Alien species and the EU Water Framework Directive: a comparative assessment of European approaches

Philip J. Boon · Stacey A. Clarke · Gordon H. Copp

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Abstract Although the European Water Framework Directive (WFD) does not refer explicitly to alien species (AS), it is clear that invasive AS (IAS) are considered a pressure on WFD water bodies. This article discusses the results of a questionnaire sent to all EU Member States, demonstrating considerable variability in the way that AS data are used in implementing the WFD. Responses were received from 18 countries. Most countries define AS in a similar way, but there are discrepancies, for example, in the use of historical dates to determine whether or not a species is

considered non-native biogeographically. All countries have developed lists of AS, but those specific for WFD assessments are only used at present in the UK and the Republic of Ireland. Few countries monitor AS specifically for the WFD, or assess the risk that IAS are likely to cause water bodies to fail to achieve Good Ecological Status. This article discusses the results of a questionnaire sent to all EU Member States, demonstrating considerable variability in the way that AS data are used in implementing the WFD. Perhaps the most important difference among countries is in the use of AS data in WFD classification; many countries assume that classification methods take account of the impacts of AS, whereas separate ‘downgrading’ procedures that modify classification based on the presence and impact of IAS are used more rarely. New approaches merit further consideration, such as the application of ‘biopollution indices’ to highlight the impact of AS without affecting WFD classification. Alien species feature to some extent in river basin management plans, but more emphasis on action is needed. In addition, closer links with the Marine Strategy Framework Directive and with the 2014 EU Regulation on alien species are required to improve the control of aquatic AS.

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P. J. Boon
The Freshwater Biological Association, The Ferry
Landing, Far Sawrey, Ambleside, Cumbria LA22 0LP,
UK
e-mail: pboon@fba.org.uk

S. A. Clarke · G. H. Copp (✉)
Centre for Environment, Fisheries and Aquaculture
Science, Pakefield Road, Lowestoft NR33 0HT, UK
e-mail: gordon.copp@cefas.co.uk

G. H. Copp
Department of Life and Environmental Sciences,
Bournemouth University, Poole, UK

G. H. Copp
Faculty of Biology and Environmental Protection,
University of Łódź, Łódź, Poland

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Introduction

There are numerous well-documented cases of alien (non-indigenous, non-native, locally-absent) species becoming established both in marine and freshwater systems—in rivers and streams, lakes and ponds, estuaries, and in coastal and marine waters (Gherardi et al. 2009; Katsanevakis et al. 2013; Nunes et al. 2015). The adverse impacts on native biodiversity of alien species (AS) that become invasive are many and varied, including displacement of indigenous species through competition or predation (Findlay et al. 2015; Truhlar et al. 2014), structural damage to aquatic habitats (Loureiro et al. 2015), and loss of genetic integrity (Gederaas et al. 2012). The threats posed by invasive AS (IAS) to native biota, ecosystem function and services, and resulting economic impacts (Tricarico et al. 2016) are therefore global in character (Díaz et al. 2019).

Despite these threats, it is only comparatively recently that legislation has been passed at a European level to tackle the problems of IAS. For example, the principal piece of EU legislation governing the management of freshwater and coastal environments, the European Water Framework Directive (WFD), does not specifically mention AS or IAS (Council of the European Communities 2000). The potential impact of AS on the classification of inland water bodies under the WFD has long been recognised (e.g. Noble et al. 2007; Schmutz et al. 2007; Shine et al. 2008) and has been reiterated in a recent set of recommendations that AS be systematically incorporated into WFD assessments because of their potential to alter significantly aquatic ecosystem structure and function (Filipe et al. 2019). The omission of AS in the WFD was rectified for the marine environment in the enactment of the Marine Strategy Framework Directive (MSFD), which makes explicit reference to ‘non-indigenous species introduced by human activities’ as one of the 11 ‘descriptors’ used to assess ‘Good Environmental Status’ (Council of the European Communities 2008). Concurrently, the European Union passed ‘Council Regulation No. 7087/2007 of 11 June 2007 concerning use of alien and locally absent species in aquaculture’ (Council of the European Communities 2007), which is applicable to all aquatic species used in aquaculture and for stocking to enhance wild stocks, with the exception of species used in the ornamental trade only.

The urgent need to counteract IAS was further recognised in Target 5 of the EU Biodiversity Strategy (European Commission 2011): ‘By 2020, Invasive Alien Species (IAS) and their pathways are identified and prioritised, priority species are controlled or eradicated, and pathways are managed to prevent the introduction and establishment of new IAS’. This was followed in 2014 by enactment of EU Regulation No. 1143/2014 on the Prevention and Management of Invasive Alien Species (Council of the European Communities 2014), hereafter the ‘EU Regulation’, which sets out a series of measures for preventing the introduction of AS, for their early detection and rapid eradication, and for management to halt the further spread of invasive species. These measures are directed specifically at an initial list of 37 species of ‘Union concern’, which was approximately half the number identified as potential future invaders in a horizon-scanning study (Roy et al. 2019), with 20 of the 37 species being found in or around water.

A principal environmental objective of the WFD, which was developed from an earlier proposal for an EC directive on the ‘ecological quality of surface waters’ (Boon et al. 2010), is to achieve ‘Good Ecological Status’ (henceforth ‘GES’) in ‘water bodies’ (rivers, lakes, transitional waters and coastal waters)—originally by 2015, although targets for restorative action have since been revised for achievement by 2021 and 2027. The WFD set in place for the first time a statutory process of river basin planning aimed at maintaining or improving the quality of surface waters, thus widening the scope of aquatic ecosystem assessment and management well beyond previous limits. Good status is the second point on a five-point scale from ‘high status’ to ‘bad status’, measured with reference to a suite of quality assessment parameters that encompass water chemistry, hydromorphology (a combination of hydrological and morphological attributes) and ‘biological quality elements’ (BQEs), which include phytoplankton, macrophytes and phytobenthos, benthic invertebrates and fish. Although AS are not specifically mentioned in the text of the WFD, Annex II, Sect. 1.4 identifies pressures, including ‘other pressures’—a category under which AS could be considered relevant (Olenin et al. 2007). Annex V, Sect. 1.2 of the WFD defines high status for each BQE, and includes the statement that ‘the taxonomic composition corresponds totally or nearly totally to undisturbed conditions’. Departure

from naturalness is therefore a key principle of the WFD, and it is reasonable to suggest that the presence of AS, by definition, undermines naturalness. Alien species are also mentioned in some of the documents describing the European Commission's Common Implementation Strategy, such as guidance on pressures and impacts (IMPRESS; European Communities 2003).

