Risk assessment template developed under the "Study on Invasive Alien Species – Development of risk assessments to tackle priority species and enhance prevention" Contract No 07.0202/2017/763379/ETU/ENV.D.2[1]

Name of organism: white perch *Morone americana* (Gmelin, 1789)

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Risk Assessment Area: The risk assessment (RA) area is the territory of the European Union, excluding the outermost regions.

Peer review 1: Felipe Ribeiro, University of Lisbon, Lisbon, Portugal
Peer review 2: Wolfgang Rabitsch, Umweltbundesamt, Vienna, Austria

This risk assessment has been peer-reviewed by two independent experts and discussed during a joint expert workshop. Details on the review and how comments were addressed are available in the final report of the study.

Date of completion: 24 October 2018

[1] This template is based on the Great Britain non-native species risk assessment scheme (GBNNRA).

SECTION A – Organism Information and Screening	
Organism Information	**RESPONSE**
A1. Identify the organism. Is it clearly a single taxonomic entity and can it be adequately distinguished from other entities of the same rank?	Domain: Eukaryota Kingdom: Metazoa Phylum: Chordata Subphylum: Vertebrata Class: Actinopterygii Order: Perciformes Suborder: Percoidei Family: Moronidae Genus: *Morone* Species: *Morone americana* (Gmelin, 1789) Common name: White Perch International common names: English: narrow-mouthed bass; sea perch; silver perch; wreckfish Spanish: lubina blanca French: bar blanc d'Amerique; baret; cernier atlantique; perche blanche Russian: morona Synonym: *Perca americana* Gmelin, 1789 Hybrids: *M. americana* × *M. chrysops* (Not included in this assessment; there is little information in the literature on this hybrid, which appears to be a less-successful hybrid than that of *M. saxatilis* × *M. chrysops*) Congener species: *M. saxatilis, M. chrysops, M. mississippiensis*
A2. Provide information on the existence of other species that look very similar [that may	The only other organism that is likely to look very similar to *M. americana* is the *Morone* hybrid (*M. chrysops* × *M. saxatilis*), which has been imported to some EU and neighbouring

be detected in the risk assessment area, either in the wild, in confinement or associated with a pathway of introduction]	countries for aquaculture, and there are a few reports of specimens of this hybrid being captured from EU rivers (Safner et al., 2013; Skorić et al., 2013; Kizak & Güner, 2014).
A3. Does a relevant earlier risk assessment exist? (give details of any previous risk assessment and its validity in relation to the risk assessment area)	No, this is the first full risk assessment known to have been undertaken on this species. However, a risk screening (initial step in risk analysis) of *M. americana* was undertaken for England & Wales for which the species was ranked as being a high risk of becoming invasive (Copp et al., 2009b).
A4. Where is the organism native?	Sea areas: Atlantic, Northwest Atlantic, Western Central North America: Canada: New Brunswick Nova Scotia Prince Edward Island Quebec USA: Connecticut Maryland New Jersey Rhode Island New Jersey Delaware Maryland Virginia North Carolina South Carolina (Froese & Pauly, 2004) (Fuller et al., 2006) (Able & Fahay, 2010)

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<td>A5. What is the global non-native distribution of the organism outside the risk assessment area?</td>
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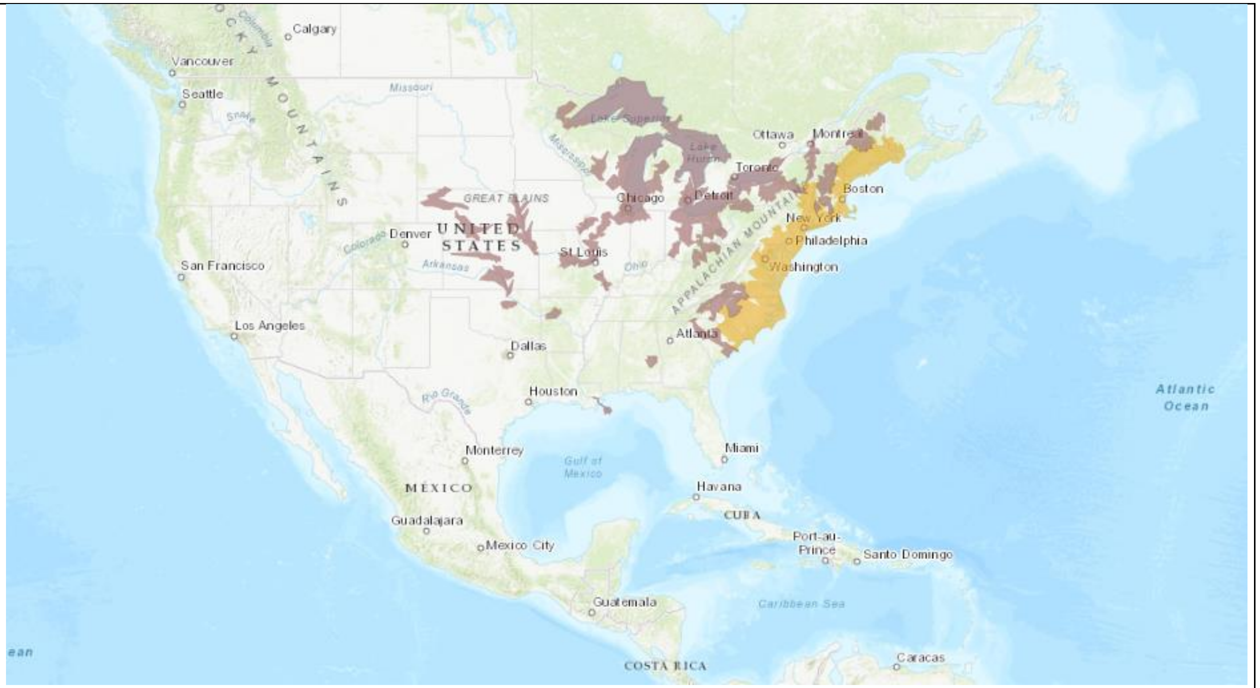

Figure 1 Map showing the native (beige) and non-native (mauve) distributions of white perch Morone americana in North America (USGS, 2018). Use of map copy permitted as per USGS Information Policies and Instructions: www.usgs.gov/information-policies-and-instructions/crediting-usgs).
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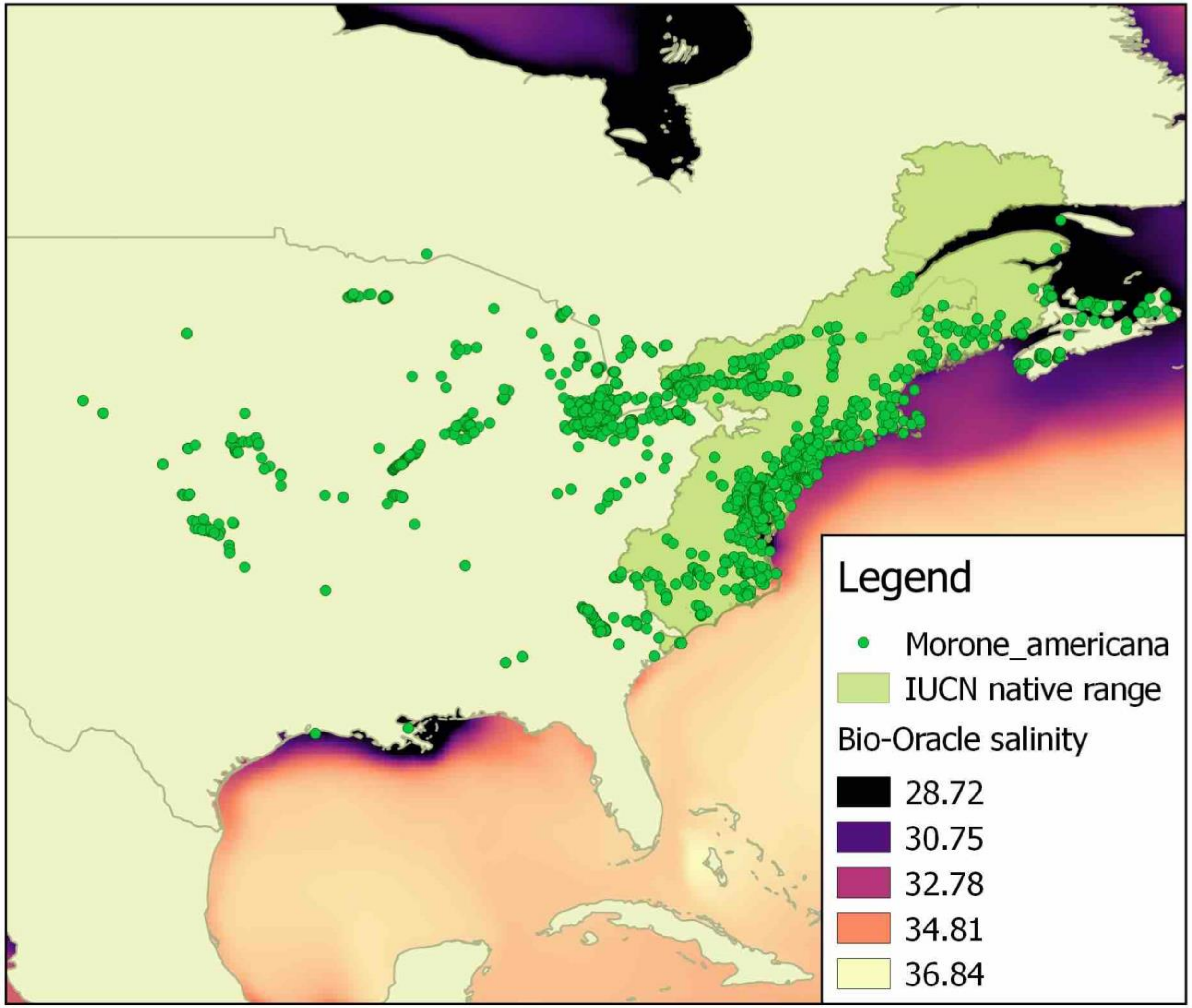
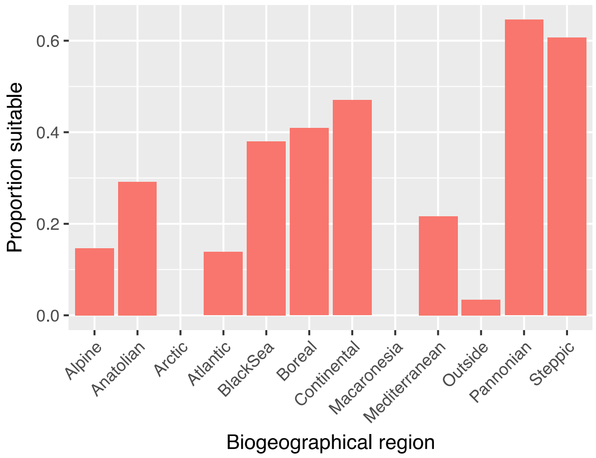


Figure 2. Map of *M. americana* native range and introduced locations in North America, with the salinity of relevant marine areas indicated (see Annex VI).

A6. In which biogeographic region(s) or marine subregion(s) in the risk assessment area has the species been recorded and where is it established?	None, however hybrids of two *Morone* species (*Morone chrysops* × *M. saxatilis*) has been reported in open waters of Croatia (Safner et al., 2013), Serbia (Skorić et al., 2013) and Turkey (Kizak & Güner, 2014), and the risk of reproduction of these hybrids in Germany has recently been examined which was deemed to be elevated (Müller-Belecke et al., 2014, 2016).
A7. In which biogeographic region(s) or marine subregion(s) in the risk assessment area could the species establish in the future under current climate and under foreseeable climate change?	The regions that span the EU projected to be suitable under current climate are examined in greater detail in the Q1.13, but in summary see Figure 3.  Figure 3. Proportion of projected suitable habitats within the RA area for *M. americana* by region in Europe (see Annex VI).
A8. In which EU member states has the species been recorded and in which EU member states has it established? List them with an indication of the timeline of observations.	None of the EU member states have been recorded to have established populations of *M. americana*.
A9. In which EU member states could the species establish in the future under current	Current climate: Most EU member states, possibly including northern parts of Sweden and Finland, but freshwater climate data were not available for the northern parts of those countries

climate and under foreseeable climate change?	so . Future climate: All EU member states because they have been reported to be able to spawn between 10–16°C and in brackish (< 4 ppt) to freshwaters, which is sufficient for reproduction under current climate conditions except for two countries whereas in the future its possible they would be able to establish in all countries. (Mansueti, 1961; Jenkins and Burkhead, 1994; Able and Fahay 2010).
A10. Is the organism known to be invasive (i.e. to threaten or adversely impact upon biodiversity and related ecosystem services) anywhere outside the risk assessment area?	*M. americana* is classified as invasive in some parts of the USA and Canada (Cooke, 1984; Boileau, 1985; Harris, 2006; Kuklinski, 2007; Cavaliere et al., 2010), and has been listed amongst invasive species recorded in about five protected areas of the south Atlantic area of North America (Benson et al., 2016). Example of this is shown in Q 1.26.
A11. In which biogeographic region(s) or marine subregion(s) in the risk assessment area has the species shown signs of invasiveness?	None
A12. In which EU member states has the species shown signs of invasiveness?	None
A13. Describe any known socio-economic benefits of the organism.	*M. americana* is used as a food source for humans (Wisconsin Sea Grant, 2002) and is considered to be a popular sport fish throughout the native range in North America, where recreational angling for them for consumption is known to occur in the Mid-Atlantic states. There is commercial fishing of the species, using trawls, haul seines and drift gill nets, in some areas, with Chesapeake Bay (USA) being the most popular (Ballinger & Peters, 1978; Etnier & Starnes. 1993; Animal Diversity Web, 2018; Page & Burr, 1991).

