

UK NON-NATIVE ORGANISM RISK ASSESSMENT SCHEME Version 3.3

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NOTE: This template contains minimal help and background. Please refer to the User Manual and examples of best practice when using this scheme.

Name of Organism, Pathway, Receptor or Policy		Zebra Mussel - <i>Dreissena polymorpha</i> (Pallas 1771)	
Objectives:		Assess the risks associated with this species in GB	
Authors, Date, Draft:			
N	QUESTION	RESPONSE	COMMENT
1	What is the reason for performing the Risk Assessment?		Now known internationally as one of the most invasive aquatic pests, the Zebra Mussel <i>Dreissena polymorpha</i> , has invaded a wide geographic area over the last century, causing economic, social and conservation concern. Originally a native of the Baltic and Black Seas, it managed to disperse through aquatic systems in western Europe, reaching Great Britain in the 1820s (Aldridge <i>et al.</i> 2004) and North America in the 1980s (Schloesser 1995). It transports easily in a variety of ways and colonises suitable habitats extremely rapidly (Ram & McMahon 1996).
2	What is the Risk Assessment area?	Great Britain	The assessment is also relevant to Northern Ireland which has recently been invaded by this species (McCarthy <i>et al.</i> 1997, Maguire 2002).
3	Does a relevant earlier Risk Assessment exist?	YES (Go to 4)	Though not full risk assessments, several authors have provided forecasts of risk for different areas (Lyons 1989, Mackie <i>et al.</i> 1989, Claudi & Mackie 1993).
4	If there is an earlier Risk Assessment is it still entirely valid, or only partly valid?	PARTLY VALID OR NOT VALID (Go to 5)	
Stage 2: Organism Risk Assessment SECTION A: Organism Screening			
5	Identify the Organism. Is the organism clearly a single taxonomic entity and can it be adequately distinguished from other entities of the same rank?	YES (Give the full name & Go to 7)	Zebra Mussel <i>Dreissena polymorpha</i> (Pallas 1771)
6	If not a single taxonomic entity, can it be redefined?		
7	Is the organism in its present range known to be invasive, i.e. to threaten species, habitats or ecosystems?	YES (Go to 9)	There is an extensive literature on this species covering its spread into western Europe and North America (Mackie <i>et al.</i> 1989, Griffiths <i>et al.</i> 1991, O'Neill & Dextrase 1994, Johnson & Padilla 1996, Karatev <i>et al.</i> 1997, Lucy & Sullivan 1999, Aldridge <i>et al.</i> 2004). The animal forms hard colonies that attach to almost any hard surface, including water pipes. Zebra Mussels can affect fish populations by colonising spawning grounds and changing populations of invertebrates which fish eat. Their filter feeding reduces the abundance of phytoplankton and increases water clarity. This results in increased growth of submerged macrophytes. These major ecological changes are known to affect whole ecosystems including fish molluscs and birds. Zebra Mussels can have a major impact on native mussels by colonising their shells to such an extent that the mussels cannot open their own shells.
8	Does the organism have intrinsic attributes that indicate that it could be invasive, i.e. threaten species, habitats or ecosystems?		
9	Does the organism occur outside effective containment in the Risk Assessment area?	YES (Go to 10)	
10	Is the organism widely distributed in the Risk Assessment area?	YES & Future conditions/management procedures/policies are being considered (Go to 19)	The species is becoming widely distributed in England (Killeen <i>et al.</i> 2004, Elliott 2005, Aldridge <i>et al.</i> 2004, 2007) and has been recorded in Scotland (Maitland & Adams 2001) and in Wales. In addition, it has reached Northern Ireland (McCarthy <i>et al.</i> 1997) where it is causing significant problems.
11	Does at least one species (for herbivores, predators and parasites) or suitable habitat vital for the survival, development and multiplication of the organism occur in the Risk Assessment area, in the open, in protected conditions or both?		
12	Does the organism require another species for critical stages in its life cycle such as growth (e.g. root symbionts), reproduction (e.g. pollinators; egg incubators), spread (e.g. seed dispersers) and transmission, (e.g. vectors)?		
13	Is the other critical species identified in question 12 (or a similar species that may provide a similar function) present in the Risk Assessment area or likely to be introduced? If in doubt, then a separate assessment of the probability of introduction of this species may be needed.		
14	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?		

15	Could the organism establish under protected conditions (e.g. glasshouses, aquaculture facilities, terraria, zoological gardens) in the Risk Assessment area?		
16	Has the organism entered and established viable (reproducing) populations in new areas outside its original range, either as a direct or indirect result of man's activities?		
17	Can the organism spread rapidly by natural means or by human assistance?		
18	Could the organism as such, or acting as a vector, cause economic, environmental or social harm in the Risk Assessment area?		
19	This organism could present a risk to the Risk Assessment area and a detailed risk assessment is appropriate.	Detailed Risk Assessment Appropriate GO TO SECTION B	
20	This organism is not likely to be a harmful non-native organism in the Risk Assessment area and the assessment can stop.		

B	SECTION B: Detailed assessment of an organism's probability of entry, establishment and spread and the magnitude of the economic, environmental and social consequences			
	Probability of Entry	RESPONSE	UNCERTAINT	COMMENT
1.1	List the pathways that the organism could be carried on. How many relevant pathways can the organism be carried on?	very many - 4	MEDIUM -1	Many pathways are known (Carlton 1993, Johnson & Padilla 1996): 1. Boating (Keevin <i>et al.</i> 1992). 2. Ballast water (Griffiths 1991). 3. Canals and water transfers (Strayer 1991). 4. Angling. 5. Aquaculture. 6. Intentional introductions. 7. Research and conservation work (Johnson & Padilla 1996).
