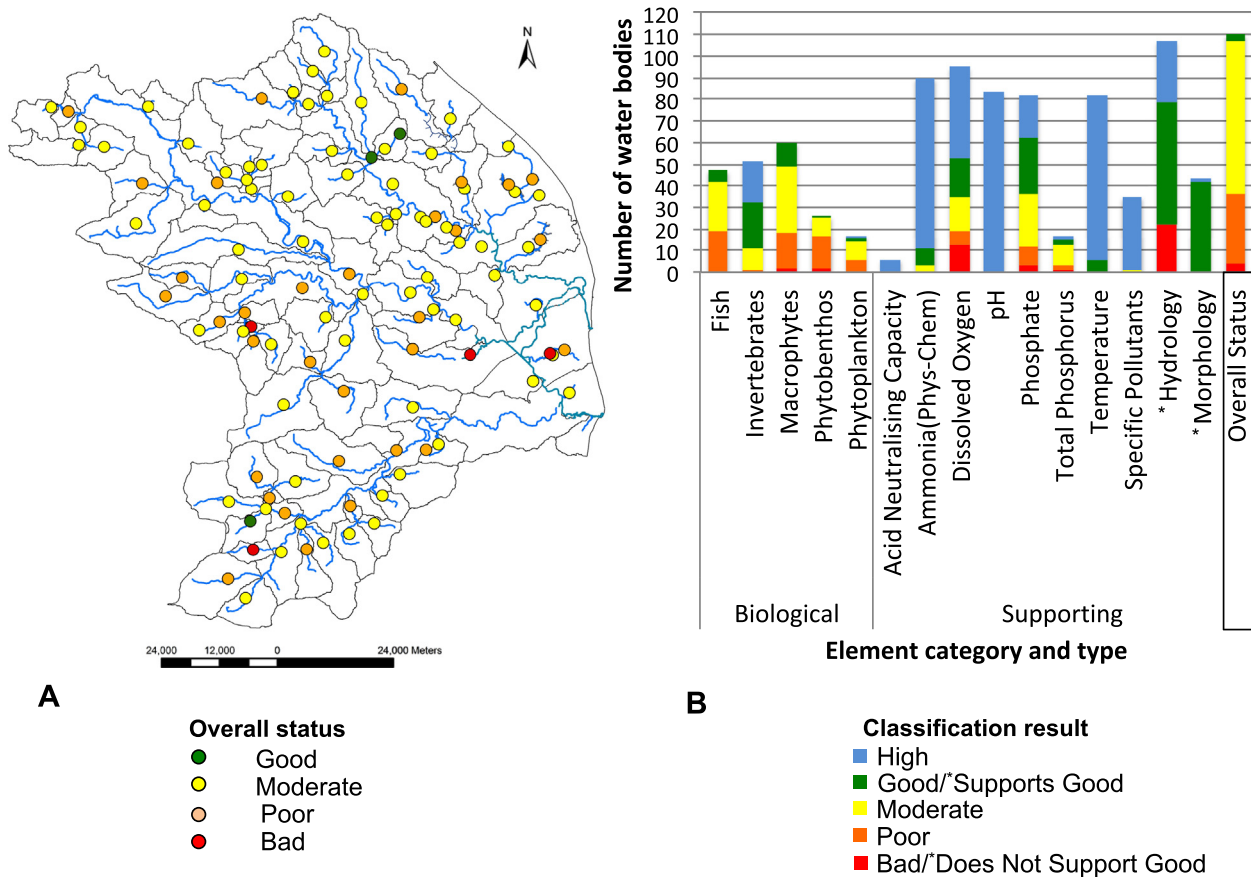
**Overall status**  
 ● Good  
 ● Moderate  
 ● Poor  
 ● Bad



**B**

**Classification result**  
 ■ High  
 ■ Good/Supports Good  
 ■ Moderate  
 ■ Poor  
 ■ Bad/Does Not Support Good

**Fig. 5.** The overall status of the surface water bodies in 2009 in the Broadlands Rivers catchment (A) and the classification results of WFD monitoring quality elements for the water bodies tested for these elements (B).



