Information about GB Non-native Species Risk Assessments

The Convention on Biological Diversity (CBD) emphasises the need for a precautionary approach towards non-native species where there is often a lack of firm scientific evidence. It also strongly promotes the use of good quality risk assessment to help underpin this approach. The GB risk analysis mechanism has been developed to help facilitate such an approach in Great Britain. It complies with the CBD and reflects standards used by other schemes such as the Intergovernmental Panel on Climate Change, European Plant Protection Organisation and European Food Safety Authority to ensure good practice.

Risk assessments, along with other information, are used to help support decision making in Great Britain. They do not in themselves determine government policy.

The Non-native Species Secretariat (NNSS) manages the risk analysis process on behalf of the GB Programme Board for Non-native Species. Risk assessments are carried out by independent experts from a range of organisations. As part of the risk analysis process risk assessments are:

- Completed using a consistent risk assessment template to ensure that the full range of issues recognised in international standards are addressed.
- Drafted by an independent expert on the species and peer reviewed by a different expert.
- Approved by an independent risk analysis panel (known as the Non-native Species Risk Analysis Panel or NNRAP) only when they are satisfied the assessment is fit-for-purpose.
- Approved for publication by the GB Programme Board for Non-native Species.
- Placed on the GB Non-native Species Secretariat (NNSS) website for a three month period of public comment.
- Finalised by the risk assessor to the satisfaction of the NNRAP.

To find out more about the risk analysis mechanism go to: www.nonnativespecies.org

Common misconceptions about risk assessments

To address a number of common misconceptions about non-native species risk assessments, the following points should be noted:

- Risk assessments consider only the risks posed by a species. They do not consider the practicalities, impacts or other issues relating to the management of the species. They therefore cannot on their own be used to determine what, if any, management response should be undertaken.
- Risk assessments are about negative impacts and are not meant to consider positive impacts that may also occur. The positive impacts would be considered as part of an overall policy decision.
- Risk assessments are advisory and therefore part of the suite of information on which policy decisions are based.
- Completed risk assessments are not final and absolute. Substantive new scientific evidence may prompt a re-evaluation of the risks and/or a change of policy.

Period for comment

Draft risk assessments are available for a period of three months from the date of posting on the NNSS website*. During this time stakeholders are invited to comment on the scientific evidence which underpins the assessments or provide information on other relevant evidence or research that may be available. Relevant comments are collated by the NNSS and sent to the risk assessor. The assessor reviews the comments and, if necessary, amends the risk assessment. The final risk assessment is then checked and approved by the NNRAP.

*risk assessments are posted online at:
https://secure.fera.defra.gov.uk/nonnativespecies/index.cfm?sectionid=51
comments should be emailed to nnss@fera.gsi.gov.uk

Rapid Risk Assessment of: *Dikerogammarus haemobaphes*
Author: David C. Aldridge
Date: First published on the NNSS website 03/09/13
Suggestion citation: Aldridge, D.C. (2013). GB Non-native Organism Rapid Risk Assessment for *Dikerogammarus haemobaphes* (Eichwald, 1841). ww.nonnativespecies.org

GB Non-native species Rapid Risk Assessment (NRRA)

Introduction:

The rapid risk assessment is used to assess invasive non-native species more rapidly than the larger GB Non-native Risk Assessment. The principles remain the same, relying on scientific knowledge of the species, expert judgement and peer review. For some species the rapid assessment alone will be sufficient, others may go on to be assessed under the larger scheme if requested by the Non-native Species Programme Board.

Guidance notes:

- We recommend that you read all of the questions in this document before starting to complete the assessment.
- Short answers, including one word answers, are acceptable for the first 10 questions. More detail should be provided under the subsequent questions on entry, establishment, spread, impacts and climate change.
- References to scientific literature, grey literature and personal observations are required where possible throughout.

1 - What is the principal reason for performing the Risk Assessment? (Include any other reasons as comments)

Response: *This species was detected in GB in September 2012. A rapid assessment is required to inform policy makers of the potential risks posed by this species.*

2 - What is the Risk Assessment Area?

Response: *GB*

3 - What is the name of the organism (scientific and accepted common; include common synonyms and notes on taxonomic complexity if relevant)?