1.2	Choose one pathway from the list of pathways selected in 1.1 to begin the pathway assessments.	Boating		Boating is considered to be the main pathway in which the Zebra Mussel has been transferred from one water to another in Great Britain and Ireland in recent years (Pollux <i>et al.</i> 2003).
1.3	How likely is the organism to be associated with the pathway at origin?	likely - 3	LOW - 0	The larvae will readily settle on the hull of all kinds of boats and can be transferred from one water to another in that way (Pollux <i>et al.</i> 2003, Aldridge <i>et al.</i> 2004). Larvae are also believed to be taken in with ballast water and able to survive for some time in bilge tanks (Carlton 1993).
1.4	Is the concentration of the organism on the pathway at origin likely to be high?	likely - 3	LOW - 0	Large numbers of larvae are produced during the breeding season (Ram <i>et al.</i> 1992). These disperse rapidly even in slight currents and soon attach to any available solid substrate (Kinzelbach 1992).
1.5	How likely is the organism to survive existing cultivation or commercial practices?	likely - 3	MEDIUM -1	The larvae will settle on all kinds of solid substrates (e.g. rocks, jetties, boats, etc.) to which they have access. Thereafter, the attached young and adults can be moved accidentally along with some of these substrates (e.g. boats) to other waters (Pollux <i>et al.</i> 2003).
1.6	How likely is the organism to survive or remain undetected by existing measures?	very likely - 4	LOW - 0	Can survive transfer out of water for some time as long as the substrate (e.g. boat hull) does not dry out completely (Alyakrinskaya 1978, Carlton 1993).
1.7	How likely is the organism to survive during transport /storage?	likely - 3	LOW - 0	Closes valves to prevent drying out during transport (Keevin <i>et al.</i> 1992, Morton 1993).
1.8	How likely is the organism to multiply/increase in prevalence during transport /storage?	unlikely - 1	MEDIUM -1	Unlikely to reproduce unless the substrate remains in water all the time - e.g. a boat moving through a canal system (Keevin <i>et al.</i> 1992).
1.9	What is the volume of movement along the pathway?	moderate - 2	MEDIUM -1	Variable according to transfer of boats and other substrates along the pathway.
1.10	How frequent is movement along the pathway?	often - 3	MEDIUM -1	This is judged on the information on the recent spread of this species in England and Ireland (McCarthy <i>et al.</i> 1997, Lucy & Sullivan 1999, Maguire 2002, Aldridge <i>et al.</i> 2004, Elliott <i>et al.</i> 2005).
1.11	How widely could the organism be distributed throughout the Risk Assessment area?	widely - 3	MEDIUM -1	Could become widely distributed in those waters with suitable physico-chemical conditions. These were reviewed by Strayer (1991) who concluded that hardwater streams and lakes are likely to be widely colonised. However small hardwater lakes are least likely to support Zebra Mussels. Extremes of high and low temperatures, together with low dissolved calcium are likely to be limiting factors. Thus lowland Britain is more likely to be affected than highland Britain.
1.12	How likely is the organism to arrive during the months of the year most appropriate for establishment ?	very likely - 4	LOW - 0	Most boat movements take place during the warmer months when attachment and transfer are most likely (McCarthy <i>et al.</i> 1997, Maguire 2002).
1.13	How likely is the intended use of the commodity (e.g. processing, consumption, planting, disposal of waste, by-products) or other material with which the organism is associated to aid transfer to a suitable habitat?	likely - 3	LOW - 0	There are thousands of boat movements (and other relevant activities) each year which could aid transfer of this species widely across Britain and Ireland.
1.14	How likely is the organism to be able to transfer from the pathway to a suitable habitat?	likely - 3	LOW - 0	Transfer is easy - especially when the mussels remain on boat hulls (and other substrates) long enough to breed (MacMahon 1992).

	Probability of Establishment	RESPONSE	UNCERTAIN	COMMENT
1.15	How similar are the climatic conditions that would affect establishment in the Risk Assessment area and in the area of current distribution?	similar - 3	LOW - 0	The species is already well established at many sites in England (Elliott 2005) and will be able to do well in lowland areas in Wales and many lowland parts of Scotland (Strayer 1991).
1.16	How similar are other abiotic factors that would affect establishment in the Risk Assessment area and in the area of present distribution?	similar - 3	LOW - 0	The fact that it is already well established in many waters in the Risk Assessment area indicates that many other waters are likely to be invaded.
1.17	How many species (for herbivores, predators and parasites) or suitable habitats vital for the survival, development and multiplication of the organism species are present in the Risk Assessment area? Specify the species or habitats and indicate the number.	very many - 4	LOW - 0	The species prefers still or slow-flowings waters (i.e. lakes, canals and lowland rivers) so these are the most vulnerable habitats and they are common across much of the Risk assessment Area.
1.18	How widespread are the species (for herbivores, predators and parasites) or suitable habitats vital for the survival, development and multiplication of the organism in the Risk Assessment area?	widespread - 4	LOW - 0	The species prefers still or slow-flowings waters (i.e. lakes, canals and lowland rivers) so these are the most vulnerable habitats and they are common across much of the Risk assessment Area.