**Fig. 6.** The overall status of the surface water bodies in 2014 in the Broadlands Rivers catchment (A) and the classification results of WFD monitoring quality elements for the water bodies tested for these elements (B).

fish improved (12 in total), ten retained the same overall status classification (Supplementary Tables S3, S4 and S5). In 11 water bodies where fish deteriorated, the overall status deteriorated in seven, but again only in four of these (GB105034045720, GB105034050920, GB105034051200, GB105034051220) fish was shown to be the critical element in the 2014 classification. This further demonstrates the limitations of the current approach and the need for developing PoMs in line with the WFD paradigm.

Changes in the overall status of all water bodies were further investigated by looking into the classification results of the failing quality elements monitored in 2009 and 2014. The data are summarised into three tables based on whether water bodies improved (Supplementary Table S3), deteriorated (Supplementary Table S4) or maintained their overall status (Supplementary Table S5). In four out of the five water bodies that improved their overall status, this was down to improvements in biological quality elements (Invertebrates, Phytobenthos and Phytoplankton) (Supplementary Table S3). For one water body (GB105034051070), the improvement in classification was down to the additional element (Invertebrates) monitored in 2014, despite the other biological elements retaining their classification status during this period (Supplementary Table S3). For the 30 water bodies where overall status deteriorated, 8 showed reductions in element classifications, while in the remaining 19, this was down to the additional elements monitored in 2014.

#### 4. Discussion

To meet the ecological objectives introduced by the WFD, PoMs are required for all waters to achieve 'high or at least good ecological status'. According to the WFD paradigm, such measures should aim to reduce

catchment pressures to levels that are compatible with the achievement of good status (Netherlands Environmental Assessment Agency, 2008). Status classification is based on several quality elements that aim to indicate the deviation of the system from its state under undisturbed/reference conditions. As the WFD treats the catchment as a well-connected system, the elements (selected according to the WFD), aim to serve as alarms for the presence of pressures.

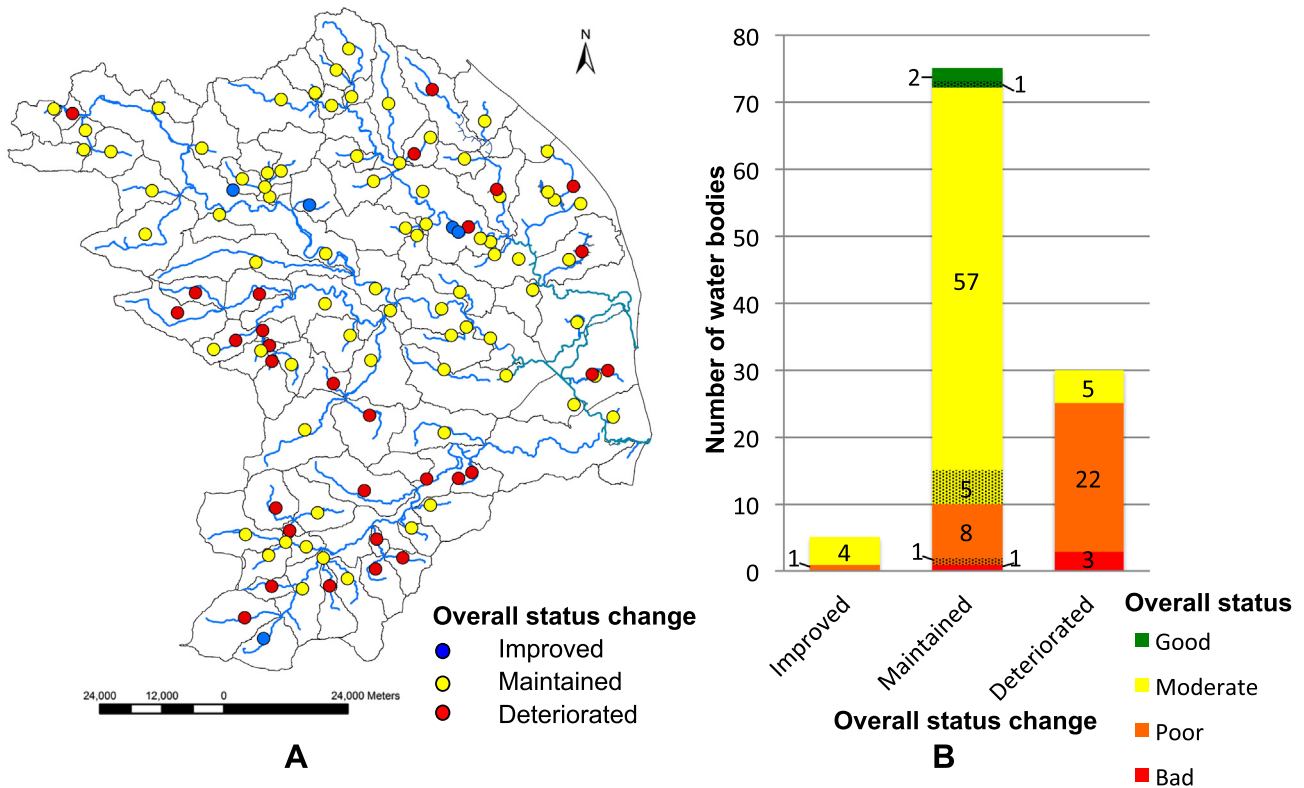
It is not the elements but the pressure–impacts analyses, surveillance monitoring and the gap analysis that should provide the in depth understanding of the catchment needed to develop PoMs targeting the appropriate catchment pressures. Identifying the relevant pressures (i.e. those affecting water quality and quantity) and assessing their impacts are integral to the development of PoMs, the actions necessary to improve water status and achieve the environmental objectives of the Directive (European Commission, 2015a; European Communities, 2003a). Unfortunately, older business as usual practices seem to have created a tendency to target WFD classification elements as a way for delivering WFD objectives.