Most of the pan-European work on the WFD has so far focused on 'inter-calibration'—the procedure described in article 1.4.1 to ensure consistency across Europe for the boundaries between high and good status, and good and moderate status. This work has been undertaken by ECOSTAT, the European Commission's working group on ecological status. However, the relevance of AS in WFD implementation had received comparatively little attention at a European level until a series of three workshops held in 2006 (Brussels), 2008 (Bordeaux) and 2009 (Ispra). The first of these was organised by the Alien Species Group (ASG)—a group set up by the UK Government's Technical Advisory Group (UKTAG) on the WFD soon after the transposition of the WFD into UK law, comprising the statutory conservation and environment agencies in the UK together with representatives from other government organisations. The second and third workshops were held under the auspices of ECOSTAT.

The outputs from the second workshop were reported to ECOSTAT members in October 2008, who agreed to obtain further information from Member States through a questionnaire, distributed via ECOSTAT in February 2009. The results were summarised at the meeting of ECOSTAT in April 2009 and published by the European Commission (Vandekerkhove and Cardoso 2010).

A detailed discussion on the results of the questionnaire took place at the third workshop in June 2009—an event whose other main theme was to share views on the role of AS in classifying ecological status. By then, classification data for specific WFD water bodies and on AS distributions were available for analysis, and this formed a project carried out by the European Commission's Joint Research Centre at Ispra, Italy (Vandekerkhove et al. 2013). The conclusions of this work, together with the absence (for many

years) of detailed discussions between specialists on aquatic AS, prompted renewed discussion and circulation around Europe of a new questionnaire.

The aims of the present study were to: (1) summarise the results of the questionnaire; (2) identify areas where more work is needed; (3) consider the links between work on AS for the WFD and other European legislation; and (4) discuss how to increase consistency of approach among Member States in a way that will help to reduce the threats to aquatic ecosystems from IAS.

Methods

Devised by the ASG in the UK, the questionnaire comprised 22 questions, i.e. 14 main questions plus subsidiary questions (Table 1). This questionnaire was based on the one distributed to Member States by ECOSTAT in 2009 (Vandekerkhove and Cardoso 2010), but with some amendments and additional questions. It was sent to all those attending the ASG workshop held in Peterborough, UK, in 2015, and later distributed more widely by ECOSTAT to all members of the group.

The questionnaire addressed five broad areas:

- (A) Clarification of the scope of work on AS and the WFD (Q1–5b)
- (B) Compiling lists of AS for use with the WFD (Q7a, 7b)
- (C) Monitoring AS (Q8a–8d)
- (D) Use of data on AS for risk assessment of water bodies (Q6) and for classifying WFD ecological status (Q9–13)
- (E) AS and WFD river basin management plans (Q14a, 14b)

Some of the questions required a simple 'Yes/No' answer, with others needing some brief explanatory text. Each contributor was also asked to supply their name, affiliation, role in their organisation, and a short description of their involvement with work on AS and with the WFD.

During the analysis of the results and the production of this manuscript all recipients of the questionnaire were contacted and given an opportunity to update and

Table 1 The content of the 2016 questionnaire on alien species and the WFD. Subsidiary questions (to provide further information regarding a previous question) are given in italics

No.	Question
1	How are 'alien species' defined in your country?
2a	Are translocated native species considered as alien species?
2b	<i>If 'yes', please give some examples</i>
3	Are casual alien species considered as alien species?
4	Are species that have expanded their range as a result of climate change considered as alien species?
5a	Are all introduced species considered as alien species, regardless of the date of introduction? If not, what cut-off date is used?
5b	<i>Is it useful to apply a historical date as one of the criteria to determine non-nativeness of a species?</i>
6	Do you use data on alien species when assessing whether particular water bodies are at risk of failing their WFD environmental objectives?
7a	Are there lists of alien species available in your country that can be used for WFD purposes?
7b	<i>Do you consider only those alien species known to be invasive, or all alien species?</i>
8a	Are there monitoring programmes specifically designed for the detection of alien species or the expansion of their ranges?
8b	<i>Would the routine monitoring programmes used in your country detect plants, invertebrates and fish in each of the WFD surface water categories (i.e. rivers, lakes, transitional waters, coastal waters)?</i>
8c	<i>If 'yes', what action is taken when an alien species is detected?</i>
8d	<i>Has the new EC Regulation introduced in January 2015 affected the extent of monitoring or the species being monitored?</i>
9a	Are alien species explicitly taken into account in ecological status assessment and classification under the WFD?
9b	<i>If the answer is 'no', what are the reasons for this position?</i>
10	Under which of the following four options does the current WFD ecological status assessment fall in your country? If none of the four options below applies, please explain the approach taken: Option 1: A water body is classified using pressure-based classification tools, and then the classification is modified in an additional step based on alien species, with the final result being either high, good, or less than good status Option 2: This option is similar in principle to option 1, but it is based upon quantitative assessments linking the abundance or percentage cover of alien species to the five WFD quality classes Option 3: The classification process for each biological quality element is undertaken as normal without any additional assessment made of alien species, on the assumption that the classification tools can adequately detect any impacts caused by alien species Option 4: Water bodies are classified without explicitly taking account of alien species. A separate 'risk assessment' for alien species is undertaken, by including various 'biopollution' indices for the risk and impact of alien species. This risk assessment is then published alongside the water body classification and used to influence the programmes of measures
11	Please state why the option given as your answer to Question 10 was chosen
12	Which option would be the most appropriate considering both feasibility and usefulness in ecological status assessment and classification under the WFD?
13	Are the classification tools used to make WFD assessments in your country 'pressure-based' or 'community-based'?
14a	Are there specific measures identified in the WFD river basin plans in your country for controlling alien species or preventing their spread?
14b	<i>If 'yes', please provide web-links to the river basin plans</i>

Detailed responses are given in supplementary Table S1

correct anything contained within the answers given at the time, to ensure that it still remained consistent with the countries' understanding, methods and regulations.