Response:

Dikerogammarus haemobaphes (Eichwald, 1843). This species has no common name. Historically, there has been some confusion with the identity of the *Dikerogammarus* spp. across Europe. *D. haemobaphes* appears to be synonymous with *Dikerogammus fluviatilis* (Jazdzewski, 1980). Molecular studies by Muller et al. (2002) has confirmed the taxonomic status of three distinct species: *D. haemobaphes, D. villosus, D. bispinosus.*

4 - Is the organism known to be invasive anywhere in the world?

Response:

Yes. The species has invaded much of Western Europe. It was first reported outside its native Ponto-Caspian range in Lake Balaton, Hungary, in 1955 after which it continued to spread along the Southern Corridor (connecting the Danube and Rhine rivers) (Bij de Vaate et al., 2002). The first record for the upper Danube in Germany was 1976, followed by observations in the Main-Danube Canal in 1993 (Schleuter et al., 1994), the German Rhine in 1994, and the Dutch Rhine in 2000 (Bij de Vaate et al., 2002). The species also spread along the Central Corridor (connecting the rivers Dneiper, Vistula, Elbe and Rhine), with first records in the Vistula, Poland, in 1997 (Konopacka, 1998). The precise impact of the species has been hard to disentangle because *D. haemobaphes* has typically invaded European systems alongside other non-native amphipods. However, the dramatic ecological changes associated with its presence (albeit alongside other non-natives) suggests the species can be considered truly invasive.

5 - What is the current distribution status of the organism with respect to the Risk Assessment Area?

Response:

The species was first reported on 21st September 2012 by APEM Ltd. It was found in preserved samples collected on 14th May 2012 from the River Severn at Tewkesbury (NGR SO8355759115). Preserved material collected on the same date yielded more specimens from the River Severn at Cheltenham (SO8794831682). Subsequent field surveys up to 12 November 2012 revealed *D. haemobaphes* in The River Severn and Trent catchments and associated canals; these locations are spread over a wide area and give an indication of the potential extent of the population. The species has also been found at sites on the Foss Dyke, on the River Witham in Anglian Region and over a 12km reach of the Thames (https://secure.fera.defra.gov.uk/nonnativespecies/news/index.cfm?id=97).

6 - Are there conditions present in the Risk Assessment Area that would enable the organism to survive and reproduce? Comment on any special conditions required by the species?

Response:

Yes. The existing widespread distribution of the species indicates that it is both surviving and reproducing in GB. The species is not, as yet, found at very high abundance in the areas surveyed and co-occurs with other amphipod species.

D. haemobaphes is found within a broad range of conditions, but prefers solid substrates, macrophytes and filamentous algae in rivers, lakes and canals (Kititsyna, 1980; Musko, 1994). It tolerates salinities from freshwater up to 8‰ (Pontomareva, 1976) and is able to tolerate temperatures up to 30°C (Kititsyna, 1980). Like the killer shrimp, *D. villosus*, *D. haemobaphes* shows a strong preference for beds of the Ponto-Caspian zebra mussel, *Dreissena polymorpha*. In laboratory experiments Kobak & Zytkowicz (2007) found *D. haemobaphes* to choose live zebra mussels over dead shells, and to select these two habitats over stones and empty plates. It is likely that zebra mussels in GB may provided important habitats in many locations, and may be especially important in facilitating spread through the Midland canal system. Zebra mussels are distributed broadly through GB from East Anglia to Cardiff Bay and from West Sussex to the Forth & Clyde Canal in Scotland (Aldridge, 2010).

In Lake Balaton, *D. haemobaphes* was especially abundant on the submerged macrophytes *Potamogeton perfoliatus* and *Myriophyllum spicatum* (Musko, 1990). However, it is unlikely that these particular taxa represent an especially important predictor of habitat suitability.

7 - Does the known geographical distribution of the organism include ecoclimatic zones comparable with those of the Risk Assessment Area or sufficiently similar for the organism to survive and thrive?

Response:

Yes. The Western European regions already invaded by *D. haemobaphes* include regions such as The

Netherlands which share a strong bioclimatic match to much of Britain's freshwaters. Recent studies by Ermgassen et al. (in review) show that 50% of GB's established freshwater invaders since 1973 were previously established in The Netherlands, which in part reflects the similarity between the ecoclimates of the two regions.

8 - Has the organism established viable (reproducing) populations anywhere outside of its native range (do not answer this question if you have answered 'yes' to question 4)?

Response:

N/A

9 - Can the organism spread rapidly by natural means or by human assistance?