SECTION B – Detailed assessment **Important instructions:** • In the case of lack of information the assessors are requested to use a standardized answer: "No information has been found." • The classification of pathways developed by the Convention of Biological Diversity shall be used For detailed explanations of the CBD pathway classification scheme consult the IUCN/CEH guidance document[2] and the provided key to pathways[3]. • With regard to the scoring of the likelihood of events or the magnitude of impacts see Annexes I and II. • With regard to the confidence levels, see Annex III.			
PROBABILITY OF INTRODUCTION and ENTRY			
Important instructions: • Introduction is the movement of the species into the risk assessment area. • Entry is the release/escape/arrival in the environment, i.e. occurrence in the wild. Not to be confused with spread, the movement of an organism within the risk assessment area. • For organisms which are already present in the risk assessment area, only complete this section for current active or if relevant potential future pathways. This section need not be completed for organisms which have entered in the past and have no current pathway of introduction and entry.			
QUESTION	**RESPONSE** [chose one entry, delete all others]	**CONFIDENCE** [chose one entry, delete all others]	**COMMENT**
1.1. How many active pathways are relevant to the potential introduction of this organism? (If there are no active pathways or potential future	none **very few** few moderate number	low **medium** high	*M. americana* is not present in the risk assessment (RA) area. Expansions from the NE coast of the USA further west occurred mainly by natural migration via canals. Other pathways described by

[2] https://circabc.europa.eu/sd/a/738e82a8-f0a6-47c6-8f3b-aeddb535b83b/TSSR-2016-010%20CBD%20categories%20on%20pathways%20Final.pdf
[3] https://circabc.europa.eu/sd/a/0aeba7f1-c8c2-45a1-9ba3-bcb91a9f039d/TSSR-2016-010%20CBD%20pathways%20key%20full%20only.pdf

pathways respond N/A and move to the Establishment section)	many very many		Fuller et al. (2008) are accidental introduction of young of the year, produced in a hatchery, into a reservoir, intentional stocking for sportfishing, stock contamination from a striped bass stocking, illegal stocking and via ships' ballast water. Only the last pathway can possibly be an active pathway of introduction into the RA area. There is no evidence of introduction of white bass (eggs, larvae, …) for aquaculture in the EU (Froese and Pauly, 2018).
1.2. List relevant pathways through which the organism could be introduced. Where possible give detail about the specific origins and end points of the pathways as well as a description of any associated commodities. For each pathway answer questions 1.3 to 1.10 (copy and paste additional rows at the end of this section as necessary). Please attribute unique identifiers to each question if you consider more than one pathway, e.g. 1.3a, 1.4a, etc. and then 1.3b, 1.4b etc. for the next pathway.	a. TRANSPORT - STOWAWAY (Ship/boat ballast water) b. TRANSPORT – CONTAMINANT Contaminant on animals i.e. for aquaculture		a). There are huge transports of ballast water between the native range of *M. americana* (East USA) to the RA area. However, up till now, no populations or even specimens of *M. americana* have been reported for Europe. New stricter regulations for ballast water treatment are in force since 2017 (Ballast Water Convention) so the potential of introduction via ballast water would be further limited. b). *Morone* species, including *M. americana* (Hushak et al., 1993), are of aquaculture interest, and a hybrid of two *Morone* species has been imported to some EU and neighbouring countries (e.g. Israel) for aquaculture (Nelson, 1994), i.e. *Morone saxatilis* × *M. chrysops*, with specimens having been reported in open waters in Croatia (Safner et al., 2013), Serbia (Skorić et al., 2013) and Turkey (Kizak & Güner, 2014). This hybrid seems to be considered as an attractive game fish in Italy, Germany and Turkey (Roncarati et al., 2009; Müller-Belecke et al., 2016). *M. americana* may be

	c. RELEASE IN NATURE (Fishery in the wild)		a stowaway in aquaculture transports of hybrid *Morone*. In the USA, *M. americana* have been stocked intentionally in non-native waters by voluntary and incidental agency stocking, and possibly by angler introductions in other areas for sport fishing (CABI, 2018). Intentional stocking of *M. americana* in the RA area should not be possible or should be well regulated as it concerns an alien species (under the EU Regulation on the Use of Alien Species in Aquaculture; European Council 2007) but illegal stocking by individual anglers for sport fishing would be hard to prevent. Of course, the anglers would first have to be able to obtain a sufficient number of *M. americana* specimens, transport them between North American and Europe, which would be difficult to do with low mortality rates.
Pathway name:	TRANSPORT - STOWAWAY (Ship/boat ballast water)		
1.3a. Is introduction along this pathway intentional (e.g. the organism is imported for trade) or unintentional (e.g. the organism is a contaminant of imported goods)? (if intentional, only answer questions 1.4, 1.9, 1.10, 1.11 – delete other rows)	intentional **unintentional**	low medium **high**	
1.4a. How likely is it that large numbers of the organism will travel along this pathway from the point(s) of origin over the course of one year?	very unlikely unlikely **moderately likely** likely	low **medium** high	Although there are huge transports of ballast water between the native range of *M. americana* (East USA) to the RA area, the chance for *M. americana* to be taken in ballast water tanks in large numbers

Subnote: In your comment discuss how likely the organism is to get onto the pathway in the first place. Also comment on the volume of movement along this pathway.	very likely		seems small since *M. americana* spawn in shallow waters and the eggs sink to the bottom. Despite the daily shipping transport between native range and Europe no single *M. americana* was ever recorded in the RA area.
1.5a. How likely is the organism to survive during passage along the pathway (excluding management practices that would kill the organism)? Subnote: In your comment consider whether the organism could multiply along the pathway.	very unlikely **unlikely** moderately likely likely very likely	low **medium** high	Survival of eggs or young-of-the-year fish in ballast water tanks is likely to be low-to-moderate due to ballast water treatment (e.g. filters, UV radiation) and other sub-optimal conditions like low dissolved oxygen, etc. as well as shear stress in relatively confined spaces (Morgan et al., 1979). Also, the exchange of ballast water from fresh/brackish to sea water (if applied) will be detrimental to young-of-the-year *M. americana*. Reproduction will not occur since adult specimens are unlikely to survive being taken up via ballast water pumps.
1.6a. How likely is the organism to survive existing management practices during passage along the pathway?	very unlikely **unlikely** moderately likely likely very likely	low **medium** high	See Q1.5
1.7a. How likely is the organism to enter the risk assessment area undetected?	very unlikely unlikely moderately likely likely **very likely**	low medium **high**	If *M. americana* would arrive by ballast water, then it would go entirely unnoticed until larger specimens would be found in the receiving waters, this happened to many aquatic species before (e.g. in the Laurentian Great Lakes (USA), Vander Zanden et al., 2010).
1.8a. How likely is the organism to arrive during the months of the year most appropriate for establishment?	very unlikely unlikely moderately likely likely	low medium **high**	Extensive daily transports occur between the native range of *M. americana* and the RA area, so this would also cover the most appropriate time of the year for establishment.

	very likely		
1.9a. How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?	very unlikely unlikely moderately likely likely **very likely**	low medium **high**	The organism would be transferred straight from the ballast water into the receiving waters of the main European ports, which are situated in estuaries where circumstances suitable to the species exist, mainly brackish water (North & Houde, 2003).
1.10a. Estimate the overall likelihood of entry into the risk assessment area based on this pathway?	**very unlikely** unlikely moderately likely likely very likely	low **medium** high	In absence of detailed information on ballast water exchanges between North America and the RA area, it is difficult to predict whether or not *M. americana* could be introduced via this pathway. However, locations where ballast water could be taken on in the native range could contain small *M. americana*, but their survival through the pumps and during the trans-Atlantic voyage would seem to be unlikely – otherwise, the species would have most likely been reported from somewhere in the RA area.
Pathway name:	TRANSPORT – CONTAMINANT (Contaminant on animals e.g. for aquaculture or stocking)		
1.3b. Is introduction along this pathway intentional (e.g. the organism is imported for trade) or unintentional (e.g. the organism is a contaminant of imported goods)? (if intentional, only answer questions 1.4, 1.9, 1.10, 1.11 – delete other rows)	intentional **unintentional**	low medium **high**	The organism can be a contaminant of imported fish for aquaculture/stocking. The source of *M. americana* in two Kansas reservoirs is a result of stock contamination from a striped bass stocking (Fuller et al., 2018).
1.4b. How likely is it that large numbers of the	very unlikely	low	Production of *Morone* hybrids in Europe is limited

organism will travel along this pathway from the point(s) of origin over the course of one year? Subnote: In your comment discuss how likely the organism is to get onto the pathway in the first place. Also comment on the volume of movement along this pathway.	**unlikely** moderately likely likely very likely	**medium** high	to Italy, Portugal, France, Germany, Italy, with the nearest non-EU state being Israel (Gottschalk et al., 2005; FAO, 2018) and information on the import of *Morone* species or hybrids to the RA area were not accessible. Also stocking with *Morone* species in the EU is undocumented with *M. americana* infested transports of other *Morone* species in large numbers from the native area to Europe therefore seem unlikely.
1.5b. How likely is the organism to survive during passage along the pathway (excluding management practices that would kill the organism)? Subnote: In your comment consider whether the organism could multiply along the pathway.	very unlikely unlikely moderately likely **likely** very likely	low medium **high**	If live transport of *Morone* species were to be organised, then survival during the passage would be high as with other fish transports. Reproduction during the transport is very unlikely.
1.6b. How likely is the organism to survive existing management practices during passage along the pathway?	very unlikely unlikely moderately likely **likely** very likely	low medium **high**	As the introduction of other *Morone* species for aquaculture is intentional, no management practices will be employed to kill the animals. Therefore, *M. americana* would be likely to survive in the absence of management practices. .
1.7b. How likely is the organism to enter the risk assessment area undetected?	very unlikely unlikely moderately likely **likely** very likely	low **medium** high	In the unlikely event of *M. americana*, a species not the subject of aquaculture, to find its way into an aquaculture facility that rears the hybrid *M. chrysops* × *M. saxatilis*, then it is likely that *M. americana* would go undetected in consignments of the above-mentioned hybrid from the USA to the RA area, especially if the consignments were those of eggs or fry.
1.8b. How likely is the organism to arrive during the months of the year most appropriate for establishment?	very unlikely unlikely moderately likely **likely**	low medium **high**	Live transports of *Morone* species for aquaculture could be organised at any time of the year.

	very likely		
1.9b. How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?	very unlikely unlikely **moderately likely** likely very likely	low **medium** high	Successful incidental escape from an aquaculture facility may happen, which is likely to be within the vicinity of a water course and its estuary, where circumstances suitable to the species exist, mainly brackish water (North & Houde, 2003). The occurrences of *Morone* hybrids in the Danube attest this possibility (Safner et al. 2013; Skorić et al. 2013).
1.10b. Estimate the overall likelihood of entry into the risk assessment area based on this pathway?	very unlikely **unlikely** moderately likely likely very likely	low **medium** high	Since there is limited use of this species in aquaculture in its native range, and no apparent link with non-native species imported from the native range and aquaculture in the RA area, importation as a contaminant is unlikely.
Pathway name:	RELEASE IN NATURE – Fishery in the wild		
1.3c. Is introduction along this pathway intentional (e.g. the organism is imported for trade) or unintentional (e.g. the organism is a contaminant of imported goods)? (if intentional, only answer questions 1.4, 1.9, 1.10, 1.11 – delete other rows)	**intentional** unintentional	low medium **high**	
1.4c. How likely is it that large numbers of the organism will travel along this pathway from the point(s) of origin over the course of one year? Subnote: In your comment discuss how likely the organism is to get onto the pathway in the first place. Also comment on the volume of movement along this pathway.	very unlikely **unlikely** moderately likely likely very likely	low **medium** high	*M. americana* are being illegally stocked for sport fishing in inland lakes in Indiana (Fuller et al., 2018). In some Member States of the EU, illegal stocking of non-native species for sport fishing has happened (or still is happening) e.g. asp *Aspius aspius* in the River Meuse in the Netherlands and Belgium (Verreycken et al., 2007) (and probably many more). This could also happen with *M.*

			americana provided a sufficient number of specimens would be available in the RA area. However, except for direct import from North America, these fish would be very hard to get in sufficient numbers to originate a viable population.
1.5c. How likely is the organism to survive during passage along the pathway (excluding management practices that would kill the organism)? Subnote: In your comment consider whether the organism could multiply along the pathway.	very unlikely unlikely moderately likely **likely** very likely	low **medium** high	*Morone* species e.g. *M. saxatilis* have a high tolerance for environmental stress such as elevated temperature (28°C) or hypoxia (3 mg/L O2) although a combination of stress factors will affect their metabolic performance (Lapointe et al., 2014). It can thus be assumed that *M. americana* can survive transport and stocking, especially since people who would perform the stocking would try to keep the environmental factors during transport as optimal as possible. Reproduction during the introduction would be very unlikely since suitable habitat is missing.
1.6c. How likely is the organism to survive existing management practices during passage along the pathway?	very unlikely unlikely moderately likely **likely** very likely	low **medium** high	As the introduction of other *Morone* species for angling is intentional, no management practices will be employed to kill the animals. Therefore, *M. americana* would be likely to survive in the absence of management practices. It would, however, be easy to kill *M. americana* with piscicides. But tracing and locating illegal transport and stocking would be difficult.
1.7c. How likely is the organism to enter the risk assessment area undetected?	very unlikely unlikely moderately likely **likely** very likely	low **medium** high	It will be difficult to trace and halt illegal stocking of fishes. Although many MSs have fish monitoring programmes, it could take several years before *M. americana* was noticed, depending upon the monitoring systems and public awareness at the national, regional and local levels.
1.8c. How likely is the organism to arrive during the	very unlikely	low	Live transports of *Morone* species for stocking

months of the year most appropriate for establishment?	unlikely moderately likely **likely** very likely	medium **high**	could be organised at any time of the year.
1.9c. How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?	very unlikely unlikely moderately likely **likely** very likely	low medium **high**	Intentional stocking of fish species, e.g. for angling purposes, would be expected to be transferred to receiving waters that are suitable habitat for the species. Many of the European waters seem to be suitable habitat for *M. americana* (see Figure 3).
1.10c. Estimate the overall likelihood of entry into the risk assessment area based on this pathway?	very unlikely **unlikely** moderately likely likely very likely	low **medium** high	Although illegal stocking of fishes for angling purposes is an on-going problem (e.g. Aps et al., 2004; Copp et al., 2010), illegal stocking of *M. americana* in the RA area will be limited and thus the likelihood of entry via this pathway unlikely.
1.11. Estimate the overall likelihood of entry into the risk assessment area based on all pathways and specify if different in relevant biogeographical regions in current conditions (comment on the key issues that lead to this conclusion).	very unlikely **unlikely** moderately likely likely very likely	low **medium** high	Of all of the above-mentioned pathways, the TRANSPORT – STOAWAY pathway is the most likely way for *M. americana* to enter the EU. But despite the large number of daily shipping transports between the native range and Europe no single *M. americana* was ever recorded in the RA area even although most of the EU is suitable habitat in current conditions.
1.12. Estimate the overall likelihood of entry into the risk assessment area based on all pathways in foreseeable climate change conditions?	very unlikely **unlikely** moderately likely likely very likely	low **medium** high	Of all of the above-mentioned pathways, the TRANSPORT – STOAWAY pathway is the most likely way for *M. americana* to enter the EU. But despite the large number of daily shipping transports between the native range and Europe no single *M. americana* was ever recorded in the RA area. However, trade may get more intense in the future thus increasing the possibility of entry and, on top of that, climate warming would slightly enlarge the

			number of MSs where suitable habitat would be available. Therefore, the overall likelihood of entry into the RA area based on all pathways in foreseeable climate change conditions is estimated as moderately likely.