Results

Eighteen countries returned the completed questionnaire (Table 2), with two-thirds compiled by 2–4 colleagues, resulting in 42 participating contributors in total. For some countries, separate responses were given according to habitat and taxa (Italy),

geographical location (Spain) or devolved administration (UK); this yielded 22 responses per question. Where more than one person provided the information, this was to cover different surface water types (e.g. Spain), different WFD biological quality elements (e.g. Latvia), or different organisations, roles and responsibilities (e.g. Czech Republic). Most of the organisations represented were government agencies, regulatory authorities, or research institutes, with individual expertise including scientific research on specific groups of organisms, environmental policy, management of work programmes, and membership of the ECOSTAT group. Almost everyone replying had specific first-hand experience of working with AS (only two stated that they did not).

All contributors were working on aspects of the WFD, with specific areas listed including water body characterisation, typology, survey and monitoring, ecological status classification, inter-calibration, river basin management planning, reporting, and providing

guidance and advice. A summary of responses to each question is given below:

Clarification of the scope of work on AS and the WFD (Qs1–5b)

Most countries use the definition of ‘alien species’ (or a similar one) published by the International Union for Conservation of Nature (IUCN) (McNeely et al. 2001) and adopted (with minor modifications) in the EU Regulation on Invasive Alien Species (Council of the European Communities 2014): ‘A species, subspecies, or lower taxon introduced outside its normal past or present distribution; includes any part, gametes, seeds, eggs, or propagules of such species that might survive and subsequently reproduce.’ The common aspects of the definitions provided by questionnaire responses are the introduction of organisms, rather than their natural spread, and their subsequent location outside their native range (Table S1).

Some contributors offered a definition of the term ‘invasive alien species’, all of which were broadly in line with definitions such as those (i) in the Convention on Biological Diversity: ‘Invasive alien species are plants, animals, pathogens and other organisms that are non-native to an ecosystem, and which may cause economic or environmental harm or adversely affect human health’ (www.cbd.int/idb/2009/about/what), (ii) IUCN: ‘An alien species whose establishment and spread threatens ecosystems, habitats or species with economic or environmental harm.’ (McNeely et al. 2001), or (iii) the EU Regulation: ‘invasive alien species’ means an AS whose introduction or spread has been found to threaten or adversely impact upon biodiversity and related ecosystem services’ (Council of the European Communities (2014). One response (from Spain) added the phrase ‘risk of genetic contamination’.

Eleven of the 18 contributing countries (Croatia, Estonia, Hungary, Italy, Norway, Portugal, Republic of Ireland, Slovakia, Spain, Turkey, UK) included ‘translocated native species’ in their definition of AS. Translocated species are those native to part of a country or smaller region that have been deliberately moved outside of their native range to parts of that country or region where they are not native. In some cases, the ‘yes’ response to this question was qualified: for example, the lack of boundaries for defining translocation (Republic of Ireland), the restriction of

Table 2 Countries submitting questionnaire returns

Belgium (Flanders)
Croatia
Czech Republic
Denmark
Estonia
Hungary
Ireland
Italy—(a) lakes
Italy—(b) river macrophytes
Italy—(c) river fish
Latvia
Lithuania
Norway
Poland
Portugal
Slovakia
Spain—(a) Ebro basin
Spain—(b) transitional and coastal waters
Sweden
Turkey
UK (Scotland)
UK (England)

translocation to a particular species group (Portugal—for fish), or noting that translocation is not incorporated in legislation (Slovakia) or not formally applied when implementing the WFD (UK—England). Specific examples of translocated native species were provided by some countries. In Croatia, northern pike (*Esox lucius*) is one of a few species native to the Danube basin but alien in the Adriatic basin. In Italy, the riparian plant species chaste tree (*Vitex agnus-castus*) and rose bay (*Nerium oleander*) are defined as alien only in the west part of northern Italy. In the UK, there is a long history of freshwater fish movements within the country, leading to several fish translocations, principally from England to Scotland and Wales, where these introduced fishes are considered AS (Dodd et al. 2018).

The responses from all countries stated that ‘casual species’ (those that may flourish and even reproduce occasionally in an area, but which do not form self-sustaining populations, and which rely on repeated introductions for their persistence) are included in the AS category. Some responses were qualified (Table S1). For example, macrophytes in rivers and lakes in Latvia are not included as casual species; in transitional and coastal waters in Spain, casual species are not given priority in actions for IAS; and in England casual species are included, but only in part (management of repeated introductions or eradication of a single population are encouraged), whereas reproducing species are included in WFD classification and prevent a water body achieving HES.

Two-thirds of the countries responded that native species that have expanded their range as a result of climate change are not considered as AS (Table S1). The response from Croatia pointed out that this is in line with Article 2 of the EU Regulation, which states that ‘this Regulation does not apply to species changing their natural range without human intervention, in response to changing ecological conditions and climate change’ (Council of the European Communities 2014). In the Great Britain Non-Native Risk Assessment scheme (www.nonnativespecies.org/index.cfm?pageid=143), which is used in England, Scotland and Wales, climate change is not included as a factor in the main sections of the assessments. However, there are three additional, post-assessment, questions on how climate change could affect the risk assessment, the likely time frame of those changes in

risk, and which aspects of the assessment are likely to be affected.

Question 5 (Table 1) raised the issue of using historical dates when determining whether a species should be classed as ‘alien’. This had also been considered at the workshops in 2008 and 2009, and in the previous questionnaire (Vandekerckhove and Cardoso 2010). It is clear that there remains a very wide range of views and approaches to this subject (Table S1). Some countries (e.g. UK, Republic of Ireland, Portugal, Denmark) replied unequivocally that dates are not used in defining whether or not a species should be considered as an alien. On the other hand, in some countries species are considered as alien only if they were introduced after a specific date. For example, in Italy the date is set at 1492—the year that Columbus discovered a sea route to the Americas, opening new opportunities for trade, and potentially for the spread of AS. In many cases, the situation is more complicated. In Flanders (Belgium), ‘neophytes’ are classified pragmatically as species introduced after 1500, although this is not legally defined; plants that arrived earlier by human agency are classified as ‘archaeophytes’. In Estonia, some species introduced before the end of the 19th Century and plants introduced before the middle of the 18th Century are not considered alien, owing to undisclosed ‘practical reasons’.

