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Contents

Summary

This report presents a risk assessment of the alien smallmouth bass (*Micropterus dolomieu*). This fish species was recently identified in a horizon scanning as a potentially invasive alien species with a limited distribution in the European Union (EU). The species is native to the Mississippi River and Great Lakes basins of eastern North America. It is invasive in western North America, South Africa and eastern Asia. Introduction of the species has occurred in several European countries, but the species did not successfully establish and recent observations are lacking. No information or data could be found on the keeping of this species for recreational fisheries or other purposes (e.g., hobbyists), which suggests that it is hardly, if at all, kept this way.

The present risk assessment is based on a detailed risk inventory of *M. dolomieu*, which includes a science based overview of the current knowledge on taxonomy, habitat preference, introduction and dispersal mechanisms, current distribution, ecological impact, socio-economic impact and consequences for public health of the species. A team of experts used this information to assess and classify the (potential) risks of spread, invasiveness and impact of *M. dolomieu* in the EU using the Harmonia$^+$ and Invasive Species Environmental Impact Assessment (ISEIA) protocols. The report also includes a risk assessment of *M. dolomieu* that has been undertaken for the Netherlands.

The climatic and habitat requirements for *M. dolomieu* establishment are met in the EU. The climate zones of many EU member states match with the climatic zones of the native and introduced ranges of the species, with emphasis on the southern half of the continent featuring mean July temperatures of over 18 °C. Climate warming is expected to result in an increase in the suitable habitat area and potential distribution of *M. dolomieu* within the EU due to improved thermal conditions in northern countries. Suitable habitat is expected to be available in Europe in relatively large, clear lakes and rivers. However, there is some uncertainty concerning habitat suitability because reported early introductions in Europe have not yet been successful. It is unknown whether the environmental conditions at these locations of introduction posed a barrier for the establishment of *M. dolomieu* populations, stockings occurred in unsuitable habitat or with misidentified specimens.

The endangered areas are all clear water lakes and rivers in Austria, Bulgaria, Croatia, Cyprus, Czech Republic, France, Germany, Greece, Hungary, Italy, Poland, Portugal, Romania, Slovakia, Slovenia, and Spain. Currently, Belgium, the Netherlands, Latvia and Lithuania are on the limit of the area of potential establishment according to climate. When temperature increases due to climate change, the potential area of establishment will expand northward. In future, the species could potentially establish in Denmark, the United Kingdom, Sweden and Estonia.

The capacity of *M. dolomieu* to disperse within the EU by natural means is very high because the species can easily disperse over large distances using interconnected rivers, canals, and lakes which form the European waterways network. There is a medium risk of spread within the EU as a result of other human vectors. Examples of these vectors are introductions with respect to fisheries and related unintentional introductions by inter-basin transfer via Angler's bait buckets.

M. dolomieu is a voracious predator in both North America and South Africa that can reduce the abundance of small prey fish, frogs and invertebrates. Even the elimination of certain native species is described for these regions. The species is a significant top-down predator and may indirectly affect the primary producers and nutrient fluxes in the ecosystem by altering the aquatic food web. The expert team expect that these negative effects may also occur after the establishment of *M. dolomieu* in the endangered area of the EU. Therefore, the potential impact of *M. dolomieu* on native species is classified as very high.

The overall impact on ecosystem services is expected to be neutral. Direct predation on, and competition with, economically valuable fish species will negatively affect fisheries, but positive effects may occur due to the appreciation of bass species by anglers.

The expert team classified the risk of entry of *M. dolomieu* into the EU as low. This classification is based on the current native and introduced geographical ranges of this fish species and the fact that it is not regarded as a successful aquaculture or game species in Europe. The risks of establishment, spread and environmental impact are classified as high. Therefore, the total score for the ecological risks of *M. dolomieu* in the EU is high according to both the Harmonia$^+$ and ISEIA protocols. According to the list system proposed by the Belgian Forum on Invasive Species (BFIS), the total risk score of *M. dolomieu* implies its addition to the alert list, both for the current and future situations (class A0).

The expert team expects that climate change will have no effects on the ecological risks of *M. dolomieu* in the EU. Only the potential distribution within the EU will increase due to increased suitability of thermal conditions in northern countries, making establishment more probable.

1. Introduction

1.1 Background and problem statement

Recently, several horizon scanning reports have been published to identify potential invasive alien species (IAS) that may be introduced or have a very limited distribution in the Netherlands or the European Union (EU) (Matthews et al. 2014, 2017, Roy et al. 2014a, 2015, Gallardo et al. 2016). Smallmouth bass (*Micropterus dolomieu*) was one of the species that received a high potential risk score for the Netherlands and larger areas of the EU, and is currently expected to be absent or very rare in the EU. Therefore, the Office for Risk Assessment and Research of the Netherlands Food and Consumer Product Safety Authority (NVWA) requested to perform a scientific risk assessment for this species.

M. dolomieu is native to the north-eastern part of the United States of America (USA) and Canada and is invasive in western North America, South Africa and eastern Asia. The species has been introduced to several EU member states and several old records of occurrence in the wild are available (e.g., Welcomme, 1988). However, these introductions appear not to have been successful because there are no recent observations. No information or data could be found on the keeping of this species in the EU, which probably means that it is rarely kept, if at all. Nevertheless, *M. dolomieu* has been described as the "world's most disastrous invasive species" (Brown et al. 2009). Moreover, the species is reported to be a voracious predator that can reduce the abundance of other fish species and invertebrates, and even eliminate native species (MacRae & Jackson 2001, Loppnow et al. 2013).

The present report presents the risk assessment of *M. dolomieu* for the EU. Additionally, appendix 2 presents a risk assessment of the species that has been undertaken for the Netherlands. The risk assessments are based on a detailed risk inventory. The analyses of available data and risk classifications of the species have been performed by a team of experts using the Harmonia$^+$ and Invasive Species Environmental Impact Assessment (ISEIA) protocols. The report has been peer reviewed by two external experts (Appendix 4).

1.2 Research goal

The goal of this study is to conduct a risk assessment of the alien *M. dolomieu* for the EU that complies with the criteria for listing IAS of EU concern described in Regulation 1143/2014. This risk assessment concerns the probability of introduction, establishment, spread, colonisation of high conservation value habitats, (potential) ecological and socio-economic effects, and impact on public health.

1.3 Outline and coherence of the research

The coherence between various research activities and outcomes of the study are visualised in Figure 1.1.