Response:

Yes. The rate of spread across broad geographies is illustrated through the species' advancement along the Southern and Central Corridors (see section 4). No specific studies have been reported on the vectors and pathways for *D. haemobaphes* spread, but downstream drift is likely to generate the fastest dispersal within a catchment (van Riel et al., 2006). The discovery of specimens in two canals adjacent to the River Severn, separated by many locks, suggests it may be distributed with boat traffic. The association of the species with macrophytic vegetation (Musko, 1990) suggests that overland transport may be possible on contaminated outboard engines and fishing gear.

Studies in GB of possible vectors and pathways for the congeneric, *D. villosus*, suggests that particularly important overland vectors might include outboard engines, rubber waders, fishing gear (such as keep nets), and pleasure craft. There is some uncertainty over the role of wildfowl as vectors for *Dikerogammarus* spp., but this cannot be ruled out as snails have been shown to be transported long distances in this manner (Gittenberger et al., 2005).

10 - Could the organism itself, or acting as a vector, cause economic, environmental or social harm in the Risk Assessment Area?

Response:

Yes. The greatest immediate harm is likely to come in the form of ecological damage to other biota through either direct predation, or through cascading indirect effects at different trophic levels. In Poland, the species has come to dominate amphipod communities in the middle and lower reaches of the Vistula River (Grabowski et al., 2006). Amphipods play a major part in energy flow within freshwater systems through their shredding and decomposition activities (Grabowski et al., 2007; MacNeil et al., 2011) and a shift in dominant amphipod species may alter decomposition rates. Densities of *D. haemobaphes* within invaded regions of Europe have been reported as 150 individuals m^{-2} during the early stages of invasion in the Odra River, Poland (Wawrzyniak-Wydroska & Gruska, 2005), and 563 ind. m^{-2} in Lake Balaton, Hungary (Musko, 1993).

Like its congener, the killer shrimp, *D. haemobaphes* is a major intraguild predator, feeding on both native and invasive amphipods, and is also cannibalistic (Kinzler et al., 2009). There are no data in the published literature to indicate the wider extent of predation by *D. haemobaphes*, but it is reasonable to expect that diets may be similar to that of *D. villosus*, and to include detritus feeding, coprophagy and predation on a wide variety of benthic and free-swimming invertebrates (Platvoet et al., 2009). It has been difficult to attribute ecosystem shifts in Europe specifically to the establishment of *D. haemobaphes*, because such changes are often coincident with the arrival of multiple invasives (Jazdzewski et al., 2004; MacNeil et al (in press).

Van der Velde et al. (2009) found that the diet of *D. haemobaphes* changed through the year, with the greatest proportion of animal material in the gut during the spring (ca. 80% by mass) and lowest in winter (ca. 20% by mass).

One of the most dramatic impacts of the arrival of *D. villosus* in Grafham Water was the shift in distribution of trout as they began to focus their feeding on this novel food resource. *D. haemobaphes* has been found to be an important prey item for many fish species, especially members of the Percidae, Gobiidae and Anguillidae (Kelleher et al., 1998) and so we might expect to see some changes in fish species of conservation or recreational importance.

Dikerogammarus spp. have been found to serve as vectors for a number of parasites such as gregarines (Codrenau-Balcescu, 1995) and a microsporidium, first described in 2010 and named as *Cucumispora dikerogammari* (Ovcharenko et al., 2010). *C. dikerogammari* reduces survival of its native Ponto-Caspian hosts, and while there is evidence of transmission to amphipods native to GB in laboratory studies, it is not thought that the microsporidium poses a current threat to novel host species (Bacela-Spychalska et al., 2012).

There is some evidence to suggest that the impact of *D. haemobaphes* may not be as extreme in GB as that anticipated by *D. villosus*. First, Kley & Meir (2006) reported that the species coexisted with native species (including *Gammaus pulex*) in parts of the Danube, although it is possible that such co-occurrence could be attributed to the early stage of an invasion. It is notable that *D. villosus* has often quickly displaced *D. haemobaphes* in many European freshwaters (e.g. Muller et al., 2002). However, it has been seen in The Netherlands that the two species may separate into adjacent microhabitats, with *D. haemobaphes* finding refugia within the mud and macrophyte regions less favoured by *D. villosus* (D. Platvoet, personal communication). The wider apparent habitat tolerance of *D. haemobaphes*, which includes mud and macrophytes, makes it especially well-suited to canal systems where it may become more widespread and dominant than *D. villosus*, which is typically restricted to hard substrates.

