UK TECHNICAL ADVISORY GROUP ON THE WATER FRAMEWORK DIRECTIVE

Guidance on the assessment of alien species pressures

Revised March 2013

1. Aims and scope

The aim of this paper is to provide guidance on (a) the pressures from alien species on river, lake, transitional and coastal water bodies; (b) data required for carrying out risk assessments for Article 5 analyses; and (c) pressure thresholds at which water bodies are at risk of failing the environmental objectives of the Water Framework Directive (WFD). Specific guidance is given on the work required for the river basin characterisation exercise in 2013, but the paper is also intended to inform the further extension of this work beyond that date.

2. Alien species and the Water Framework Directive

This guidance document principally focuses on two of the tasks described in Article 5 of the WFD: the characterisation of river basin districts and a review of the impact of human activity on the status of surface waters. This exercise is described in detail in Annex II of the Directive, with the aim of assessing '*the likelihood that surface water bodies within the river basin district will fail to meet [their] environmental quality objectives….*' (Annex II, 1.5). To assist in this process of risk assessment, Annex II (1.4) lists potentially '*significant anthropogenic pressures*'.

While the text of the Directive does not explicitly mention alien species, Annex II lists specific pressures to which water bodies may be subjected, including '*…other significant anthropogenic impacts on the status of surface water bodies*'. In the knowledge that many alien species have been deliberately or accidentally introduced, such species should be considered as a potential 'anthropogenic impact' on the biological elements listed in Annex V[1]. Guidance from the European Commission (e.g. REFCOND: http://circa.europa.eu/../_EN_1.0_&a=d) as well as further work on this subject within the Commission's ECOSTAT group clearly supports the inclusion of alien species data in work to implement the WFD.

It could be argued, of course, that the presence of alien species makes it difficult to achieve '*a taxonomic composition that corresponds totally or nearly totally to undisturbed conditions*' (Annex V, Table 1.2.1). In other words, the presence of alien species detracts from the concept of 'naturalness' that underlies the Directive. Indeed, some ecological and conservation assessment systems (e. g. SERCON (System for Evaluating Rivers for Conservation – Boon *et al*., 1997)) evaluate the presence of established alien species (reducing naturalness) separately from the impact that they may exert. Nevertheless, it is the degree of damage that alien species cause to native biota that is the focus of concern in WFD assessments. Thus, the CIS guidance on reference conditions (http://circa.europa.eu/../_EN_1.0_&a=d) refers to the impact of alien species under the general heading of '*Biological Pressures*'.

[1] It should be noted that the definition of good status as applied to fish in rivers, lakes and transitional waters refers to slight changes in conditions '*attributable to anthropogenic impacts on physico-chemical and hydromorphological quality elements*'. At first sight, this might suggest that the pressure exerted by alien fish species on native fish cannot be considered an '*anthropogenic impact*' unless '*physico-chemical and hydromorphological*' quality elements are directly affected by alien species. Examples where this does occur include (a) disturbance to river substrata by introduced common carp and subsequent nutrient release, (b) plant habitat destruction through the activities of common carp, and (c) overcutting of the redds of indigenous salmonids by introduced salmonids. Even where there may be no direct hydromorphological or physico-chemical impact observed (e.g. the severe effects of introduced ruffe on native fish species in Loch Lomond – see below) the broader ecological impact of such introductions must be included in the process of risk assessment.

3. Principles for handling alien species under the WFD

In summary, there are two management options for a water body at risk of failing to achieve good ecological status because of the impact of invasive alien species:

- where feasible and cost-effective, pursue eradication; and/or
- focus on local containment, preventing further spread into other water bodies within the same catchment or in neighbouring catchments. In any eradication programme, the benefits of eliminating alien species should be balanced against possible damage to other habitats and species through the removal process itself.

For water bodies affected by species for which there are currently no feasible control and eradication techniques (such as *Crassula helmsii*), extended deadlines (i.e. beyond 2015) can be justified where it is thought possible that techniques could be developed, given appropriate research effort and resource, to enable a target of good status some time after 2015. Where a species occurs, for which feasible techniques are not thought likely to be developed within the current timetables for river basin plans (e.g. signal crayfish in large water bodies) this can form justification for setting less stringent objectives for those water bodies. However, there should still be a strong focus on containment and biosecurity and the requirement to tackle other impacts affecting the ecological status of these water bodies (other than those from alien species) will still apply. In addition, attempts at eradication should be made in small water bodies (e.g. ponds) where the presence of species such as signal crayfish poses a risk of spread to larger water bodies.

It is also recommended that:

- an alien species strategy for each water body affected should be drawn up within the programme of measures
- research should continue into more effective control methods, with the results applied to restoring water bodies when new techniques become available
- targeted education and awareness strategies should be devised for individual alien species

In 2003 a Defra review recommended that, among other things, there was a need for a more coordinated response to the threat of invasive non-native species across Great Britain. As a result the Invasive Species Framework Strategy for Great Britain (Defra, 2008) was produced with a Programme Board and Non-native Species Secretariat (NNSS) responsible for its application. Among other things the Strategy is intended to provide a guiding framework for national, regional and local initiatives helping to reduce the impact of non-native species on sensitive and vulnerable habitats and species.

The objectives of the Strategy and the WFD are closely aligned and there are benefits expected of close cooperation between the two initiatives. Particular areas of cross-over include assessing the threat posed by non-native species, monitoring their distribution, and providing timely and effective management responses where possible.

In line with the Strategy the NNSS is coordinating the production of non-native species risk assessments for GB. To date, more than 50 species have been risk-assessed with plans to assess further species, including those listed on the WFD high-impact list. A protocol for rapid response to new and emerging threats is also being developed under the Strategy. This usually applies where a new, high priority non-native species is detected within GB and helps identify which government organisations are likely to be involved in coordinating a response.