1.19	If the organism requires another species for critical stages in its life cycle then how likely is the organism to become associated with such species in the risk assessment area?	N/A		
1.20	How likely is it that establishment will not be prevented by competition from existing species in the Risk Assessment area?	very likely - 4	LOW - 0	Zebra Mussels appear to outcompete, physically smother or preferentially occupy habitat important for several native species.
1.21	How likely is it that establishment will not be prevented by natural enemies already present in the Risk Assessment area?	very likely - 4	LOW - 0	There are natural predators of Zebra Mussels (e.g. Tufted Duck <i>Aythya fuligula</i>) but there is no indication that these are able to prevent or even control invasions of these mussels (Wormington & Leach 1992, Molloy <i>et al.</i> 1997).
1.22	If there are differences in man's management of the environment/habitat in the Risk Assessment area from that in the area of present distribution, are they likely to aid establishment? (specify)	moderately likely - 2	MEDIUM -1	Zebra Mussels are known to establish best in the presence of hard substrates. In lowland rivers, these tend to be man-made, and so in these rivers management may impact establishment by providing substrate.
1.23	How likely is it that existing control or husbandry measures will fail to prevent establishment of the organism?	likely - 3	LOW - 0	There are no adequate existing controls once mussels are established, and prevention of access is the most important control activity.
1.24	How often has the organism been recorded in protected conditions, e.g. glasshouses, elsewhere?	very rare - 0	MEDIUM -1	
1.25	How likely is the reproductive strategy of the organism and duration of its life cycle to aid establishment?	very likely - 4	LOW - 0	The hardness of Zebra Mussels, their ability to close valves during poor conditions (e.g. when chlorine may be applied) and their high fecundity over several months of the year and years of life mean that they are very successful in many situations.
1.26	How likely is it that the organism's capacity to spread will aid establishment?	very likely - 4	LOW - 0	Their planktonic larvae mean that it is easy for Zebra Mussels to spread throughout connected water systems.
1.27	How adaptable is the organism?	adaptable - 3	MEDIUM -1	The species prefers still or slow-flowings waters (i.e. lakes, canals and lowland rivers) so these are the most vulnerable habitats and they are common across much of the Risk assessment Area.
1.28	How likely is it that low genetic diversity in the founder population of the organism will not prevent establishment?	moderately likely - 2	MEDIUM -1	There is little evidence that this is relevant.
1.29	How often has the organism entered and established in new areas outside its original range as a result of man's activities?	very many - 4	LOW - 0	The Zebra Mussel is a well know invasive species in many countries across both Europe and North America.
1.30	How likely is it that the organism could survive eradication campaigns in the Risk Assessment area?	likely - 3	LOW - 0	Can be controlled by chlorine and other chemicals in contained, usually artificial, systems - e.g. water supply systems. Eradication is much more difficult in open, natural situations.
1.31	Even if permanent establishment of the organism is unlikely, how likely is it that transient populations will be maintained in the Risk Assessment area through natural migration or entry through man's activities (including intentional release into the outdoor environment)?	likely - 3	MEDIUM -1	Small populations have been know to exist in some ares and eventually die out. However, during this time they could reproduce and invade other systems.

	Spread	RESPONSE	UNCERTAINT	COMMENT
2.1	How rapidly is the organism liable to spread in the Risk Assessment area by natural means?	slow - 1	LOW - 0	It is most likely to spread naturally downstream of any established population, mainly through the planktonic larvae. There is also a small chance that they can be transported upstream by birds.
2.2	How rapidly is the organism liable to spread in the Risk Assessment area by human assistance?	rapid - 3	LOW - 0	The number of possible pathways is high. See 1.1
2.3	How difficult would it be to contain the organism within the Risk Assessment area?	very difficult - 4	LOW - 0	This would require controls on all the pathways concerned. See 1.1. In response to the recent invasion of waters in Northern Ireland, a mussel education and awareness programme has been initiated there (www.invasivespeciesireland.com). This comprises exhibitions, fact sheets, press releases and media coverage and has mainly targeted recreational water users such as anglers, yachtsmen, canoeists, etc. Training is available for high risk user groups and hundreds of Zebra Mussel awareness signs have been placed around vulnerable water bodies. In California, control of the spread of the related Quagga Mussel (<i>Dreissena bugensis</i>), which it is assumed will be distributed mainly by boats, has been initiated by having strategically placed checkpoints where specially trained sniffer dogs are used to detect mussels on boat hulls and trailers (www.dfg.ca.gov/invasives/quaggamussel). The California Department of Fish & Game propose to train 22 dogs over the next three years at a cost to the state of \$250,000.
2.4	Based on the answers to questions on the potential for establishment and spread define the area endangered by the organism.	4	MEDIUM -1	Most of the Risk Assessment area except highland and northern areas.

	Impacts	RESPONSE	UNCERTAINT	COMMENT
2.5	How important is economic loss caused by the organism within its existing geographic range?	moderate - 2	MEDIUM -1	More information is needed, but there is some direct evidence from water treatment companies that Zebra Mussels in the UK cost in the order of £1million/year to control (Elliott, 2005). Since the Zebra Mussel appeared in the Great Lakes, via the ballast water from European ships, the impact of biofouling of cooling water pipes is estimated to have cost the power industry more than three billion US dollars over the last 15 years (http://www.chesapeakebay.net/zebramussel).