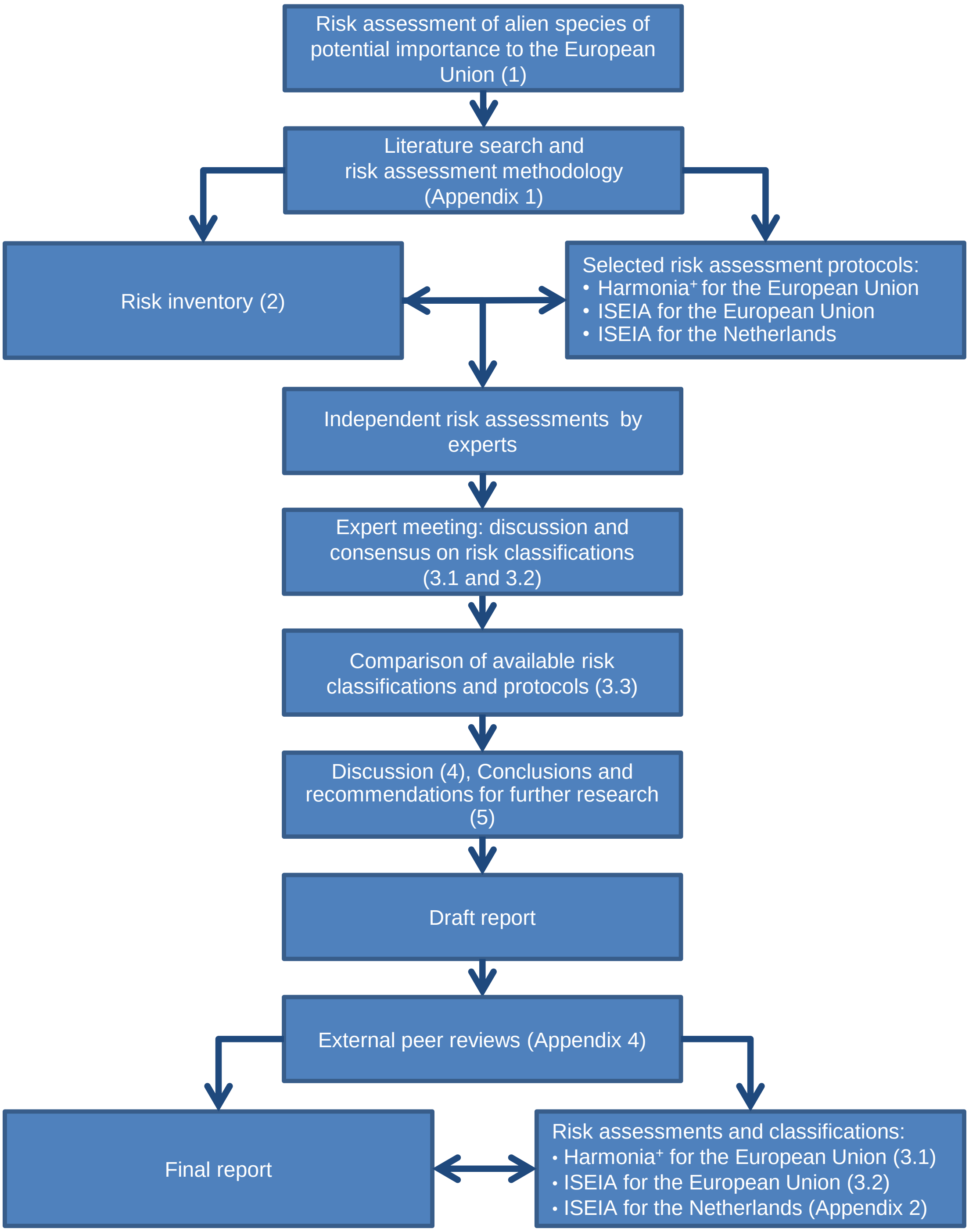


Figure 1.1: Flow chart visualising the coherence of various research activities (chapter numbers are indicated between brackets; ISEIA: Invasive Species Environmental Impact Assessment protocol).

The present chapter describes the problem statement, goals and research questions in order to assess and classify the risks of *M. dolomieu* in the EU. Chapter 2 describes the results of the risk inventory, which includes a science based overview of the current knowledge on taxonomy, habitat preference, introduction and dispersal mechanisms, current distribution, ecological impact, socio-economic impact and consequences for public health of the species. A team of experts used the information provided in the risk inventory to assess and classify the (potential) risks of spread, invasiveness and impact of *M. dolomieu* in the EU using the Harmonia$^+$ and ISEIA protocols. Chapter 3 includes the results of these risk assessments and classifications. Moreover, in this chapter, the results of other available risk classifications are summarized and compared with results of the present risk assessments. The uncertainties in the risk assessments, relevant knowledge gaps and differential outcomes of risk classifications are discussed in chapter 4. Chapter 5 draws conclusions and describes relevant knowledge gaps. Appendix 1 describes the methods used for the inventory (including literature review and data collection), assessment and classification of the risks of the introduction and spread of this species. Appendix 2 summarizes the results of the risk classification of *M. dolomieu* for the Netherlands using the ISEIA protocol. Appendix 3 includes an identification key for *M. dolomieu* and related species. Finally, details on outcomes of the peer review procedure for this report are summarized in appendix 4.

2. Risk inventory

2.1 Species description

2.1.1 Nomenclature and taxonomical status

The smallmouth bass *Micropterus dolomieu* Lacépède, 1802 (Figure 2.1) is a member of the genus *Micropterus*, belonging to the centrarchid fishes (sunfishes) that are collectively known as black basses (Table 2.1). All species of the genus are native to northeast North America, east of the Rocky Mountains (USA and Canada) (Froese & Pauly 2016).

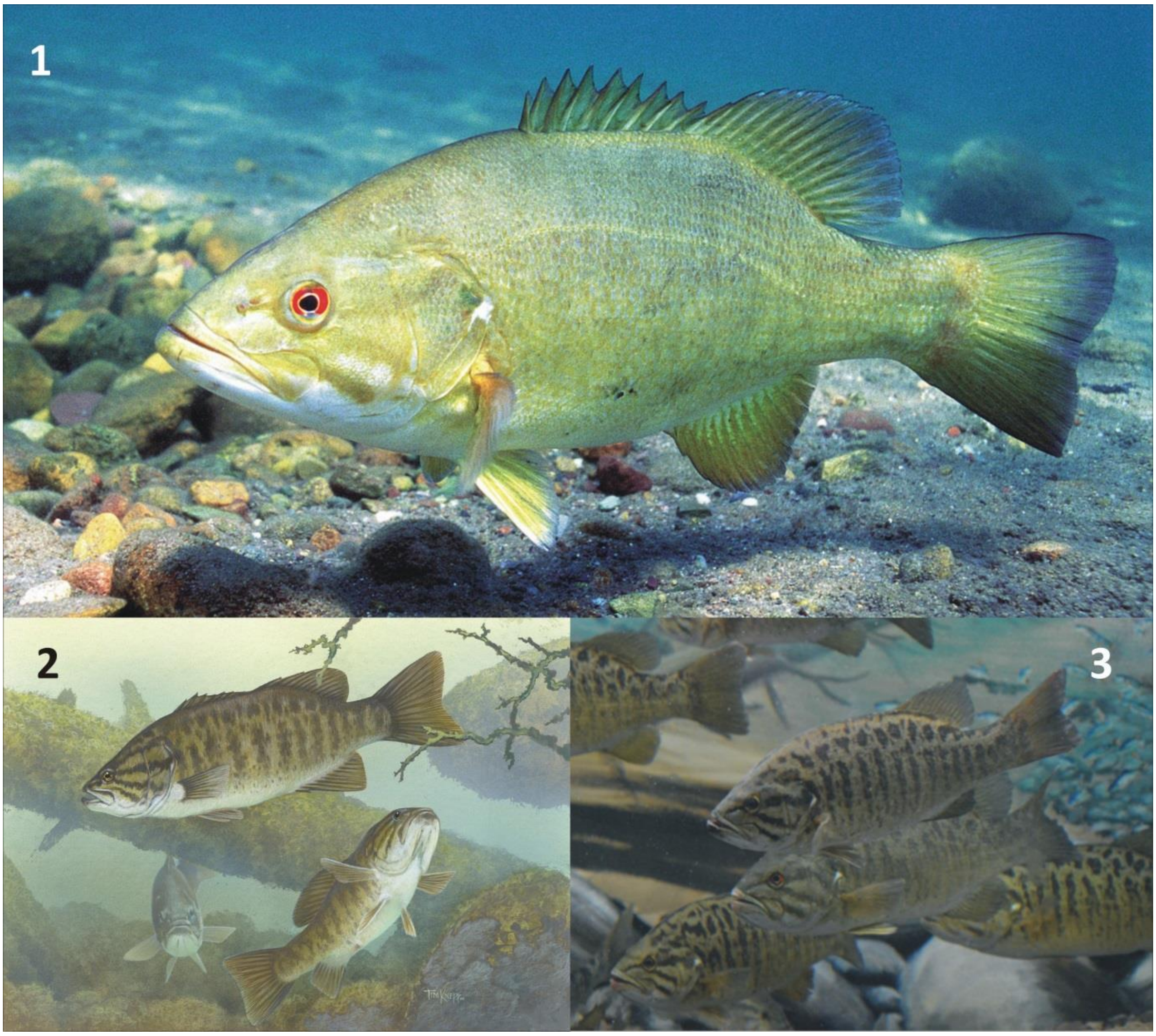


Figure 2.1: Smallmouth bass (*Micropterus dolomieu*). Source 1: © E. Engbretson, US Fish and Wildlife Service [Public domain, via Wikimedia Commons]; 2: © T. Knepp, US Fish and Wildlife Service [Public domain, via Wikimedia Commons]; 3: © F.M. Greco [CC-BY, FishBase].

The genus name *Micropterus* means “small fin”. “Small fin” is actually a misnomer. The holotype had a damaged fin, which gave the appearance of a small fin behind the first dorsal fin (Brown et al. 2009). The species name honours the French mineralogist Dieudonne de Dolomieu.

Table 2.1: Nomenclature and taxonomical status of smallmouth bass (*Micropterus dolomieu*).