In Ireland, the ‘Invasive Species in Ireland report’ was presented both to ministers in Northern Ireland and the Republic of Ireland in 2004. It was agreed that NI and ROI would work together with others to implement the 10 key recommendations contained within the report. In May 2006, NIEA and NPWS jointly commissioned the ‘Invasive Species Ireland Project’ to start to implement the report recommendations. An important aspect of this project has been to oversee the development of invasive alien species strategies for both NI and ROI. It is anticipated that the strategy for Northern Ireland will be completed by the end of March 2103. The strategy for RoI is still in preparation.

4. Terminology

Definitions of the terms below, as used in this guidance document, are as follows:

(i) General

Relevant environmental objectives

(a) Protecting, enhancing and restoring all natural surface water bodies with the aim of achieving good ecological status and surface water chemical status by 22nd December 2015.

(b) Protecting and enhancing all artificial surface water bodies with the aim of achieving good ecological potential and good surface water chemical status by 22nd December 2015.

(c) Protecting and enhancing the status of wetlands directly depending on aquatic ecosystems

(d) Preventing deterioration of water bodies from one status class to another.

(e) Achieving compliance with any water-related standards and objectives for Protected Areas by 22nd December 2015, unless another deadline is specified in the Community legislation establishing the Protected Area.

Pressure

The proximate cause of any human-induced alterations to the biological quality elements.

By this definition, the introduction of alien species constitutes a pressure.

Significant pressure

A pressure that on its own or in combination with other pressures and in the absence of suitable measures, including existing controls, is liable to cause a failure to achieve one or more of the Directive's environmental objectives.

The introduction of an alien species constitutes a significant pressure on the biological quality elements when, for example, its presence (a) causes a deterioration from high status to a lower status class, (b) leads to conditions that prevent the achievement of good ecological status, or causes a decline in ecological status from one class to a lower one, or (c) prevents the conservation objectives for water-dependent Special Areas of Conservation (SACs) and Special Protection Areas (SPAs) from being met.

The term '*pressure*' (and other terms such as '*impact*' and '*activity*') are often used to mean different things. For the purpose of this guidance, the 'DPSIR' model has been adopted, where:

D = Driver
P = Pressure
S = State
I = Impact
R = Response

An example of the DPSIR model relevant to alien species pressures is:

Driver: Aquaculture
Pressure: Introduction of North American signal crayfish
State: Alterations to the taxonomic composition of invertebrate communities
Impact: Introduction of crayfish plague; damage to native crayfish populations
Response: Initiating a control or eradication programme for signal crayfish

In this example, the introduction of North American signal crayfish is known to have a direct effect on the *'taxonomic composition of invertebrate communities'* – a biological quality element listed in Annex V of the WFD.

(ii) Specific

There are several terms currently used with respect to the distribution, introduction and establishment of alien species. In the interests of consistency, and in view of the European focus of the WFD, the definitions used in this guidance document are those published by the International Union for Conservation of Nature and Natural Resources (McNeely *et al*., 2001):

Alien species (synonyms: non-native, non-indigenous, foreign, exotic): '*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.*'

Casual alien species: '*Alien species that may flourish and even reproduce occasionally in an area, but which do not form self-replacing populations, and which rely on repeated introductions for their persistence*.'

Establishment: '*The process of a species in a new habitat successfully reproducing at a level sufficient to ensure continued survival without infusion of new genetic material from outside the system.*'

Intentional introduction: '*The purposeful movement by humans of a species outside its natural range and dispersal potential (such introductions may be authorised or unauthorised).*'

Introduction: '*The movement, by human agency, of a species, sub-species, or lower taxon (including any part, gametes, seeds, eggs, or propagule that might survive and subsequently reproduce) outside its natural range (past or present). This movement can be either within a country or between countries.*'

Invasive alien species: '*An alien species whose establishment and spread threatens ecosystems, habitats or species with economic or environmental harm*.'

Locally absent: '*A species or subspecies of an aquatic organism which is locally absent from a zone within its natural range of distribution for biogeographical reasons. (Definition from Council of the European Union, 2007.)*

Native species (synonym: indigenous species): '*A species, sub-species, or lower taxon living within its natural range (past or present), including the area which it can reach or occupy using its own legs, wings, wind/water-borne or other dispersal systems, even if it is seldom found there.*'

Unintentional introduction: '*An introduction of a species outside its natural range introduced unwittingly by humans or human delivery systems*.'

5. Threats to aquatic ecosystems from alien species

There is growing evidence world-wide that alien species constitute a major threat to native biota and habitats in aquatic ecosystems. Many cases are documented from regions as far apart as North America (Karr *et al*., 2000), southern Africa (Davies and Wishart, 2000) and Australia and

New Zealand (Schofield *et al*., 2000). The impacts of alien species on native biodiversity are many and varied, including displacement of indigenous species through competition or predation, structural damage to aquatic habitats, and loss of genetic integrity. Climate change is also likely to have an impact on alien species, e.g. by extensions or retractions of the range of both native and alien species as temperatures change. The effect of climate change is likely to be complex and the response of both native and non-native species is difficult to predict. The Marine Climate Change Impacts Partnership (MCCIP) has produced report cards that outline the possible effects (see http://www.mccip.org.uk/media/6665/mccip-report-2010-2011.pdf).

In the UK, there are many well-documented cases of alien species becoming established both in marine and freshwater systems. Publications such as those on alien marine species in British waters (Eno *et al*., 1997) and on alien freshwater and terrestrial species in Scotland (Welch *et al*., 2001) are useful collations of data on this subject.