2.6	Considering the ecological conditions in the Risk Assessment area, how serious is the direct negative economic effect of the organism, e.g. on crop yield and/or quality, livestock health and production, likely to be? (describe) in the Risk Assessment area, how serious is the direct negative economic effect of the organism, e.g. on crop yield and/or quality, likely to be?	major - 3	LOW - 0	Zebra Mussels can cause major blockages in intake pipes which increases costs at water treatment plants and are a major risk to the future of some freshwater fisheries (http://www.ni-environment.gov.uk/zebramusselsreport_web.pdf). This may result in a decline in income generated in commercial rod fisheries and the tourist industry associated with recreational fisheries. Also, in Northern Ireland, excessive weed growth as a result of Zebra Mussels is causing serious problems for boat users and consequently for tourism. There are also implications for birds - some positive, others negative (Wormington & Leach 1992). Control measures are difficult and should be concentrated on preventing Zebra Mussel access to water supply systems and waters of conservation importance. Though the biggest economic effect is usually felt by the water supply industry, there are indirect costs to fisheries and there are certainly major ecological changes in some waters due to smothering of substrates and increased water clarity due to the removal of phytoplankton by the mussels.
2.7	How great a loss in producer profits is the organism likely to cause due to changes in production costs, yields, etc., in the Risk Assessment area?	major - 3	MEDIUM -1	Costs of eradication in water supply systems can be high. In Northern Ireland, the Water Service has already had to modify water treatment plants at a cost of over £100,000. If the spread of Zebra Mussels continues, costly refits of water treatment plants will be required in several areas (http://www.ni-environment.gov.uk/zebramusselsreport_web.pdf). In the United States, costs over the last 15 years are estimated at \$3 billion.
2.8	How great a reduction in consumer demand is the organism likely to cause in the Risk Assessment area?	major - 3	MEDIUM -1	Water supplies may be reduced in affected areas and supplies brought in from elsewhere (Griffiths <i>et al.</i> 1989). New industry may be reluctant to move in. Anglers and other boat users may stop coming to the waters affected because of a decline in fish numbers and excessive weed growth (Maguire 2002).
2.9	How likely is the presence of the organism in the Risk Assessment area to cause losses in export markets?	unlikely - 1	MEDIUM -1	Not likely to have an effect on export markets other than where industries are affected by restricted water supply as a result of Zebra Mussel impact on water supply systems.
2.10	How important would other economic costs resulting from introduction be? (specify)	major - 3	LOW - 0	Can cause major problems in the fouling and obstruction of water supply systems (Le Page 1989, Kovalak <i>et al.</i> 1993). These need to be cleaned (Fellers <i>et al.</i> 1998) and further access by Zebra Mussels prevented (MacMahon 1990).
2.11	How important is environmental harm caused by the organism within its existing geographic range?	minor - 1	MEDIUM -1	Zebra Mussels do have an environmental impact within their existing geographic range but this appears to be less than in newly inhabited waters where predators and parasites have had no time to adapt to the changing situation (Mackie <i>et al.</i> 1989).
2.12	How important is environmental harm likely to be in the Risk Assessment area?	major - 3	LOW - 0	There is evidence that Zebra Mussels can impact on several native species (including other mussels) by smothering, occupation of habitat, reduction of phytoplankton and other aspects of its ecology. Zebra Mussels are capable individually of filtering one litre of water per day and it is estimated that the population in Lough Erne can filter the entire lake volume every fortnight (Maguire 2002). Such impacts are likely to increase with increased range and density, which is currently being observed, especially in Northern Ireland. In Loch Erne, researchers have found major ecological changes, including among fish populations. Roach have decreased and this will impact on recreational fishing - a major source of tourist income in the area.
2.13	How important is social and other harm caused by the organism within its existing geographic range?	minor - 1	MEDIUM -1	Although water clarity is increased by the presence of Zebra Mussels and this may lead to increased catches of Trout (<i>Salmo trutta</i>) - though not to increased numbers - there is much more marginal weed growth, which frustrates anglers. Also, in Upper Lough Erne, the greatly increased weed growth has become a serious issue for boat users. In the worst affected areas warning signs have been erected advising that vessels do not attempt to enter these areas (http://www.ni-environment.gov.uk/zebramusselsreport_web.pdf).
2.14	How important is the social harm likely to be in the Risk Assessment area?	major - 3	MEDIUM -1	Can cause problems by fouling underwater structures and reducing fish productivity. Some positive evidence of people appreciating much clearer waters due to the filtering activities of Zebra Mussels. In Northern Ireland, Zebra Mussels were first recorded in 1997 in Lough Derg (McCarthy <i>et al.</i> 1997). Since then the species has spread rapidly to the Boyle, Erne and Shannon catchments (http://www.ni-environment.gov.uk/zebramusselsreport_web.pdf). Densities of mussels have been extremely high in some waters - e.g. 2,500 per square metre in Lough Erne and over 35,000 per metre square in Lough Key (Lucy & Sullivan 1999, Maguire 2002).
2.15	How likely is it that genetic traits can be carried to native species, modifying their genetic nature and making their economic, environmental or social effects more serious?	very unlikely - 0	MEDIUM -1	No evidence that this is likely to happen in the Risk Assessment Area.