##### 4.1. Measures that focus on indicator improvements

Not limited to the case study, where PoMs have been developed to address element classification failures, there has been a tendency across Europe (Behagel, 2012), to base management actions on an assumption of linear causality (Hjorth and Bagheri, 2006). This tendency to target WFD classification elements, is often based on the assumption that easy, rapid ecological status improvements, will be achieved by compliance with certain standards for the monitored indicators.

For example, migration facilities have a low effect on other organism groups than fish, and thus there is a high risk to fail the environmental





**Fig. 7.** Changes of water body overall status during the period 2009–2014 (A), and numbers of water bodies that improved, maintained or deteriorated their overall status (B). From those that maintained their 2009 status in 2014, those that retained it throughout this period are shown with solid colours.

objectives of the WFD by solely enhancing river continuity (Kail and Worter, 2011). Such actions enable fish to reach suitable habitats rather than improving the whole system. Another example comes from a National Trust scheme aiming to reintroduce coarse woody debris to a 2 km river stretch in order to address physical modification and diversify in-stream habitat for fish (Native brown trout and river lamprey populations) and invertebrates (Supplementary Table S1: Measure 62). This measure has positive effects for only some fish species. Although at a population level, trout respond positively to increases in the amount of large woody debris (average increase of 87.7%) (Sievers et al., 2017), other species have been found to respond with a reduced density (Jowett et al., 2009). In a recent meta-analysis to exploring how trout respond to key drivers of riparian alteration, Sievers et al. (2017) found some evidence that positive riparian changes may just attract fish (i.e. increase abundance or density) rather than enhance actual population production (i.e. individual size and growth). Restoration measures require a holistic understanding of the interactions and more widespread improvement of habitat quality on the catchment scale rather than targeting relatively short river stretches as Hering et al. (2010) also suggested. Creating favourable conditions for a range of fish species, by “mimicking” natural ecosystems as Behagel (2012) suggests, does not seem to target the anthropogenic drivers behind those pressures.