There is no reason to expect *D. haemobaphes* to create a nuisance to the treatment of potable water supplies or to represent a direct risk to recreational users of GB freshwaters.

Entry Summary

Estimate the overall likelihood of entry into the Risk Assessment Area for this organism (comment on key issues that lead to this conclusion).

Response: *very likely*

Confidence: *very high*

Comments:

The species is already present in GB. It is reasonable to assume that repeated introductions are likely, although the vector responsible for the recent invasion is unknown. The species is present in high abundance in the lower Rhine (Bij de Vaate et al., 2002) and this may represent a source for repeated invasion in GB (Ermgassen et al., in review). The Netherlands is currently the EU country that exchanges the greatest volume of trade with the UK, with the largely freshwater port of Rotterdam accounting for 7.6% of total tonnage loaded and unloaded at UK ports (Talbot et al., 2009). The relatively low salinity tolerance exhibited by *D. haemobaphes* (up to 8‰ (Pontomareva, 1976) will reduce the likelihood of entry through ballast water exchanges in brackish waters of some GB ports. Additional potential routes of entry include the movement of recreational boat traffic between GB and The Netherlands/France. Live shrimps may be carried in bilge water and released during bilge pumping or held in the bait buckets of occasional anglers. International watersports and angling events may provide a further route of entry, with fouled equipment representing a real risk. Of particular importance may be macrophytic vegetation which has not been cleaned from an outboard or other kit; such weeds may provide a moist environment sufficient to enable transport of live *D. haemobaphes* into GB.

While entry into GB is considered highly likely it is notable that *D. haemobaphes* arrived in the Rhine in 2000 and yet took 12 years to enter GB. While propagule pressure will have increased considerably since 2000 as distributions and densities have increased within The Netherlands, repeated entry into GB of *D. haemobaphes* may still remain a sufficiently uncommon event to make the initiation of control measures an appealing option, despite the species being present within the highly interconnected Midland canal system. Prevention of repeat invasions may be especially worthwhile if it is found that the existing population has been subject to a genetic bottleneck through a founding event. Eradication attempts would only be viable if new populations are small and discrete (i.e. within small lentic systems).

Establishment Summary

Estimate the overall likelihood of establishment (comment on key issues that lead to this conclusion).

Response: *very likely*

Confidence: *very high*

Comments:

The species is already established within GB, as evidenced by the relatively large numbers of individuals and relatively wide geography in which it has been collected.

Much of GB is likely to be climatically matched with the native and invaded range. A predictive map, using bioclimatic parameters from the native and invaded range of *D. haemobaphes*, is given in Figure 1 (Gallardo & Aldridge, 2013). The predicted distribution shows a strong overlap with the subsequent distribution recorded in England.

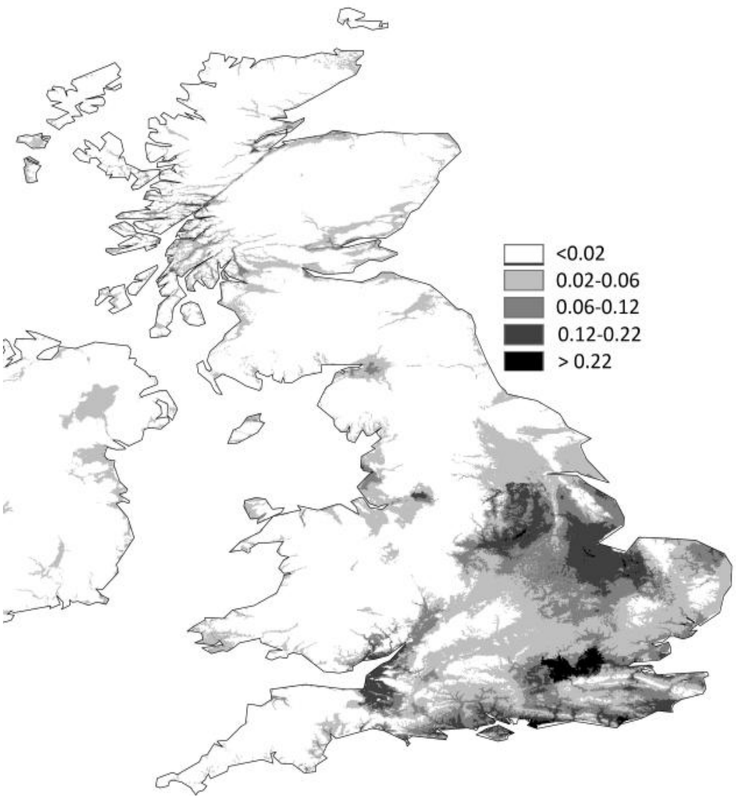

Figure 1. Habitat suitability for D. haemobaphes in GB based on distributions in mainland Europe. Model based on climate variables and water chemistry: annual temperature, seasonality, temperature of the warmest and coldest months, annual precipitation, precipitation of the driest month and seasonal precipitation, altitude, conductivity, alkalinity, nitrate, pH, dissolved organic carbon and sulphate concentration (from Gallardo & Aldridge, 2013, where more details on methodology can be found).