Scientific name *Micropterus dolomieu* Lacépède, 1802
Synonyms *Bodianus achigan* Rafinesque, 1817 *Centrarchus fasciatus* (Lesueur, 1822) *Cichla fasciata* Lesueur, 1822 *Cichla minima* Lesueur, 1822
Taxonomic tree According to Froese & Pauly (2016) and Encyclopedia of Life (2016): Domain: Eukaryota Kingdom: Animalia Phylum: Chordata Superclass: Osteichthyes Class: Actinopterygii Order: Perciformes Family: Centrarchidae Genus: *Micropterus* Species: *Micropterus dolomieu*
Preferred Dutch name Kleinbekbaars (Froese & Pauly 2016, Waarneming.nl 2016)
Preferred English name Smallmouth bass (Froese & Pauly 2016, Encyclopedia of Life 2016)
Other Dutch names Zwartbaars (RAVON 2016, Soes et al. 2011). 'Zwartbaars' is a direct translation of "black bass" which is the collective noun of the *Micropterus* species
Other English names Black bass, bronzeback, brown bass, brown trout, brownie, gold bass, green bass, jumper, northern smallmouth bass, redeye, small-mouth black bass, smallie, smallmouth black bass, streaked-cheek river bass, swago bass, trout bass, white trout (Froese & Pauly 2016)
Native range North-eastern United States of America and Canada: St. Lawrence Great Lakes system, Hudson Bay and Mississippi River basins from southern Quebec in Canada to North Dakota and south to northern Alabama and eastern Oklahoma in the USA (Froese & Pauly 2016). Endemic to North America east of the Rocky Mountains (Near et al. 2003)

Recently the genus has been thoroughly phylogenetically studied, with the result that up to 13 separate species have been described, and more will probably follow in the near future (Freeman et al. 2015, Kassler et al. 2002, Near et al. 2003).

M. dolomieu is genetically closely related to spotted bass *M. punctulatus* (Near et al. 2003). Hybridization between these two species is known to occur (Hubbs & Bailey 1940, Kassler et al. 2002). There are no subspecies recognised. The subspecies *velox* is no longer recognised.

2.1.2 Species characteristics

Members of the sunfish family have two dorsal fins which appear joined. The anterior fin has spines and the posterior one has soft rays (Scott & Crossman 1973). Although members of the sunfish family are usually laterally flattened (compressiform), basses tend to be slightly more fusiform (streamlined), with an emarginated tail. This implies that they can swim faster in open water and have excellent acceleration (Brown et al. 2009).

M. dolomieu has the general body shape of a slender, streamlined perch. Length at age varies among populations, but median length at age ranges from 90 to 457 mm for estimated 1 year to 15 year old fish. Most *M. dolomieu* caught in Canada range from 20-38 cm in length (Scott & Crossman 1973). The maximum reported length is around 70 cm, the maximum reported weight is 5.4 kg (Froese & Pauly 2016; International Game Fish Association 1991; Quinn 2001).

The dorsal colouring of adult *M. dolomieu* can vary from dark brown to dark olive green to bronze. The sides are lighter than the dorsal surface and the underside is cream to white. Olive green bars radiate dorsally from the eye and one bar radiates from the eye to the snout. The sides can have 8 to 15 pronounced or vague vertical bars that are sometimes broken (Scott & Crossman 1973). Juvenile *M. dolomieu* have similar colours, but the vertical bars or rows of spots are more pronounced (Brown et al. 2009).

Differences with visually similar species

M. dolomieu is related to the largemouth black bass (*Micropterus salmoides*; Figure 2.2), which has settled in parts of Europe and has also been incidentally recorded in the rivers Meuse and Waal in the Netherlands (Soes et al. 2011).

Distinguishing the different species within *Micropterus* is not straightforward. However, *M. dolomieu* and *M. salmoides* can be easily separated. While the maxilla of the *M. dolomieu* is roughly even with the pupil of the eye and the upper jaw reaches to near the rear margin of the eye, *M. salmoides'* upper and lower jaws extend past the back edge of the eye (Schiphouwer & Van Delft 2013). *M. salmoides* has a more pronounced notch between the spiny and soft parts of the dorsal fin, while this notch is more broadly connected in the smallmouth. *M. dolomieu* has irregular dark brown dorsal vertical bars or shading, while *M. salmoides* has irregular bars forming a strip along the side and is often dark green on the dorsal surface. The eye of *M. salmoides* is gold, while the eye of *M. dolomieu* is often red (Figure 2.2; Brown et al. 2009). A key for identification of these species is presented in Appendix 3.

Figure 2.2: Smallmouth bass (*Micropterus dolomieu*; top) and largemouth black bass (*Micropterus salmoides*; bottom) (Source: Wikimedia, Public Domain: Raver Duane, US Fish and Wildlife Service).

Reproduction

M. dolomieu is oviparous and fertilisation occurs externally. The species shows delayed maturation and reproduces for the first time at the age of 3 to 6 years at a length of 25-33 cm (MacKay 1963; Withlock 2004; Dunlop et al. 2005). However, the species has a high reproductive potential which is reflected by high fecundity and egg/fry protection by males (Scott & Crossman 1973). Female *M. dolomieu* lay approximately 2,000-10,000 eggs at each spawning (MacKay 1963), they can use multiple nests and spawn over a longer period (Brown et al. 2009; Hubbs & Lagter 2004; Moyle 2002). The total seasonal number of eggs is usually around 5,000 to 14,000 (Scott & Crossman 1973), a large female can produce up to 21,000 eggs per season (Moyle 2002).

Life cycle

M. dolomieu is a relatively long lived species: generally 6 to 12 years, occasionally 15 years and older (Brewer & Orth 2014; Murdy et al. 2013; Froese & Pauly 2016, International Game Fish Association 1991; Quinn 2001). The maximum reported age of this species is 26 years (Froese & Pauly 2016; International Game Fish Association 1991; Quinn 2001).

Feeding strategy and diet

Brown et al. (2009) state that the primary prey items of larval smallmouth bass are copepods, water fleas and other small zooplankton. Juveniles predominantly feed on aquatic insects and other invertebrates. When individuals grow above 50 mm in total length, crayfish and fish become more important food items (Brown et al. 2009). Adults are opportunistic top carnivores and effective predators, particularly preying on fishes and crayfish (Brewer & Orth 2014).

Nestbuilding

Male *M. dolomieu* establish territories and build nests by excavating small, saucer-shaped depressions in coarse substrates, such as gravel, in the littoral zones of lakes and in rivers. Nests are 30 to 183 cm in diameter (Scott & Crossman 1973). The males exhibit strong nest site fidelity and nest within 20 m of their previous year's nest site (Brown et al. 2009). *M. dolomieu* starts nest building at 12.5 °C, and mating commences when water warms to 16 °C (Scott & Crossman 1973). There is conflicting information available regarding some aspects of courtship and spawning behaviour. Brown et al. (2009) suggest that courtship and spawning behaviour always occurs between one female and one male, while Scott & Crossman (1973) describe several females spawning in the nest of one male, and individual females spawning in the nests of several males. The males show nest guarding behaviour and parental care (see paragraphs below).

Spawning

Spawning occurs within the littoral zone of lakes and nearshore in flowing waters (Brown et al. 2009). The onset of spawning is associated with rising water temperature and increasing photoperiod in spring. Spawning only takes place within a well-defined temperature range of 15 to 21 °C. A spawning period generally lasts from 6 to 10 days, up to a maximum of 60 days (Brown et al. 2009). Falling temperatures lead to suppression of spawning.

Spawning times and success vary annually and geographically (Brown et al. 2009). In lake systems, spawning time is mainly associated with water temperature and its rate of increase. In lotic environments, hydrological factors like discharge and flooding additionally influence the timing of spawning.

Larger males spawn first, and multiple nesting may occur if early broods fail due to extreme high flows or cold fronts. Larger males tend to mate with larger, more fecund females, account for the highest production of free swimming larvae, and make the most re-nesting attempts (Brewer & Orth 2014).

Parental care

Males provide parental care during egg incubation, larval development, and the juvenile dispersal stage. *M. dolomieu* males are known to vigilantly guard their nests from crayfish and fishes that prey on eggs and fry. They also aerate developing fry. Parental care behaviour consists of fanning with pectoral and median fins, and pivoting in order to detect rivals or predators (Brewer & Orth 2014). This protection continues over a variable time from as short as 2 weeks to as long as 7 weeks following egg deposition (Brewer & Orth 2014). During parental care feeding by the guardian male is curtailed, and energy reserves are depleted. Protracted periods of guarding may lead to an increase in post breeding mortality.