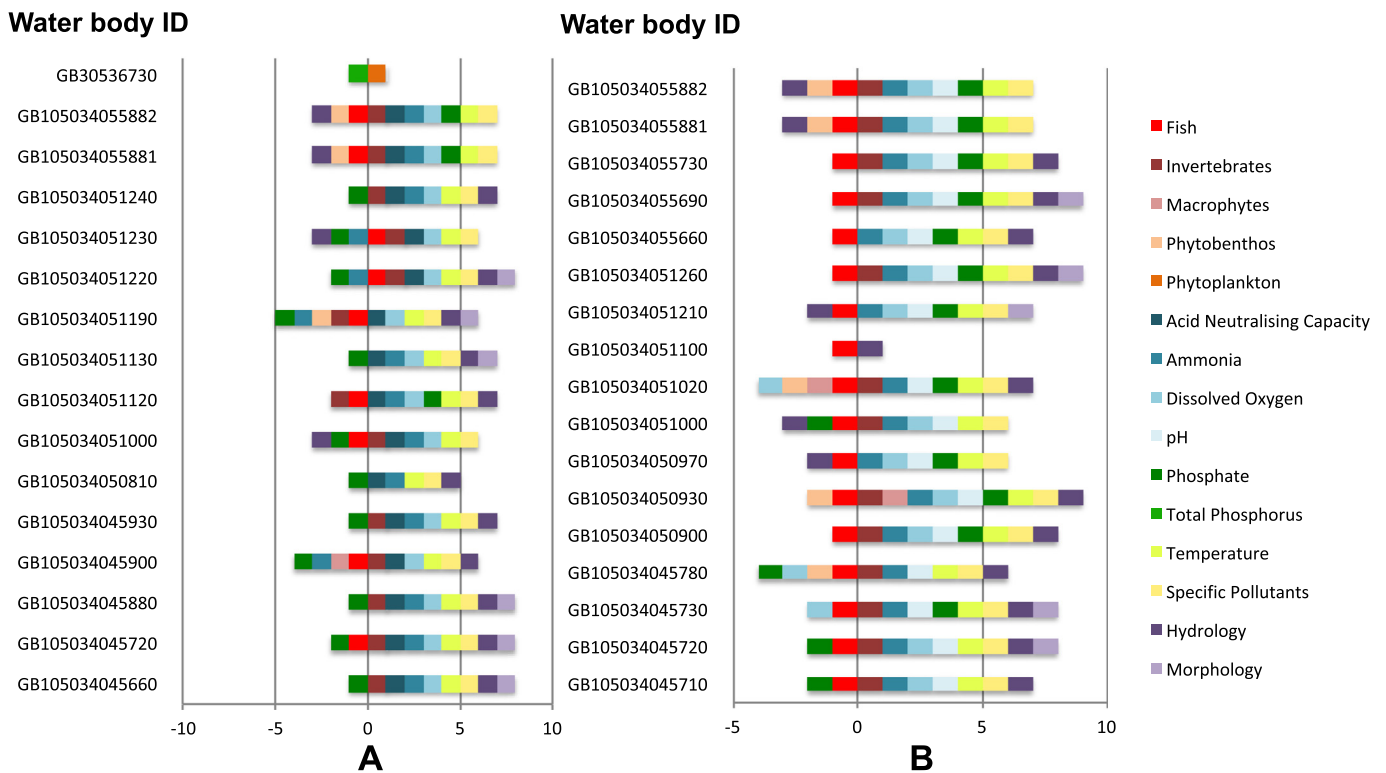
But even when taking a whole catchment approach proposing restorative actions such as the River Wensum Restoration Strategy Project (Supplementary Table S1: Measure 81) in relation to the main Wensum river<sup>7</sup> and three of its tributaries,<sup>8</sup> only one of the water bodies improved and then only from bad to poor overall status. Such measures can help to

restore human-impacted river ecosystems (Thompson et al., 2017), but cannot fully deliver unless the causes are understood and targeted. The Suffolk Broads Living Landscape Project (Supplementary Table S1: Measure 66) is an example of an integrated measure that combines restoration with promotion of “more sustainable low input farming practices” to target sources of fine sediments and nutrient pollution from agricultural land in Waveney river (GB105034045900). More specifically, it is a 30 year project, which has been led by the Suffolk Wildlife Trust with the intention to “apply a landscape scale approach to the management of this part of the Waveney Valley” via “seeking opportunities to reconnect, expand and buffer the areas of highest quality habitat and restoring habitats degraded by either intensive management or neglect.” Despite the improvement in the classification result of fish, the macrophytes deteriorated to poor (the additional element phytobenthos was also assessed as poor) and there has been a deterioration in the overall status of the water body from moderate to poor. Riparian management may effectively reduce diffuse fine sediment pollution, when buffers are sufficiently wide (20–30 m wide), consist of multiple zones (trees, shrubs, grass strips) and accompany the entire stream length impacted by diffuse nutrient and sediment pollution (MARS, 2018). However, an integrated management approach at a wider (catchment) scale would have been more appropriate to prevent fine sediments already entering the stream system from further upstream. Additionally, the measure has not considered that in stream fine sediment loads are also controlled by in stream bank erosion, in particular in lowland regions such as the Broadland Rivers catchment, where surface erosion is fairly low (Lam et al., 2011). The case of the river Waveney (GB105034045900) does not undermine the importance of extensive restoration projects or the other six measures<sup>9</sup> that have been selected, but it demonstrates the complexity of what needs to be