2.16	How probable is it that natural enemies, already present in the Risk Assessment area, will have no affect on populations of the organism if introduced?	moderately likely - 2	MEDIUM -1	Natural enemies (e.g. Tufted Duck) are likely to be present in The Risk Assessment Area but there is no evidence that they are capable of preventing establishment and growth of Zebra Mussel populations.
2.17	How easily can the organism be controlled?	very difficult - 4	LOW - 0	The species is very robust and is very difficult to control except in contained areas - see 1.30. However, there is significant current research on control measures and there have been some promising results using chlorine and bromine (Fellers <i>et al.</i> 1988), heat (Feigina 1959), high pressure water (Glover 1988), microencapsulated toxins (Elliott 2005) and other techniques (Greenshields & Ridley 1957, Jenner 1983). For example, research at the New York State Museum has described a new technique for eradicating Zebra Mussels using a highly specific strain of the bacterium <i>Pseudomonas fluorescens</i> (www.nysed.gov/press/releases/mdan.cfm).
2.18	How likely are control measures to disrupt existing biological or integrated systems for control of other organisms?	moderately likely - 2	MEDIUM -1	Control measures, such as the use of chlorine, are likely to impact on existing biological or integrated systems for control of other organisms, unless targeted very carefully.
2.19	How likely is the organism to act as food, a host, a symbiont or a vector for other damaging organisms?	unlikely - 1	MEDIUM -1	There is insufficient evidence here, but it is likely that Zebra Mussels could provide food or shelter for other invading organisms, most of which have not yet reached the Risk assessment area. Dr Ed Peeler (CEFAS) has commented that 'Zebra Mussels have been introduced into many aquatic ecosystems around the world. However, there are no reports of the introduction and establishment of Zebra Mussels causing disease in native aquatic animal populations. Some work has been done identifying pathogens and parasites of Zebra Mussels. I do not think any experimental work has investigated whether these agents may infect other species.'
2.20	Highlight those parts of the endangered area where economic, environmental and social impacts are most likely to occur	Waters used for public water supply; waters of conservation importance	LOW - 0	Problems are most likely to be encountered by recreational water users where boat hulls, water intakes, etc. are affected by fouling. Thus the most likely waters to show the greatest impact are those where boat usage is high for angling or recreation (i.e. important for tourism) or where conservation interest is high due to the presence of rare or important species or habitats.

Summarise Entry	likely - 3	LOW - 0	The species has shown its ability to gain entry to many countries, including Great Britain, and continues to spread outwith its area of natural occurrence.
Summarise Establishment	likely - 3	LOW - 0	The species is already well established at many sites in England and will be able to do well in Wales and many parts of Scotland.
Summarise Spread	rapid - 3	LOW - 0	The Zebra Mussel has spread relatively rapidly in recent years through many parts of England.
Summarise Impacts	major - 3	LOW - 0	There have been major problems with the fouling of water supply systems by this species and considerable evidence of environmental impact in some waters.
For pathway/policy risk assessment Assess the potential for establishment and economic/environmental/social impacts of another organism or stop			
Conclusion of the risk assessment	HIGH -2	LOW - 0	The species is already present in many waters in the Risk Assessment Area and is likely to spread to many others in the foreseeable future. Control is difficult except in very contained situations and prevention of entry should be a major part of any policy.
Conclusions on Uncertainty		LOW - 0	Much research has been carried out on the Zebra Mussel, especially in Europe and North America in recent years and so there is a good foundation of scientific knowledge on which to base future management.
Should risk management options be considered?	YES (Go to Risk Management)		

References

- Ackerman, J.D., Sim, B., Nichols, S.J. & Claudi, R.. 1994. A review of the early life history of Zebra Mussels (*Dreissena polymorpha*): comparisons with marine bivalves. *Canadian Journal of Zoology*, 72, 1169-1179.
- Aldridge, D.C. & Müller, S.J. 2001 The Asiatic clam, *Corbicula fluminea*, in Britain: current status and potential threats. *Journal of Conchology*, 37, 177-184.
- Aldridge, D.C. 2004. Conservation of freshwater unionid mussels in Britain. *Journal of Conchology*, Special Publication No. 3, 81-90
- Aldridge, D.C., Elliott, P. & Moggridge, G.D. 2004. The recent and rapid spread of the zebra mussel (*Dreissena polymorpha*) in Great Britain. *Biological Conservation*, 119, 253-261.
- Aldridge, D.C., Fayle, T. & Jackson, N. 2007. Freshwater mussel abundance predicts biodiversity in UK lowland rivers. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 17, 554-564
- Aldridge, D.C., Moggridge, G.D. & Elliott, P. 2006. A microencapsulated 'BioBullet' for the control of biofouling zebra mussels. *Environmental Science and Technology*, 40, 975-979.
- Alyakrinskaya, I.O. 1978. Biochemical adaptations to drying conditions in bivalves in the Kurski Zaliv Baltic Sea, USSR. *Zool. Zh.*, 5, 136-138.
- Antonov P.I. 1996. The bivalve species *Dreissena bugensis* Ant. as new to the Volga fauna. In: Kutikova L.A. (ed.) *Problemy gidrobiologii kontinental'nykh vod i ikh malakofauna*. International conference.
- Antsulevich, A.E., Lebardin, M.V. 1990. *Dreissena polymorpha* Pall. in the vicinity of Leningrad Russian SSR. *Vestnik Leningradskogo Univ. Ser. Biology.*, 24, 109-110.