Guarding males are particularly vulnerable to angling. Removal of the guarding male for even a short period may allow egg predators to feed on the brood and may induce nest abandonment by the guarding male. Moreover, angled males are less willing or less able to defend their broods after their release than non-angled fish and are more likely to abandon the nest (Philipp et al. 1997; Steinhart et al. 2005). Nest desertion also occurs when temperatures drop and reach values below the necessary range for spawning (Shuter et al. 1980).

Hatching

Eggs hatch after 2 to 10 days of fertilization (Shuter et al. 1980; Scott & Crossman 1973, Brewer & Orth 2014). At hatching, the larvae range from 4.0 mm to 5.9 mm (Scott & Crossman 1973). Fry remain in the nest for 3 to 16 days until they rise and begin to feed in schools (Brewer & Orth 2014; Scott & Crossman 1973; Shuter et al. 1980).

Nest success

The success of a nest in producing swim-up larvae varies from 33% to 92%, and is dependent on prevailing weather during the spawning season and the density of nest predators. While extreme weather events (cold fronts and floods) will cause nest abandonment and failure, the sources of mortality that occur during parental care are highly variable, and depend on predator type and abundance, and male size (Steinhart et al. 2005). Mortality is highest during the swim-up to metamorphosis stage, when larvae begin active feeding but have limited escape abilities, and may total 94% from egg to juvenile stage. Fishing of nest guarding *M. dolomieu* can also reduce nest success (Philipp et al. 1997; Steinhart et al. 2005; Brewer & Orth 2014). If temperatures rise slowly after egg fertilization and egg development is slowed, fungal infections are more likely to develop (Olah & Farkas 1978).

Growth

At ideal circumstances the development of *M. dolomieu* from fertilized egg to free swimming fish is fairly rapid (Brown et al. 2009). Habitats supporting high densities of prey, particularly small fish, likely increase growth of juvenile fish; however, crayfish availability is particularly important to larger *M. dolomieu* as they comprise nearly 60% of the caloric intake for some populations (Brewer & Orth 2014).

There is a strong relationship between the size of a cohort (abundance of individuals), when it recruits to the adult segment of a population, and the temperature regime it experiences during its first year of life. The critical early life history stages during which variations in water temperature are fundamental occur directly after fertilization and during the first overwintering of the fry (Shuter et al. 1980).

Survival and mortality
Annual mortality estimates differ for unexploited and exploited populations. Annual survival is high in unexploited populations (84 - 89%), but stream drying and increased predation can reduce survival (66 - 71%). Survival is lower in streams heavily accessed by anglers (>50% mortality) (Brewer & Orth 2014).

Survival estimates differ by age class and season. Egg and fry survival to age 1 is low, often less than 0.5%. Factors relating to egg and fry survival include reservoir habitat features (nest cover, substrate size), fungus, predation, temperature, streamflow, and parental behaviour (Brewer & Orth 2014). Young-of-year first winter survival is positively related to body size in some populations. The smallest individuals are most likely to experience winter starvation, but other environmental factors likely interact to mitigate overwinter mortality (e.g., favourable dissolved oxygen concentrations, habitat availability, acclimation period, gradual temperature fluctuations). Annual survival may be as low as 7% for age 1 fish, and approximately 20% for older age classes (Dauwalter & Fisher 2008). Exposure to multiple common stressors (e.g., parasites) may increase mortality rates in *M. dolomieu* populations (Blazer et al. 2012; Brewer & Orth 2014).

Conclusion
The smallmouth bass *M. dolomieu* is native to North America, east of the Rocky Mountains (USA and Canada). It has a high reproductive potential which is reflected by high fecundity and parental care by males (egg and fry protection). In Europe, successful reproduction has not been documented.

2.2 Probability of introduction

The available data on (assumed) introductions of *M. dolomieu* in EU member states are summarized in Table 2.2. The (potential) pathways for introduction and spread of the species are described in paragraph 2.4.

The success of introductions in aquaculture is not extensively reported and is ambiguous as *M. dolomieu* has often been misidentified as *M. salmoides* which was introduced in the same period and was more successful in aquaculture (Mulier 1900; Nijssen & De Groot 1987; Soes et al. 2011). *M. dolomieu* has been erroneously reported to be stocked in Italy (Gherardi et al. 2009). In the primary source, the introduced species appears to be *M. salmoides* (Bianco 1998). The species was reported as introduced to the Netherlands several years before 1900 for aquaculture purposes (Mulier 1900). Welcomme (1988) does not report any introduction of *M. dolomieu* to the Netherlands. However, FAO (2016) reports that the species was introduced to the Netherlands from the USA in 1884.

Table 2.2: Assumed first introductions and last observations of smallmouth bass (*Micropterus dolomieu*) in EU member states.

Member state	First introduction / first observation	Last observation	Reference
Belgium	1873, 1972 (ambiguous)	Not recently observed	Vooren (1972); Vrielynck et al. (2003); Verreycken et al. (2007); Loppnow et al. (2013)[1]; Verreycken pers. comment (2016)
Czech Republic	1889	Not recently observed	Lusk et al. (2010); Musil et al. (2010)
Germany	1883	Not recently observed	Wiesner et al. (2010)
Austria	1887	2001, single specimen at single location	Nehring et al. (2010); Wiesner et al. (2010) Prochinig et al. (2001)
Denmark	1958	Not recently observed	Loppnow et al. (2013)[1]
Finland	1873, 1966	Not recently observed	Welcomme (1988)[2]
The Netherlands	1884-1890	Not recently observed	Mulier (1900); Soes et al. (2011); FAO (2016); NDFF (2016)
Norway	1887-1895	Not recently observed	Welcomme (1988)[2]
Sweden	1890,1920s-60s	Not recently observed	Welcomme (1988)[2]
Slovakia	unknown	Not recently observed	Welcomme (1988)[2]
United Kingdom	1878-1890	Not recently observed	Welcomme (1988)[2]
France	~1900	Not recently observed	Vooren (1972); Loppnow et al. (2013)[1]

[1]: This citation concerns data on first introduction that do not originate from Welcomme (1988); [2]: This source contains several erroneous data on introductions and it has only been used in case of lack of other information or documents.

Limited documentation indicates that *M. dolomieu* did not become a successful aquaculture or game fish species in the EU. In spite of several (assumed) introductions, no data was found describing any recent observations of this species in EU member states. Available data strongly indicates that introductions of *M. dolomieu* to EU member states were not successful. No information or data could be found on the keeping of this species in the EU, which suggests that this species is not kept for recreational fishing or hobbyists, if at all. However, *M. dolomieu* could easily be transported and introduced to the EU from its native or introduced ranges (e.g., North America), if there was renewed interest in importing the species (e.g., for game fishing).

Conclusion

Actual introductions of *M. dolomieu* to North America and historic introductory events in Europe are all based on intentional human actions in favour of aquaculture or angling activities. Because of its status as a popular game fish, without strict regulations this pathway may pose a risk for European introduction again.

2.3 Probability of establishment

2.3.1 Current global distribution

M. dolomieu is native to fresh water river basins in the US and Canadian regions of eastern-central North America. There the species originally occurs in the Ohio, Tennessee, upper Mississippi basin, Saint Lawrence River and Great Lakes systems (Brown et al. 2009; Lyons 2011; Fuller 2016). The species has been successfully introduced outside its native range to many other North American river basins (including Mexico and Hawaii) (Brown et al. 2009; Froese & Pauly 2016; Fuller et al. 2016).

The species has established after introduction in several countries on other continents: South Africa, Tanzania, Japan, Vietnam and Mauritius (Iguchi et al. 2004; Mukai & Sato 2009; Loppnow et al. 2013; Ellender & Weyl 2014; Froese & Pauly

2016; Goka 2016). In numerous other countries the species has been introduced, but establishment in nature has not been reported (Welcomme 1988; Froese & Pauly 2016). The status of the establishment or invasion of the species in Tanzania, Mauritius and Vietnam has not been reported recently (Loppnow et al. 2013; Froese & Pauly 2016). Figure 2.3 gives a global overview of the distribution of *M. dolomieu*. Records of establishment mentioned in Welcomme (1988) or subsequent resources (e.g., Fishbase.org & Cabi.org) without further reliable documentation could not be verified and were omitted.