In addition to the threat posed by alien species to native biodiversity, there may often be an unquestionably significant economic impact, although it is not surprising that this is difficult to quantify (Oreska and Aldridge, 2011). However, as an example, the U.S. Fish and Wildlife Service estimates that the potential economic impact of introducing zebra mussel (*Dreissena polymorpha*) into the North American Great Lakes (through the ballast water of cargo ships in 1988) will be in billions of dollars over the next 10 years
(http://www.glsc.usgs.gov/main.php?content=research_invasive_zebramussel&title=Invasive%20Invertebrates0&menu=research_invasive_invertebrates)
The potential magnitude and economic costs of the alien species problem have been emphasised in the Non-native Species Framework Strategy for GB (Defra, 2008), which also refers to the need for the signatories to the Convention on Biological Diversity to address these threats. An investigation by CABI, funded by the Scottish Government, Defra and Welsh Assembly Government, found that invasive non-native species directly cost the British economy approximately £1.7 billion per annum (Williams *et al.* 2010). While indirect costs were not measured, it is likely they would have significantly increased this figure. Much of the direct cost was the result of crop pests; however, of the top 20 species that inflict the highest cost, seven are listed on the UKTAG high-impact list (Table 1). The report also highlighted the economic benefits of rapidly responding to new invasions (Table 2). The promotion of '*sustainable water use*' as one of the purposes described in Article 1 of the WFD may be at risk in certain water bodies through the impact of alien species.

Table 1. The cost of species which occur in both the UKTAG list and the top 20 most economically expensive

Species	**Cost £m pa**
Japanese knotweed	166
Floating pennywort	25
Rhododendron	9
Slipper limpet	6
Signal crayfish	3
Giant hogweed	2
Himalayan balsam	1

Table 2. Example costs associated with rapid response compared with late-stage eradication

Species	Approx. cost of rapid response	Approx. cost of late stage eradication
Water primrose	£0.07M	£242M
Carpet sea-squirt	£2.4M	£927M

(i) Drivers that may lead to alien species pressures

Examples of drivers ('sectors' of human activity) with the potential for causing pressures from alien species are listed in Table 3.

Table 3. Examples of drivers with the potential for causing pressures from alien species

Driver	**Alien species example**
Freshwater aquaculture	North American signal crayfish (*Pacifastacus leniusculus*), Rainbow trout (*Oncorhynchus mykiss*)
Marine aquaculture	Slipper limpet (*Crepidula fornicata*)
Angling	Common carp (*Cyprinus carpio*)
Aquatic habitat management	Grass carp (*Ctenopharyngodon idella*)
Shipping	Chinese mitten crab (*Eriocheir sinensis*)
Water supply (inter-basin transfer)	Pikeperch (*Sander lucioperca*)
Horticulture	Australian swamp stonecrop (*Crassula helmsii*)

(ii) Examples of alien species introduced into the UK

The following examples of alien species introduced into the UK illustrate the threat that they pose to native biodiversity and to economic interests.

(a) *Crassula helmsii* – Australian swamp stonecrop

This is a small, evergreen perennial plant that was first recorded in Britain in the late 1950s. Once established in standing waters (and occasionally in running waters) it can quickly cover the surface in dense swards such that it can often exclude almost all competitors, resulting in marked impacts on native aquatic plants. Able to grow from small fragments (propagules), it has spread widely since introduction, and has now been recorded from 903 of the 3050 10 x 10 km squares in the UK (Source, NBN Gateway).

While it occurs principally in England and Wales, it has also spread north of the border, with 45-50 of the sites in the UK located in Scotland (European and Mediterranean Plant Protection Organization, 2007). In Ireland *Crassula* was first recorded in 1984 at a pond in Gosford Forest Park (10 miles from Newry, NI). *Crassula* in NI is confined to only four or five sites, mostly garden ponds and water fountains, although there has been a heavy infestation in Glastry Clay Pits.
In the Republic of Ireland *Crassula* has been found growing in the wild in just two areas – an extensive area (> 1 km long) on the Grand Canal in the midlands and a small stream that enters Lough Corrib on its north-western shore. Both infestations are currently being treated by Inland Fisheries Ireland (IFI). *Crassula* occupies many garden ponds and golf course lakes throughout RoI but rarely presents serious problems, even in these artificial habitats.

Management implications

Although recorded from a total of about 10,000 individual sites in the UK, many of these are small ponds. Thus, except for a few where their ecological status would be classified because of their nature conservation importance, many of these small water bodies would not fall under the monitoring requirements of the WFD. If caught early, eradication may be a feasible option; measures to prevent further spread are essential.

<u>(b) *Pacifastacus leniusculus* – North American signal crayfish</u>

The North American signal crayfish was introduced into England in the mid-1970s for aquaculture purposes. Signal crayfish escaped from holding areas and feral populations became established, with their spread facilitated by the deliberate introduction of signal crayfish into the wild by humans. Other vectors, such as the accidental transport of signal crayfish with consignments of live fish for stocking, are also likely to have played a role in the expansion of the species' geographical range. Signal crayfish are highly fertile and aggressive, and their establishment in many water bodies in England and Wales has led to the widespread extinction of native white-clawed crayfish populations. This has occurred not only through competitive exclusion but also through the transmission of a fungal disease (known as 'crayfish plague'). This parasite is carried by signal crayfish but is one to which native crayfish are highly susceptible. Signal crayfish are also known to damage invertebrate communities; in some rivers in the Clyde and Thames catchments, for example, invertebrate communities have undergone significant change.