PROBABILITY OF ESTABLISHMENT			
Important instructions: • For organisms which are already established in parts of the risk assessment area, answer the questions with regard to those areas, where the species is not yet established. If the species is established in all Member States, continue with Question 1.16.			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENT**
1.13. How likely is it that the organism will be able to establish in the risk assessment area based on the similarity between climatic conditions within it and the organism's current distribution?	very unlikely unlikely moderately likely **likely** very likely	Low **medium** high	Comparison of the species' current native and introduced ranges in North America in terms of Köppen-Geiger climate type (Peel et. al., 2007) suggest largely similar climatic conditions to the RA area, and this is further supported by GIS-generated map overlays (Figure 4), with parts of Central Europe (Pannonian and Steppic regions) projected to be particularly suitable. Not included in these overlays are salinity levels and the presence of water retention structures, which are well-known barriers to migration (Ovidio & Philippart, 2002). Further uncertainty in these projections arises from the fact that the species has not yet been observed invading outside North America, where it has a strong association with major river systems. Based on the species mostly occupying major river systems in North America, the model identified large rivers as the main limiting factor in Europe, but if the species is able to invade smaller water courses in Europe, then the suitable region could be larger than estimated in Figure 4.

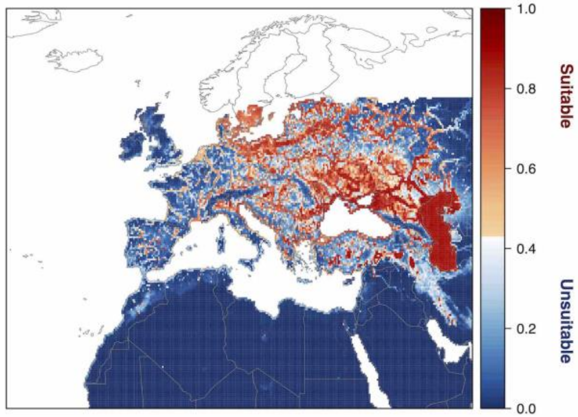
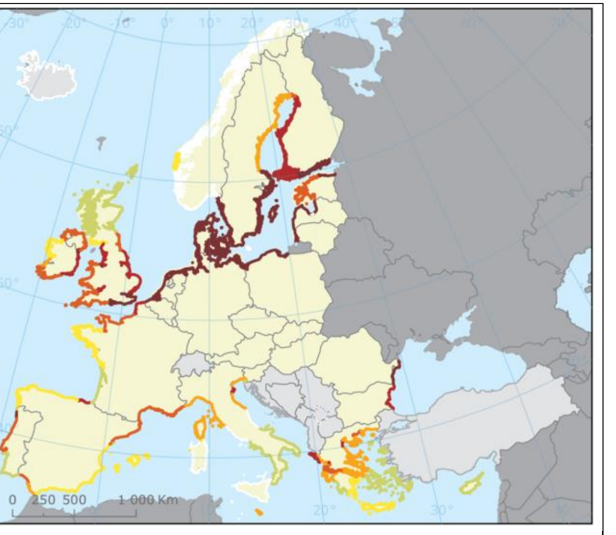


Figure 4. Map of projected suitable habitat for *M. americana* in the RA area (see Annex VI) – See also Figure 3 for the proportions of projected suitable habitat by biogeographic region within the RA area.

The most compelling evidence available for *M. americana* establishment risk comes from Germany (Müller-Belecke et al., 2014, 2016), where a recent study reported successful spawning of the *Morone* hybrid (*M. saxatilis* x *M. chrysops*) in static outdoor water tanks without hormonal treatment, followed by the collection of hundreds of "hatched larvae". This strongly suggests, given the lentic condition of the outdoor tanks and the similar climate range and environmental biology of the parent species of the hybrid (Fuller 2018; Fuller & Neilson, 2018), that natural

			reproduction of other *Morone* species, such as *M. americana*, is likely.
1.14. How likely is it that the organism will be able to establish in the risk assessment area based on the similarity between other abiotic conditions within it and the organism's current distribution?	very unlikely unlikely moderately likely likely **very likely**	low **medium** high	The abiotic conditions in its current distribution are similar to the RA area and there are no obvious differences between the two to indicate that establishment would not be likely in the risk assessment area.
1.15. How widespread are habitats or species necessary for the survival, development and multiplication of the organism in the risk assessment area?	very isolated isolated Moderately widespread **widespread** ubiquitous	low medium **high**	The species occurs in fresh, brackish and coastal waters. Usually found in brackish waters or close to shore, however it can be found in rivers or ponds usually over muddy substratum. (Able & Fahay, 2010; Cabi, 2018). Transitional waters, which offer conditions suitable to the species (North & Houde, 2003; Able & Fahay, 2010), are abundant throughout the RA area, suggesting an elevated likelihood of establishment throughout the region. (See also response to Q1.13). All EU countries except Hungary, Slovakia, Austria, Luxembourg and the Czech Republic, i.e. 82% of the EU, possess transitional waters (Figure 5), with coastal and estuary habitat representing 45 000 km^2 of EU territory (European Council 1992: Pariona, 2018). This suggests the species would find suitable habitat (see also Figures 3 and 4) throughout most of the RA area.

			 **Figure 5. Map indicating the coastal and transitional waters across Europe (EEA, 2018).** (Use of map copy permitted as per EEA Copyright Notice: www.eea.europa.eu/legal/copyright).
1.16. 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** very unlikely unlikely moderately likely likely very likely	low medium **high**	There is no evidence to suggest, and it is unlikely that, this species requires another species to complete its lifecycle
1.17. How likely is it that establishment will occur despite competition from existing species in the risk assessment area?	very unlikely unlikely moderately likely **likely** very likely	low **medium** high	The species has been shown to successfully compete, and in some cases outcompete other species. Based on examples from locations in North America, such as the US state of Indiana and the Great Lakes (e.g. Michigan) where the species has been translocated, it is likely that *M. americana* could establish

			within the RA area irrespective of competition from native species (Encyclopedia of Life, 2018; Schaeffer & Margraf, 1986). Moreover, being a species with high temperature and salinity range limits (Able & Fahay, 2010), this specie might circumvent any competition effect by occupying different habitats .
1.18. How likely is it that establishment will occur despite predators, parasites or pathogens already present in the risk assessment area?	very unlikely unlikely moderately likely **likely** very likely	low **medium** high	The main fish predator in the RA area is the northern pike (*Esox lucius*), although it has been known to be eaten by walleye (*Sander vitreus*), which has at least two congeners in Europe that could exert similar predation pressure (biological resistance) (Ward and Neumann, 1998): pikeperch (*Sander lucioperca*), and Volga pikeperch (*Sander volgensis*). Other potential fish predators include the European catfish (*Silurus glanis*), which is known to predate on a wide range of fish species (Copp et al., 2009a). However, there are relatively few cases of biological resistance amongst large-bodied fishes, and no such biological resistance has been evidenced for the species introduced range in North America where at least as many potential predators exist than the RA area, so it is unlikely predators would impede establishment. *Kudoa* sp. is a known parasite infecting this *M. americana*, being present in other fish in RA (Buton & Poyton, 1991; Yurakhno et al., 2007), but no information about its potential impact in the RA was found. Other potential predators include seals,

			marine/brackish fishes and piscivorous birds although there is no evidence to suggest otherwise these predators would limit establishment.
1.19. How likely is the organism to establish despite existing management practices in the risk assessment area?	very unlikely unlikely moderately likely **likely** very likely	**low** medium high	Given that the species has successfully established outside of the native range in parts of the USA and Canada, this would indicate that *M. americana* could establish within the RA area dependent on where they are introduced. Another factor to consider is there are a range of non-native species that have established within the EU such as *Pseudorasbora parva* and *Lepomis gibbosus*, which would suggest that it is unlikely that current management practices would impede establishment of *M. americana* (Leppäkoski et al., 2011).
1.20. How likely are existing management practices in the risk assessment area to facilitate establishment?	very unlikely unlikely moderately likely **likely** very likely	low medium **high**	Existing management practices for brackish waters and coastal areas are very limited, so this would help to facilitate establishment of this species as there would be very little disturbance to the habitat except for commercial fishing vessels trawling. In relation to lowland water courses, there is no information to suggest that it would affect the establishment of *M. americana*.
1.21. How likely is it that biological properties of the organism would allow it to survive eradication campaigns in the risk assessment area?	very unlikely unlikely moderately likely **likely** very likely	low **medium** high	*M. americana* inhabit coastal and transitional waters which would suggest that any eradication campaign would be likely to be unsuccessful due to the ability of the species to inhabit a range of habitats and they are predominately found to be in brackish waters

			(estuaries) and it is not possible to isolate the water body, it would be impossible for all the species to be eradicated (Williams & Grosholz, 2008). If they were to be introduced in to lakes or rivers that do not discharge into the sea, then it is likely that eradication could be possible. However, if the river does discharge into the sea then this would again likely prevent the successful eradication of the population. The only situations in which it is likely that eradication would be successful would be those of enclosed waters of limited surface area.
1.22. How likely are the biological characteristics of the organism to facilitate its establishment in the risk assessment area?	very unlikely unlikely moderately likely likely **very likely**	low **medium** high	*M. americana* are known to spawn in fresh waters in temperatures of between 10–16°C, but spawning has been shown in temperatures up to ≈20°C (Mansueti, 1961; Jenkins and Burkhead, 1994; Able and Fahay, 2010). The species does not show a preference with regard to habitat type during spawning and egg deposition (Zuerlein, 1981), however, there is evidence of specific parts of rivers being selected for spawning (Kraus & Secor, 2004). Optimal nursery conditions are believed to involve turbid (food rich) brackish areas with low salinities, which are predicted to be influenced by river discharge (North & Houde, 2003). This suggests that the species could spawn in a range of different countries within the RA area if they were to be introduced into suitable open waters.
1.23. How likely is the adaptability of the organism	very unlikely	low	The adaptability of the species has received

to facilitate its establishment?	unlikely moderately likely **likely** very likely	**medium** high	limited research however, there is some information on habitat preferences, e.g. temperature (Hall et al., 1979), and it has been shown that when it has been introduced into a water body, it can establish if the food source and water quality is within its parameters (Johnson & Evans, 1990). Laboratory experiments provided evidence that "differences in overwinter behaviour, metabolism, and survival appear to be adequate to account for observed differences in survival of these species in the wild" (Johnson & Evans, 1991). *Morone* species e.g. *M. saxatilis* have a high tolerance for environmental stress such as elevated temperature (28°C) or hypoxia (3 mg/L O_2) although a combination of stress factors will affect their metabolic performance (Lapointe et al., 2014). Moreover, considering both the latitudinal range in the native area and the different occupied habitats, *M. americana* is highly like to exhibit some degree of adaptability in the RA (Able & Fahay, 2010).
1.24. How likely is it that the organism could establish despite low genetic diversity in the founder population?	very unlikely unlikely moderately likely **likely** very likely	low **medium** high	Although no research has been carried out on this, it is possible to come to the assumption that due to this species prolific reproduction, the species is very likely to establish with a low genetic diversity in the founder population (Jenkins & Burkhead, 1994).
1.25. Based on the history of invasion by this organism elsewhere in the world, how likely is it to establish in the risk assessment area? (If possible,	very unlikely unlikely moderately likely	low medium **high**	This species is known to be established within large parts of The USA and Canada (CABI, 2018). This question is partially answered in

specify the instances in the comments box.)	**likely** very likely		Q1.13 in relation to the similarities in climate conditions. Bethke et al. (2014) reported through various sources that *M. americana* are “excellent competitors and invaders due to a variety of life history traits…”, which emphasises that it is likely they would be able to establish within the RA area.
1.26. If the organism does not establish, then how likely is it that casual populations will continue to occur? Subnote: Red-eared Terrapin, a species which cannot re-produce in GB but is present because of continual release, is an example of a transient species.	**very unlikely** unlikely moderately likely likely very likely	low **medium** high	It is unlikely that a casual population will be possible to continue to occur because as records shows, there is no indication that the species is kept anywhere within the RA area meaning that it’s not possible for continual release or any similar methods. In Indiana (USA), where the species is classified as invasive, there are laws that force anglers or someone that finds the species to kill them and they could be prosecuted if released alive (State of Indiana, 2005).
1.27. Estimate the overall likelihood of establishment in relevant biogeographical regions in current conditions (mention any key issues in the comment box).	very unlikely unlikely moderately likely likely **very likely**	low **medium** high	*M. americana* can tolerate a range of water quality parameters such as salinity tolerances and water temperature etc. which would allow establishment in a range of locations in current conditions located within the Pannonian and Steppic biogeographic region as well as the Continental, Boreal and Black Sea regions (see Figure 3). Although the species is not in the RA area yet, it is possible to assume due to the parameters it can withstand, that if the species was to get to the area through abovementioned pathways, then it is very likely they could establish.
1.28. Estimate the overall likelihood of establishment	very unlikely	low	With the increase in water temperatures

in relevant biogeographical regions in foreseeable climate change conditions	unlikely moderately likely likely **very likely**	**medium** high	forecasted through climate change, this would suggest that more locations within the risk assessment area will become more accessible for *M. americana* especially in north and central Europe as well as parts of the Mediterranean and Atlantic biogeographical regions (Lindner et al., 2010; Baki, 2018). Although it is hard to give definitive answers on how much temperatures will increase, it has been shown that it is currently on a rising trend and no evidence to prove otherwise (www.GlobalChange.gov, 2018).