When asked in subsidiary questions (5a, 5b) whether the use of ‘cut-off dates’ is a useful approach for defining alien status, again a wide range of views was expressed (Table S1). Some contributors (e.g. from Hungary) considered that a specified date provides a pragmatic way of determining whether a particular species should or should not be considered as an alien. Counter to this argument, the reply from Sweden, while recognising that the use of historical dates offers value through its simplicity, suggested that it also risks some species with significant impacts ‘going under the radar’. Several countries expressed the view that the ‘naturalisation’ of introduced species (e.g. zebra mussel in Lithuania; red swamp crayfish (*Procambarus clarkii*) in the lower River Guadalquivir in Spain) should be a factor in determining whether they should be considered as aliens.

Compiling lists of AS for use with the WFD (Qs 7a and 7b)

All countries stated that they have lists of AS that can be used to help with implementing the WFD, and many provided web-links and other references (Table S1). However, most of these lists cover a range of habitats, and it seems that AS lists specifically for use with the WFD are only available for Ecoregion 17 (the island containing Northern Ireland (part of the UK) and the Republic of Ireland) and Ecoregion 18 (England, Wales and Scotland—GB). The situation is likely to be different for the Marine Strategy Framework Directive (MSFD; Council of the European Communities 2008), owing to the explicit reference in the Directive to ‘non-indigenous’ species—one of the 11 ‘descriptors’ used to assess Good Environmental Status. Indeed, the questionnaire response from Spain referred to an inventory of AS compiled in 2012 for all the coastal and marine waters in Spain to assist in implementing the MSFD.

Not all AS are invasive (some may never become invasive, others may after a time lag), hence question 7b, which asked whether Member States consider all AS in their work on the WFD or only those known to be invasive (Table 1). The results revealed that many countries do not restrict their consideration only to IAS (e.g. Croatia, Hungary, Norway, the UK), although some countries (e.g. Spain) give more attention to AS that are known to be invasive compared with those that are not (Table S1). This contrasts with the UK in which published lists for Ecoregion 18 (GB) are continually updated for all aquatic and riparian AS (UKTAG, 2015) according to their degree of impact (‘high’, ‘moderate’, ‘low’, ‘unknown’). These classifications are based on AS risk assessments carried out by the GB Non-Native Species Secretariat (www.nonnativespecies.org/home/index.cfm), with only those species classified as high impact used in WFD assessment.

Monitoring AS (Qs 8a–8d)

Responses to the questionnaire suggest that at present few countries have comprehensive monitoring programmes specifically designed to detect AS or their spread, and they rely instead on data collected from broader monitoring programmes (Table S1). Countries that do monitor AS include Belgium, Czech

Republic, Estonia, Hungary, Lithuania, Spain and the UK. These tend to do so for only a few targeted species or only in certain aquatic environments. In contrast to a lack of AS monitoring for the WFD, some countries (e.g. Denmark, Poland, Spain) have set up AS monitoring programmes for the MSFD (Council of the European Communities 2008). At the time of the questionnaire, only a few countries (e.g. Belgium, Croatia, Denmark, Estonia, Italy) had set up, or were in the process of setting up, monitoring programmes to meet the requirements of the EU Regulation (Council of the European Communities 2014).

The questionnaire asked whether routine monitoring programmes would be likely to detect AS in all the BQE classes and surface water types in the WFD (Table 1). Responses varied, with almost no countries answering with an unqualified ‘yes’ (Table S1). Instead, some surface water types are likely to be covered better than others (e.g. lakes and rivers in Belgium and in Italy) and some groups of organisms are more likely to be monitored than others (e.g. fish in lakes, and pondweeds (*Elodea* spp.) in rivers and lakes in Latvia; phytoplankton, macrophytes, benthic invertebrates in lakes, and plants and invertebrates in transitional waters in Spain).

When an AS is detected in a water body, the extent of any ameliorative action is extremely limited and patchy at a European level. The most common responses referred to sending reports to authorities, adding records to databases, and further monitoring of the species detected. Few specific actions that attempt to manage, control or eradicate AS were described. Exceptions included efforts at controlling: (1) parrot’s feather (*Myriophyllum aquaticum*) and evening primroses (*Ludwigia* spp.) in Flanders; (2) zebra mussel, Asian clam (*Corbicula fluminea*) and New Zealand mud snail (*Potamopyrgus antipodarum*) in Croatia; (3) improved biosecurity measures in the UK; and (4) restrictions in Spain on boat movements to slow the spread of zebra mussels.

Use of data on AS for risk assessment (Q6) and for classifying WFD ecological status (Qs 9–13)

Seven questions (main and subsidiary) (almost a third of the total) covered the area of water body risk assessment and classification (chiefly the latter) owing to the central importance of ecological status and its

implications for the WFD river basin management plans (Table 1). Discussions at the previous workshops, and the results of the 2009 questionnaire (Vandekerckhove and Cardoso 2010) have shown this to be a contentious topic about which the approaches of EU Member States differ markedly. The results of the present questionnaire show that this is still the case (Table S1). An analysis of the responses to Q6—‘Do you use data on AS when assessing whether particular water bodies are at risk of failing their WFD environmental objectives?’ revealed that many contributors confused ‘risk assessment’ with ‘classification’. Responses in which these two activities were not confused suggest (i) that only the UK, the Republic of Ireland, Norway and Sweden (where data are available) consider AS in water body risk assessments (with the exception of translocated native species); and (ii) that some countries (Lithuania, Spain) do not.

The answers to the question on whether the classification tools used to make WFD assessments are ‘pressure-based’ or ‘community-based’ show that some countries use one method, some the other, and some both (Table S1). For example, in Denmark and Sweden, pressure-based tools are used, whereas in other countries (e.g. Hungary) community-based tools are used instead. Both are used in some countries (e.g. Belgium, Croatia, Portugal), and some contributors explained that their community-based tools have been calibrated against specific pressures (e.g. organic pollution in Slovakia).