Sibley (2003) reported that signal crayfish had been recorded from 256 of the 3050 10 x 10 km squares in the UK, although it was clear that the exact number of water bodies inhabited by signal crayfish was not known. Although most records for this species occur in England and Wales, signal crayfish have now become established in Scotland. Following their discovery in 1995, they have been found in a number of major river catchments throughout the country. These include the rivers Clyde, Esk (North and South), Kirkcudbrightshire Dee, Forth, Nairn, Tay, and Tweed. A recent review of signal crayfish distribution within Scotland by SNH showed that this species now occupies at least 175 km of river length and is also present in a number of standing waters. These range in size from small garden ponds to large lochs (e.g. Loch Ken). Where possible, a programme of eradication and control has been initiated.

Signal crayfish is absent from the island of Ireland; however, Irish fresh waters would be highly susceptible to invasion if it were introduced. A high priority, therefore, is to prevent the introduction of this species to Ireland.

Management implications

In most waters eradication at present is not feasible and programmes of measures should focus on preventing spread into new areas. However, chemical treatment using pyblast (where approved by the relevant regulatory body) may be successful in eradicating signal crayfish from small, enclosed ponds. Control methods, such as repeated trapping or removal using electrofishing, have been tried but have not proved effective. A novel technique using a specially constructed barrier to prevent the spread of crayfish into adjacent water bodies is being tested in a catchment in southern Scotland.

<u>(c) *Dreissena polymorpha* – zebra mussel</u>

It is only in the last 200 years that zebra mussel has expanded its range from the Black Sea and Aral-Caspian Sea basins. It is a small freshwater mussel species but it is tolerant of brackish waters. Its post-glacial re-colonisation of Europe has been greatly accelerated by the development of a canal network connecting the major European river systems accompanying an increase in shipping trade resulting from the Industrial Revolution (Morton, 1993). Zebra mussels were first recorded in Britain in the Surrey docks (London) and at Wisbech, Cambridgeshire in 1824. By 1834, zebra mussels were recorded in the lowlands of Scotland and by 1850 they were widespread in England. The distribution largely corresponded with the extent to which interconnected canals and rivers formed a linked network of navigable waterways (Coughlan, 1998).

After establishment in Britain, zebra mussel did not arrive in Ireland for another 170 years. It was first recorded in 1997 in Lough Derg on the Shannon (McCarthy *et al*., 1997). When zebra mussels arrived the population increased extremely rapidly to estimated densities of 10,000-100,000 individuals per m^2. Noted impacts have included a reduction in plankton, changes in fish population structure, local extinction of native *Anadonta*, increased water clarity resulting in increased aquatic plant growth, as well as clogging intake pipes at water abstraction works and heavily fouling hard structures and boats. In February 2006 a new population of zebra mussels was discovered in Cardiff Bay, which was believed to have been the first time zebra mussels had been found in Wales. In Scotland, a new record of zebra mussels was made in July 2010 on a boat at Carron sea lock, Forth & Clyde Canal; a further discovery was made in the canal in September 2010 on a boat at Auchinstarry marina, with a second boat found to be infected in the same marina in November 2010.

Dispersal to water bodies outside these connected navigable waterways has been slower, with the first record at Lough Derravaragh, Co. Westmeath in 2002. Since then, several new unconnected sites have been discovered to have zebra mussel populations. In Britain the most notable increases have been in southern, central and eastern England. A recently recorded population of *Dreissena polymorpha* in the River Darent, Kent, included dense mats of up to 11,000 individuals per m^2 and up to 20cm in depth (Aldridge *et al.,* 2004). There is evidence that the ecology of recently invaded sites has been adversely affected.

Management implications

Once zebra mussels become established in a water body control and eradication is almost impossible. Research carried out by Cambridge University has explored various control and mitigation options such as a 'bio-bullet' for zebra mussels. To date, efforts across the UK and Ireland have focused on putting measures in place to prevent spread into new areas. For example, a zebra mussel management strategy has been developed for Northern Ireland.

(d) *Sargassum muticum* – wire weed

This is a large brown seaweed, with fronds often more than 1m long. It first appeared in Britain in 1973 (on the Isle of Wight) having arrived here from France. Since its introduction, *S. muticum* has spread along the south coast to the Isles of Scilly, along the north Cornish coast to Lundy, and along the west coast of Wales and Scotland. Populations have also become established in Strangford Lough in Northern Ireland and it has been recorded around the coast of the Republic of Ireland (Harries *et al*., 2007a, b; Davison, 2009).

The plant grows on hard substrata in shallow waters and can also tolerate estuarine conditions. It can out-compete local species because it is fast-growing, can reproduce within the first year of life, and can self-fertilise. It competes with native species such as sea grasses and is considered a nuisance in harbours, beaches and shallow waters. A risk assessment has been carried out on behalf of the GB Programme Board (https:// nonnativespecies/index.cfm?sectionid=51). The assessment concluded that *S. muticum* is likely to spread rapidly and become established, leading to changes in community structure and dominance.

Management implications

Although eradication is not considered practicable, there may be scope for halting the spread of *S. muticum* if caught early. Where appropriate, such action should be contained within programmes of measures. An overview of control methods is given by Cook and Harries (2007); the only practical method for controlling *S.muticum* appears to be physical removal of unattached or attached plants. However, this method requires regular monitoring and repeated efforts to control the weed.

(e) *Spartina anglica* – common cord-grass

Spartina alterniflora is thought to have been introduced to Britain in the 19th Century in ships' ballast water. Subsequent crossing with the native *S. maritima* resulted in the appearance of the hybrid *Spartina anglica,* which was extensively planted throughout Britain to stabilise soft sediments. In Britain *S. anglica* is widespread around the east and west coasts and is still expanding in the west. A recent survey of the distribution has been carried out in Northern Ireland (Robb *et al*., 2009) and *S. anglica* was found at all five areas sampled. It is generally found in sheltered, estuarine conditions where mudflats are present. It usually produces a monoculture which has much less intrinsic value to wildlife than naturally species-diverse marsh. The rapid colonisation of *Spartina* over extensive mudflats has also had adverse effects on wintering populations of waders and wildfowl through loss of habitat for feeding and roosting. A risk assessment for the GB Programme Board in is progress (March 2013). Eight water bodies in Scotland have been downgraded from high to good on the basis of *Spartina* presence.

