**Rapid Assessment of: *Dikerogammarus villosus***
**Date: 14th September 2010**

***This is a rapid risk assessment coordinated by the NNSS on behalf of the GB Programme Board and completed by an independent expert. It is not a full risk assessment and has not been through the full GB Risk Analysis Process. The information provided should be considered initial advisory guidance from an independent expert.***

## Rapid Risk Assessment:

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

**Response:**

**An established infestation has been discovered in the RA area. Samples were collected of suspected *D. villosus* on 3rd September 2010 and identification was verified by Dr Dirk Platvoet (Zoological Museum of Amsterdam) on 9th September 2010.**

**2** - What is the Risk Assessment Area?

**Response: GB**

**3** - What is the name of the organism? (Other names used for the organism can be entered in the comments box)

**Response:**

***Dikerogammarus villosus* (Sowinsky, 1894). Common names include the 'killer shrimp' and 'pink peril'.**

**4** - Is the organism in its present range known to be invasive?

**Response:**

**Yes. Because of its predatory voracity and aggressive behaviour, *D. villosus* is known as the 'killer shrimp'. It is widely regarded as one of the most damaging invaders across Western Europe, being listed on the DAISIE database (www.europe-aliens.org) as one of Europe's 100 'worst' invasive species. *D. villosus* has a native Ponto-Caspian range, being naturally distributed in the lower courses of large rivers in the Black and Caspian Sea basins (Mordukhai-Boltovski, 1969). After the opening of the Danube-Main-Rhine canal in 1992, and as a result of both natural expansion and ballast waters (Casellato et al., 2007), the species extended its range rapidly. It was first found in the upper Danube in 1992 (Nesemann et al. 1995) and was soon after discovered in the lower Rhine (Bij de Vaate et al., 2002). The species is considered invasive in Germany (Kinzler et al., 2009), France (Piscart et al., 2010), Italy (Tricarico et al., 2010), Switzerland (Bollache, 2004), Belgium (Boets et al., 2010) , The Netherlands (Josens et al., 2005), Hungary (Musko et al., 2007), Austria (Pöckl, 2007) and the Czech Republic (Berezina & Ďuriš, 2008).**

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

**Response:**

**The current known GB distribution is Grafham Water reservoir (Ordnance Survey TL150680),**

**Cambridgeshire, and the Diddington Brook (sometimes called Grafham Brook) to the east (TL173668), which receives a compensation flow from the reservoir.**

**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. Preliminary surveys indicate a large and recruiting population which has now become established in Grafham Water. Boets et al. (2010) used a combination of field data, laboratory experiments and modelling techniques to show that *D. villosus* is found mainly in habitats with an artificial bank structure, a high oxygen saturation and a low conductivity. Such features are characteristic of many GB canals, rivers and reservoirs.**
**The importance of refugia is further indicated by studies of MacNeil et al. (2008) who demonstrated *D. villosus* is typically associated with boulder substrates in Dutch lakes and Devin et al. (2003) who found a strong association in the Moselle River with cobbles and tree roots. In Lake Constance, *D. villosus* shows a strong preference for hard structures like stones while avoiding sand and leaf litter (Hesselschwerdt et al., 2008).**

**A further strong association has been reported between *D. villosus* and the zebra mussel, *Dreissena polymorpha*, another Ponto-Caspian invader. Gergs & Rothhaupt (2008) used laboratory experiments to conclude that zebra mussels provide *D. villosus* with habitat complexity through the production of byssus threads and shells and food material through biodeposition of faeces and pseudofaeces. However, field studies in the Dutch Ijsselmeer by Noordhuis et al. (2009) found the species was virtually absent from *D. polymorpha* beds but abundant in stony marginal areas. MacNeil et al. (2008) found that habitat complexity mediated the interactions of *D. villosus* and other freshwater amphipods, thus illustrating that many factors are involved in explaining distributions and abundance. It is likely that zebra mussels in GB may therefore provide important habitats in some, but perhaps not all locations. 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).**

**Brooks et al (2008) found that the species could tolerate salinities of up to 20 ppt and acclimated quickly to changes in ionic concentrations. We might therefore expect the species to penetrate into brackish zones of GB rivers. Felten et al. (2008) showed that *D. villosus* is restricted to flow refuges in fast flowing rivers.**

**While Bruijs et al. (2001) report that the species has a wide temperature tolerance there are few data on the specific tolerances of *D. villosus*. Wijnhoven et al. (2005) reported that the species tolerated temperatures up to 35 °C in the laboratory, but that this tolerance was reduced when the species was exposed to brook water with low ion concentrations.**

**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. villosus* include regions such as northern France and the Netherlands which share a strong bioclimatic match to much of Britain's freshwaters. Recent studies by Ermgassen et al. (in review) show that over 50% of GB's established freshwater invaders 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?