Spread Summary

Estimate overall potential for spread (comment on key issues that lead to this conclusion).

Response: *very rapid*

Confidence: *moderate*

Comments:

The discovery of the species over such a wide area suggests that spread has been rapid, especially as the Environment Agency has been on high alert since 2010 to monitor specifically for *Dikerogammarus* spp. and has not recorded the species. The fact that the species is predicted to establish across much of central, southern and eastern GB, and that it is already present in the Midland canal system, suggests that spread will be very rapid. Dispersal may be facilitated by boat movements and angling. The experiences of this species' spread across Europe is also indicative of rapid spread rates. Although no estimates of spread rate have been published, records from the Danube-Main-Rhine (Bij de Vaate et al., 2002) suggest that the species may be able to spread downstream along rivers many hundreds of kilometres a year. Spread of the congener *D. villosus* was estimated at 124 km per year in the Rhine (Leuven et al., 2009).

Van der Velde et al. (2000) defined the traits important for the success of crustacean invaders. According to these criteria, along with other species, *D. haemobaphes* shows early sexual maturity, very high fecundity (mean of 52 eggs per clutch in Central Europe) and short generation time (three generations per year). This may to large extent explain the rapid expansion and high abundances of the species in many European rivers (Bacela et al., 2009). This may be further enhanced by the species' wide environmental tolerances and plastic feeding biology.

Impact Summary

Estimate overall severity of impact (comment on key issues that lead to this conclusion)

Response: *high*

Confidence: *moderate*

Comments:

Experience elsewhere in Europe suggests that densities may exceed 500 ind. m^{-2}, and so can be expected to lead to marked ecological change. While relatively few data exist on the direct impacts of *D. haemobaphes*, there is good reason to believe that the published impacts of *D. villosus* may be similarly to those expected for *D. haemobaphes*. Grabowki et al. (2007) analysed eight different life-history traits within 13 native and invasive gammarid species and found that the *Dikerogammarus* spp. grouped closely together. Taking this assumption forward, we might expect reduced species diversity in invaded habitats, with a direct deleterious impact on *Gammarus pulex* (MacNeil & Platvoet, 2005) through intraguild predation. A broader array of invertebrates are likely to be heavily predated, belonging to a range of trophic niches including mayflies (scrapers), damselflies (predators), leeches (parasites), chironomids (collector-gatherers), cladocera (filterers) and isopods (detritivore-shredder) (Dick et al., 2002; MacNeil & Platvoet, 2005; Bollache et al., 2008). We can also anticipate changes in leaf litter processing and diet shift in a number of fish species (Kelleher et al., 2000).

Impacts are expected to be high because of the likely ecological impacts across all trophic levels and the wide potential geographic spread of the species. The evidence of possible co-occurrence of *D. haemobaphes* with native amphipods in the Danube Kley & Meir (2006) and the absence of any species-specific data from continental Europe on the ecosystems effects of *D. haemobaphes* makes confidence in these assertions only moderate.

Climate Change

What is the likelihood that the risk posed by this species will increase as a result of climate change?

Response: *moderate*

Confidence: *moderate*

Comments:

Invasive species are often associated with greater tolerance of environmental change than native species. *D. haemobaphes* has been shown to tolerate temperatures up to 30 °C and the species showed especially good growth and reproduction within heated waters from a power station, while other gammarid species died (Kititsyna, 1980). While existing evidence suggests *D. haemobaphes* could benefit considerably from climate change, there are too many unknowns to make confident predictions. Bioclimatic models can be produced to include climate change scenarios, and this would help to better understand the likely effects of climate change on the species.

Conclusion

Estimate the overall risk (comment on the key issues that lead to this conclusion).