Management implications

Chemical control has been used with mixed success. As with *Sargassum muticum*, complete eradication is not an option, but if caught early it may be possible to prevent further spread. Where appropriate, such action should be contained within programmes of measures. A recent systematic review and meta-analysis of management options found that a combination of herbicides and smothering could be effective at reducing *S. anglica* densities but the effectiveness of control was variable depending on the application method (Roberts and Pullin, 2008). In Northern Ireland, methods such as strimming, using sheets to cover the plants, glyphosphate (alone and in combination with plastic sheets) and Fusilade Max (a chemical used with 100% success rate in Australia) were tested and a control programme is now going ahead using Fusilade Max. (Further details are given in the *Spartina* Management Strategy for Northern Ireland 2010-2013.)

(f) *Crepidula fornicata* – slipper limpet

Crepidula fornicata is known to have been introduced to Essex between 1887 and 1890 from North America, in association with imported American oysters *Crassostrea virginica*. It showed fairly rapid spread from Essex to Weymouth, Dorset, by 1945 and by the early 1950s its range had extended to Northumberland. This species now occurs in south-west, south and south-east Britain and as far north as Pembrokeshire on the west coast and Yorkshire on the east coast. Minimum winter temperatures may be important in limiting the growth of extensive populations in the north of Britain. It has been introduced accidentally to several locations in Ireland but populations only seem to be able to persist in Belfast Lough (McNeill *et al*., 2010). It was also introduced accidentally to North Wales with mussel spat, but early action to remove the affected mussels and relay spat in high densities to smother *C. fornicata* seems to have resulted in a successful eradication (Kate Smith, CCW, pers.comm).

Crepidula fornicata is typically found attached to shells (often the mussels *Mytilus edulis and oy*sters *Ostrea edulis*) and stones on soft substrata around the low water mark and the shallow sublittoral. It competes with other filter-feeding invertebrates (including commercially reared oysters) for food and space, and in waters of high concentrations of suspended material it encourages the deposition of mud. A risk assessment has been completed on behalf of the GB Programme Board, which has concluded that the potential impact of *Crepidula fornicata* is ‘massive’.

Management implications

Local eradication is possible in some places – dredging and disposal above high water mark has been used as one way of clearing large beds of *C. fornicata*. There may be scope for halting its spread if caught early; where appropriate, such action should be contained within programmes of measures. It is unlikely that derogations would be considered for water bodies with respect to this species.

(g) *Pseudorasbora parva* – topmouth gudgeon

Pseudorasbora parva is known to have been introduced to Hampshire in the mid-1980s, probably as a contaminant of imported fish from the Continent (e.g. golden orfe *Leuciscus idus*) much in the same manner that it spread throughout Europe in consignments of Asian carp species (Gozlan *et al.*, 2010). *Pseudorasbora parva* dispersed fairly rapidly in the UK, particularly in consignments of golden orfe (Copp *et al*., 2010) and became established in all regions of England and in a few locations in Wales (Pinder *et al.* 2005). The species is extremely robust and is able to persist in virtually all types of water body, but in at least one case an illegal introduction failed to result in an established population (Copp *et al.*, 2007).

Pseudorasbora parva is considered to be a pond and/or canal species in some European countries, but it is well known as a stream fish in parts of its native range (e.g. Japan) and at least one stream population is believed to exist in England, downstream of the original introduction site (Beyer *et al*., 2007). Besides being a facultative parasite, *P. parva* is more widely known as a healthy host of the rosette agent, which is a pathogen lethal to both salmonids and cyprinids (Gozlan *et al*., 2005). Evidence also suggests that the presence of *P. parva* can impede native fish species from successfully reproducing and recruiting offspring (Britton *et al.*, 2009). A risk assessment, including pre-screening (Copp *et al.*, 2009), has been carried out on behalf of the GB Programme Board
(https:// nonnativespecies/index.cfm?sectionid=51) and the overall assessment was that *P. parva* poses a high risk and is likely to spread more or less rapidly and establish in most lentic fresh waters, with impacts as described above.

Management implications

Eradication has proved possible in some water bodies, mostly those that are small and isolated (or that can be made isolated), using either a piscicide (rotenone; Britton *et al.*, 2008), drain-down and disinfection (Britton *et al.*, 2010), or repeated removal when population densities are low (Copp *et al*., 2007). This last approach is currently being examined as an alternative to rotenone treatment (K.J. Wesley, M.J. Godard & G.H. Copp, unpublished data). The small size and ability of *P. parva* to persist in low oxygen and even toxic waters makes its dispersal and persistence more likely than with some other species. However, there appears to be scope for halting its dispersal, especially if eradicated early (Britton *et al.*, 2011). Programmes of measures should focus on preventing spread into new areas.

(h) *Ludwigia grandiflora* - water primrose

Ludwigia grandiflora is a recent invader which escaped into the wild after being introduced as an ornamental garden / pond plant. Originally from South America, it has invaded Europe and spread to countries including Spain, Switzerland, Belgium and the Netherlands. The GB risk assessment ranks this species as a high risk because of its ability to outcompete other plant species, deoxygenating water, clogging watercourses and reducing recreational value.

The first established population in GB was recorded in the 1990s. Defra commissioned an assessment of eradication options in 2007 and since then the Environment Agency has been undertaking rapid response eradication of any populations found. To date, a total of 18 populations have been found, mainly in the south of England, and these are being managed.