<sup>7</sup> The overall status of GB105034055881 improved from bad to poor (fish and phytobenthos improved).

<sup>8</sup> GB105034055860 and GB105034051110 maintained their overall status (fish improved) and GB105034051140 deteriorated from moderate to poor (due to the additional element monitored in 2014).

<sup>9</sup> The water body has also been subject measures (Supplementary Table S1: Measures 9, 11, 16, 25, 50, 51) the first three on which were related to phosphate pollution and have been effective in improving phosphate classification from moderate to good in 2014.



**Fig. 8.** The 2009 baseline conditions of the water bodies for which A) phosphate specific and B) fish-specific measures, were developed. The x axes represent number of elements that were classified as below good (if negative) and good or high (if positive).

done according to the WFD to ensure the protection and sustainable use of freshwater resources.

Most of European waters are exposed to multiple pressures (Navarro-Ortega et al., 2015) and therefore there is a need to identify and rank the influence of co-existing pressures to implement efficient mitigation measures. Unfortunately, these cannot be prioritised based on single driver and/or response approaches, no matter how much time and effort are invested in characterising these relationships, because of unknown interactions between pressures (Jackson et al., 2016). Yet, not only most biological assessment systems used in European surface waters build on systems that are tailored to detect the impact from specific pressures (Birk et al., 2012; Hering et al., 2010), but also internationally monitoring and management strategies do not consider the relationships and feedbacks between pressures, and their influence on ecosystem properties, despite these being embedded in new statutory regulatory requirements (Jackson et al., 2018). As a result, there is a high risk of/for not correctly detecting environmental degradation in sites affected by multiple pressures, and an even higher one of adopting mitigation measures under the assumption that there is a direct linkage between the element assessed and a specific pressure (Baatrup-Pedersen et al., 2019).

Described as the Sisyphus Complex, when we “become fixated on treating symptoms rather than the root of the problem and so become susceptible to failure” (Hilderbrand et al., 2005), the focus has been on improving element classifications. This is also captured by the Goodhart's law, an adage named after economist Charles Goodhart, which can be stated as: “When a measure becomes a target, it ceases to be a good measure”. One way in which this can occur is when the anticipation of the effect of a policy can often result in taking actions, which alter its outcome. Instead, the improvement in element classifications results should not be perceived as the end point when PoMs are selected, but rather as something that happens as a side effect when catchment pressures are reduced and the overall state of the ecosystem improves.

#### 4.2. Not targeting all pressures and sources

Considering the link between pressures and system state, significant catchment pressures must be tackled to address the gap from the current status to good status. A good example comes from phosphates where large differences in the percentages of phosphate pathways targeted by measures have been observed between point sources of phosphates and diffuse sources (including arable fields, mixed agricultural land and pig fields). The strong focus of the current approach on easy technological fixes without addressing the relationship of either the perceived problem, or of the proposed solution, to catchment-scale ecosystem functioning (Everard and Powell, 2002), has in fact left diffuse phosphate pollution largely untargeted. For example, the Wensum tributary (GB105034051120) was found to be managed with a scheme to improve discharges (Supplementary Table S1: Measure 15) in 2012 and yet to deteriorate for phosphates in 2014, while various studies (Cooper et al., 2015; Outram et al., 2014) suggest that arable topsoil, agricultural field drains, stream channel banks and road runoff were the likely sources that should have instead been targeted. Cooper et al. (2015) suggests that developing mitigation measures that target agricultural field drains, can be important for controlling the in stream concentration of reactive phosphorus, while Taylor et al. (2016) found that introducing buffer strips of 2 m and 6 m width to arable land was the most effective mitigation option that could be applied to reduce losses of total phosphorus, achieving reductions of 12.2% and 16.9%, respectively. This tendency to plan actions mainly for point sources from heavily regulated sectors such as the water industry has been common to whole England and Wales (European Commission, 2015b). The European Commission attributed this phenomenon to the uncertainties associated with the detailed knowledge of sources and pathways, which in turn compromised the design of measures that would be feasible and effective, particularly at a detailed site-specific level (European Commission, 2015b). Measures included in the 1st RBMPs in England and Wales were criticised for focusing on actions planned for other drivers,