PROBABILITY OF SPREAD			
Important notes: • Spread is defined as the expansion of the geographical distribution of an alien species within the risk assessment area. • Repeated releases at separate locations do not represent spread and should be considered in the probability of introduction and entry section. In other words, intentional anthropogenic "spread" via release or escape should be dealt within the introduction and entry section.			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENT**
2.1. How important is the expected spread of this organism within the risk assessment area by natural means? (Please list and comment on each of the mechanisms for natural spread.)	minimal minor **moderate** major massive	low **medium** high	In North America, *M. americana* is known to have actively migrated from its native range to the Great Lakes region through canals and waterways between drainage basins. The introduction and spread of *M. americana* in the USA is detailed in Fuller et al. (2008). If this species were to be introduced in the RA area, then it could spread easily through watersheds because of the many connections between them. The temperate climate in most of the area would fit perfectly for the *M. americana*. As *M. americana* is an estuarine species with a broad salinity range (Natureserve, 2008; Able & Fahay, 2010), it probably can find suitable habitats easily. It is possible that natural disasters such as flooding could provide an opportunity for *M. americana* to spread across water bodies and through rivers (Jackson et al., 2001). However, *M. americana* have been classified as a

			partial migratory species. It has been known to migrate from fresh to brackish waters or coming in from the sea to freshwater to spawn. However, no research has shown that they have migrated across the sea which could limit their distribution (Kerr & Secor, 2009; Chapman et al., 2012). In fact, the population structure observed in the native range supports this (Mulligan & Chapman, 1989; Bian et al., 2016). For example, if they were found in the UK, it may be possible that they will not migrate to mainland Europe and establish a population. This would require human intervention for dispersal across a sea. All these dispersals are dependent on where the species is first (and subsequently) introduced in the RA area. The species is only semi-diadromous, which means spread from one river catchment to another would require a reduced-salinity 'bridge' between adjacent river estuaries in order to spread along a coastline.
2.2. How important is the expected spread of this organism within the risk assessment area by human assistance? (Please list and comment on each of the mechanisms for human-assisted spread) and provide a description of the associated commodities.	minimal minor **moderate** major massive	low **medium** high	In the USA, *M. americana* have been stocked intentionally in non-native waters by voluntary and incidental agency stocking, and possibly by angler introductions in other areas for sport fishing (CABI, 2018). Under EU legislation, intentional importations of *M. americana* in the RA area would be regulated under Use of Alien Species in Aquaculture Regulation, and most likely limited to enclosed facilities. But, once in the EU, if unauthorised persons were able to access the enclosed facilities, then illegal

			stocking by individual anglers for sport fishing would be possible. This would seem unlikely due to the necessary security measures associated with enclosed aquaculture facilities. It is possible humans could introduce them as a means of sport fishing as they were in parts of The USA (Wisconsin Sea Grant, 2002b). Previously, it has been stocked into Kansas reservoirs accidentally as it got contaminated with a striped bass stocking (Fuller et al., 2018).
2.2a. List and describe relevant pathways of spread. Where possible give detail about the specific origins and end points of the pathways. For each pathway answer questions 2.3 to 2.9 (copy and paste additional rows at the end of this section as necessary). Please attribute unique identifiers to each question if you consider more than one pathway, e.g. 2.3a, 2.4a, etc. and then 2.3b, 2.4b etc. for the next pathway.	a. UNAIDED – NATURAL DISPERSAL		
Pathway name:	UNAIDED - NATURAL DISPERSAL		
2.3a. Is spread along this pathway intentional (e.g. the organism is released at distant localities) or unintentional (the organism is a contaminant of imported goods)?	intentional **unintentional**	low medium **high**	
2.4a. How likely is it that a number of individuals sufficient to originate a viable population will spread along this pathway from the point(s) of origin over the course of one year?	very unlikely unlikely **moderately likely** likely very likely	low **medium** high	Introductions from the NE coast of the USA to water bodies further west mainly happened through active migration via canals (Fuller et al., 2018). If *M. americana* would arrive in large numbers in the RA area, e.g. via ballast water,

			then active migration would certainly be the main factor for spread. However, since only young life stages of *M. americana* (eggs, young-of-the-year) are expected to be introduced, viable populations will only be formed a few years after the introduction (males may spawn for the first time at age 2 years, and females usually by age 3 years).
2.5a. How likely is the organism to survive during passage along the pathway (excluding management practices that would kill the organism)? Subnote: In your comment consider whether the organism could multiply along the pathway.	very unlikely unlikely moderately likely **likely** very likely	low medium **high**	The waters of the temperate part of the RA area would offer a suitable habitat for the spread and survival of *M. americana*, and also reproduction would certainly be possible along this pathway (cf. invasion history in the USA; CABI, 2018).
2.6a. How likely is the organism to survive existing management practices during spread?	very unlikely unlikely moderately likely **likely** very likely	low **medium** high	*M. americana* can easily be killed by rotenone (acute toxicity to *M. americana* was anticipated to be within recommended concentration levels on product label for similar fish and was corroborated by laboratory bioassay (LC_{100} of 0.15 mg/L Wujtewicz et al., 1997) or other piscicides. However, it would be difficult (if not impossible) to make an effective eradication in the lower course of rivers, especially large ones. Also, rotenone application is illegal in several EU member states.
2.7a. How likely is the organism to spread in the risk assessment area undetected?	very unlikely unlikely moderately likely **likely** very likely	low medium **high**	There exists no dedicated monitoring of invasive fish species in European rivers and canals, so once introduced, *M. americana* would be able to spread unnoticed until captured.
2.8a. How likely is the organism to be able to transfer to a suitable habitat or host during spread?	very unlikely unlikely	low medium	The organism would be introduced from ballast water into the receiving waters of the main

	moderately likely **likely** very likely	**high**	European ports where ideal circumstances exist (mainly brackish water) for survival of *M. americana*. Spread from there to suitable habitat will be easy.
2.9a. Estimate the potential rate of spread within the Union based on this pathway (please provide quantitative data where possible)	very unlikely unlikely **moderately likely** likely very likely	low **medium** high	The potential for spread based on this pathway (CORRIDOR – INTERCONNECTED WATERWAYS) will depend on the success of the primary introduction and entry pathway (TRANSPORT -STOWAWAY (Ship/boat ballast water)). If several independent introductions (in different river basins) would occur then the overall spread would be greater than when it would with a single introduction.
End of pathway assessment, repeat as necessary.			
2.10. Within the risk assessment area, how difficult would it be to contain the organism in relation to these pathways of spread?	very easy easy with some difficulty **difficult** very difficult	low **medium** high	Spread of *M. americana* in the RA area through 'CORRIDOR – Interconnected waterways' is currently non-existing (no records of *M. americana* in the area yet). However, would the species arrive in the area, it would be difficult to contain because natural dispersal is difficult to prevent.
2.11. Estimate the overall potential rate of spread in relevant biogeographical regions under current conditions for this organism in the risk assessment area (using the comment box to indicate any key issues and please provide quantitative data where possible).	very slowly **slowly** moderately rapidly very rapidly	**low** medium high	The potential for spread will depend on the number of introductions and the interconnectivity of the waterways. Overall spread risk would be greater in the case of several independent introductions (in different river basins) than in the case of a single introduction. *M. americana* is a semi-anadromous fish, which reduces slightly its ability to migrate from one river estuary to another. However, elevated precipitation on land results in elevated river discharges, which leads

			to a much wider dilution of coastal marine waters (in terms of salinity), and during such events, it is likely that *M. americana* could migrate between river estuaries of close proximity due to the reduced-salinity bridge created during concurrent high discharge events in the two neighbouring river estuaries. Still this would be uncommon events so spread though the RA area is likely to be slow.
2.12. Estimate the overall potential rate of spread in relevant biogeographical regions in foreseeable climate change conditions (please provide quantitative data where possible)	very slowly slowly **moderately** rapidly very rapidly	**low** medium high	Given the species' temperature tolerances (preferred mean temperature of coldest month >0°C and <18°C; mean warmest month >10°C (CABI, 2018)), climate change could potentially exert an influence on dispersal throughout most of the RA area. But see 2.11.

MAGNITUDE OF IMPACT			
Important instructions: • Questions 2.13-2.17 relate to biodiversity and ecosystem impacts, 2.18-2.20 to impacts on ecosystem services, 2.21-2.25 to economic impact, 2.26-2.27 to social and human health impact, and 2.28-2.30 to other impacts. These impacts can be interlinked, for example a disease may cause impacts on biodiversity and/or ecosystem functioning that leads to impacts on ecosystem services and finally economic impacts. In such cases the assessor should try to note the different impacts where most appropriate, cross-referencing between questions when needed. • Each set of questions starts with the impact elsewhere in the world, then considers impacts in the risk assessment area (=EU excluding outermost regions) separating known impacts to date (i.e. past and current impacts) from potential future impacts (including foreseeable climate change). • Only negative impacts are considered in this section (socio-economic benefits are considered in Qu. A.7)			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**
Biodiversity and ecosystem impacts			
2.13. How important is impact of the organism on biodiversity at all levels of organisation caused by the organism in its non-native range excluding the risk assessment area?	minimal minor **moderate** major massive	low **medium** high	There is evidence that *M. americana* have had adverse effects on biodiversity and ecosystems in various locations in The USA and Canada – see response to A4 (Allan & Zarull, 1995; Schaeffer & Margraf, 1987; CABI, 2018). For example, this species has been known to predate on fish eggs, adversely effecting on the recruitment of the predated fish populations (Schaeffer et al., 1987), e.g. in Lake Erie, predation on eggs of walleye (*Sander vitreus*), white bass (*Morone chrysops*) as well as cannibalism of their own eggs (Schaeffer et al., 1987). It remains unknown whether or not these reported cases of *M. americana* predation on native fish

			eggs have exerted an adverse effect on biodiversity.
2.14. How important is the current known impact of the organism on biodiversity at all levels of organisation (e.g. decline in native species, changes in native species communities, hybridisation) in the risk assessment area (include any past impact in your response)?	Not applicable	low medium **high**	Not applicable because the species does not occur, and has never occurred in the RA area.
2.15. How important is the potential future impact of the organism on biodiversity at all levels of organisation likely to be in the risk assessment area?	minimal minor **moderate** major massive	**low** medium high	It is possible that the impacts will be similar to those stated in Q2.13 because the species has already been found to have these characteristics when previously invaded other areas and there is no evidence to suggest that this would be any different if found in the RA area.
2.16. How important is decline in conservation value with regard to European and national nature conservation legislation caused by the organism currently in the risk assessment area?	Not applicable	low medium **high**	The species does not occur, and to our knowledge never occurred, in the RA area, so no impact could have been registered.
2.17. How important is decline in conservation value with regard to European and national nature conservation legislation caused by the organism likely to be in the future in the risk assessment area?	minimal minor **moderate** major massive	**low** medium high	If the species is found in the RA area, then it could potentially influence native species of conservation value with regard to European and national nature conservation legislation due to predation on eggs as seen in previous studies, although it has not been known to cause a major effect (Schaeffer et al., 1987). The Eurasian perch (*P. fluviatilis*) is virtually identical to *P. flavescens* (Thorpe, 1977), and there are likely to be other native species in the RA area, e.g. *Sander volgensis* (a near-threatened species in some EU countries within the Danube drainage basin), that could also be adversely affected if *M. americana* were to be introduced and establish in the RA area

Ecosystem Services impacts			
2.18 How important is the impact of the organism on provisioning, regulating, and cultural services in its non-native range excluding the risk assessment area?	minimal **minor** moderate major massive	**low** medium high	In its current non-native range, which does not include the RA area, *M. americana* is known to predate on the eggs of native fishes and to have the ability to out compete other species for food. For example, in Lake Erie, *M. americana* was found to have predated on walleye (*Sander vitreus*), white bass (*Morone chrysops*) as well as their own eggs (Schaeffer et al., 1987). These pressures could have an indirect, i.e. minor, impact on cultural services.
2.19. How important is the impact of the organism on provisioning, regulating, and cultural services currently in the different biogeographic regions or marine sub-regions where the species has established in the risk assessment area (include any past impact in your response)?	Not applicable.	low medium **high**	The species does not occur, and to our knowledge never occurred, in the RA area, so no impact could have been registered.
2.20. How important is the impact of the organism on provisioning, regulating, and cultural services likely to be in the different biogeographic regions or marine sub-regions where the species can establish in the risk assessment area in the future?	minimal **minor** moderate major massive	**low** medium high	With climate change predictions from Q2.28, it provides evidence that establishment is possible within the RA area in the future and the answer to this question would be similar to the impacts in Q2.18. There is no evidence to say a different outcome would occur in the RA area. The main difference would be that this species would be predating and outcompeting different species although some species are very similar to species found within the RA area as stated in Q2.23.
Economic impacts			
2.21. How great is the overall economic cost caused by the organism within its current area of distribution (excluding the risk assessment area), including both costs of / loss due to damage and the cost of current	**minimal** minor moderate major	low medium **high**	In terms of costing, there is no evidence to give a monetary value on it but it has shown through previous questions that is has impacted other species which has had an effect on recreational

management	massive		angling. An example is explained in Q2.23.
2.22. How great is the economic cost of / loss due to damage* of the organism currently in the risk assessment area (include any past costs in your response)? *i.e. excluding costs of management	Not applicable.	low medium **high**	The species does not occur, and to our knowledge never occurred, in the RA area, so no impact could have been registered.
2.23. How great is the economic cost of / loss due to damage* of the organism likely to be in the future in the risk assessment area? *i.e. excluding costs of management	minimal **minor** moderate major massive	low **medium** high	The possible negative impact of *Morone americana* on ecosystem services is caused predation on and competition with native species. *Morone americana* is considered to have had a moderate socio-economic impact in the Great Lakes of North America (Fuller et al., 2018): “The collapse of the walleye (*Sander vitreus*) fishery in the Bay of Quinte (on the north shore of Lake Ontario) coincided with an increase in the white perch population and may have been a result of egg predation and lack of recruitment (Schaeffer & Margraf, 1987). Other recreationally/commercially important species, such as white bass (*Morone chrysops*), yellow perch (*Perca flavescens*), and species of forage fish are likely negatively affected by white perch through competition, egg predation, or hybridization.” The Eurasian perch (*P. fluviatilis*) is virtually identical to *P. flavescens* (Thorpe, 1977), and there are likely to be other native species in the RA area, e.g. *Sander volgensis* (a near-threatened species), that could also be adversely affected if *M. americana* were to be introduced and establish in the RA area. The ‘minor’ response reflects the