- Beeton, R.E.H., 1991. Plankton diatoms in Hatchery Bay, western Lake Erie, before and after the invasion of the zebra mussel. *Journal of Shellfish Research*, 10, 250.
- Biochino, G.T. 1989. A phenetic method of *Dreissena polymorpha* (Pallas) investigation. *Nauchnye Doklady Vysshego Shkoly*, 10, 36-41.
- Borcherding, J. 1992. Morphometric changes in relation to the annual reproductive cycle in *Dreissena polymorpha* - a prerequisite for biomonitoring studies with Zebra Mussels. pages 87-99 in: Neumann, D. & Jenner, H.A. (eds.), *The Zebra Mussel Dreissena polymorpha*. Gustav Fisher Verlag, New York.
- Carlto, J. T. 1993. Dispersal mechanisms of the Zebra Mussel *Dreissena polymorpha*. Pages 677-697 in: Nalepa, T.F., Schloesser, D.W. & Lewis, L.W. (eds.) *Zebra Mussels: biology, impact and control*. CRC Press, Ann Arbor, Michigan.
- Casey, G.E. 1988. Introduction to chemical cleaning of service water systems. Pages 147-167 in: *Proceedings Service Water System Reliability Improvement Seminar*. Electric Power Research Institution, Palo Alto, California.
- Claudi, R. & Mackie, G.L. 1993. Practical manual for Zebra Mussel monitoring and control. Lewis Publishers, Boca Raton, Florida.
- Daily, J.V. 1988. A unique alternative for internally cleaning and coating of in-place service water systems. Pages 183-201 in: *Proceedings Service Water System Reliability Improvement Seminar*. Electric Power Research Institute, Palo Alto, California.
- Dario D.A., 1978. Distribuzione verticale di *Dreissena polymorpha* Pallas nel Lago di Garda. *Bull. Zool*, 453, 257-260.
- Effler, S.W., Brooks, C.M., Whitehead, K., Wagner, B., Doerr, S.M., Perkins, M.G., Siegfried, C.A., Walrath, L. & Canale, R.P. 1996. Impact of zebra mussel invasion on river water quality. *Water Environment Research*, 682, 205-214.
- Elliott, P. 2005. The zebra mussel in England: biology, impacts and control using microencapsulated toxins. PhD Thesis, University of Cambridge.
- Elliott, P., Aldridge, D.C. & Moggridge, G.D. & Chipps, M. 2005. The increasing effects of zebra mussels on water installations in England. *Water and the Environment Journal*, 19, 367-375.
- Feigina Z.S. 1959 Thermal method of fight against *Dreissena* fouling using heated water in condition of thermal Power plants. *Elektricheskije stanzii*, 10, 1-42.
- Fellers, B.D., Flock, E.L. & Conley, C.C. 1988. Bromine replaces chlorine in cooling-water treatment. *Power*, June 1988.
- Fisher, S.W., Dabrowska, H., Waller, D.L., Babcock-Jackson, L. & Zhang, X. 1994. Sensitivity of zebra mussel *Dreissena polymorpha* life stages to candidate molluscicides. *Journal of Shellfish Research*, 132, 373-377.
- French, J.R.P. 1993. How well can fishes prey on Zebra Mussels in Eastern North America? *Fisheries*, 18, 13-19.
- Ghedotti, M.J., Smihula, J.C. & Smith, G.R. 1995. Zebra Mussel predation by Round Gobies in the laboratory. *Journal of Great Lakes Research*, 21, 665-669.
- Gillis, P.L. & Mackie, G.L. 1994. The impact of *Dreissena polymorpha* on populations of Unionidae in Lake St. Clair. *Canadian Journal of Zoology*, 72, 1260-1271.
- Glaxton W.T., Wilson A.B., Mackie G.L. & Boulding E.G. 1998. A genetic and morphological comparison of shallow- and deep-water populations of the introduced dreissenid species *Dreissena bugensis*. *Canadian Journal of Zoology*, 76, 1269-1276.
- Glover, W.A. 1988. High pressure water cleaning service water systems. Pages 195-201 in: *Proceedings Service Water Systems Reliability Improvement Seminar*. Electric Power Research Institute, Palo Alto, California.
- Green Shields, F. & Ridley, J.E. 1957. Some researches on the control of mussels in water pipes. *Journal of the Institution of Water Engineers*. 11, 300-306.
- Griffiths, R.W., Kovalak, W.P. & Schloesser, D.W. 1989. The Zebra Mussel, *Dreissena polymorpha* (Pallas, 1997), in North America: impact on raw water users. Pages 11-27 in: *EPRI Service Water System Reliability Improvement Seminar*; Electric Power Research Institute, Palo Alto, California.
- Griffiths, R.W., Schloesser, D.W., Leach, J.H. & Kovalak, W.P. 1991. Dispersal of the Zebra Mussel *Dreissena polymorpha* in the Great Lakes Region. *Canadian Journal of Fisheries and Aquatic Sciences*, 48, 381-388.
- Hebert, P.D.N., Muncaster, B.W., & Mackie, G.L. 1989. Ecological and genetic studies on *Dreissena polymorpha* (Pallas): a new mollusc in the Great Lakes. *Canadian Journal of Fisheries and Aquatic Sciences*, 4, 1587-1591.