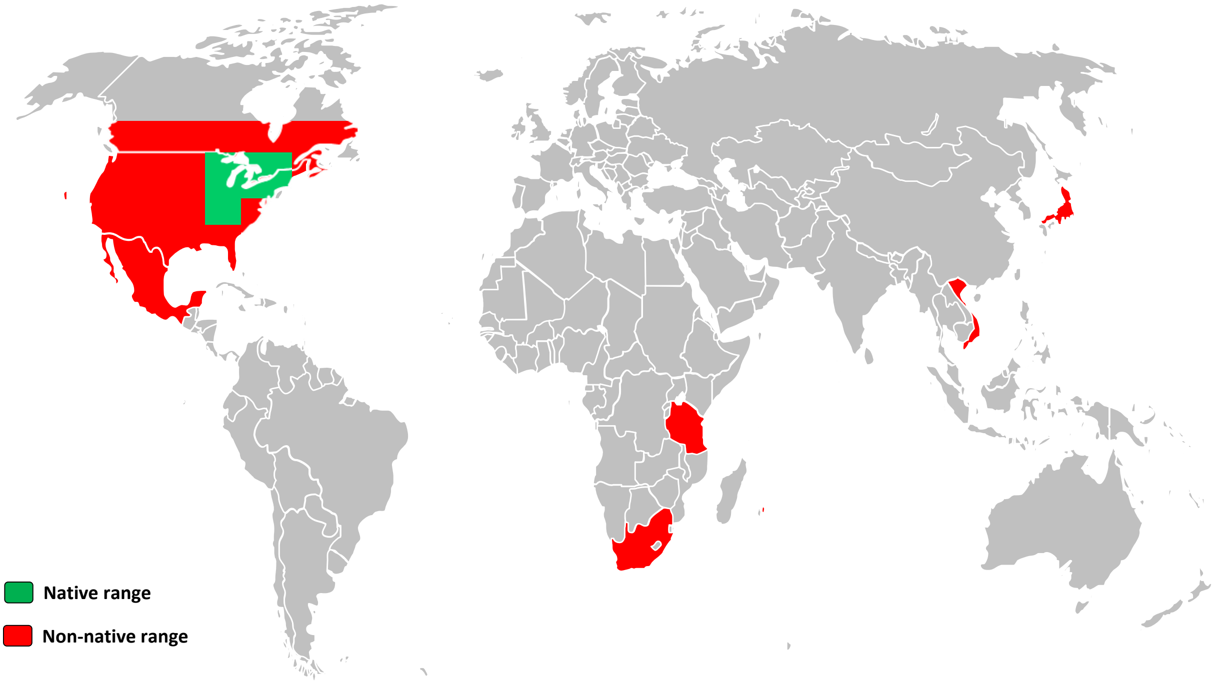


Figure 2.3: Global distribution of smallmouth bass (*Micropterus dolomieu*) (on the level of nations) (Sources: Table 2.2, §2.3.1 and §2.3.2). Establishments without reliable documentation were omitted.

2.3.2 Current distribution in the EU

Despite several introductions of the species (Table 2.2) there are no recent reports of *M.dolomieu* occurring in Europe, except for a single specimen observed at one location in Austria in 2001 (Prochinig et al. 2001). The species has never been recorded in natural European waters according to Köttelat & Freyhof (2007).

Conclusion

Based on available literature, the species is considered to be currently absent from the EU.

2.3.3 Habitat description and physiological tolerance

Habitats

M. dolomieu prefers fresh water lake habitats, but also lives in rivers and sometimes occupies low salinity tidal areas (Brown et al. 2009; Lyons 2011). Adaptation for life history strategies (age at maturation and habitat selection) is known for fish that reproduce in flowing or stagnant water bodies (Barthel et al. 2008). Larger lakes (>40.5 ha, average depth >9 m) and wider rivers (>10.5 m) with mesotrophic clear water, rocky bottom substrates and littoral zones with aquatic vegetation cover, woody structures and shaded areas are preferred (Brown et al. 2009; Lyons 2011). The species is a sight predator and foraging success is impaired in situations with elevated turbidity due to high discharge (Sweka & Hartman 2003).

Shallow areas with structure are of special importance to the younger life stages, larger specimens inhabit deeper waters near cover of rocks or wood. In winter, *M. dolomieu* uses deep water (>3 m). The species spawns from May to July at a depth of 1 to 3 m on gravel with a diameter of approximately 30 mm, in protected coves, bays, and shorelines where the water warms the earliest. Nest sites are usually associated with cover like fallen trees, boulders or dense vegetation (Brown et al. 2009).

Migration and physiological tolerance

The species is a good swimmer and can migrate for spawning and disperse through waterways (Brown et al. 2009). It has a long history of dispersion in its native and introduced ranges (Stepien et al. 2007; Brown et al. 2009). The distribution range of *M. dolomieu* is limited by climate, the lower temperature limit is an average July air temperature of 18 ^{0}C (Sharma & Jackson 2008; Brown et al. 2009). Winter survival of juveniles is related to the length of the growing season, as growth ceases below 7 to 10 ^{0}C (Brown et al. 2009). Adaptation of the species to colder climates has not been described. However, the tolerance to warmer water temperatures increases when the species is acclimatized to warm waters (Brown et al. 2009). The species can survive for long periods in water temperatures of up to 35 ^{0}C (Brown et al. 2009). Data on its physiological tolerance are summarized in Table 2.3. Habitats suitable for *M. dolomieu* are available in EU member states where yearly temperatures are high enough. If measures are taken to effectively prevent introduction, occupation of these habitats in the near future is not foreseen due to the absence of the species from the EU.

Table 2.3: Physiological conditions tolerated or preferred by smallmouth bass (*Micropterus dolomieu*).

Parameter	Medium	Data origin	Value	References
Habitat morphology, depth of spawning maximum	Water	North America	6.1 m	Scott & Crossman (1973 cf. Brown et al. 2009)
Habitat morphology, depth of spawning, preference	Water	North America	1-3 m	Clark et al. (1998 cf. Brown et al. 2009)
Habitat morphology, depth of winter habitat	Water	North America	>3 m	Stuber et al. (1982 cf. Brown et al. 2009)
Habitat morphology, lake size preference	Water	North America	>40.5 ha; depth >9 m	Brown et al. (2009)
Habitat morphology, river size preference	Water	North America	>10.5 m	Brown et al. (2009)
Habitat morphology, stream gradient	Water	North America	0.75-4.7 m/km	Edwards et al. (1983 cf. Brown et al. 2009)
Habitat morphology, substrate avoidance	Water	North America	Avoids silt	Paragamian (1991 cf. Brown et al. 2009)
Habitat morphology, substrate preference	Water	North America	Rocky bottom	Brown et al. (2009)
Habitat morphology, substrate spawning	Water	North America	Gravel near 30 mm diameter	Clark et al. (1998 cf. Brown et al. 2009)
Oxygen 100 % loss of equilibrium, size 4g at 11-27 °C	Water	North America	0.5-1.0 mg/l	Burdick et al. (1954 cf. Doudoroff and Shumway 1977)
Oxygen 50% loss of equilibrium, size 4g at 11-27 °C	Water	North America	0.6-1.2 mg/l	Burdick et al. (1954 cf. and Shumway 1977)
Oxygen first loss of equilibrium,	Water	North America	0.9-1.6 mg/l	Burdick et al. (1954 cf. and Shumway