The answers to Qs 9–12 are best considered together (Table S1), as they all shed light on the approach of Member States to the way that AS do, or do not, contribute to the ecological status assessment for a given water body. The four options presented (and discussed at previous workshops) were essentially to modify the classification based on the presence of AS (Option 1) or in terms of abundance (Option 2); to assume that the classification tools will already have responded to the impacts of AS (Option 3); or to remove AS assessments from classification altogether and to report the results separately (Option 4).

The UK and Norway appear to be the only countries that apply Option 1. In the UK, this takes place as a separate step in the classification process by downgrading to GES any water bodies that would otherwise be at HES if any high-impact species are established. In Scotland (but not yet in England), a further

downgrading to moderate status takes place if an established high-impact species is shown to be exerting more than a slight adverse impact on any biological element. In Norway, a water body containing any of the high-impact AS on its ‘black list’ (Gederaas et al. 2012) cannot be at HES. As with Option 1, Option 2 is similarly little used, with Italy the only country applying it—for downgrading the classifications of lakes when alien macrophyte species exceed 70% of abundance, and when alien fish species (in lakes) exceed 20%.

The results of the questionnaire showed that almost all countries use Option 3, either partly or wholly, or some similar version (Table S1). This assumes that the classification tools adequately detect any impacts caused by AS, so no additional step in the process is needed. Occasionally this was stated explicitly in the returns from some of the countries. The responses from Belgium and the Czech Republic, for instance, refer to the impacts of AS affecting Ecological Quality Ratios (EQRs) by virtue of being embedded within other WFD metrics. Similarly, in Croatia, the impact of alien fish species in rivers, and in transitional and coastal waters is considered to be covered by incorporation in the general metrics for fish. This is in direct contrast with the reason for developing and using Option 1 in the UK, where WFD classification tools that were constructed to detect other pressures (e.g. nutrient enrichment) are considered ineffective in detecting all the impacts of AS.

Option 4 (the use of a ‘biopollution index’ for classifying water bodies separate from ecological status) is used only in Sweden, in Spain (for transitional and coastal waters), and in Norway when a water body contains AS known to cause severe impacts.

The reason why each country has chosen a particular option was raised in Q11 (Table 1), and again the responses varied considerably. Apart from the assumption (referred to above) that the effect of AS will automatically be taken into account by other pressure-based classification tools, responses from the Czech Republic, Denmark, and Poland pointed to a lack of guidance on how to assess the impacts of AS, or to the present scarcity of aquatic IAS (e.g. fish in Latvian lakes and rivers). When asked (in Q12), ‘Which option would be the most appropriate considering both feasibility and usefulness in ecological status assessment and classification under the WFD?’

the results show that despite the overwhelming majority of countries using Option 3, only three countries (Lithuania, Norway and Portugal) named this as the most appropriate (Table S1). Instead, opinion was divided among the others, with some countries choosing Option 1 (e.g. Slovakia), some Option 2 (e.g. Hungary) and some Option 4 (e.g. Estonia).

AS and WFD river basin management plans (Qs 14a and 14b)

River basin management plans (RBMPs) vary in their coverage of AS. Nine of the 18 contributing countries (Belgium, Croatia, Hungary, Italy, Norway, Portugal, Spain, Sweden, the UK) have inserted at least some AS actions in RBMPs. All of these countries supplied web-links to plans (Table S1), but these are predominantly written in their own language and English versions are rarely available. The response from Norway included some further details on measures in the RBMPs for 2016–2021. Most of these are for rivers and lakes rather than transitional and coastal waters, and include chemical treatment, the removal of alien fish species, and promoting understanding using information campaigns.

Discussion

Variability in responses among countries and the need for a consistent approach

One of the most striking observations was the high level of variability among those countries responding to the questionnaire (Table S1). For example, among the most consistent responses were to Q3 (Are casual alien species considered as alien species?), with 17 of the responses being ‘Yes’, one ‘No’ and one ‘Yes and No’ (for different types of water bodies). This contrasts with the near equal split in responses to Q2a (Are translocated species aliens?), with 10 for ‘Yes’, seven for ‘No’, and two countries responding ‘Yes and No’ (for different types of water bodies).

Perhaps the widest variety of responses were to Q1 (How are ‘alien species’ defined in your country?), but with all 18 of the country definitions containing the fundamental component of the species not being native to that country. This is essentially based (either

intentionally or not) on the definition given in the European Regulation on the prevention and management of the introduction and spread of IAS (Council of the European Communities 2014).

Six definitions also mentioned human involvement in species introductions and two included an aspect of ‘adverse impacts’ (Table S1), which is consistent with the definition given in Richardson et al. (2000) that was cited in one response. Only one of the relatively simple responses (definitions) referred to a specific year, i.e. the discovery of North America by Columbus in 1492 after which an introduced species is considered alien. This issue of a threshold date for species to be considered alien was covered in Q5a, eliciting perhaps the broadest range of responses, ranging from a simple ‘Yes’ to lengthy descriptions, which in some cases indicate different dates for different types of water body or taxonomic group.

This brief summary shows clearly that there is very little consistency in the way that EU Member States include AS in implementing the WFD, a point illustrated in the study by Vandekerckhove et al. (2013). The need for greater uniformity in confronting AS problems has been reflected in the European Regulation on AS (Council of the European Communities 2014). There are, of course, many constraints—historical, financial, political and practical—why Member States do not at present take the same approach, but the effectiveness of the WFD in achieving GES in rivers, lakes and transitional waters will be reduced without a greater consistency in dealing with the pressures from AS. For example, agreement by Member States of what is considered to be an ‘alien species’ is surely a basic necessity when monitoring AS, for classifying ecological status, and for setting up ‘programmes of measures’ under the WFD. Yet, there is no consensus on whether specific historical dates should be used for determining what constitutes an AS. In addition, few Member States have created purpose-built lists of AS for use with the WFD, as developed in the UK (www.wfduk.org/search/alien%20species).