- Jenner, H.A. 1983. Control of mussel fouling in the Netherlands: experimental and existing Methods. In: Diaz-Tous, I.A., Miller, M.A. & Y.G. Mussalli, Y.G. (eds.), *Symposium on Condenser Macrofouling Control Technologies: The State of The Art*. Electric Power Research Institute, Palo Alto, California.
- Johnson, L.E., Padilla, D.K. 1996. Geographic spread of exotic species: Ecological lessons and opportunities from the invasion of the Zebra mussel *Dreissena polymorpha*. *Biological Conservation*, 78, 23-33.
- Karataev A. Y., Burlakova L.E. & Padilla D.K. 1997. The effects of *Dreissena polymorpha* Pall. invasion on aquatic communities in Eastern Europe. *Journal of Shellfish Research*, 16, 187-203.
- Karataev A.Y., Burlakova L.E., Padilla D.K. 1998. Physical factors that limit the distribution and abundance of *Dreissena polymorpha* Pall. *Journal of Shellfish Research*, 17, 1219-1235.
- Kevin, T.R., Yarbrough, R., & Miller, A. 1992. Inadvertent transport of live zebra mussels on barges - experiences in the St. Louis District, Spring 1992. *Zebra mussel Research Technical Notes*, 4, ZMR-1-07, Nov. 1992, U.S. Army Corps of Engineers Waterways Experiment Station.
- Killeen, I.J., Aldridge, D.C. & Oliver, P.G. 2004. *Freshwater Bivalves of Britain and Ireland*. FSC, AIDGAP Occasional Publication 82, 1-114.
- Kinzelbach, R. 1992. The main features of the phylogeny and dispersal of the Zebra Mussel *Dreissena polymorpha*. Pages 5-17 in Neumann, D. & Jenner, H.A. (eds.), *The Zebra Mussel Dreissena polymorpha*. Gustav Fisher Verlag, New York.
- Kovalak, W.P., Longton, G.D. & Smith, D. 1993. Infestation of power plant water systems by the Zebra Mussel (*Dreissena polymorpha* Pallas) Pages 359-380 in: Nalepa, T.F. & Schloesser, D.W. (eds.), *Zebra Mussels: Biology, Impacts, and Control*. Lewis Publishers, Boca Raton, Florida.
- Le Page, W.L. 1989. Zebra Mussel fouling of water intakes: impacts on water treatment plants. Presented at the Zebra Mussel (*Dreissena polymorpha*) in The Great Lakes, Second International Conference. Sponsored By The New York Sea Grant Extension and The U.S. Fish and Wildlife Service, 28-29 November 1989. Rochester, New York.
- Le Page, W.L. 1993. The Impact of *Dreissena polymorpha* on water works operations at Monroe, Michigan: a case history. Pages 333-358 in: Nalepa, T.F. & Schloesser, D.W. (eds.), *Zebra Mussels: Biology, Impacts, and Control*. Lewis Publishers, Boca Raton, Florida.
- Lucy, F. & Sullivan, M. 1999. The investigation of an invasive species, the zebra mussel *Dreissena polymorpha* in Lough Key, Co. Roscommon. *Environmental Research Desk Study Report No. 13*. Environment Protection Agency, Ireland.
- Lyakhov, S.M. 1968. Work of the Institute of Biology of Inland Waters, Academy of Sciences of the USSR. In B.K. Shtegman, B.K. (ed.), *Biology and Control of Dreissena*. Israel Program For Scientific Translations Ltd., IPST Cat. No. 1774, Jerusalem, Israel.
- Lyons, L.A. 1989. Monitoring and control. Presented at the First International Zebra Mussel Workshop. Sponsored By the U.S. Fish and Wildlife Service, June 13, 1989. Ann Arbor, Michigan.
- MacIsaac, H.J., Sprules, W.G., Johannsson, O.E. & Leach, J.H. 1992. Filtering and impacts of larval and sessile Zebra Mussels in western Lake Erie. *Oecologia*, 92, 30-39.

- MacIsaac H. 1994. Comparative growth and survival of *Dreissena polymorpha* and *Dreissena bugensis*, exotic molluscs, introduced to the Great Lakes. *Journal of Great Lakes Research*, 204, 783-790.
- Mackie, G. L., Gibbons, W. N., Muncaster, B. W., & Gray, I. M. 1989. The zebra mussel, *Dreissena polymorpha*: a synthesis of European experiences and a preview for North America. Toronto, Queens Printer for Ontario.
- Maitland, P.S & Adams, C.E. 2001. Introduced freshwater invertebrates in Scotland: enhanced biodiversity or a threat to native species? *Glasgow Naturalist*, 23, 26-34.
- Mackie, G.L. 1993. Biology of the Zebra Mussel (*Dreissena polymorpha*) and observations of mussel colonization on unionid bivalves in Lake St. Clair of the Great Lakes. Pages 153-165 in: Nalepa, T.F. & Schloesser, D.W. (eds.), *Zebra Mussels: Biology, Impacts, and Control*. Lewis Publishers, Boca Raton, Florida.
- Maguire, C.M. 2002. The Zebra Mussel *Dreissena polymorpha* in the Erne system: invasion, population dynamics and early ecological impacts. PhD Thesis, Queens University, Belfast.