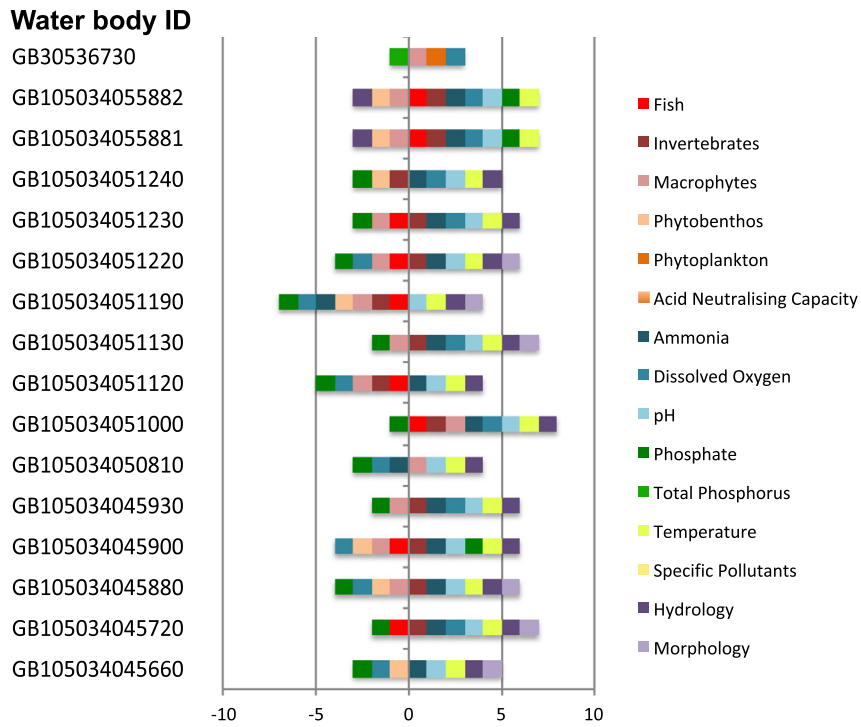


Fig. 9. Classification results of water body monitoring elements following phosphate-specific measures (2014). The x axes represent number of elements that were classified as below good (if negative) and good or high (if positive).

national measures, and locally targeted actions to control pollution (European Commission, 2015a) leading to end of pipe solutions rather than “source control” measures (EurEau, 2018).

Although the achievement of good status might take more time in some water bodies, which is the reason the WFD allows Member States to rely on exemptions on the basis of natural conditions and extend the

deadline up to 2027 or beyond, it could also be the nature of the measures selected requiring more time to work (62% of the measures targeting diffuse pollution from agriculture were mainly advisory services) that could explain the lack of improvements at the end of the cycle. During the 1st Cycle, diffuse pollution from agriculture significantly affected 47% of surface water bodies and 30% of groundwater