An Invasive Species Action Plan (ISAP) has been developed for *Ludwigia* (https://secure.fera.defra.gov.uk/nonnativespecies/index.cfm?sectionid=92). It is the first ISAP that has been developed in GB (others are in production) and states that *Ludwigia* is a high priority species with eradication in GB as the agreed policy.

Several small and localised infestations of *L. grandiflora* have been reported in the south west of Ireland, near Sneem in Co. Kerry. All of the infestations are in confined garden ponds and currently pose little risk to the country at large.

Management implications

As a recent invader, management of this species is relatively feasible and affordable. Rapid action now is considered highly cost-effective compared with undertaking control once the species is widely established (Table 2). Eradication at the early stages of infestation is also considerably more feasible given the resources involved and the plant's ability to spread through tiny fragments of material.

In summary:

- Many alien species may not become established, but those that do may exert an adverse impact on native species and habitats and on economic interests.
- The effect that an invasive alien species has on its native surroundings may not always be apparent; this suggests the need for a precautionary approach as supported by the Convention on Biological Diversity.
- Once well established, eliminating many alien species (except in small, isolated water bodies) can be extremely costly and sometimes impossible. Emphasis should therefore be placed on early detection and rapidly responding to new / small infestations as soon as possible.
- The effects of climate change are likely to provide conditions that encourage the spread of certain invasive alien species beyond their present range.
- In view of the difficulties of eradicating alien species once established, efforts should be made to restrict their further spread.

6. Risk assessment for alien species

Risk assessment is an important tool in developing policy and control programmes for invasive alien species. The GB review of non-native species policy (Defra, 2003) recommended the use of a comprehensive risk assessment procedure for determining (a) the likelihood of a particular species entering and becoming established within a given area, and (b) the impact of this occurring.

Following the Defra review (Defra 2003) a national risk assessment mechanism was established to provide assessments of the risk posed by any non-native species in GB (Baker *et al*., 2008). Within this mechanism risk assessments are carried out by independent experts, peer reviewed and placed on the NNSS website for public comment before being finalised. The entire process is overseen by an independent panel of risk analysis experts (NNRAP) on behalf of the GB Programme Board which approves the assessments once they are completed. All completed risk assessments are reviewed when appropriate. Although thorough, the national mechanism is a relatively slow process and does not focus specifically on issues relating to the WFD.

(i) Alien species impact categories

For the purpose of risk assessment under the WFD (i.e. the risk of failing one or more of the environmental objectives), alien species are assigned to one of four categories: 'high', 'moderate', 'low' , and 'unknown' impact, except for Ireland (Ecoregion 17) where there is only one list of high-impact species. The four categories are based on concepts in the Defra review (2003) and in the IUCN strategy, from which the following definitions have been taken and amended:

High Impact: alien species, known to be invasive, which have caused documented harm in habitats where they have become established.

Low Impact: alien species known on the basis of stringent criteria to have a low probability of becoming invasive, and where field observations have shown no adverse impacts over many years of establishment.

Unknown Impact: alien species whose probability of becoming invasive is unknown, and for which a full risk assessment is required.

(**NB:** Species which clearly fall between the low and the high impact categories are assigned to the **Moderate Impact** category.)

High-impact species are likely to become established and cause problems in any habitat in which they persist. Their propensity to spread rapidly means that prevention is the only effective way of dealing with problems, as control is likely to be prohibitively expensive and/or unsuccessful.

Species assigned to the low-impact category will have been subject to a comprehensive evaluation. If conditions change (e.g. through climate change) then species on the low-impact list may be moved to the high-impact list until there is sufficient evidence to support a continued low-impact classification.

Species of unknown impact (the great majority of alien species) are those for which adequate ecological information is unavailable and where the potential impacts on recipient habitats and biota are not yet known. Species will remain on this list until there is sufficient scientific justification to classify them as either high or low impact.

(ii) Assigning species to impact categories

The UK TAG Alien Species Group (ASG) is a technical sub-group that provides scientific advice to the Water Framework Directive UK Technical Advisory Group. ASG uses the best available information to decide how an invasive non-native species should be categorised in relation to the potential level of adverse impact and risk it poses to the water environment; economic considerations or other issues are not taken into account at this stage.

Where risk assessments have been completed by GBNNSS the results of these are used to allocate the species to one of the UKTAG categories. However, many non-native species have not yet had a risk assessment carried out or not yet completed. These species have been allocated to one of the UKTAG categories based on expert judgement.

The guidance is used by the relevant environment agency in each UK country to develop classification systems to assess the status of individual water bodies. Objectives for water bodies classified as less than good status, and timescales for improvement, are agreed by the statutory agencies dependent on the availability, or feasibility of developing, suitable techniques for eradication, control, or prevention of further spread. However, the presence of a species on the high-impact list does not necessarily mean that action will be taken. Measures to improve these water bodies are agreed with stakeholders including central and devolved government, statutory agencies, non-governmental organisations, local authorities, water companies, industry representatives, rivers and fisheries trusts, and land managers and owners.

When new risk assessments are completed these are reviewed by ASG and the species added to the appropriate list. Where the listing of a species is challenged or the information available does not allow a consensus, ASG may request a more in-depth analysis for that species through the comprehensive risk assessment process undertaken by the GB Non-Native Species Secretariat (https://secure.fera.defra.gov.uk/nonnativespecies/index.cfm?pageid=216)

It is intended that in time all species listed on the high-impact list and some on the unknown impact list will be subject to formal risk assessments.

The table on the UKTAG website (http://www.wfduk.org/tag_guidance/Article_05/Folder.2004-02-16.5332/alien_tag_table) is a continually updated list of alien species according to impact category, but does not purport to be a comprehensive list of all aquatic alien species, or of other alien species that may affect aquatic ecosystems. Over time, the details in the table will change as new species invade, others cease to be a problem, or scientific knowledge of particular alien species increases.