size 4g at 11-27 °C				1977)
Oxygen LC100 size 255 g at 15-25°C	Water	North America	<2.0 mg/l	Black et al. (1954 cf. and Shumway 1977)
Oxygen minimum requirement	Water	North America	>6 mg/l	Davis (1975 cf. Brown et al. 2009)
Oxygen minimum requirement embryo/larvae development	Water	North America	>6.5 mg/l	Davis (1975 cf. Brown et al. 2009)
Oxygen minimum requirement spawning	Water	North America	>7 mg/l	Davis (1975 cf. Brown et al. 2009)
pH adverse effects	Water	North America	< 5.1	Kane & Rabeni (1987 cf. Brown et al. 2009)
pH combined with aluminium toxicity adverse effects	Water	North America	< 5.5	Kane & Rabeni (1987 cf. Brown et al. 2009)
pH preference	Water	North America	7.9 - 8.1	Lasenby & Kerr (2000 cf. Brown et al. 2009)
pH tolerance	Water	North America	5.7 - 9.0	Lasenby & Kerr (2000 cf. Brown et al. 2009)
Salinity	Water	Chesapeake Bay, USA	<7 ‰	Murdy et al. (2013)
Temperature average 96-hr low temperature TL50 values (median tolerance limit)	Water	North America	1.6 °C for fish acclimated to 15 °C	Horning & Pearson (1973)
Temperature average 96-hr low temperature TL50 values (median tolerance limit)	Water	North America	10.1 °C for fish acclimated to 26 °C	Horning & Pearson (1973)
Temperature cold shock	Water	North America	Secondary fungal infections, up to 100% mortality	Horning & Pearson (1973)
Temperature decrease in winter survival	Water	North America	<18 °C July air temperature	Jackson & Mandrak (2002 cf. Brown et al. 2009), Shuter et al. (1980 cf. Brown et al. 2009)
Temperature estimated upper ultimate incipient lethal temperature	Water	North America	37 °C	Wrenn (1980 cf. Brown et al. 2009)
Temperature laboratory preference	Water	North America	28 °C	Ferguson (1958 cf. Brown et al. 2009)
Temperature loss of righting response	Water	Canada	28.3 °C	Lutterschmidt & Hutchison (1997)
Temperature maximum	Water	North America	32 °C	Edwards et al. (1983 cf. Brown et al. 2009)
Temperature negative growth rate juveniles	Water	North America	35 °C	Horning & Pearson (1973)
Temperature no feeding	Water	North America	<8.5 °C	Keast (1968 cf. Brown et al. 2009)
Temperature no winter survival	Water	North America	<16.6 °C July air temperature	Jackson & Mandrak (2002 cf. Brown et al. 2009), Shuter et al. (1980 cf. Brown et al. 2009)
Temperature onset of lethargy	Water	Illinois, USA	<4.4 °C	Sallee et al. (1991 cf. Brown et al. 2009)
Temperature onset of spasms	Water	Canada	34.8 °C	Lutterschmidt & Hutchison (1997)
Temperature optimum growth rate juveniles	Water	North America	26 °C	Horning & Pearson (1973)
Temperature optimum rearing	Water	North America	21-27 °C	Edwards et al. (1983 cf. Brown et al. 2009)
Temperature spawning	Water	North America	>15 °C	Brown et al. (2009)
Temperature tolerated for 9 days, no effect	Water	Virginia, USA	35 °C	Stauffer et al. (1976 cf. Brown et al. 2009), Wrenn (1980 cf. Brown et al. 2009)
Water velocity, fry displacement	Water	North America	0.8 mm/s	Simonson & Swenson (1990 cf. Brown et al. 2009)
Water velocity, maximum swimming speed size 2.2 cm (5-30 °C)	Water	North America	4.8-29.9 cm/s	Keiffer & Cooke (2009)
Water velocity, maximum swimming speed size 24-38 cm	Water	North America	81.4-122.9 cm/s	Peake & Farrell (2004 cf. Brown et al. 2009)
Water velocity, maximum swimming speed size 26.2-37.8 cm (15-20 °C)	Water	North America	50-118 cm/s	Keiffer & Cooke (2009)
Water velocity, maximum swimming speed size 31cm (17 °C)	Water	North America	111 cm/s	Keiffer & Cooke (2009)
Water velocity, optimum yearling juveniles	Water	North America	1 cm/s	Paragamian & Wiley (1987 cf. Brown et al. 2009)
Water velocity, preference	Water	North America	<20 cm/s	Todd & Rabeni (1989 cf. Brown et al. 2009)

Relations to other species

In its native range in Wisconsin, *M. dolomieu* were closely associated with one particular fish community which indicates wider (>6 m) water bodies with a dominance (>40%) of rocky substrate and an average water temperature in May and June higher than 15.6 ^{0}C (Lyons et al. 1988). This fish assemblage included rosyface shiner (*Notropis rubellus*), stonecat (*Noturus flavus*), hornyhead chub (*Nocomis biguttatus*), shiner (*Notropis cornulus*) and golden redhorse (*Moxostoma erythrurum*). In Eastern Canadian water bodies *M. dolomieu* can often be found in the same waters as walleye (*Sander vitreus*) and northern pike (*Esox lucius*) (Johnson et al. 1977 and Kerr et al. 2004 cf. Brown et al. 2009). *M. dolomieu* are more abundant than walleye in water bodies with a low abundance of forage fish, a high degree of shoreline irregularity, rocky boulder substrates, and high transparency (Kerr & Grant 1999 cf. Brown et al. 2009). The two species appear to co-exist well in larger lakes with a diversity of different habitats. Walleye fitness related factors (i.e. abundance and condition) remained unchanged in lakes of South Dakota after *M. dolomieu* introductions (Galster et al. 2012). In Virginia an important predator of eggs and young life stages is the American eel (*Anguilla rostrata*) (Knotek & Orth 1998). Potentially, all large predatory fish in Europe can be predators of *M. dolomieu* or can be competitors depending on niche overlap. The European eel (*Anguilla anguilla*) could be an important predator if it displays similar behaviour towards early life stages of *M. dolomieu* as the American eel.

Genetic diversity and hybridization

Low genetic diversity of founder populations does not affect the ability of *M. dolomieu* to establish. The invasive alien populations of *M. dolomieu* in Japan originated from a low diversity stock (Mukai & Sato 2009; Goka 2016). Despite low genetic diversity, *M. dolomieu* was able to establish and rapidly spread to many lakes and rivers within approximately 10 years and exhibit invasive characteristics in Japanese aquatic ecosystems (Mukai & Sato 2009; Goka 2016).

M. dolomieu is known to hybridize with related species such as *M. salmoides*, spotted bass (*Micropterus punctulatus*) and Guadalupe bass (*Micropterus treculii*) (Whitmore 1983; Whitmore & Hellier 1988; Loppnow et al. 2013). Hybridization with native fish species of the EU is not likely due to the absence of closely related species.

Conclusion

Habitat suitable for the establishment of *M. dolomieu* is available in relatively large and clear lakes and rivers in EU regions with suitable climate.

2.3.4 Climate match and bio-geographical comparison

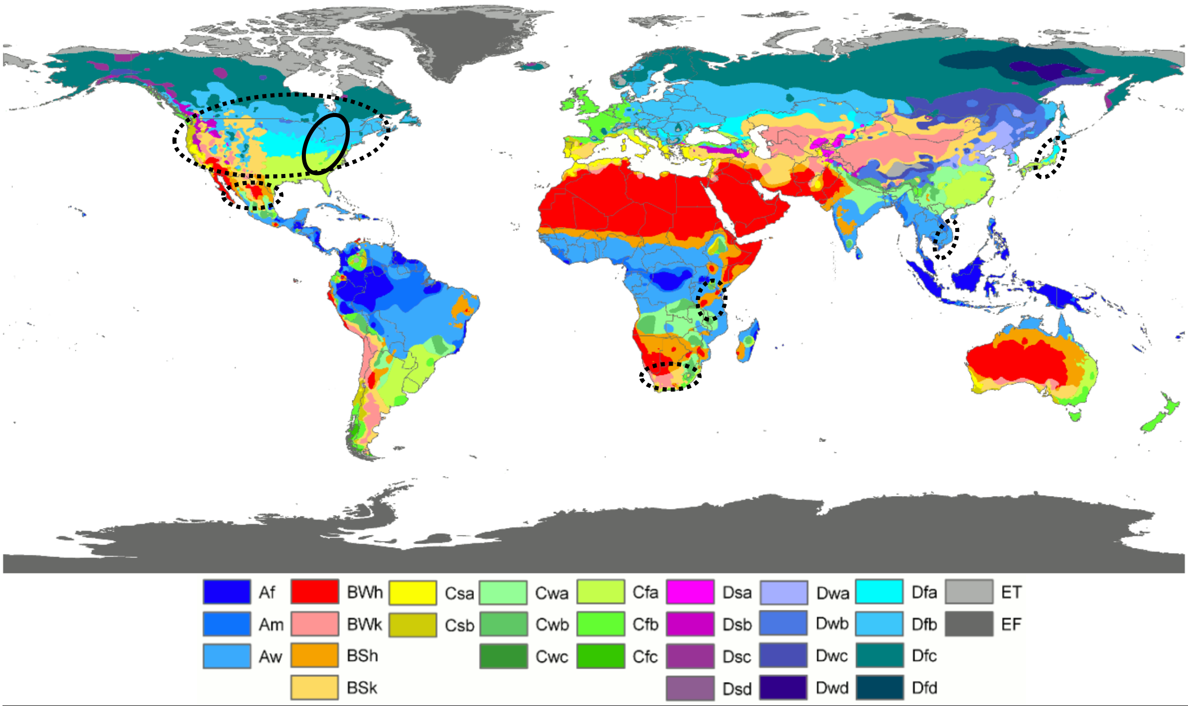
M. dolomieu inhabits the climates with warm to hot summers in its native range (Kottek et al. 2006; Brown et al. 2009), classified by Köppen-Geiger (see: http://koeppen-geiger.vu-wien.ac.at/) as (Figure 2.4):

- **Cfa** - *Warm temperate, fully humid and hot summer*;
- **Dfa** - *Humid continental hot summer, wet all year*;

- **Dfb** - *Humid with severe winter, no dry season, warm summer*.