			unlikelihood of *M. americana* being imported to EU countries due to current legislation in place to prevent this species entering the RA area.
2.24. How great are the economic costs / losses associated with managing this organism currently in the risk assessment area (include any past costs in your response)?	Not applicable.	low medium **high**	The species does not occur, and to our knowledge never occurred, in the RA area, so no impact could have been registered.
2.25. How great are the economic costs / losses associated with managing this organism likely to be in the future in the risk assessment area?	minimal **minor** moderate major massive	low **medium** high	See response to Q2.23. Although there are no management costs in relation to the future, it is hard to give an estimate due to there being no cost estimates in relation to its current non-native range, which does not include the RA area.
Social and human health impacts			
2.26. How important is social, human health or other impact (not directly included in any earlier categories) caused by the organism for the risk assessment area and for third countries, if relevant (e.g. with similar eco-climatic conditions).	**minimal** minor moderate major massive	low **medium** high	No direct information was found from the species non-native range outside of the RA area with regard to social, human health or other impact (not directly included in any earlier categories).
2.27. How important is social, human health or other impact (not directly included in any earlier categories) caused by the organism in the future for the risk assessment area.	**minimal** minor moderate major massive	low medium **high**	With the species unlikely to established in the RA area in the future due to legislation put in place to prevent this however the response is similar to Q2. 26. Possible wider societal impacts could arise if the invasion has negative impacts on fisheries and other ecosystem services (see 2.23) and starts to threaten local livelihoods. However, there is no evidence to indicate major impacts of this type from the species' current introduced range, which does not include the RA area.
Other impacts			
2.28. How important is the impact of the organism as	**minimal**	low	No information was found on *M. americana*

food, a host, a symbiont or a vector for other damaging organisms (e.g. diseases)?	minor moderate major massive	**medium** high	exerting damage to other organisms (other than predation, mentioned previously), however with any importation of non-native species from another continent, there is a risk of infectious agents being introduced. If *M. americana* were to be introduced for any aquaculture use, then it would fall under the EU Regulation on the use of alien species in aquaculture (European Council, 2007) for which a full risk analysis scheme has been developed, including an assessment module specifically on infectious agents (Copp et al., 2016). One parasite group mentioned as associated with *M. americana* is the myxosporean parasite genus *Kudoa* (Bunton & Poynton, 1991), and a review of this genus lists some European fish species of commercial and agriculture interest as being susceptible (Moran et al., 1999). The parasites and pathogens of this *M. americana* are likely to infect other Moronidae species native to RA (due to co-evolutionary history and phylogenetic relatedness), with some highly important in terms of fisheries management and aquaculture (eg. *Dicentrarchus labrax* – sea bass).
2.29. How important might other impacts not already covered by previous questions be resulting from introduction of the organism? (specify in the comment box)	**NA** minimal minor moderate major massive	low medium high	None come to mind.
2.30. How important are the expected impacts of the organism despite any natural control by other organisms, such as predators, parasites or pathogens	minimal **minor** moderate	low **medium** high	There are reports that *M. americana* poses a problem for freshwater fisheries managers due to this species being excellent competitors and as

that may already be present in the risk assessment area?	major massive		previously said feeding on eggs of native species (Madenjian et al., 2000; Gosch et al., 2010). *M. americana* is likely to be a prey species to some European piscivorous species of fish and bird, but none is likely to exert a level of predation pressure that would result in *M. americana* extirpation should the species be introduced and establish itself in RA area waters.

RISK SUMMARIES			
	RESPONSE	**CONFIDENCE**	**COMMENT**
Summarise Entry	very unlikely **unlikely** moderately likely likely very likely	low **medium** high	There exists the possibility of *M. americana* being introduced to, and establishing in the RA area. The TRANSPORT – STOAWAY pathway (ballast water) is the most likely way for *M. americana* to enter the EU. But despite the large number of daily shipping transports between the native range and Europe no single *M. americana* was ever recorded in the RA area even although most of the RA area is suitable habitat in current conditions. Deliberate introduction (e.g. for aquaculture or angling) is less likely as countries are unlikely to be interested in this species because they have native fish species of equivalent or higher commercial interest. Similarly, there are other fish species native to Europe that can be imported more easily from other EU countries than would be the transport of *M. americana* to Europe from North America.
Summarise Establishment	very unlikely unlikely moderately likely likely **very likely**	low **medium** high	*M. americana* have been shown to have the ability to inhabit a wide range of aquatic environments throughout its native and introduced ranges in North America. The comparison of Köppen-Geiger climate types (Peel et al., 2007) and the habitat suitability (invasibility) modelling undertaken for this RA (see Figures 3–5 here above) indicate that the RA area currently possesses suitable climate conditions for establishment of *M. americana*. In view of these factors, the species is likely to establish self-sustaining populations in the RA area if introduced under both current and future climate

			conditions.
Summarise Spread	very slowly slowly **moderately** rapidly very rapidly	low **medium** high	*M. americana* is a semi-anadromous fish, which reduces slightly its ability to migrate from one river estuary to another. However, elevated precipitation on land results in elevated river discharges, which leads to a much wider dilution of coastal marine waters (in terms of salinity), and during such events, it is likely that *M. americana* could migrate between river estuaries of close proximity due to the reduced-salinity bridge created during concurrent high discharge events in the two neighbouring river estuaries. Equally, should the species be imported and become established, the risk of human-aided dispersal would increase, given the propensity of humans to translocate and release fish species for a wide variety of reasons, including angling amenity (Copp et al., 2005, 2007, 2010; Britton & Davies, 2006).
Summarise Impact	minimal minor **moderate** major massive	**low** medium high	The literature evidence for the species' introduced range in North America (e.g. the Great Lakes) suggests that it can exert both competitive and predatory pressures on native fish species, but the extent of adverse impacts on other taxonomic groups, either directly (e.g. non-fish prey during early ontogeny) or indirectly (i.e. food web linkages) remains largely unstudied even in North America. However, in absence of direct evidence of native species extirpation due to *M. americana* introductions, the likely impact of this species is currently estimated to be moderate, but with a caveat of low confidence.
Conclusion of the risk assessment	low	low	Overall, the range of risk responses and there is a

	moderate high	**medium** high	generally low-to-moderate level of confidence associated with some aspects of the risk assessment. For this species, the overaly risk, if it gains entry to the RA area is considered to be moderate, and that is with an overall moderate level of confidence. Whereas, escapee specimens of the Morone hybrid (*M. saxatilis* x *M. chrysops*) are known to persist in water courses of some EU countries (e.g. Safner et al., 2013; Skorić et al., 2013), and apparently has the capacity to spawn in Continental European climate conditions (Müller-Belecke et al., 2014, 2016). This suggests that the indicated moderate risk level for *M. americana* is appropriate. Given this information, as well as information acquired (during this RA) that refer to impacts of the three parent *Morone* species in their introduced North American ranges, it is recommended that a risk assessment be carried out for the EU on the *Morone* hybrid (*M. saxatilis* x *M. chrysops*).

Distribution Summary:

Please answer as follows:
Yes if recorded, established or invasive
– if not recorded, established or invasive
? Unknown; data deficient

The columns refer to the answers to Questions A5 to A12 under Section A.
For data on marine species at the Member State level, delete Member States that have no marine borders. In all other cases, provide answers for all columns.

Member States

	Recorded	Established (currently)	Established (future)	Invasive (currently)
Austria	–	–	?	–
Belgium	–	–	?	–
Bulgaria	–	–	?	–
Croatia	–	–	?	–
Cyprus	–	–	?	–
Czech Republic	–	–	?	–
Denmark	–	–	?	–
Estonia	–	–	?	–
Finland	–	–	?	–
France	–	–	?	–
Germany	–	–	?	–
Greece	–	–	?	–
Hungary	–	–	?	–
Ireland	–	–	?	–
Italy	–	–	?	–
Latvia	–	–	?	–

Lithuania	–	–	?	–
Luxembourg	–	–	?	–
Malta	–	–	?	–
Netherlands	–	–	?	–
Poland	–	–	?	–
Portugal	–	–	?	–
Romania	–	–	?	–
Slovakia	–	–	?	–
Slovenia	–	–	?	–
Spain	–	–	?	–
Sweden	–	–	?	–
United Kingdom	–	–	?	–

Biogeographical regions of the risk assessment area

	Recorded	Established (currently)	Established (future)	Invasive (currently)
Alpine	–	–	?	–
Atlantic	–	–	?	–
Black Sea	–	–	?	–
Boreal	–	–	?	–
Continental	–	–	?	–
Mediterranean	–	–	?	–
Pannonian	–	–	Yes	–
Steppic	–	–	Yes	–

Marine regions and subregions of the risk assessment area

	Recorded	Established (currently)	Established (future)	Invasive (currently)

Baltic Sea	–	–	–	–
Black Sea	–	–	–	–
North-east Atlantic Ocean	–	–	–	–
Bay of Biscay and the Iberian Coast	–	–	–	–
Celtic Sea	–	–	–	–
Greater North Sea	–	–	–	–
Mediterranean Sea	–	–	–	–
Adriatic Sea	–	–	–	–
Aegean-Levantine Sea	–	–	–	–
Ionian Sea and the Central Mediterranean Sea	–	–	–	–
Western Mediterranean Sea	–	–	–	–

ANNEXES

ANNEX I Scoring of Likelihoods of Events
ANNEX II Scoring of Magnitude of Impacts
ANNEX III Scoring of Confidence Levels
ANNEX IV Ecosystem services classification (CICES V5.1) and examples
ANNEX V Biogeographic Regions and MSFD Subregions

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ANNEX I Scoring of Likelihoods of Events
(taken from Baker et al. (2005) and Mumford (2007)

Score	Description	Frequency
Very unlikely	This sort of event is theoretically possible, but is never known to have occurred and is not expected to occur	1 in 10,000 years
Unlikely	This sort of event has not occurred anywhere in living memory	1 in 1,000 years
Possible	This sort of event has occurred somewhere at least once in recent years, but not locally	1 in 100 years
Likely	This sort of event has happened on several occasions elsewhere, or on at least one occasion locally in recent years	1 in 10 years
Very likely	This sort of event happens continually and would be expected to occur	Once a year

References: Baker, R., Hulme, P., Copp, G.H., Thomas, M., Black, R. and Haysom, K. 2005. UK non-native organism risk assessment scheme user manual: version 3.3. Great Britain Non-native Species Secretariat, York.

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ANNEX II Scoring of Magnitude of Impacts
(modified from Baker et al. (2005) and Mumford (2007)

Score	Biodiversity and ecosystem impact	Ecosystem Services impact	Economic impact (Monetary loss and response costs per year)	Social and human health impact
	Questions 2.18–2.22	*Questions 2.23–2.25*	*Questions 2.26–2.30*	*Questions 2.31–2.32*
Minimal	Local, short-term population loss, no significant ecosystem effect	No services affected[4]	Up to 10,000 Euro	No social disruption. Local, mild, short-term reversible effects to individuals.
Minor	Some ecosystem impact, reversible changes, localised	Local and temporary, reversible effects to one or few services	10,000–100,000 Euro	Significant concern expressed at local level. Mild short-term reversible effects to identifiable groups, localised.
Moderate	Measureable long-term damage to populations and ecosystem, but little spread, no extinction	Measureable, temporary, local and reversible effects on one or several services	100,000–1,000,000 Euro	Temporary changes to normal activities at local level. Minor irreversible effects and/or larger numbers covered by reversible effects, localised.
Major	Long-term irreversible ecosystem change, spreading beyond local area	Local and irreversible or widespread and reversible effects on one / several services	1,000,000–10,000,000 Euro	Some permanent change of activity locally, concern expressed over wider area. Significant irreversible effects locally or reversible effects over large area.
Massive	Widespread, long-term population loss or extinction, affecting several	Widespread and irreversible effects on one / several services	Above 10,000,000 Euro	Long-term social change, significant loss of employment, migration from affected area. Widespread, severe, long-term,

[4] Not to be confused with “no impact”.

	species with serious ecosystem effects			irreversible health effects.

References: Baker, R., Hulme, P., Copp, G.H., Thomas, M., Black, R. and Haysom, K. 2005. UK non-native organism risk assessment scheme user manual: version 3.3. Great Britain Non-native Species Secretariat, York.
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ANNEX III. Scoring of Confidence Levels
(modified from Bacher et al., 2018)

Confidence level	**Description**
Low	There is no direct observational evidence to support the assessment, e.g. only inferred data have been used as supporting evidence *and/or* Impacts are recorded at a spatial scale which is unlikely to be relevant to the assessment area *and/or* Evidence is poor and difficult to interpret, e.g. because it is strongly ambiguous *and/or* The information sources are considered to be of low quality or contain information that is unreliable.
Medium	There is some direct observational evidence to support the assessment, but some information is inferred *and/or* Impacts are recorded at a small spatial scale, but rescaling of the data to relevant scales of the assessment area is considered reliable, or to embrace little uncertainty *and/or* The interpretation of the data is to some extent ambiguous or contradictory.
High	There is direct relevant observational evidence to support the assessment (including causality) *and* Impacts are recorded at a comparable scale *and/or* There are reliable/good quality data sources on impacts of the taxa *and* The interpretation of data/information is straightforward *and/or* Data/information are not controversial or contradictory.

Reference: Bacher, S., Blackburn, T.M., Essl, F., Genovesi, P., Heikkilä, J., Jeschke, J.M., Jones, G., Keller, R., Kenis, M., Kueffer, C. and Martinou, A.F. 2018. Socio-economic impact classification of alien taxa (SEICAT). *Methods in Ecology and Evolution* **9**, 159–168.

ANNEX IV. Ecosystem services classification (CICES V5.1, simplified) and examples

For the purposes of this risk assessment, please feel free to use what seems as the most appropriate category / level / combination of impact (Section – Division – Group), reflecting information available.