The remainder of the Discussion considers in more detail three other topics for which the results of this study suggest a need for greater alignment—risk assessment of water body status, monitoring and WFD classification, and links with other legislation—and offers some suggestions for future work in this area.

Risk assessment of AS within the WFD context

A key aspect of the WFD is the classification of water bodies within River Basin Districts (RBDs) within which each water body is assessed for the risk that it will not achieve GES. As such, species risk assessments are an essential aspect of WFD implementation in order to identify which AS are likely to be invasive and exert an adverse impact that could put the water body at risk of not achieving or maintaining at least GES. The WFD grouping of water bodies with RBDs provides a useful framework for assessing the potential invasiveness of AS introduced to RBDs because RBDs are, in general, more closely aligned with biogeographical species distributions than with regional or national boundaries. However, assessments of AS for their potential invasiveness at the RBD level are extremely rare, such as the preliminary assessment of the impacts of killer shrimp (*Dikerogammarus villosus*) on ecological status at various spatial scales, including RBDs, within England and Wales (Gallardo et al. 2012).

The RBD as a spatial scale is of particular relevance to nation states that encompass more than one RBD, where species may be translocated from one RBD where they are native to one or more other RBDs in that nation state where the species is not native. As ‘translocated species’ are not native to the RBDs where they are introduced, they can therefore pose threats to native species and ecosystems of the same magnitude as alien species. An example is the recent risk screening of translocated freshwater fishes in Great Britain (GB: England, Scotland, and Wales), which comprises 12 RBDs but where Scotland encompasses only one complete RBD and part of a second that overlaps some northern parts of England. In that study, historical records were used by the ASG to identify the RBDs where fish species were most likely native (Dodd et al. 2018). Each species was screened for its potential invasiveness in each of the other RBDs in GB where the species was not native using the Aquatic Species Invasiveness Screening Kit (AS-ISK; Copp et al. 2016), which complies with the ‘minimum standards’ required for risk assessment under the EU Regulation (Roy et al. 2018). The translocated freshwater fishes were also screened for GB overall (i.e. all RBDs where the species was not native). Limited variation among RBDs was found for the 16 species assessed (Dodd et al. 2018), with all the

species receiving the same risk ranking across all RBDs except for silver bream (*Blicca bjoerkna*). With decreasing RBD latitudinal location, AS-ISK scores showed an increasing trend, with one species, bleak (*Alburnus alburnus*), having significantly higher risk scores in southern than in northern RBDs, although within the same (high) risk ranking. In contrast, for tench (*Tinca tinca*), AS-ISK scores were significantly higher in west-coast RBDs than in those to the north and east, although again within the same (high) risk ranking. For Scotland, ‘climate and aquatic habitat vary from north to south and west to east, which is recognised in the freshwater ecoregions of Abell et al. (2008). As such, the fact that [most of] Scotland is classified as comprising a single RBD is very unhelpful from a regulatory perspective.’ (Dodd et al. 2018, p. 129).

The above examples for England and Wales (Gallardo et al. 2012) and for all of GB (Dodd et al. 2018) highlight the potential advantages for environmental and conservation managers of using the RBDs rather than national borders for WFD assessments, but also the potential regulatory disadvantages (e.g. for Scotland) if the RBD is too expansive spatially. Such disparity is also apparent in the results of the questionnaire, which demonstrate a clear lack of consensus among Member States on whether or not to include or exclude translocated species in their AS assessments. Differences were also apparent in the extent to which Member States carried out risk assessments to determine the likelihood of AS invading water bodies and influencing ecological status.

Alien species monitoring and water body classification

One of the most significant conclusions from the present study is the lack of a uniform approach to monitoring AS for the WFD, and in the use of the results to contribute to the classification of ecological status. The variability between Member States in the way that AS are monitored is shown in: (i) the lack of comprehensive monitoring programmes for aquatic AS, (ii) the uneven monitoring of different types of water bodies, and (iii) the patchy coverage in monitoring the main species groups (the ‘BQEs’ in Annex V of the WFD). To some extent, this is probably a reflection of limited resources for monitoring. In recognition of the requirement for EU Member States

to establish programmes of surveillance for AS (Council of the European Communities 2014), some Member States have developed environmental DNA (eDNA) methods for detecting species from the DNA they release into the water. This use of eDNA is anticipated to lead to new monitoring tools for WFD compliance, and thereby reduce the costs of monitoring (e.g. Hänfling et al. 2016). For example, multi-species detection (so-called meta-barcoding) methods are being developed to complement (or replace) the potentially destructive conventional methods (Filipe et al. 2019), such as gill netting to assess fishes in lakes under the WFD (Hänfling et al. 2016). Single-species detection methods are more appropriate to the detection of species present in densities too low for detection using conventional sampling methods, such as is needed to inform management decisions with regard to eradication measures. For example, Davison et al. (2016) developed PCR primers for detecting four freshwater fish species alien to the UK (pumpkinseed *Lepomis gibbosus*, sunbleak *Leucaspis delineatus*, fathead minnow *Pimephales promelas*, and topmouth gudgeon *Pseudorasbora parva*). This eDNA approach subsequently provided a reliable means of assessing the effectiveness of AS eradication procedures undertaken to achieve GES through the elimination of this pressure (Davison et al. 2017, 2019). Elsewhere, eDNA methods have been developed for detecting seven of the commonest AS in European fresh waters (Clusa and García-Vázquez 2018), including the two species mentioned above (*L. gibbosus*, *P. parva*) and also black bullhead (*Ameiurus melas*), brown bullhead (*Ameiurus nebulosus*), eastern mosquitofish (*Gambusia holbrooki*), western mosquitofish (*Gambusia affinis*), and largemouth (black) bass (*Micropterus salmoides*). The authors of these eDNA articles emphasised the potential use of eDNA as a sensitive and economical tool to help detect and manage invasions of these species in Europe.