**Response:**

**Yes, viable populations have been established in all countries detailed in section 4. Populations in the Danube produced a mean of 43 eggs per female and a maximum of 194. The smallest gravid female was 12mm in length. Highest fecundity was observed in April and May where overwintering females benefitted from plentiful food and rising water temperatures (Pöckl, 2007). Devin et al. (2004) reported that French populations in the Moselle River reached sexual maturity at 6mm length (4 to 8 weeks old) and displayed three reproductive peaks within each year. Reproduction happens when water temperature reaches 13°C and hatching length is approximately 1.8mm (www.europe-aliens.org). Kley & Maier (2003) reported mean clutch sizes ranging from 29 to 136 in Germany's Main River, with a maximum of 188 eggs.**

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

**Response:**

**Yes. Perhaps the most detailed documentation of the species has been its spread through the Rhine, where it has spread at a mean downstream rate of 124 km per year (Leuven et al., 2009) and an upstream dispersal rate of 30-40 km per year (Josens et al., 2005). Downstream dispersal is likely to be achieved through drift (van Riel et al., 2006), while both upstream and downstream spread is likely to be facilitated by human mediated actions such as shipping (Leuven et al., 2009), boating and angling. Construction and interlinking of waterways has played a major role in facilitating spread across Europe (Leuven et al., 2007). Preliminary observations at Grafham Water suggest that waders and rubber boats are particularly vulnerable to fouling by *D. villosus* (A. Brown, Anglian Water, pers. Comm.). The species is often associated with macrophytic vegetation (Musko, 1994) and so outboard motors and keep nets may serve as vectors when boats and angling gear are transported between waterbodies. The role of birds as vectors cannot be ruled out given that snails can be dispersed in such a manner (Gittenberger et al., 2005), although the large size of the species makes birds a relatively unlikely vector (D. Platvoet, pers. comm.). The species may be moved around with fish stocks being introduced from one waterbody to another. Bruijs et al (2001) conducted salinity tolerance tests and concluded that the species could not only be transported in ballast water but could even survive incomplete ballast water exchange.**

**10** - Could the organism as such, 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 through different trophic levels. European field studies have shown that macroinvertebrate populations decline after the establishment of *D. villosus*. *D. villosus* has been shown to be a major predator of native shrimps (MacNeil & Platvoet, 2005), other invasive shrimps (MacNeil et al., 2008), mayflies, damselflies, leeches, chironomids, cladocera, isopods and snails (Dick et al., 2002; MacNeil & Platvoet 2005; Bollache et al., 2008; Noordhuis et al., 2009). Platvoet et al. (2009) observed the species to engage in detritus feeding, coprophagy, predation on benthic and free swimming invertebrates, predation on fish eggs and larvae, and feeding on the byssus threads of zebra mussels. Sometimes macroinvertebrates are killed but not eaten (Dick et al., 2002), and this may reflect a method of competitive removal.**

**Particular attention has been paid to the role of intraguild predation between *D. villosus* and native amphipods, which can lead to displacement of native taxa (Dick & Platvoet, 2000). A recent mesocosm study (MacNeil et al., in review) found that displacement of native shredding amphipods by *D. villosus* resulted in declined leaf processing. Reduced shredding could have dramatic knock-on impacts on nutrient dynamics within an invaded system.**

**Indirect effects of *D. villosus* may lead to the increase of some taxa, such as through the reduction of their predators or the creation of a new food resource. Kelleher et al (1998) compared the diet of eels (*Anguila***

***anguila*) before and after the establishment of *D. villosus* in the lower Rhine. Chironomidae decreased greatly in dietary importance as *D. villosus* began to dominate gut contents.**

**The greatest direct economic and social harm is likely to come from changes to fishery quality, and therefore a knock-on impact on recreational use of invaded waterbodies. Current observations of *D. villosus* in Grafham Water suggest that the species forms a key prey item of trout and perch (A. Brown, Anglian Water, pers. Comm.). A shift in diet may drive a change in distribution of trout and a change in their catchability for anglers. Moreover, it is possible that *D. villosus* can serve as an intermediate host for acanthocephalan parasites including *Echinorhyncus truttae* and *Pomphorynchus laevis* which both infect salmonids and can have deleterious impacts on fisheries (Alison Dunn, University of Leeds, pers. Comm.).**

**There is no reason to expect that an abundance of *D. villosus* would negatively impact a potable water supply. While *D. villosus* can bite this is considered no worse than that of an insect and no public concerns have been raised over this issue in other invaded regions. As *D. villosus* can lead to reduced species diversity at invaded sites, this could have implications for scoring of water quality using biological metrics and have implications for the Water Framework Directive (Arnt et al., 2009).**

## Entry Summary

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

**Response: very likely**

**Confidence: high**

**Comments (include list of entry pathways in your comments):**

***D. villosus* has already entered GB and is very likely to do so again. The species is present in high abundance in the lower Rhine (Leuven et al., 2009), 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 salinity tolerance exhibited by *D. villosus* (up to 20 ppt.; Brooks et al., 2008) will facilitate 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 macrophtyic vegetation which has not been cleaned from an outboard or other kit; such weed may provide a moist environment sufficient to enable transport of live *D. villosus* into GB.**

**While entry into GB is considered highly likely it is notable that *D. villosus* arrived in the Rhine in 1995 and yet took 15 years to enter GB. While propagule pressure will have increased considerably since 1995 as distributions and densities have increased within The Netherlands, repeated entry into GB of *D. villosus* may still remain a sufficiently uncommon event to make the initiation of control measures an appealing option.**