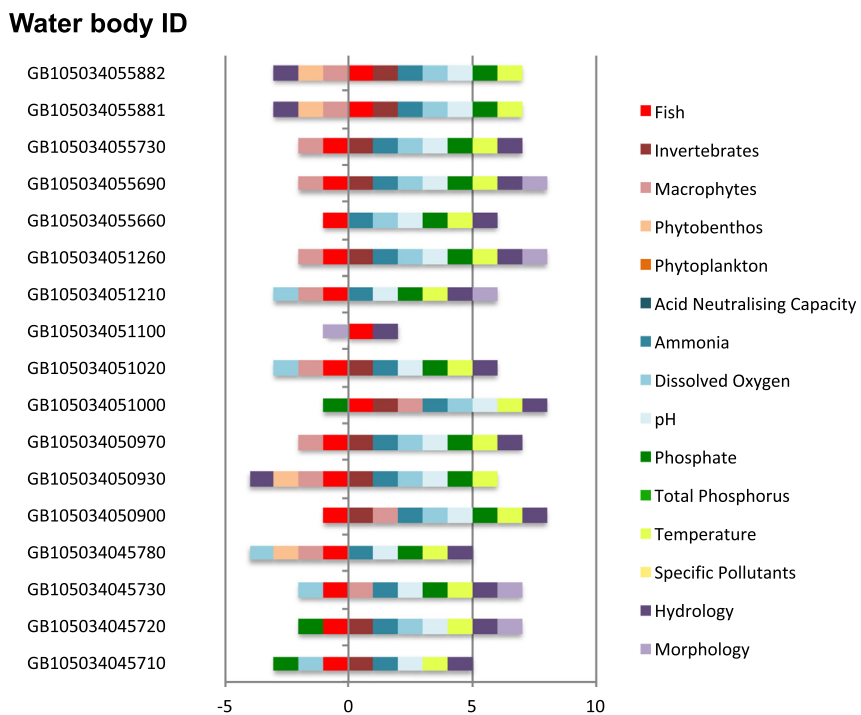


Fig. 10. Classification results of water body monitoring elements following fish-specific measures (2014). The x axes represent number of elements that were classified as below good (if negative) and good or high (if positive).

bodies across the EU, while for the UK these numbers were 61% and 60% respectively. However, there has been a gap of basic measures to control agricultural pressures including lack of measures to address phosphate and nitrates emissions outside nitrate vulnerable zones established under the Nitrates Directive, while supplementary measures reported in agriculture were largely voluntary (European Commission, 2013 & 2015a). Instead, advisory services offered to farmers normally need to be carried out over a relatively lengthy period to be effective. Flexible approaches at farm level can increase farmers' ownership and level of engagement but can only bring results if accompanied by clear environmental objectives and targets coupled with effective advice and support to the farmers to select and implement the right measures, stricter enforcement mechanisms and accurate nutrient management planning (European Commission, 2018).

#### 4.3. Lessons and recommendations for improving measures and monitoring

The link between classification, the pressures to be managed and the development of measures is complex, not straightforward and by no means linear. Improving water quality historically was based on specific parameters monitored at the point of discharge to control the emissions of individual pollutants beyond specified limits (Petersen et al., 2009; Porto and Lobato, 2004). Although this approach had been effective, it was in the 1980's, when policy makers started to question it, as well as the potential of water quality objectives to improve the ecological quality of water bodies. Its limitations when considering the complexity of ecosystems or the interactions and trade-offs at different scales (Müller-Grabherr et al., 2014), and the need for integration, coordination and, for systems-level, decision-making in water management problems, led to the introduction of the WFD, the adoption of a more systems-based, much broader view of the dynamic nature of freshwater resources and the short-term and long-term benefits they provide.

While the WFD classification process can capture stressors related to anthropogenic impacts on streams, it however does not reveal specific causes of why sites may fail to reach good ecological status and consequently does not point at specific mitigation measures (Baattrup-Pedersen et al., 2019). Developing PoMs requires understanding of the critical linkages among pressures and impacts and knowledge of what can be done to deliver ecosystem benefits (Voulvoulis et al., 2017). PoMs should target pressures in order to deliver ecological improvements based on in depth understanding of the catchment as a system, partially derived from the pressure–impacts analysis and the surveillance monitoring both critical steps of the planning process (European Communities, 2003a). If catchment pressures as causes of deterioration are not identified and managed, any attempt at delivering ecological improvements could be compromised. For example, many measures developed in the catchment were found to be investigatory, which indicates gaps or incomplete pressures and impacts analyses, as Kail and Worter (2011) also reported for cases in Germany. This is in line with the findings of Baaner (2011) who analysing the PoMs of river basins in Denmark, Sweden and Norway, suggested that activities concerning monitoring, mapping and development of knowledge should have been embedded primarily in the characterization processes, in line with Article 5.