- McCarthy, T.K.J., Fitzgerald, P., Cullen, D., Doherty, J. & Copley, L. 1997. Zebra mussels in the River Shannon. A report to ESB Fisheries Conservation. November 1997. Zoology Department, National University of Ireland, Galway, 1-49.
- McCarthy, T.K., Fitzgerald, J. & O'Connor, W. 1997. The occurrence of the zebra mussel *Dreissena polymorpha* (Pallas 1771), an introduced biofouling freshwater bivalve in Ireland. *Irish Naturalists' Journal*, 25, 413-416.
- McMahon R.F. 1990. The Zebra Mussel: U.S. utility implications. Research Project 1689-24. EPRI GS-6995. Electric Power Research Institute, Palo Alto, California.
- McMahon, R.F. 1992. The Zebra Mussel - the biological basis of its macrofouling and potential for distribution in North America. Pages 1-14 in: *Corrosion '92: Proceedings of The 47th NACE Annual Conference, National Association of Corrosion Engineers, Houston, Texas*.
- Molloy, D. P., Karataev, A. Yu., Burlakova, L.T., Kurandina, D. P. & Laurelle, F. 1997. Natural enemies of Zebra Mussels: predators, parasites, and ecological competitors. *Fisheries Science*, 51, 27-97.
- Morton, B. 1993. The anatomy of *Dreissena polymorpha* and the evolution and success of the heteromyarian form in the Dreissenidae. Pages 185-216 in: Nalepa, T.F. & Schloesser, D.W. (eds.), *Zebra Mussels: Biology Impacts and Control*. Lewis/CRC Press, Inc., Boca Raton, Florida.
- Nalepa, T. F. 1994. Decline of native bivalves (Unionidae: Bivalvia) in Lake St. Clair after infestation by the Zebra Mussel, *Dreissena polymorpha*. *Canadian Journal of Fisheries and Aquatic Sciences*, 51, 2227-2223.
- O'Neill, C.R. & Dextrase, A. 1994. The introduction and spread of the Zebra Mussel in North America. Pages 433-446 in: Miller, A.H. (ed.), *Proceedings: Fourth International Zebra Mussel Conference*. Wisconsin Sea Grant Institute, Madison, Wisconsin.
- Ovchinnikov, I.F. 1933. Modern dispersal of *Dreissena polymorpha* (Pallas) Mollusca in Belourussian Republic. *Proceedings of the Zoological Institute*. 1, 365-375.
- Pollux, B., Minchin, D., Van der Velde, G., Van Alen, T., Moon-Van der Staay, S.Y. & Hackstein, J. 2003. Zebra mussels (*Dreissena polymorpha*) in Ireland, AFLP-fingerprinting and boat traffic both indicate an origin from Britain. *Freshwater Biology*, 48, 1127-1139.
- Ram, J. L., Fong, P.P., Croll, R.P., Nichols, J.S. & Wall, D.M. 1992. The Zebra Mussel (*Dreissena polymorpha*), a new pest in North America: reproductive mechanisms as possible targets of control strategies. *Invert. Rep. Dev.* 22, 77-86.
- Ram, J.L. & McMahon, R.F. 1996. Introduction: The biology, ecology, and physiology of Zebra Mussels. *American Zoologist*, 36, 239-243.
- Schloesser, D.W. 1995. Introduced species, Zebra Mussels in North America. In: *Encyclopedia of Environmental Biology*, Pages 337-356. Academic Press, Inc., San Diego, California.
- Schloesser, D.W., Nalepa, T.F. & Mackie, G.L. 1996. Zebra Mussel infestation of unionid bivalves (Unionidae) in North America. *American Zoologist*, 36, 300-310.
- Smirnova, N.F., Biochino, G.I. & Vinogradov, G.A.. 1993. Some aspects of the Zebra Mussel (*Dreissena polymorpha*) in the former European USSR with morphological comparisons to Lake Erie. Pages 217-226 in: Nalepa, T.F. & Schloesser, D. (eds.), *Zebra Mussels: Biology, Impacts, and Control*. Lewis Publishers, Boca Raton, Florida.
- Stanczykowska, A. 1977. Ecology of *Dreissena polymorpha* (Pallas) (Bivalvia) in lakes. *Pol. Arch. Hydrobiol.*, 24, 461-530.
- Strayer, D.L. 1991. Projected distribution of the Zebra Mussel, *Dreissena polymorpha*, in North America. *Canadian Journal of Fisheries and Aquatic Sciences*. 48, 1389-1395.
- Strayer, D.L., D.C. Hunter, L.C. Smith, & C. K. Borg. 1994. Distribution, abundance, and roles of freshwater clams (Bivalvia, Unionidae) in the freshwater tidal Hudson River. *Freshwater Biology*, 31, 239-248.
- Tucker, J. K., Theiling, C.H., Blodgett, K.D. & Theil, P.A. 1993. Initial occurrence of Zebra Mussels (*Dreissena polymorpha*) on freshwater mussels (Family Unionidae) in the Upper Mississippi River system. *Journal of Freshwater Ecology*, 8, 245-251.
- Walton, W.C. 1996. Occurrence of Zebra Mussel *Dreissena polymorpha* in the oligohaline Hudson River. *Estuaries*, 1, 612-618.
- Wormington, A. & Leach, J.H. 1992. Concentration of migrant diving ducks at Point Pelee National Park, Ontario, in response to invasion of zebra mussels, *Dreissena polymorpha*. *Canadian Field Naturalist*, 106, 376-380.