Section	Division	Group	Examples (i.e. relevant CICES "classes")
Provisioning	**Biomass**	**Cultivated *terrestrial* plants**	Cultivated terrestrial plants (including fungi, algae) grown for nutritional purposes; Fibres and other materials from cultivated plants, fungi, algae and bacteria for direct use or processing (excluding genetic materials); Cultivated plants (including fungi, algae) grown as a source of energy *Example: negative impacts of non-native organisms to crops, orchards, timber etc.*
		Cultivated *aquatic* plants	Plants cultivated by in- situ aquaculture grown for nutritional purposes; Fibres and other materials from in-situ aquaculture for direct use or processing (excluding genetic materials); Plants cultivated by in- situ aquaculture grown as an energy source. *Example: negative impacts of non-native organisms to aquatic plants cultivated for nutrition, gardening etc. purposes.*
		Reared animals	Animals reared for nutritional purposes; Fibres and other materials from reared animals for direct use or processing (excluding genetic materials); Animals reared to provide energy (including mechanical) *Example: negative impacts of non-native organisms to livestock*
		Reared *aquatic* animals	Animals reared by in-situ aquaculture for nutritional purposes; Fibres and other materials from animals grown by in-situ aquaculture for direct use or processing (excluding genetic materials); Animals reared by in-situ aquaculture as an energy source *Example: negative impacts of non-native organisms to fish farming*

		Wild plants (terrestrial and aquatic)	Wild plants (terrestrial and aquatic, including fungi, algae) used for <u>nutrition</u>; <u>Fibres and other materials</u> from wild plants for direct use or processing (excluding genetic materials); Wild plants (terrestrial and aquatic, including fungi, algae) used as a <u>source of energy</u> *Example: reduction in the availability of wild plants* (*e.g. wild berries, ornamentals*) *due to non-native organisms* (*competition, spread of disease etc.*)
		Wild animals (terrestrial and aquatic)	Wild animals (terrestrial and aquatic) used for <u>nutritional purposes</u>; <u>Fibres and other materials</u> from wild animals for direct use or processing (excluding genetic materials); Wild animals (terrestrial and aquatic) used as a <u>source of energy</u> *Example: reduction in the availability of wild animals* (*e.g. fish stocks, game*) *due to non-native organisms* (*competition, predations, spread of disease etc.*)
	Genetic material from all biota	**Genetic material** from plants, algae or fungi	<u>Seeds, spores and other plant materials</u> collected for maintaining or establishing a population; Higher and lower plants (whole organisms) used to <u>breed new strains or varieties</u>; Individual genes extracted from higher and lower plants for the <u>design and construction of new biological entities</u> *Example: negative impacts of non-native organisms due to interbreeding*
		Genetic material from animals	Animal material collected for the purposes of maintaining or establishing a population; Wild animals (entire organisms) used to breed new strains or varieties; Individual genes extracted from organisms for the design and construction of new biological entities *Example: negative impacts of non-native organisms due to interbreeding*

	Water[5]	**Surface water** used for nutrition, materials or energy	Surface water for drinking; Surface water used as a material (non-drinking purposes); Freshwater surface water, coastal and marine water used as an energy source *Example: loss of access to surface water due to spread of non-native organisms*
		Ground water for used for nutrition, materials or energy	Ground (and subsurface) water for drinking; Ground water (and subsurface) used as a material (non-drinking purposes); Ground water (and subsurface) used as an energy source *Example: reduced availability of ground water due to spread of non-native organisms and associated increase of ground water consumption by vegetation.*
Regulation & Maintenance	**Transformation** of biochemical or physical inputs to ecosystems	**Mediation of wastes or toxic substances** of anthropogenic origin by living processes	Bio-remediation by micro-organisms, algae, plants, and animals; Filtration/sequestration/storage/accumulation by micro-organisms, algae, plants, and animals *Example: changes caused by non-native organisms to ecosystem functioning and ability to filtrate etc. waste or toxics*
		Mediation of nuisances of anthropogenic origin	Smell reduction; noise attenuation; visual screening (e.g. by means of green infrastructure) *Example: changes caused by non-native organisms to ecosystem structure, leading to reduced ability to mediate nuisances.*
	Regulation of physical, chemical, biological conditions	**Baseline flows and extreme event** regulation	Control of erosion rates; Buffering and attenuation of mass movement; Hydrological cycle and water discharge regulation (Including flood control, and coastal protection); Wind protection; Fire protection

[5] Note: in the CICES classification provisioning of water is considered as an abiotic service whereas the rest of ecosystem services listed here are considered biotic.

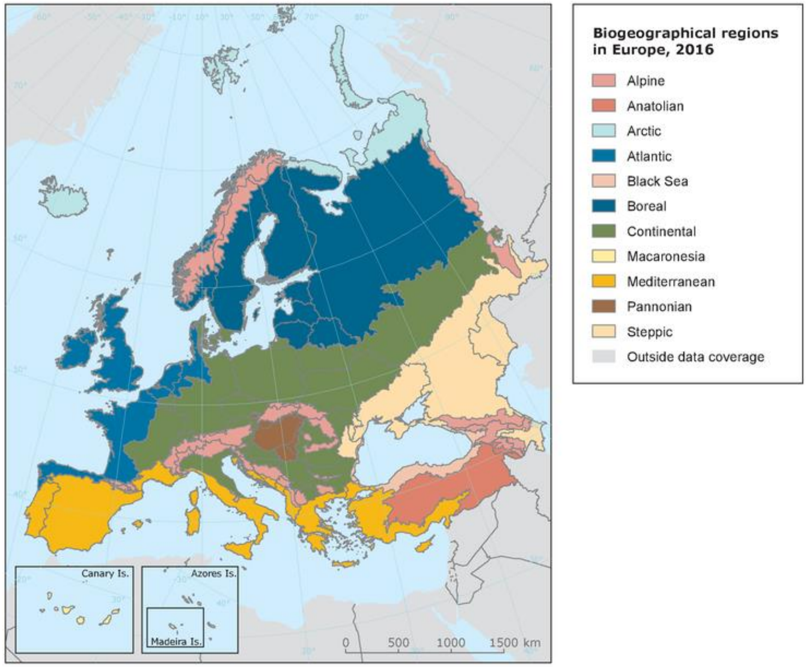
			Example: changes caused by non-native organisms to ecosystem functioning or structure leading to, for example, destabilisation of soil, increased risk or intensity of wild fires etc.
		Lifecycle maintenance, habitat and gene pool protection	Pollination (or 'gamete' dispersal in a marine context); Seed dispersal; Maintaining nursery populations and habitats (Including gene pool protection) *Example: changes caused by non-native organisms to the abundance and/or distribution of wild pollinators; changes to the availability/quality of nursery habitats for fisheries*
		Pest and disease control	Pest control; Disease control *Example: changes caused by non-native organisms to the abundance and/or distribution of pests*
		Soil quality regulation	Weathering processes and their effect on soil quality; Decomposition and fixing processes and their effect on soil quality *Example: changes caused by non-native organisms to vegetation structure and/or soil fauna leading to reduced soil quality*
		Water conditions	Regulation of the chemical condition of freshwaters by living processes; Regulation of the chemical condition of salt waters by living processes *Example: changes caused by non-native organisms to buffer strips along water courses that remove nutrients in runoff and/or fish communities that regulate the resilience and resistance of water bodies to eutrophication*
		Atmospheric composition and conditions	Regulation of chemical composition of atmosphere and oceans; Regulation of temperature and humidity, including ventilation and transpiration *Example: changes caused by non-native organisms to ecosystems' ability to*

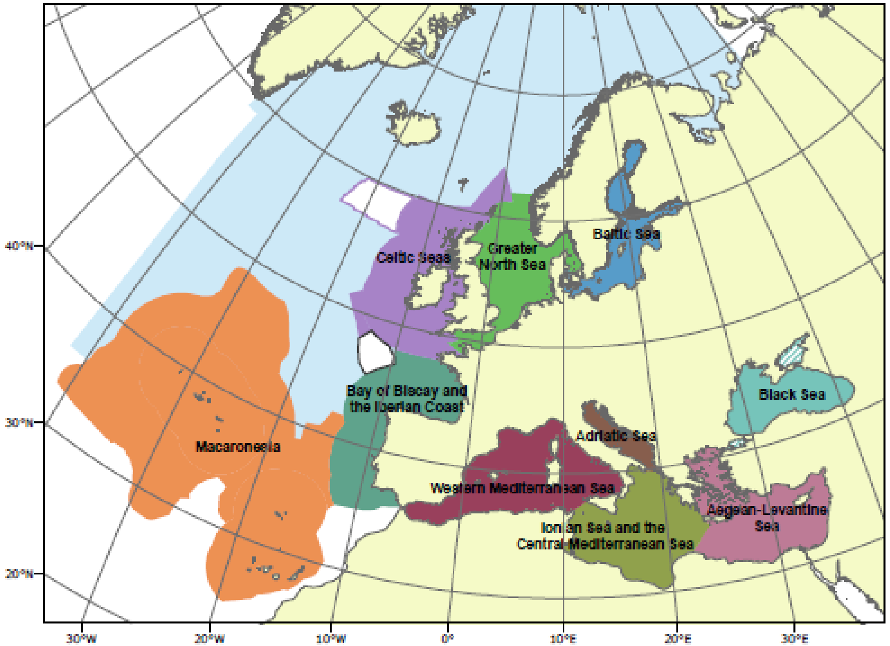
			sequester carbon and/or evaporative cooling (*e.g. by urban trees*)
Cultural	**Direct, in-situ and outdoor interactions** with living systems that depend on presence in the environmental setting	**Physical and experiential** interactions with natural environment	Characteristics of living systems that that enable activities promoting health, recuperation or enjoyment through active or immersive interactions; Characteristics of living systems that enable activities promoting health, recuperation or enjoyment through passive or observational interactions *Example: changes caused by non-native organisms to the qualities of ecosystems* (*structure, species composition etc.*) *that make it attractive for recreation, wild life watching etc.*
		Intellectual and representative interactions with natural environment	Characteristics of living systems that enable scientific investigation or the creation of traditional ecological knowledge; Characteristics of living systems that enable education and training; Characteristics of living systems that are resonant in terms of culture or heritage; Characteristics of living systems that enable aesthetic experiences *Example: changes caused by non-native organisms to the qualities of ecosystems* (*structure, species composition etc.*) *that have cultural importance*
	Indirect, remote, often indoor interactions with living systems that do not require presence in the environmental setting	**Spiritual, symbolic** and other interactions with natural environment	Elements of living systems that have symbolic meaning; Elements of living systems that have sacred or religious meaning; Elements of living systems used for entertainment or representation *Example: changes caused by non-native organisms to the qualities of ecosystems* (*structure, species composition etc.*) *that have sacred or religious meaning*
		Other biotic characteristics	Characteristics or features of living systems that have an existence value;

		that have a **non-use value**	Characteristics or features of living systems that have an option or bequest value *Example: changes caused by non-native organisms to ecosystems designated as wilderness areas, habitats of endangered species etc.*

ANNEX V. EU Biogeographic Regions and MSFD Subregions

See www.eea.europa.eu/data-and-maps/figures/biogeographical-regions-in-europe-2,
http://ec.europa.eu/environment/nature/natura2000/biogeog_regions/
and www.eea.europa.eu/data-and-maps/data/msfd-regions-and-subregions-1/technical-document/pdf





ANNEX VI. Projection of climatic suitability for *Morone americana* establishment

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21 May 2018

Aim
To project the climatic suitability for potential establishment of *Morone americana* in Europe, under current and predicted future climatic conditions.

Data for modelling
Species occurrence data were obtained from the Global Biodiversity Information Facility (GBIF), VertNet, iNaturalist, iDigBio, Ocean Biogeographic Information System (OBIS) and USGS Biodiversity Serving Our Nation (BISON). We removed records where the geo-referencing was too imprecise or estuarine records that were outside the coverage of the terrestrial predictor layers. The remaining records were gridded at a 0.25 × 0.25 degree resolution for modelling (Figure 1a). This resulted in a total of 571 grid cells containing records of *M. americana* for the modelling (Figure 1a), which is adequate for distribution modelling. All records were from North America, and they were divided into native and introduced adventive records using a published native range polygon (NatureServe, 2013).
Climate data were taken from freshwater-specific versions of the 'Bioclim' variables (Domisch et al., 2015) aggregated to a 0.25 × 0.25 degree grid for use in the model. The following variables were used in the modelling:

- Mean upstream temperature of the coldest month (Hydro6°C) reflecting the winter cold stress. Low winter temperatures have been shown to cause very high juvenile mortality (Johnson & Evans, 1991).
- Mean upstream temperature of the warmest quarter (Hydro10°C) reflecting the summer thermal regime. Adults show a behavioural preference for water temperatures between 15 and 30°C (Hall et al., 1979) and larvae do not grow below 13°C (Margulies, 1989; Hanks & Secor, 2011).
- Mean upstream annual precipitation (Hydro12 mm, log+1 transformed) was used as an indicator of the availability of aquatic habitats.

Unfortunately, future scenarios for these variables are not available, precluding assessment of climate change on the potential distribution.
As an additional habitat variable, the proportion cover of inland water (log+1 transformed) was derived from the Global Inland Water database (Feng et al., 2016).
Finally, the recording density of Actinopterygii on GBIF was obtained as a proxy for spatial recording effort bias (Figure 1b).