## Establishment Summary

Please estimate the overall likelihood of establishment (mention any key issues in the comment box)

**Response: very likely**

**Confidence: very high**

**Comments (please state where in GB this species could establish in your comments):**

***D. villosus* has already established in Grafham Water, as evidenced by the high density and large size of individuals collected. During the establishment at Grafham Water, but prior to the identification of this species, a licensed compensation flow has been leaving the reservoir and entering the Diddington Brook, which in turn enters the River Great Ouse. Physical control measures have now been implemented.**

**Much of GB is likely to be climatically matched with the native and invaded range. A very preliminary bioclimatic model using the invaded distribution in Europe suggests that *D. villosus* has the potential to establish throughout much of central, southern and eastern England (B. Gallardo, University of Cambridge, pers. comm.). The widespread presence of zebra mussels, and the extensive midland canal system with its hard walls, ensures that considerable habitat is available in GB freshwaters to facilitate establishment.**

## Spread Summary

Please estimate overall potential for spread (using the comment box to indicate any key

issues).

**Response: very likely**

**Confidence: very high**

**Comments (include list of entry spread in your comments):**

**As the species has already established, it is highly likely that it will spread from Grafham unless a major eradication programme is initiated. The high density of individuals already present at Grafham, coupled with the requirement for only a small number of gravid females to initiate a new population, means that spread is very likely. Once the species establishes outside a contained waterbody spread will be quick and inevitable, especially given the average downstream rate of 124 km per year reported for the Rhine by Leuven et al (2009). The waterways of GB are highly interlinked and have been shown to play an important part in facilitating the spread of other invasive organisms such as zebra mussels (Aldridge, 2010). The GB canal system provides ideal habitat throughout much of its range in the form of hard marginal walls and boulders. The free movement of boats throughout this system is likely to provide an additional vector for rapid spread, especially if hulls are fouled with zebra mussels (D. Platvoet, pers. comm.). With angling such a major pastime in GB it is likely that unintentional spread will be facilitated by movement between waterbodies of contaminated equipment and bait buckets.**

## Impact Summary

Overall impact rating (please comment on the main reasons for this rating)

**Response: very high**

**Confidence: very high**

**Comments (include list of impacts in your comments):**

**All invaded regions of Western Europe have reported dramatic changes in biota following *D. villosus* establishment; there is no reason to expect that the situation in GB will be any different given the similarity of community structure and habitats. We can expect *D. villosus* to spread and establish across large parts of England. On a broadscale, we can 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 (MacNeil et al., in review) and diet shift in a number of fish species (Kelleher et al., 2000).**

## Conclusion

Please estimate the overall risk (comment on the main reasons for this rating)

**Response: very high**

**Confidence: high**

**Comments:**

**Risk is considered to be very high based on the fact that *D. villosus* has already entered GB and established a large viable population, that repeated invasions are very likely, that GB is climatically similar to many parts of the invaded range, that the interconnectivity of the UK water network will**

**facilitate rapid spread, and that the ecological impacts experienced throughout the invaded range have been very large and dramatic.**

**There is an important caveat to this expectation relating to founder effects. While the spread of *D. villosus* 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. villosus* did not bring with it microsporidian parasites typically associated with the species, and this could give *D. villosus* an added advantage in GB. Wattier et al. (2007) reported no evidence of bottlenecks or parasite loss through the invaded range of *D. villosus* in mainland Europe.**

## Management options (brief summary):

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

**Response:**

**No management attempts have been documented. Therefore, options suggested below require testing and development.**

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

**Response:**

**Bruijs et al. (2001) suggest that salinities >25 ppt are lethal to *D. villosus*. Other possible options include the use of sodium hypochlorite, hot water, dewatering of a site, pyrethrin (Pyroblast), rotenone or BioBullets (Aldridge et al., 2006). Deployment of porous house bricks to provide refugia for *D. villosus* 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. villosus* 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:**

**No intracontinental pathway management options have been described for mainland Europe (www.europe-aliens.org), although containment procedures should be employed (and have been employed by Anglian Water) at Grafham Water. Inspection of kit leaving affected waterways should be encouraged, along with the deployment of public advisory signage. Public access sites, and especially boat launches, should provide washdown facilities. Routine inspections of kit and boats should be undertaken. A GB-wide system of monitoring should be initiated to maximise the opportunities for containment and eradication of newly established populations. A standard cleaning and inspection procedure should be developed for boats that are transported out of locations known to contain *D. villosus*.**
**Transoceanic options relate to the full exchange of ballast water within fully marine conditions, although Bruijs et al. (2001) highlight the euryhaline nature of *D. villosus* which reduces the efficacy of this procedure. Tighter regulation and monitoring of contamination at international watersports events should be encouraged, and a public outreach programme to likely vectors (e.g. anglers) should be considered.**

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

**Response:**

***D. villosus* reproduces at water temperatures above 13°C, a female carries up to 200 eggs and can reach maturity in 4 to 8 weeks. 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) 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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