Response: *high*

Confidence: *moderate*

Comments:

Risk is considered to be high based on the fact that *D. haemobaphes* has already entered GB and established a widespread viable population, that repeated invasions are very likely, that GB is climatically similar to many parts of the invaded range and that the interconnectivity of the UK water network will facilitate rapid spread. The paucity of data on the ecological impacts that can be attributed directly to *D. haemobaphes* invasion in Europe, and that fact that existing GB populations are widespread but not especially dense, means that the impacts may not be as severe as those anticipated for *D. villosus*. For these reasons, overall risk and confidence of assertions cannot be classed as 'very high'.

There is an important caveat to this expectation relating to founder effects. While the spread of *D. haemobaphes* through mainland Europe is likely to have involved a broadscale movement of many individuals, entry into GB may have come from a small number of founding individuals. It is therefore possible that the GB population may display atypical invasive characteristics due to a genetic bottleneck, and limited genetic diversity has the potential to limit spread, establishment and resistance in the face of natural enemies. Conversely, it is possible that a small founding population of *D. haemobaphes* did not bring with it microsporidian parasites typically associated with the species, and this could give *D. haemobaphes* an added advantage in GB.

Management options (brief summary):

1 - Has the species been managed elsewhere? If so, how effective has management been?

Response:

The species has not been specifically managed elsewhere.

2 - List the available control / eradication options for this organism and indicate their efficacy.

Response:

Santagata et al. (2009) investigated the use of concentrated sodium chloride brine for controlling a range of non-native freshwater invaders. A lethal dosage of 110 ppt for 1hr, or 60 ppt for >6h proved lethal to 95% of the species tested. This approach is especially well suited to ballast water treatment.

Santagata et al (2008) investigated the potential for osmotic shock treatment of aquatic invaders. By using seawater exposure, they found that species from mesohaline habitats (which includes the upper salinity range tolerated by *D. haemobaphes*) experienced 100% mortality in 40% to 53% of experimental treatments. The greatest survivorship was in amphipod species such as *D. haemobaphes*, illustrating that osmotic shock methods may not be an ideal option.

Addtional possible options include the use of sodium hypochlorite, hot water, dewatering of a site, pyrethrin (Pyblast), rotenone or BioBullets (Aldridge et al., 2006). Truhlar (2012) showed that the provision of microencapsulated BioBullets containing pyrethrins was especially effective at killing female D. villosus, and could thusoffer management through driving a population skew. Deployment of porous house bricks to provide refugia for *D. haemobaphes* may enable the species to be 'mopped-up' through regular lifting (J. Dick, Queen's University, pers. comm.). Introduction of predators such a brown trout may assist in localised control efforts. No data are available on the efficacy of these options against *D. haemobaphes* and application of such methods is likely to result in mortality to non-target biota. High concentrations of some control agents, such as hypochlorite, can cause some materials to perish.

3 - List the available pathway management options (to reduce spread) for this organism and indicate their efficacy.

Response:

Check, Clean, Dry procedures will help to raise awareness and slow spread. Engagement with key stakeholders, and especially the angling and boating communities of the canal system, will be an important route to slowing spread. Dispersal through the canal system may be facilitated especially by boats that have not been antifouled or whose hulls have not been regularly jet-washed. Such boats can attract large densities of zebra mussel growths, which provide ideal habitat for *D. haemobaphes* (Kobak & Zytkowicz (2007). Inspection of boat hulls during the 2012/13 winter draw-outs may be very informative on the distribution of the species and the potential role of boats as vectors. Any management operations that involve removal of mud and macrophytes should risk-assess the potential for shrimp transport.

4 - How quickly would management need to be implemented in order to work?

Response:

The species is already too widespread in its existing location to warrant any major eradication/management attempt. However, a rapid response may be suitable should a new localised population be discovered. At present, management options should focus on reinforcing and applying the Check, Clean, Dry protocols with recreational users of the Severn and Midland canal system to slow spread through and away from this system.

In Central Europe, *D. haemobaphes* reproduces first in April, a female carries up to 98 eggs and eggs can reach maturity in 4 to 8 weeks (Bacela et al., 2009). Populations therefore have the potential to increase rapidly. Control and eradication efforts should therefore be attempted immediately upon the discovery of new populations and early warning monitoring systems may prove especially important in enabling containment. Wintertime discoveries of new populations may provide more time for a planned control programme as populations are unlikely to be increasing in numbers and activity of potential vectors (angling, watersports, boating) is likely to be lower. However, control agents are less likely to be effective at cold temperatures.

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Provide here a list of the references cited in the course of completing assessment

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