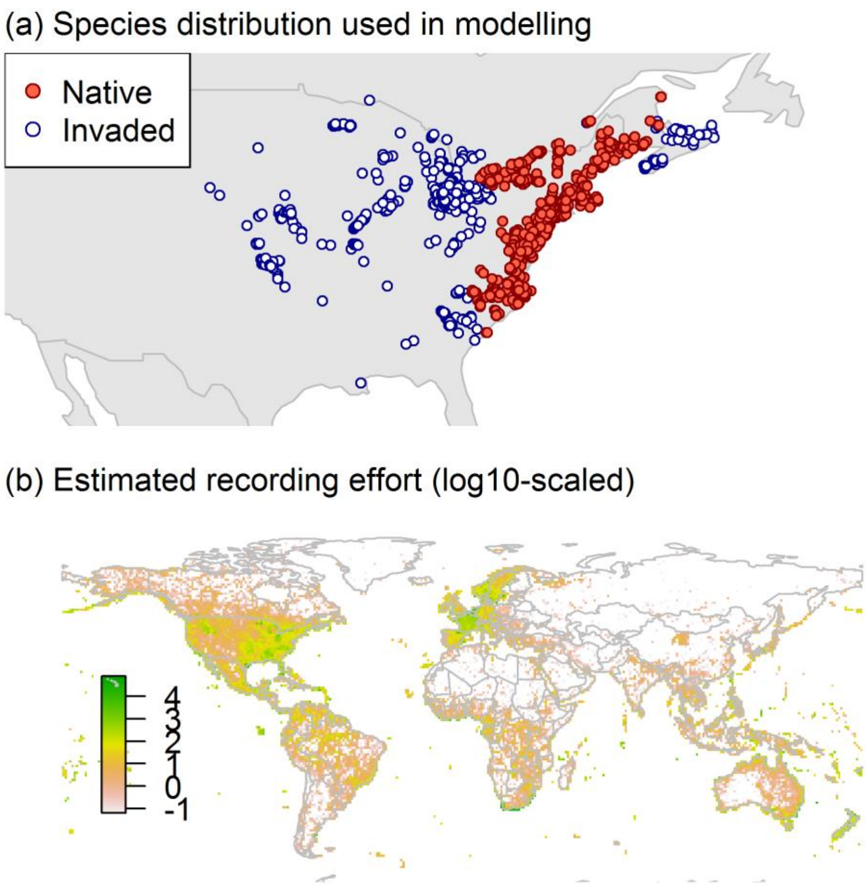

Figure 1. (a) Inland occurrence records obtained for *Morone americana* and used in the modelling, showing the native range and introduced occurrences, and (b) a proxy for recording effort – the number of Actinopterygii records held by the Global Biodiversity Information Facility, displayed on a $\log_{10}$ scale.

Species distribution model

A presence-background (presence-only) ensemble modelling strategy was employed using the BIOMOD2 R package v3.3–7 (Thuiller et al., 2009, 2016). Because invasive species' distributions are not at equilibrium and subject to dispersal constraints at a global scale (Elith et al., 2010), we took care to minimise the inclusion of locations suitable for the species but where it has not been able to disperse to. Therefore background samples (pseudo-absences) were sampled from two distinct regions:

- An <u>accessible background</u> includes places close to *M. americana* populations, in which the species is likely to have had sufficient time to disperse and sample the range of environments. The accessible background was defined as both the native range polygon (NatureServe, 2013) and watershed polygons in which the introduced records fell. Watersheds were defined as level 6 polygons from the HydroBASINS dataset (Lehner & Grill, 2013).
- An <u>unsuitable background</u> includes places with an expectation of environmental unsuitability, e.g. places too cold. Absence from these regions should be irrespective of dispersal constraints, allowing inclusion of this background in the modelling. Ecophysiological information suggested that temperature was a key limiting factor, so unsuitable regions were defined based on the extremes of the temperature values at species occurrences:
    - Minimum temperature of the coldest month (Bio6) < –17°C, OR
    - Mean temperature of the warmest quarter (Hydro10) < 14°C, OR
    - Mean temperature of the warmest quarter (Hydro10) > 27°C

Only nine of the 571 occurrences (1.6%) fell within the unsuitable background.
Ten random background samples were obtained:

- From the accessible background 571 samples were drawn, which is the same number as the occurrences. Sampling was performed with similar recording bias as the distribution data using the target group approach (Phillips, 2009). In this, sampling of background grid cells was weighted in proportion to Actinopterygii GBIF recording density (Figure 1b). Taking the same number of background samples as occurrences ensured the background sample had the same level of bias as the data.
- From the unsuitable background 3000 simple random samples were taken. Sampling was not adjusted for recording biases as we are confident of absence from these regions.

Model testing on other datasets has shown that this method is not overly sensitive to the choice of buffer radius for the accessible background or the number of unsuitable background samples.

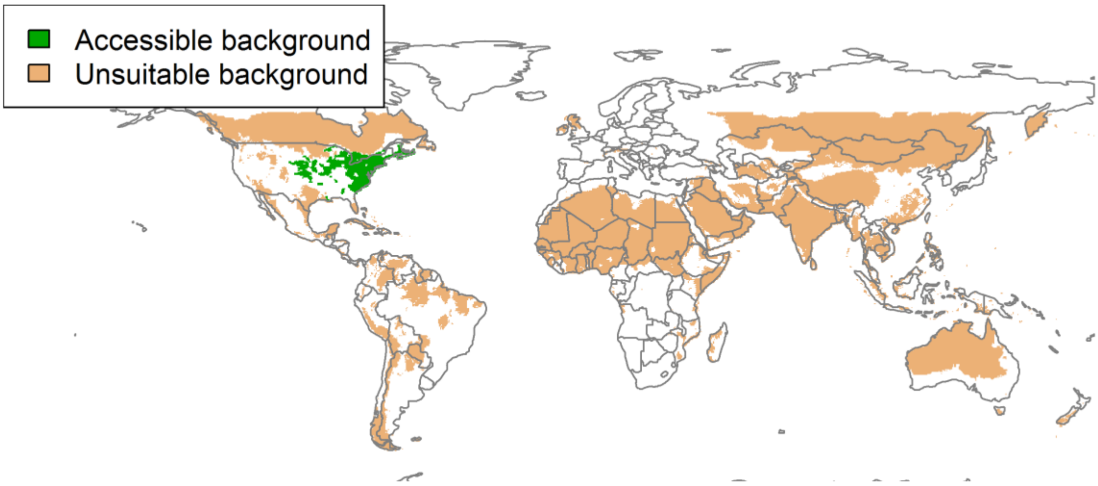

Figure 2. The background regions from which 'pseudo-absences' were sampled for modelling. The accessible background is assumed to represent the range of environments the species has had chance to sample. The unsuitable background is assumed to be environmentally unsuitable for the species.

Each dataset (i.e. combination of the presences and the individual background samples) was randomly split into 80% for model training and 20% for model evaluation. With each training dataset, seven statistical algorithms were fitted with the default BIOMOD2 settings (except where specified below) and rescaled using logistic regression:

- Generalised linear model (GLM)
- Generalised boosting model (GBM)
- Generalised additive model (GAM) with a maximum of four degrees of freedom per effect.
- Artificial neural network (ANN)
- Multivariate adaptive regression splines (MARS)
- Random forest (RF)
- Maxent (Phillips et al., 2008)

Since the background sample was much larger than the number of occurrences, prevalence fitting weights were applied to give equal overall importance to the occurrences and the background. Normalised variable importance was assessed and variable response functions were produced using BIOMOD2's default procedure. Model predictive performance was assessed by calculating the Area Under the Receiver-Operator Curve (AUC) for model predictions on the evaluation data, which were reserved from model fitting. AUC is the probability that a randomly selected presence has a higher model-predicted suitability than a randomly selected pseudo-absence.

An ensemble model was created by first rejecting poorly performing algorithms with relatively extreme low AUC values and then averaging the predictions of the remaining algorithms, weighted by their AUC. To identify poorly performing algorithms, AUC values were converted into modified z-scores based on their difference to the median and the median absolute deviation across all algorithms (Iglewicz & Hoaglin, 1993). Algorithms with $z < -2$ were rejected. In this way, ensemble projections were made for each dataset and then averaged to give an overall suitability.

Global model projections were made for the current climate and for the two climate change scenarios, avoiding model extrapolation beyond the ranges of the input variables. The optimal threshold for partitioning the ensemble predictions into suitable and unsuitable regions was determined using the 'minimum ROC distance' method. This finds the threshold where the Receiver-Operator Curve (ROC) is closest to its top left corner, i.e. the point where the false positive rate (one minus specificity) is zero and true positive rate (sensitivity) is one.

Limiting factor maps were produced following Elith et al. (2010). Projections were made separately with each individual variable fixed at a near-optimal value. These were chosen as the median values at the occurrence grid cells. Then, the most strongly limiting factors were identified as the one resulting in the highest increase in suitability in each grid cell. Partial response plots were also produced by predicting suitability across the range of each predictor, with other variables held at near-optimal values.

Results

The ensemble model suggested that at the global scale and resolution of the model suitability for *M. americana* was most strongly determined by winter and summer temperatures and habitat availability, with little effect of precipitation (Table 1, Figure 3).

Global projection of the ensemble model in current climatic conditions indicates that the native and introduced records from North America fell within regions predicted to have high suitability (Figure 4). The model also predicts that further infilling and westwards range expansion of the introduced North American range is climatically possible, though this will be restricted by the availability of major river systems.

In Europe, most major river systems were predicted as being climatically suitable (Figure 5). The freshwater predictor variables do not extend to the northernmost parts of Europe, but it seems likely that at least southern Scandinavia would be climatically suitable. The model also suggests that suitability for invasion of Europe may be largely limited by the availability of inland water bodies (Figure 6), based on nearly all North American records coming from major river systems. However, if the species is able to colonise more minor rivers in Europe then the species may be able to establish more widely than is shown in Figure 5.

Most European Biogeographical Regions (Bundesamt fur Naturschutz (BfN), 2003) are projected to be suitable for invasion, with the Pannonian and Steppic and Continental regions predicted to be the most at risk in the current climate (Figure 7). However, this analysis may be sensitive to caveats around the distribution of inland water habitat and the northern limit of the predictor variables.

Table 1. Summary of the cross-validation predictive performance (AUC) and variable importances of the fitted model algorithms and the ensemble (AUC-weighted average of the best performing algorithms). Results are the mean values from models fitted to ten different background samples of the data.

Algorithm	**AUC**	**In the ensemble**	**Variable importance**			
			Minimum temperature of coldest month	**Mean temperature of warmest quarter**	**Annual precipitation**	**Proportion inland water**
GLM	0.9458	yes	52%	31%	1%	15%
GAM	0.9454	yes	51%	29%	1%	18%
MARS	0.9429	yes	45%	36%	0%	19%
Maxent	0.9429	yes	38%	32%	3%	27%
GBM	0.9428	yes	29%	47%	0%	25%
ANN	0.9424	yes	56%	22%	4%	17%
RF	0.9247	no	31%	40%	5%	24%
Ensemble	**0.9466**		**45%**	**33%**	**2%**	**20%**

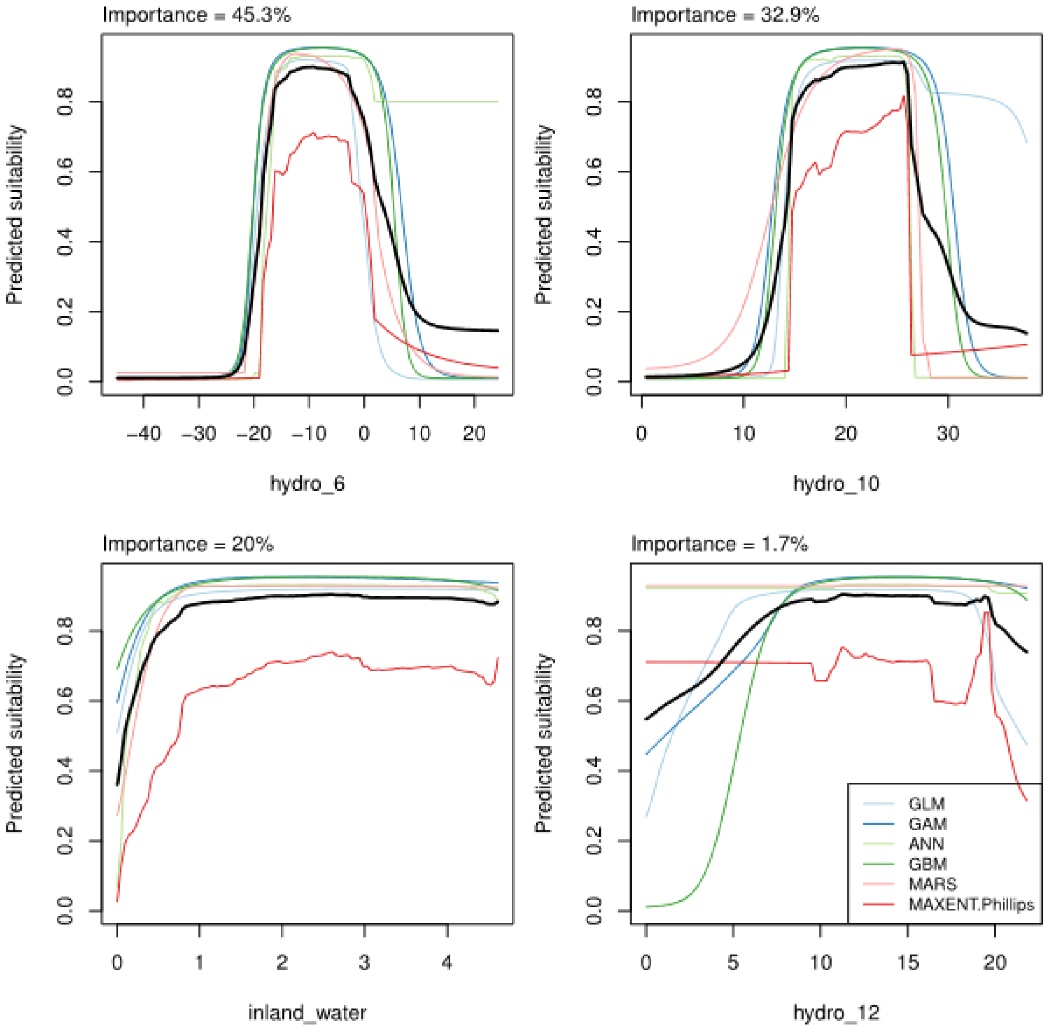

Figure 3. Partial response plots from the fitted models, ordered from most to least important. Thin coloured lines show responses from the algorithms in the ensemble, while the thick black line is their ensemble. In each plot, other model variables are held at their median value in the training data. Some of the divergence among algorithms is because of their different treatment of interactions among variables.