Designing PoMs is an iterative process involving the repetition of a series of steps involving the participation of stakeholders and political decision-making. It is the process of assessing and identifying what to manage (which catchment pressures and how) that is the main mechanism for developing the necessary measures and delivering the river basin management plan. An important precondition for successful preparation and implementation of this is the establishment of clear relationships between WFD objectives, operational environmental quality objectives for the water bodies and the associated maximum permitted pressures. The determination of the maximum pressures that the individual water bodies can tolerate if they are to fulfil the WFD objective of “good status” is critical to the development of PoMs

(BERNET CATCH, 2006). To prevent deterioration in the quality of waters and to achieve good water status, water resources should be managed through the integrated management of the wider environmental system (Bone et al., 2012; Chon et al., 2010; Giakoumis and Voulvoulis, 2018a). Although, the water body is the “assessment unit”, the river basin is the “management unit” for the WFD. Scale issues should also be considered when planning measures for multiple pressures, as one pressure (e.g. atmospheric deposition; climate change) might evolve on a completely different spatial scale to another (e.g. point source pollution) and the choice of mechanisms and actions should reflect the spatial scale of pressures.

Novel monitoring techniques and new indicators of ecosystem state should be developed to facilitate this. Although some new bio-monitoring tools, sensitive to multiple stressors, network-based approaches that can detect both initial impacts (via bacterial biosensors) and predict wider food web and ecosystem consequences as well as ecosystem service indicators are currently being produced (O'Gorman et al., 2017; Thompson et al., 2018 and 2016), significantly more needs to be done. These tools require interdisciplinary research, knowledge integration and collaboration, capable of dealing with the ecological complexity of freshwater ecosystems (Jackson et al., 2018) to support management efforts. In any case, the assessment of pressures and impacts is critical and must be seen as an on-going process within the RBMP cycle, kept up to date to enable timely, appropriate and effective water management. Developments in Natural Capital accounting offer opportunities to further support this process, for example with source apportionment, improving catchment understanding on drivers, pressures and the link between them. The traditional Driver-Pressure-State-Impact-Response (DPSIR) framework could be modified to integrate ecosystem services to support the assessment of state and impacts and the links between them (Giakoumis and Voulvoulis, 2018b; Grizzetti et al., 2016; Pistocchi et al., 2017; Terrado et al., 2016; Vlachopoulou et al., 2014). By focusing on ecosystem services (i.e. state and change), rather than simply on water status (e.g. ecological status), there could be benefits both to the development of PoMs and stakeholder acceptance and commitment to policy decisions (Howarth, 2009). The selection of best measures at river basin level can be based on the optimisation of ecosystem services using a cost-benefit analysis approach or multi-criteria assessment of ecosystem services using stakeholders' input. These assessments could also complement the analysis of PoMs presented here, to allow Member States to improve both the development of PoMs for the next cycles and their implementation potential to deliver water quality improvements. Although assessments of the effectiveness of the 1st Cycle PoMs have rarely been carried out in most of EU Member States, we hope that the analysis presented here, will encourage water managers to reflect on the way PoMs were developed for Cycle 1, and on how better understanding of pressures and their impacts to the river basins, potentially to the delivery of ecosystem services, could improve both the development and implementation of measures to deliver WFD objectives and the desired water quality improvements in the next cycles.

## 5. Conclusion

While the WFD was adopted to succeed and replace traditional management practices that looked at pressures in isolation while reducing environmental systems to their constituent elements when PoMs were developed, its current implementation shows little to have changed. Specific monitored parameters are used to develop PoMs that control pressures, under the assumption that managing individually the non-compliant elements could lead to an overall improvement in ecological status. The classifications at the end of the 1st planning cycle have demonstrated the limitations of this approach, further making the case for what the WFD was introduced for: the harmonised transposition of the IRBM paradigm, as the key for delivering good ecological status.

## Acknowledgements

This work has received funding from the European Union Seventh Framework Programme for research, technological development, and demonstration under grant agreement no. 603629-ENV-2013-6.2.1-Globaqua. We would like to thank also the Environment Agency for the provision of data licensed under the Open Government Licence v3.0. for public sector information.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.scitotenv.2019.01.405>.

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