There is no clear agreement across Member States on how AS should be used to classify water body status, and whether the presence of AS should automatically prevent the achievement of HES (Vandekerkhove and Cardoso 2010). Across water bodies, there is a link between lower water body classifications and the presence of AS, and the impacts of IAS may be interpreted as contributing to a decline in ecological status due to changes to ecosystems in their biological and physical properties, such as river bank

erosion by mitten crab (*Eriocheir sinensis*) (Olenin et al. 2007) and disease prevalence by *Pseudorasbora parva* (Gozlan et al. 2005). Consistency in how AS are dealt with when classifying water body status could help improve the consistency and effectiveness in managing AS under the WFD. However, classifying water bodies as being of lower status purely on the presence of AS is criticised by some, as it can give a greater weight to AS relative to other pressures, and thus results in a downgraded water body classification where there may be no solution to the problem (Vandekerkhove and Cardoso 2010). In the UK, for example, the approach has been to downgrade water bodies from GES only when there is a demonstrated AS impact. On the other hand, a water body cannot be considered at HES if one of the ‘high impact’ AS is present. The rationale for this is twofold: first, because there is abundant evidence that such AS always cause ecological damage when they are present; and second, because the definition of HES in Annex V of the WFD is that the taxonomic composition of the BQEs should ‘correspond totally or nearly totally to undisturbed conditions’, and it is difficult to envisage a water body with a high-impact AS meeting that criterion.

An alternative approach that gathered a degree of support from the contributors to the questionnaire is the use of a ‘biopollution index’ as a supplement to the existing classification under the WFD. This would mean that the presence of AS would not be used to modify ecological status, but the impacts of IAS would still be highlighted (Vandekerkhove and Cardoso, 2010). There are a variety of biopollution indices available: some consider only the presence or absence of AS in terms of total numbers, whereas others also evaluate the potential risk of impact and spread of the species (Vandekerkhove and Cardoso 2010). For example, the Biopollution Level (BPL) Index (Olenin et al. 2007) requires semi-quantitative data on the abundance and distribution range of AS, and on their impacts on aquatic communities (biodiversity), habitat quality and ecosystem structure and function. It should also be noted that the presence of IAS can alter the biological, chemical and physical parameters of water quality, which may increase the risk of further invasion (Olenin et al. 2007).

An alternative index is the Benthic Ecosystem Quality Index (BEQI) (www.beqi.eu), used to evaluate soft-bottom macroinvertebrate communities from coastal and transitional waters in Belgium. The BEQI

evaluates current status compared with a defined ‘reference’ state within a water body, and is applied at three levels:

- Ecosystem (Level 1) assesses the levels of primary production and overall benthic biomass—is it as expected for habitat types and region?
- Habitat (Level 2) assesses the surface area of different habitats and their associated biological elements—‘completeness’ of habitat assessed.
- Community (Level 3) assesses the density, biomass, number of species and species composition—focus on species that are good indicators of environmental status, e.g. water quality.

The BEQI, therefore, has an ecosystem-based approach and can be used at a variety of water body scales. Alien species would be detected primarily within Level 3, but their presence could then be compared with variations from the expected in levels 1 and 2 to derive an estimate of the level of impact IAS are potentially having on overall classification.

River basin management plans and the need for action

As with many other questions in the survey, the way that AS are included (or not) in RBMPs is extremely variable, yet if risk analysis, monitoring, and classification are to make a practical difference to water bodies, then action is needed. It seems from the results that RBMPs in GB are those that contain the most detail on actions to tackle AS. In England and Wales, for example, all 12 RBDs (including two shared with Scotland) mention AS, especially IAS, in their RBMPs as one of the pressures on maintaining or achieving GES. Similarly, AS feature in the actions to be taken to maintain or achieve GES. All RBMPs for the River Basin Districts in England and in Wales list AS as posing a medium level of severity in their qualitative assessments of the likelihood that climate change may increase the risk from known pressures by 2050 and beyond. In the RBMPs for the two RBDs that include all of Scotland or part of Scotland (Solway and Tweed), AS are mentioned with regard to ‘Emerging risks’ and ‘Adapting to climate change’. Indeed, these two RBMPs provide maps of those surface water bodies that are at less than GES or at risk from the spread of AS.

Various actions identified in the RBMPs include the implementation of the Invasive Non-native Species Framework Strategy for Great Britain (Defra 2008), which was updated in Defra (2015). Within this broad-scale ‘action’, several individual ‘actions’ have been identified for RBMPs (e.g. Taylor and Lycett 2008; SEPA 2013), and these include: (i) managing rivers to protect against the establishment of non-native species, (ii) raising awareness of the spread of non-native crayfish and assessing their impact on fisheries; (iii) eliminating IAS from gardens, and participation in volunteer river groups to record and remove IAS; (iv) disseminating and developing identification guides for AS, and training of key groups to improve the early detection of AS; (v) promoting existing codes of practice and guidance to the public, industry and trade to minimise the spread of IAS; (vi) implementing partnerships to develop species management plans for prioritised AS, to improve their identification, control and disposal; and (vii) establishing IAS forums for RBDs to improve communications, identify existing work, share information and best practice, identify key people, coordinate projects, and assign priorities for key AS.

WFD links with other legislation

The WFD is not the only piece of European legislation relevant to AS. When considering how to take account of AS under the WFD, the links between the WFD and other international (and national) environmental legislation are also pertinent. The European Habitats Directive, for example, has one statement in the preamble that says, ‘...provision should be made for supplementary measures governing the reintroduction of certain native species of fauna and flora and the possible introduction of non-native species’ (Council of the European Communities 1992). Although that is the only direct reference to AS in the Directive, the presence of non-native species in a ‘Special Area of Conservation’ (SAC) is not likely to support the stated aims of the Directive ‘to promote the maintenance of biodiversity’, and ‘to maintain or restore the natural habitats and the populations of species of wild fauna and flora at a favourable status’. This is reflected in the UK’s guidance on monitoring designated sites such as SACs, where there are targets for AS. For example, the guidance for river SACs (JNCC 2016) gives the target as ‘No high-impact alien species established’ and

refers to the published lists of AS for the WFD, making a clear link between these two directives. It continues, ‘A site will be assessed as unfavourable when there is good evidence that any non-native species or locally absent species [i.e. translocated] is causing an impact on site integrity’.