Some species native to the UK may be considered as aliens ('locally absent' species) when introduced into other parts of the country where they were previously absent. For example, the presence of ruffe (*Gymnocephalus cernuus*) in Loch Lomond provides a good example of an introduction of a species that is locally non-native. This species was unknown in Scotland until it was discovered in Loch Lomond in 1982, the result (it is thought) of discarded livebait by anglers from England. *Gymnocephalus cernuus* was probably a contaminant of the bait bucket rather than a bait fish itself, as anglers are not known to use this species as bait (K.J. Wesley, personal communication). Since then, the population has exploded and caused a fundamental shift in many aspects of the ecology of the loch (Doughty *et al*., 2002). Of particular concern is the predation pressure that ruffe exert on the eggs of powan, a protected fish species of high conservation value. It is unlikely that this problem can be solved even in the long term.

Although it may be difficult to distinguish between ‘natural’ expansion of range and human introductions, by adhering to the definition of a ‘native species’ given in this paper it is possible to identify species that, although resident in the UK, have been introduced beyond their natural range. Work is under way to identify high-impact, locally absent species in each of the river basin districts so that consideration may be given to use them in future assessments of ecological status. (This approach will be reviewed in the light of the new legal instrument on alien species currently in production by the European Commission.)

Terrestrial plant species on the banks of rivers (and occasionally around the shores of lakes) should also be considered in impact assessments. High-impact riparian species (Himalayan balsam, giant hogweed, Japanese knotweed and rhododendron) can out-compete native species, changing the structure and composition of riparian vegetation. In turn, this may alter the mechanical properties of river banks, for example their ability to resist erosion due to changes in root strength, root extent and bank pore-water pressure profiles; the duration of floodplain inundation; and the amount of woody material input to the channel. Consequently the morphological condition of the water body can be affected. Studies have also shown that ecosystem functioning can be impaired in adjacent river systems (Hladyz *et al*., 2011).

These alien species are commonly found along river banks throughout the UK, and can be recorded as part of the standard method of River Habitat Survey (RHS: Raven *et al*., 1997). The RHS database contains survey data from >24,000 sites, each 500 m long, of which >6000 have records of one or more of the first three species listed above. (The database does not provide a comprehensive coverage of all UK rivers so these figures are only indicative.) When one or more of these species occurs extensively on river banks, the ‘structure and condition of the riparian zones’ can no longer be considered to ‘correspond totally or nearly totally to undisturbed conditions’ (WFD Annex V definition of high status for the morphological conditions of rivers). Thus, the presence of these species should be evaluated when considering a high ecological status classification or when determining the risk of a water body deteriorating from high status to good status; however, their presence does not necessarily indicate that a water body is at risk of failing to achieve good ecological status.

The impact of these species is assessed in Scotland using the River MImAS (**M**orphological **Im**pact **A**ssessment **S**ystem); the tool used by SEPA to produce the morphology classification and to assess the impacts of engineering Controlled Activities. It is a risk-based tool that assesses the likelihood of damage being caused by different types of engineering modifications of rivers, including modifications to the riparian vegetation. The tool is based on the idea of system capacity, which states that a near-natural river will retain 100% of its capacity to absorb morphological damage. The amount of system capacity used by a modification will depend on the type of modification, its spatial extent and the sensitivity of the river on which it is located.

(iii) Datasets and data sources that may assist in alien species assessments

The GB NNSIP (Non-native Species Information Portal) has been developed to act as a central hub for non-native species data in England, Scotland and Wales. The Portal is managed by the Biological Records Centre at the Centre for Ecology and Hydrology and is directly linked to the National Biodiversity Network. Objectives of the NNSIP project include increasing the flow and quality of non-native species data into the portal, making more useful information about non-native species available to stakeholders and encouraging further recording, particularly of high priority 'alert' species. In Ireland a National Invasive Species Database has been established which is managed by the National Biodiversity Data Centre in Waterford. It holds records of invasive species from across the island of Ireland. Records in Northern Ireland are also held by the Centre for Environmental Data and Recording (CEDaR) based at the Ulster Museum in Belfast. Through the Invasive Species Ireland website an online 'Alien Watch' reporting facility has been developed that enables the general public to submit records with images to allow validation. An expert registry has been set up to assist with this process.

To improve our understanding of non-native species all non-native species records should be reported to these existing systems. Other useful information on datasets and data sources to help in the risk assessment process can be found in Defra (2003: Annex 7 – Analysis of current biological recording schemes).

The EU has made considerable research investment to improve knowledge regarding alien species (e.g. DAISIE), risk analysis methods and protocols as well as decision support schemes (e.g. ALARM, IMPASSE, PRATIQUE). The project DAISIE (Delivering Alien Invasive Species Inventories for Europe[2]) provided information on the 10,822 alien species known to exist in Europe, and identified the 100 worst invasive species (DAISIE, 2009), based mainly on current knowledge of alien species impacts in the European territory (http://www.europe-aliens.org/index.jsp). In addition, 1094 species were described as having ecological impacts, with documented economic impacts in Europe reported for a total of 1347 species (Vilà *et al*., 2009).

The project ALARM (**A**ssessing **LA**rge-scale environmental **R**isks for biodiversity with tested **M**ethods[3]) aims to develop and test methods and protocols for the assessment of large-scale environmental risks in order to minimise adverse direct and indirect human impacts, including biological invasions as a main risk to biodiversity. Outputs from this project include the creation of the on-line, open-access scientific journal *Aquatic Invasions* (www.aquaticinvasions.ru/), a biopollution index (Olenin *et al*., 2007) and a conceptual structure for an on-line risk analysis toolkit (Panov *et al*., 2009).