In North America, Japan and South Africa this fish species was successfully introduced in the additional climate zones (Iguchi et al. 2004, Kottek et al. 2006, Brown et al. 2009):

- **Cfb** - *Warm temperate, fully humid, warm summer*;
- **Bsh** - *Arid, steppe, hot arid*;
- **Bsk** - *Dry Semiarid (Steppe), average temperature less than 18 °C*;
- **Csa** - *Warm temperate, steppe, hot summer*;
- **Csb** - *Warm temperate, steppe, warm summer*.



Main climate		Precipitation		Temperature		
A: equatorial	D: snow	W: desert	s: dry summer	h: hot dry	b: warm summer	f: polar frost
B: dry	E: polar	S: prairie	w: dry winter	k: cold dry	c: cool summer	t: polar tundra
C: warm		f: fully humid	m: monsoon system	a: hot summer	d: extremely continental	

Figure 2.4: Climate zones according to the Köppen-Geiger climate classification of Kottek et al. (2006) with the black circle indicating the native range and the dotted lines indicating the introduced ranges (Adapted from Peel et al. 2007).

A climate match of European climates with the native and introduced distribution ranges of *M. dolomieu* revealed that suitable climates occur in all EU member states (**Cfb, Csa, Dfb** and **Csb**). Climates that do not match are **Cfc, Dfc** and **Et**, which are alpine regions in Norway, Switzerland and Austria and the cold Atlantic region of Scotland. An average July air temperature of 18 ^{0}C is considered to be a threshold value for the distribution of *M. dolomieu* (Brown et al. 2009). This value is reached in the southern half of the EU. For example, the mean July temperature in the middle of the Netherlands in the town of De Bilt is 17.9 ^{0}C (KNMI 2016). In 2005, the average July 17.5^{0}C European isotherm stretched from Brittany in France through Belgium, the Netherlands, north Germany, north Poland, Latvia and Lithuania (Oliver 2008).

The climate south of this line is considered suitable for *M. dolomieu*, except for high altitude areas with lower temperatures. This area includes the following European biogeographic regions: (warm) Atlantic, Mediterranean, Continental, Pannonian and (low) Alpine (EEA 2012). Furthermore, as a result of climate change, isotherms in Europe are rapidly moving north at an average of 15 km/year (Beniston 2014). The area with suitable climate for *M. dolomieu* in Europe will therefore expand in the future. A similar expansion of land area with suitable temperature conditions due to climate change has been modelled in the USA (Sharma & Jackson 2008).

Endangered areas
Based on current climatic conditions and habitat requirements, *M. dolomieu* could establish in the several EU member states. The endangered areas are all clear water lakes and rivers in Austria, Bulgaria, Croatia, Cyprus, Czech Republic, France, Germany, Greece, Hungary, Italy, Poland, Portugal, Romania, Slovakia, Slovenia, and Spain. Currently, Belgium, the Netherlands, Latvia and Lithuania are on the limit of the area of potential establishment according to climate. When temperature increases due to climate change, the potential area of establishment will expand northward. In future, the species could potentially establish in Denmark, the United Kingdom, Sweden and Estonia.

Conclusion
Under current climate conditions, *M. dolomieu* could potentially establish in clear water lakes and rivers in the southern half of Europe, where average July air temperatures exceed 18 ^{0}C. Climate change will increase habitat suitability and availability. The potential area of establishment will expand further northward, by on average 15 km/year due to climate change.

2.3.5 Influence of management practices

The current EU management practices governing the ornamental, aquaculture and fisheries trade of fish species has no influence on the potential trade of *M. dolomieu*. Trade is not regulated under the CITES convention as *M. dolomieu* is not listed as endangered (CITES 2016). The trade in ornamental species is commonly not monitored to the species level by customs (EC 2008).

The Water Framework Directive (WFD) is an important driver in the management of the water quality and morphology of water bodies across the EU. One of the goals is to ensure a good ecological potential for natural and artificial water bodies. Since the implementation of the WFD, many water bodies have become cleaner and morphologically more natural, with better connectivity for fish migration. The measures taken could make more habitats suitable for *M. dolomieu* because this species relies on clear waters with an abundance of (natural) structures. Therefore, these measures indirectly make habitats more susceptible for the establishment of *M. dolomieu*. Furthermore, enhanced connectivity within water basins for fish migration and the interconnection of rivers and lakes by canals for navigational purposes could enhance the potential for spread throughout Europe following establishment of the species. Because *M. dolomieu* inhabits predominantly larger water bodies, eradication campaigns will be very difficult or near impossible (Loppnow et al. 2013). However, in South Africa successful eradication of *M. dolomieu* (as well as non-target species) has been carried out in a mountain stream by using rotenone, a broad spectrum piscicide that may also be used as an insecticide or pesticide (Jordaan & Weyl 2013).

Conclusion

Current management practices in the EU do not directly facilitate nor prevent the introduction or establishment of *M. dolomieu*.

2.4 Pathways and vectors for introduction and spread

Pathways for introduction

In history, *M. dolomieu* has been introduced around the world for angling and aquaculture purposes (Table 2.4).

Table 2.4: Active (A) and potential (P) pathways and vectors which contribute to the spread of smallmouth bass (*Micropterus dolomieu*).

Category	Subcategory	A	P	Examples and relevant information
1. Release in nature	Fishery in the wild (including game fishing)	-	X	Potential pathway of entry and introduction into the wild in the EU if the species becomes a game fish in Europe
2. Release in nature	Other intentional release	-	X	Idem
3. Escape from confinement	Aquaculture / mariculture	-	X	Idem
4. Escape from confinement	Pet/aquarium/terrarium species (including live food for such species)	-	X	Idem
5. Corridor	Interconnected waterways/basins/seas	-	X	Potential pathway of natural dispersal within the EU if the species is introduced and becomes established in Europe
6. Unaided	Natural dispersal across borders of invasive alien species that have been introduced through pathways 1 to 5	-	X	Potential pathway if the species is introduced and becomes established in Europe. Its main habitats are rivers and lakes. Canals connecting river basins could act as pathways.

- : currently not utilised; x: present. References: Brown et al. (2009); Carey et al. (2011); Soes et al. (2011); Loppnow et al. (2013).

Nowadays, *Micropterus* species are the most popular freshwater game fishes in North America, supporting a multi-billion dollar industry (Carey et al. 2011). Centrarchids are of some importance in aquaculture in North America. Here, the primary markets are sport fish stocking and fee fishing operations, but these fish are also sold for human consumption (Soes et al. 2011). In Europe the related *M. salmoides* has become a popular game fish, particularly in Spain and France (Soes et al. 2011). Potentially, *M. dolomieu* could also be an interesting species for game fishing in Europe. Currently, there are no known fishing farms or angling related programmes that stock *M. dolomieu* in Europe (Soes et al. 2011). No data on the availability of *M. dolomieu* in the pet trade or in the aquaria and pond market were found in our internet search. There are currently no known *M. dolomieu* related aquaculture activities in Europe. In the Netherlands, no centrarchid species can be legally cultured (Soes et al. 2011). However, this is not regulated at a European level. In Europe, there has been an increase of interest in exotic fish, which has stimulated the import and keeping of several centrarchid species (Soes et al. 2011). If an increase in interest for *M. dolomieu* emerges, the species may be imported to Europe (e.g., from its native range in North America or introduced geographical ranges).

Dispersal potential by natural means
If, in future, *M. dolomieu* establishes in Europe, natural dispersion through interconnected waterways could become a secondary potential pathway since large rivers and lakes are the species' prime habitat (Table 2.4). None of the centrarchids are known to display anadromous migration, however long distance exploratory movements are not uncommon and have been recorded in several species (Soes et al. 2011).

Dispersal potential by human assistance
if introduced to a river system or lake connected to a stream, *M. dolomieu* could disperse to other river systems that are interconnected via canals (e.g., from the Rhine River to the Danube River via the Main-Danube canal).