Apart from the Habitats Directive, there are three main pieces of EU legislation relevant to the present study; the ‘Regulation on the use of aliens in aquaculture (Council of the European Communities 2007), the Marine Strategy Framework Directive (MSFD; Council of the European Communities 2008) and the ‘Regulation on the prevention and management of the introduction and spread of invasive alien species’ (Council of the European Communities 2014). The scope of the 2007 Regulation on the use of aliens in aquaculture is restricted to non-ornamental aquatic species, and this Regulation distinguishes itself from the 2014 Regulation in the use of a ‘white list’ approach, i.e. all AS are subject to regulation except those on Annex IV of the 2007 Regulation.

The 2014 Regulation, however, covers all AS, whether aquatic or terrestrial, and it employs a ‘black list’ approach whereby the Regulation’s annex contains a list of AS of ‘Union concern’ that are subject to legislative control and regulation. Development of this list involved a process that began with a ‘horizon-scanning’ exercise (Roy et al. 2019), which aimed to inform the recently established ‘Scientific Forum on Invasive Alien Species’ (<http://ec.europa.eu/transparency/regexpert/index.cfm?do=groupDetail.groupDetail&groupId=3276&NewSearch=1&NewSearch=1>), henceforth ‘The Scientific Forum’, on which species to consider for inclusion on the list of species of EU concern. The Scientific Forum coordinates the commissioning and peer-review of the full risk assessments (RAs) of the selected species, and after vetting and further peer review the RAs are submitted to the Scientific Forum for approval, further revised and approved if required, and then published online (<https://circabc.europa.eu/faces/jsp/extension/wai/navigation/container.jsp>).

There is little in the 2014 EU Regulation that refers explicitly to the WFD or the MSFD, except in the preamble, which states: ‘To support the achievement of the objectives of Directives 2000/60/EC [the WFD] 2008/56/EC [the MSFD].....this Regulation should establish rules to prevent, minimise and mitigate the

adverse effects of invasive alien species on biodiversity and related ecosystem services, and on human health and safety as well as to reduce their social and economic impact.’ Although representing a significant step in the control or eradication of AS, the 2014 EU Regulation does not fulfil all that is needed to ensure that the WFD objective of GES is met. For example, the list of ‘species of Union concern’ (which is being updated periodically) is not a comprehensive list of IAS that impair the status of aquatic ecosystems. The 2014 Regulation focuses more on the movement of, and trade in, AS through cross-border cooperation among Member States. As such, actions needed in RBMPs under the WFD remain unclear. Undoubtedly, there is scope for linking the monitoring and surveillance programmes specified in the 2014 EU Regulation with those that should be set up for the WFD, but this is an area that needs discussion and agreement at a European level. Similarly, the species risk assessments generated for this Regulation (to update the list of species of Union concern) could be used to inform national AS lists in a similar manner as the ASG in the UK currently uses risk assessments (www.nonnativespecies.org/index.cfm?pageid=143) from the GB Non-Native Species Secretariat to classify AS according to their likely impact (low, medium, high) on water bodies for the WFD.

As regards the MSFD, its focus is quite different from that of the WFD, but the two directives have similar aims. Both are aimed at improving the environmental condition of water bodies, both require links to be made to human activities and pressures and impacts on biodiversity (including assessments of cumulative effects), and both cover local and wider regional scales. The target dates and reporting cycles for achieving their various objectives also run in parallel (annual and multi-year reporting, 2020 + dates for achievement), and further alignment of these at country level would help with information sharing between those working on the two directives (Zampoukas et al. 2012). There is also some limited spatial convergence between the two directives: the ‘surface water types’ in the WFD are not only rivers and lakes, but also transitional and coastal waters (out to 1 nautical mile for the purpose of assessing ecological status). The WFD works primarily at the river basin scale, meaning that the coastal waters included are most often those connected to a river mouth (i.e. an estuary). The MSFD covers marine

environments, from mean spring high-tidal limits in transitional waters, out to the limits of a Member State's 'Exclusive Economic Zone'. Water body scale is also much broader for the MSFD, being at a 'marine region' and sub-region level e.g. Greater North Sea. The primary difference, however, is that whereas the MSFD has specific objectives for managing AS ('Descriptor 2'), the WFD does not, although this is implied under the management of pressures. The terminology also differs between the Directives, with WFD documents referring to 'alien species' and 'Good Ecological Status' and the MSFD referring to 'non-indigenous species' and 'Good Environmental Status'.

There is some scope for greater consistency in the way that the WFD and the MSFD are applied, although this is constrained by the wording of the respective pieces of legislation. For example, reaching agreement on definitions that differ between the Directives, or within a Directive across Member States, would be helpful; such as defining what makes a species 'alien', and whether any species should be considered 'naturalised'—an issue that affects both Directives and leads to much debate regarding AS management (Zampoukas et al. 2012). Unlike RBMPs for the WFD, where AS seem to be rarely included, several countries have formulated additional management measures under the MSFD for AS in the marine environment.

Areas for future development

The WFD and MSFD would both benefit from greater consistency in the terminology used in those Directives and other EU Regulations pertaining to AS. Perhaps the most obvious of these are the different, but effectively synonymous terms use for non-native species: 'locally-absent species' (EU Regulation 2007), 'non-indigenous species' (MSFD 2008), 'alien species' (EU Regulation 2014), with no specific mention of AS in the 2000 WFD but later interpreted as encompassed by 'other significant anthropogenic impacts' (Annex 2, Sect. 1.4). A common use of terminology would enable Member States to co-ordinate more effectively on actions to reduce AS introductions, implement rapid response strategies to eradicate the species, or reduce or control its spread and apply management procedures to eliminate or mitigate adverse impacts. Greater commonality is also recommended to identify the most effective means of

integrating AS as a pressure in water body classification under the WFD. For example, one or more biopollution indices should be tested to determine which index fulfils WFD requirements and highlights AS impacts most effectively without causing difficulties in water body management.

Greater consistency across EU legislation could be achieved through amendment of the WFD to include, as a requirement, the development and implementation of a programme of measures for AS management, such as is the case with the MSFD. This would ensure a statutory basis for species- and pathway-management action plans in fresh and transitional waters. As with the MSFD for marine and brackish waters under the MSFD, this would provide enforcement powers for non-compliance.

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