In response to the EU Regulation on the use of alien species in aquaculture, the project IMPASSE (Environmental impacts of alien species in aquaculture[4]) provided a review of issues associated with the use of alien species in aquaculture and produced the European Non-native Species in Aquaculture Risk Assessment Scheme (ENSARS), which applies to all forms of aquatic organisms (Copp *et al*., 2008). ENSARS was adapted from the same risk analysis protocols used in the GB Non-native Risk Analysis Scheme (Baker *et al*., 2008), which is based on principles and protocols espoused by the European and Mediterranean Plant Protection Organization (2007b). As a further enhancement of the EPPO scheme, the EU project PRATIQUE (Enhancement of Pest Risk Analysis Techniques[5]) is developing a web-based modular platform for risk assessments whereby

[2] Website: www.daisie.se/
[3] Website: www.alarmproject.net/alarm/
[4] Website: www.hull.ac.uk/hifi/IMPASSE/
[5] Website: http:/secure.csl.gov.uk/pratique/index.cfm

the assessment modules can be taken and adapted for other schemes, such as the GB and ENSARS schemes (Copp *et al*., 2008).

General information on the ecology of individual species may also be found on the web-sites of JNCC (http://jncc.defra.gov.uk) and the British Natural History Museum (http://www.nhm.ac.uk/nature-online/) as well as in a range of textbooks on aquatic ecology.

(iv) General principles for risk assessment and ecological status

The procedure for using data on alien species in classifying ecological status has been agreed by UKTAG as described in Figure 1. This approach should also be used in assessing the future risk of a water body failing to meet its environmental objectives. Note that environmental objectives include not only attaining good ecological status but also maintaining or improving the present level of status (i.e. 'no deterioration').

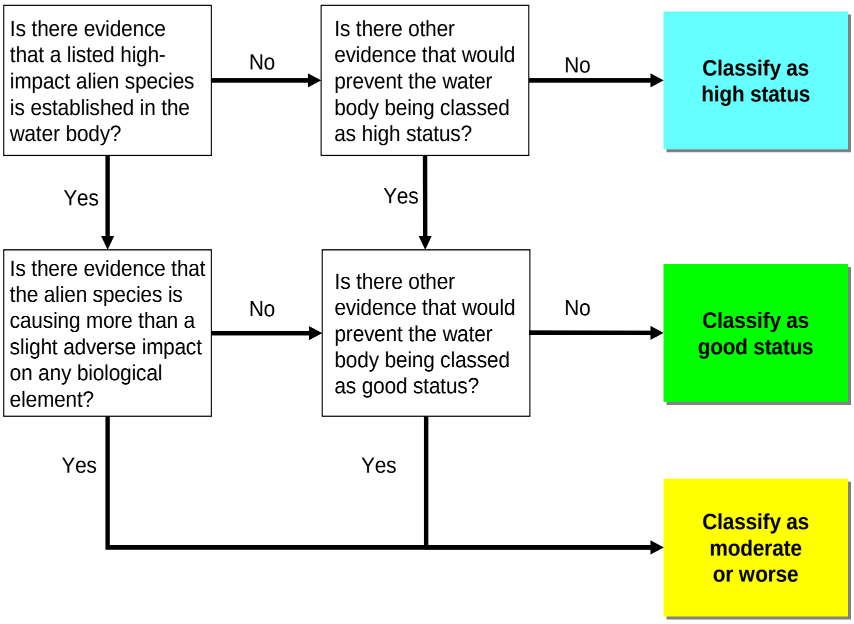

Figure 1: Procedure for using alien species data in assessing ecological status

Where the lack of established alien species, the lack of observed impacts from alien species, or any other related criterion constitute an environmental objective for a water body designated as an SAC or SPA (a 'Protected Area' under the WFD) it will be at risk of failing to achieve its environmental objectives where these criteria are not met.

The degree of risk from an alien species will vary according to the following factors, each of which should be taken into account in the risk assessment:

(a) Present location: is the alien species already in the water body, in a nearby water body, further away but still in the same catchment?

(b) Does the water body contain suitable available habitats to support the alien species?

(c) Are there any known predators or competitors that might prevent the establishment of the alien species?

(d) Are there other factors that increase the likelihood of the alien species becoming established in the water body? (e.g. live-baiting by anglers, inter-basin water transfers, nearby crayfish farms, known releases of ballast water)

(v) Specific recommendations for incorporating alien species in the 2013 risk assessment

1. The risk assessment exercise in 2013 should consider all of the species in the high-impact category of the UKTAG list. In practice, information may only be available on some of these, but efforts should be made to expand programmes of survey and monitoring to encompass as a wide a range of the listed species as possible.

2. Where data are available, water bodies containing other species in the UKTAG list may also be assessed if the data indicate a likelihood of risk. These species may include: (a) those listed in the 'moderate' impact category; (b) those listed in the 'low impact' category where they are observed to be exerting damaging effects locally; (c) those that are native to the UK but not to a particular region (e.g. ruffe in Scotland).

3. Given the limited data on the impacts of some alien species in specific sites, the presence of one or more of the high impact alien species listed in Appendix 1 will be used in the 2013 characterisation exercise to indicate water bodies at risk. This is considered a reasonable approach as there is sufficient ecological understanding of these species to demonstrate the severe threat they pose to the integrity of aquatic ecosystems. In the longer term, further work will be required to assess the impacts of alien species on specific water bodies, both to enable an accurate assessment of ecological status and to design appropriate programmes of measures.

4. Formal confidence estimates for the alien species risk assessment should be restricted to those instances where alien species constitute the only pressure leading to a water body being classified as 'at risk'.

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