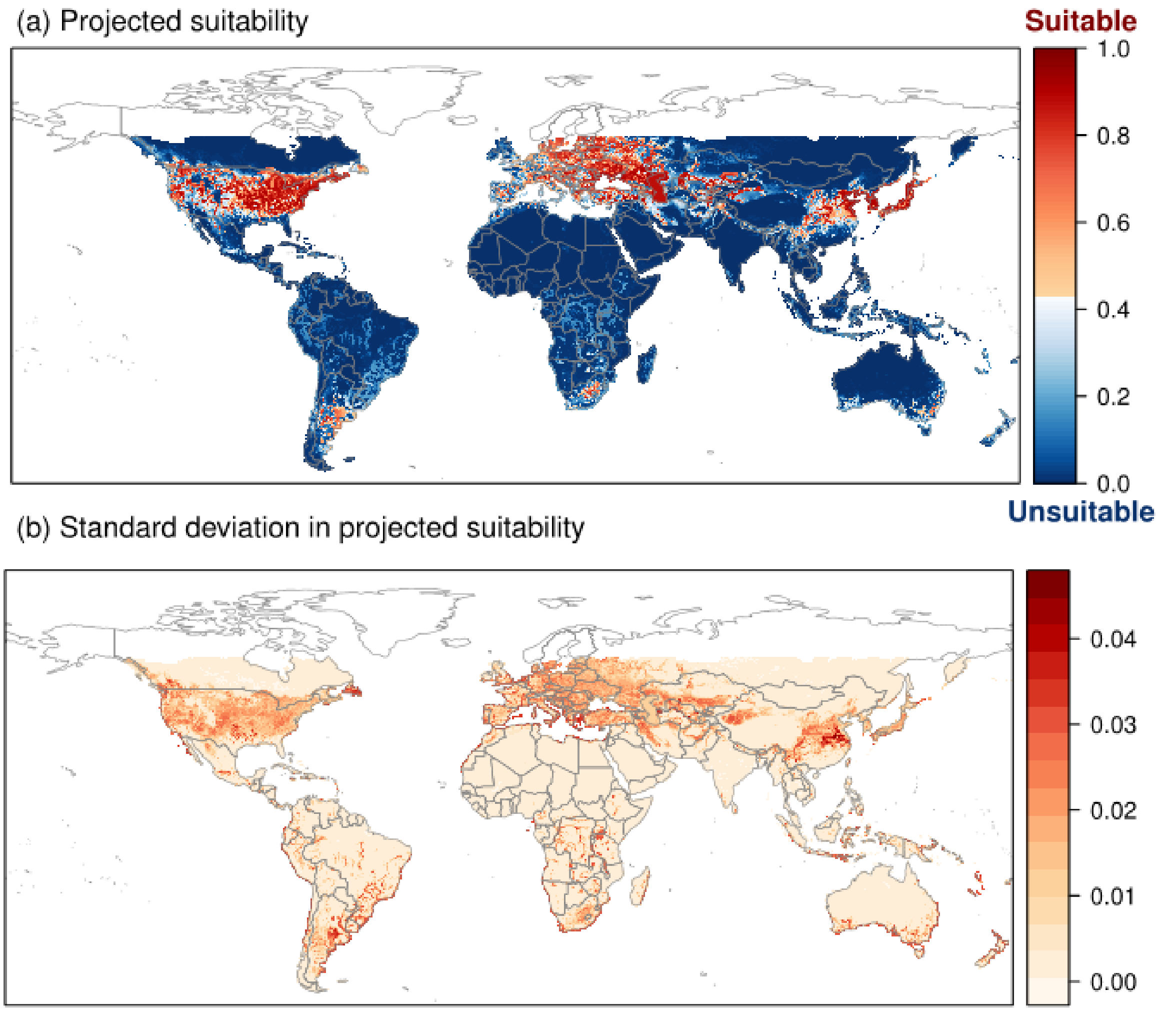

Figure 4. (a) Projected global suitability for *Morone americana* establishment in the current climate. For visualisation, the projection has been aggregated to a 0.5 × 0.5 degree resolution, by taking the maximum suitability of constituent higher resolution grid cells. Red shading indicates suitability. White areas are beyond the scope of the predictor variables preventing model projection. (b) Uncertainty in the suitability projections, expressed as the standard deviation of projections from different algorithms in the ensemble model.

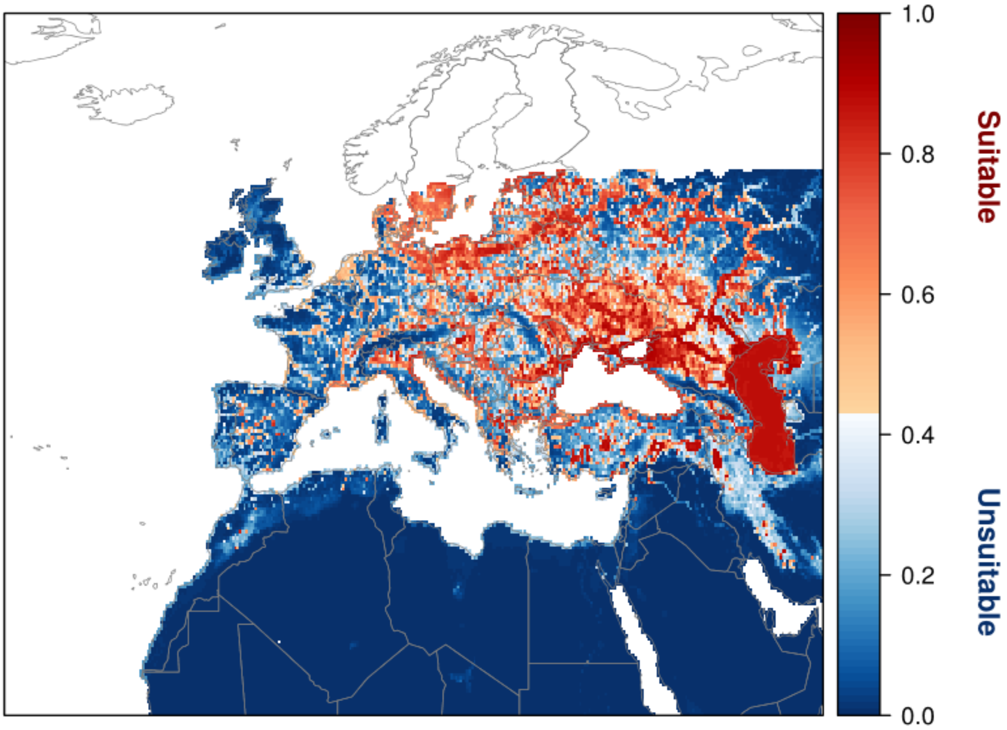

Figure 5. Projected current suitability for *Morone americana* establishment in Europe and the Mediterranean region. The white areas have climatic conditions outside the range of the training data so were excluded from the projection.

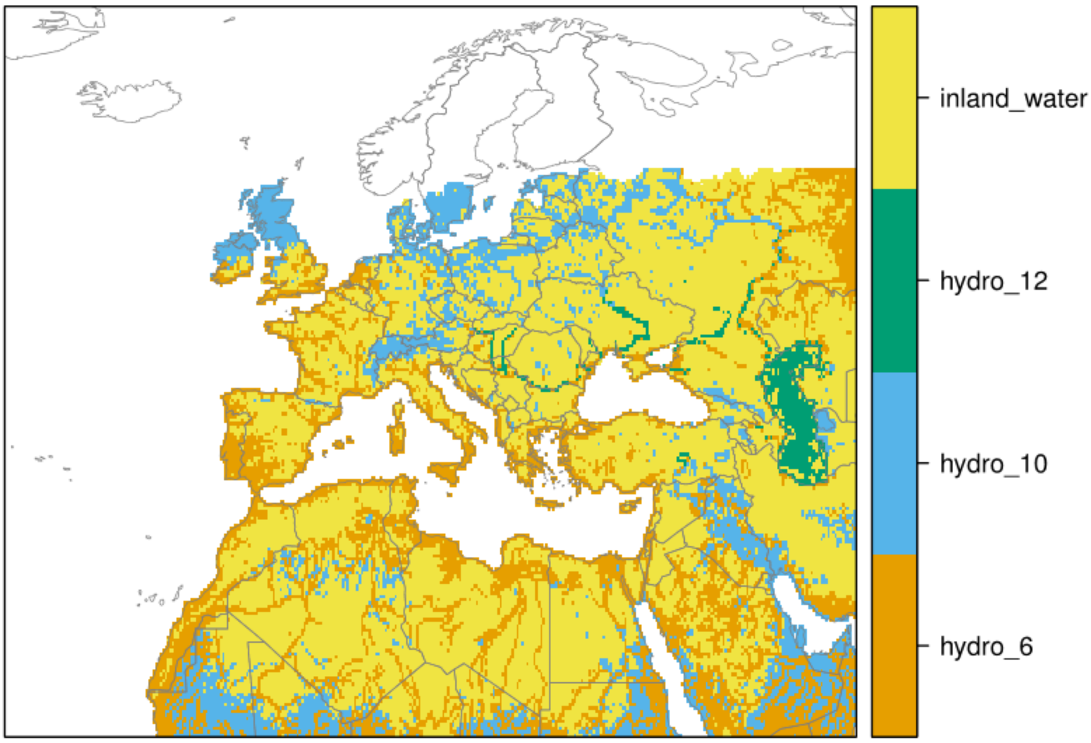

Figure 6. Limiting factor map for *Morone americana* establishment in Europe and the Mediterranean region in the current climate. Shading shows the predictor variable most strongly limiting projected suitability.

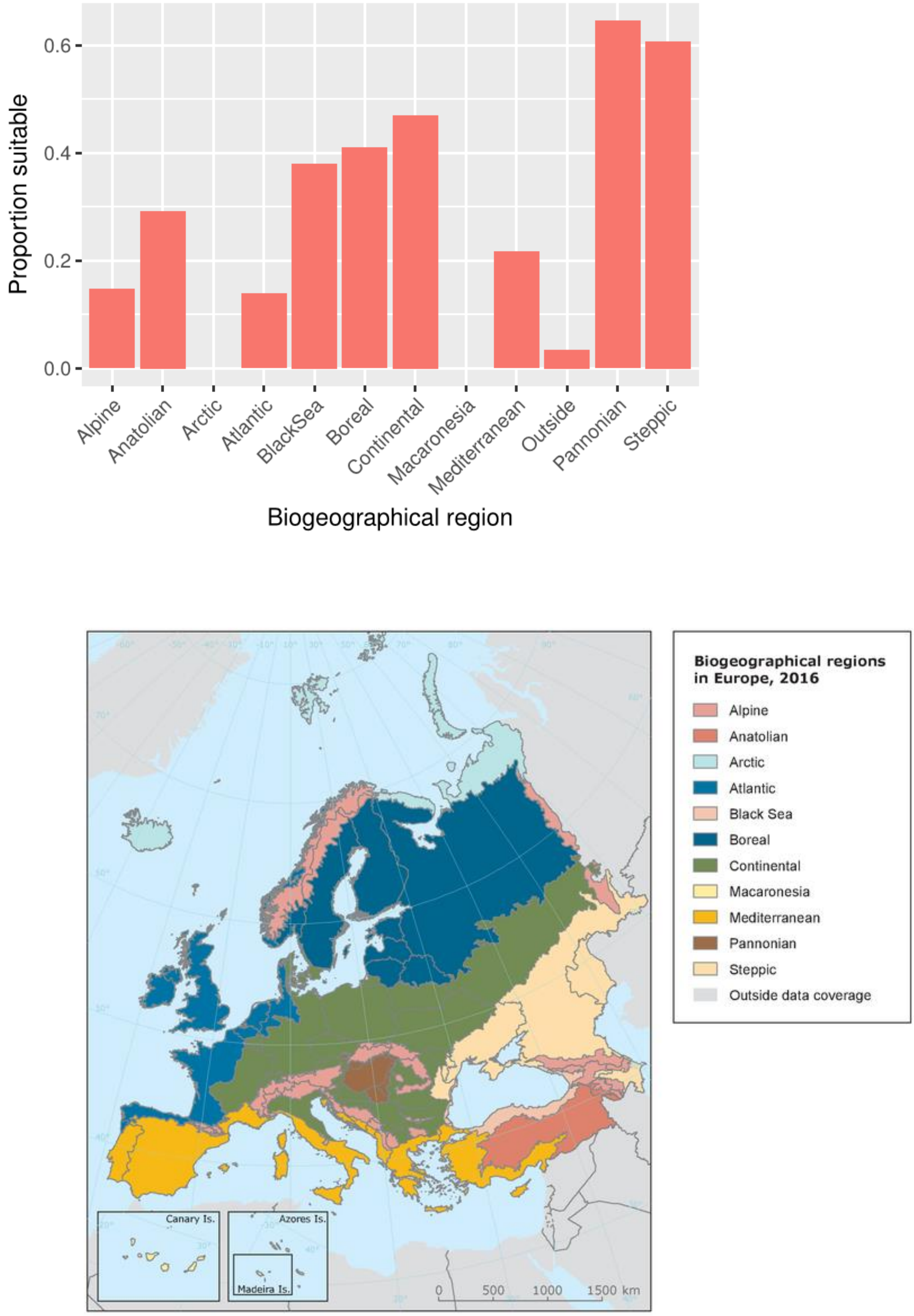

Figure 7. Upper image: Variation in projected suitability among biogeographical regions of Europe. Lower image: map of Biogeographical regions of Europe (map from: www.eea.europa.eu/data-and-maps/figures/biogeographical-regions-in-europe-2)(Use of map copy permitted as per EEA Copyright Notice: www.eea.europa.eu/legal/copyright).

Caveats to the modelling

Modelling the potential distributions of range-expanding species is always difficult and uncertain. The modelling here is subject to uncertainty for the following reasons:

- *Morone americana* exhibits invasive (adventive) behaviour in its native continent, implying that there are strong natural dispersal constraints on the native North American distribution. Even though the modelling tried to account for watershed dispersal constraints, these may have impeded the ability to characterise species-environment responses.
- Despite invasive behaviour in the native continent, there is no record of it invading outside the native continent, including in Europe. *M. americana* is known to be adaptable and capable of acclimation so may be able to expand its niche into cooler or warmer conditions than are currently observed in the native continent.
- The role of inland water habitat as a limiting factor in Europe is especially uncertain.
- The model did not include other variables potentially affecting occurrence of the species, including biotic interactions, salinity or proximity to marine spawning habitats.
- To remove spatial recording biases, the selection of the background sample was weighted by the density of Actinopterygii records on the Global Biodiversity Information Facility (GBIF). While this is preferable to not accounting for recording bias at all, a number of factors mean this may not be the perfect null model for species recording, especially because additional data sources to GBIF were used.

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