M. dolomieu could potentially become a popular game fish in European countries. In this case the same pathways and vectors that exist in North America will apply for the species in the EU (Table 2.4). In North America, unintentional introductions commonly result from 'bait bucket transfers' (i.e., when specimens are used as bait by fishermen and the surplus is released into new environments). Intentional introductions occur because *M. dolomieu* is a popular sport fish and anglers continue to deliberately introduce this species to create more fishing opportunities (Loppnow et al. 2013).

Conclusion
M. dolomieu has potentially a high commercial value in game fishing and aquaculture. If interest in *M. dolomieu* increases, the species could be transported to Europe from its native and introduced geographical ranges (e.g., North America). Release in nature, stocking and escapes could lead to further introductions. When introduced and established in Europe, natural dispersal could take place through (interconnected) waterways.

2.5 Impacts

2.5.1 Environmental effects: biodiversity and ecosystems
M. dolomieu is considered to be currently absent from Europe. The following information on environmental effects is obtained from literature describing occurrences in North America and South Africa.

Predation and competition
M. dolomieu is a voracious predator that can decrease the abundance of small prey fish and change their behaviour and habitat use which costs more energy and leads to a higher exposure to predation risks (MacRae & Jackson 2001, Loppnow et al. 2013). *M. dolomieu* has been described as the "world's most disastrous invasive species" (Brown et al. 2009). *M. dolomieu* populations on the island of Oahu (Hawaii) are thought to have eliminated all indigenous fishes and crustaceans in two local streams (Lever 1996). Factors favouring invasive *M. dolomieu* include their small size at the onset of piscivory, juvenile use of cover and high fecundity combined with parental care (Brown et al. 2009). Once established in new ecosystems, *M. dolomieu* rapidly dominate, reducing the abundance and diversity of local species (Brown et al. 2009). In South Africa, predation by *M. dolomieu* was presumed to be the critical mechanism explaining the loss of indigenous fishes in the lower Rondegat River (Woodword et al. 2005) and the main factor responsible for the differences in native fish densities in the Witte River (Shelton et al. 2015). In Ontario, North America, introduced *M. dolomieu* appear to have reduced abundance and locally extirpated many small bodied species such as brook stickleback (*Culaea inconstans*), fathead minnow (*Pimephales promelas*), pearl dace (*Margariscus margarita* and *Phoxinus* spp.). The expansion of the introduced *M. dolomieu* has been associated with a decline in native hardhead (*Aythya australis*), and predation by bass may have been a major factor in the extinction of the thicktail chub (*Gila crassicauda*) in California. Prior to *M. dolomieu* introduction, peamouth chub (*Mylcheilus caurinus*) represented 60.5% of Lake Whatcom's fish population, however fifteen years later, *M. caurinus* represented 22.2% of the populations (Brown et al. 2009).

Removal of *M. dolomieu* can lead to rapid recovery of the food web (Lepak et al. 2006). Following a 90% reduction in *M. dolomieu* abundance in an Adirondack lake, the relative abundance of six native littoral species increased from 4 to 90 times their pre-removal abundance. Increased abundance was noted for pumpkinseed (*Lepomis gibbosus*), creek chub (*Semotilus atromaculatus*), common shiner (*Luxilus cornutus*), white sucker (*Catostomus commersonii*), brook trout (*Salvelinus fontinalis*), and central mudminnow (*Umbra limi*) (Brown et al. 2009).

The reduction and/or elimination of small bodied fish following *M. dolomieu* introduction has been well documented in North America. *M. dolomieu* pose a severe threat to native fish faunas through direct predation. The spread of *M. dolomieu* into Ontario (Canada) is expected to extirpate more than 25,000 cyprinid populations (Brown et al. 2009). The loss of such species can lead to both a loss of diversity within invaded waters and a homogenization of fish fauna among invaded waters. In Europe, *M. dolomieu* may compete with European eel (*A. anguilla*) because of their reliance on crayfish (Dörner et al. 2009).

Introduction of top predators like *M. dolomieu* can lead to an alteration of prey fish behaviour. In streams, prey fish alter their behaviour to avoid invasive *M. dolomieu* by moving from pools to riffles and areas with more structural complexity. Shifting habitat use from pools to shallower areas could expose these fish to predation from terrestrial predators and result in higher energy expenditures during foraging (Loppnow et al. 2013).

Invasive *M. dolomieu* can also impact top predators. These impacts occur primarily through competition for prey and predation on juveniles of native predators. Pacific salmon (*Oncorhynchus* spp.) and lake trout *(Salvelinus namaycush)* are particularly sensitive to *M. dolomieu* invasion. Invasive *M. dolomieu* also impact sport fish by preying directly on juveniles. *M. dolomieu* is putting some threatened and endangered species of Pacific salmon (*Oncorhynchus* spp.) at greater risk of extinction (Carey et al. 2011; Loppnow et al. 2013; Brewer & Orth 2014).

Communities of mammals, birds, amphibians, reptiles, and invertebrates can be negatively impacted by *M. dolomieu* (Brown et al. 2009; Loppnow et al. 2013). Although *M. dolomieu* is considered to be a top predator, it may also take a large proportion of macroinvertebrate production. Whether this will lead to an overall decline in macroinvertebrate production in European waters will depend on the presence or absence of native predators and the level of competition between them and *M. dolomieu*.

Introduced centrarchids were suggested as the reason for the decline of native ranid frogs in California and for reduced California tiger salamander (*Ambystoma californiense*) populations (Brown et al. 2009).

Parasites

M. dolomieu host a number of bacteria, fungi, protozoans, viruses, and parasites (Brewer & Orth 2014). Although a wide variety of parasites and diseases affect *M. dolomieu*, most of these have not spread to western North America. In addition, rates of parasitism for introduced fish are generally lower than in their native range (Brown et al. 2009). The bass tapeworm (*Proteocephalus ambloplites*) introduced through invasive *M. dolomieu* can be problematic for native fish communities like trout and salmon (Brown et al. 2009).

In Europe, seven species of Monogenea have been recorded in largemouth bass (*M. salmoides*). Monogenea originate from North America and have only been recorded in Centrarchidae. Because of their host specificity, no negative impact on indigenous species is expected. Reports of parasites or diseases introduced outside North America due to the introduction of centrarchid fishes that are infectious to native species could not be found (Soes et al. 2011).

Hybridization

M. dolomieu interbreed with at least four other *Micropterus* species including *M. salmoides* (Brown et al. 2009). Only the latter species occurs in Europe, however it is an alien species. Since there are no closely related species to *M. dolomieu* that are endemic to the EU, hybridization with native species is not considered a threat here.

Ecosystem alteration

M. dolomieu plays an important role in aquatic ecosystems as a top piscivore, a dominant agent of trophic structuring and a bioaccumulator of contaminants. It interacts directly and indirectly with other fish (Brewer & Orth 2014). Invasive *M. dolomieu* can disrupt the functioning of the ecosystems to which they have been introduced, by changing the flora and fauna of the system through the alteration of fish community structure and the behaviour of fish prey species. *M. dolomieu* shifts food preference to fish and crayfish at a relatively small size (>50mm). The introduction of *M. dolomieu* may reduce crayfish abundance. Crayfish are omnivores, grazing on periphyton and macrophytes and consuming other invertebrates. A reduction in crayfish numbers might modify the abundance of macrophytes and algae as well as disrupt detrital pathways. This may indirectly contribute to differences in habitat complexity and to differences in the benthic invertebrate community (Brown et al. 2009). In some EU member states the dominant crayfish species in Europe are introduced species from North America (Holdich, 2002). In Europe, predation by *M. dolomieu* could reduce invasive crayfish populations. However, in some member states native populations of crayfish may be put under further threat by predation in the event that *M. dolomieu* were to establish populations. By preying on sessile algae grazing fish, *M. dolomieu* may indirectly stimulate algal primary productivity and the invertebrate community composition of streams (Power et al. 1985; Brown et al. 2009). Despite the impacts on ecosystems described, removal of *M. dolomieu* can lead to the rapid recovery of the food web (Lepak et al. 2006). This was demonstrated in Canada, where the trophic position of lake trout (*Salvelinus namaycush*) and food web linkages in the native fish community were restored in the two years following removal of 90% of *M. dolomieu* in an oligotrophic lake (Lepak et al. 2006).

2.5.2 Effects on cultivated plants

Being a piscivore, *M. dolomieu* potentially has an indirect impact on aquatic plants by predating herbivorous species. Due to its habitat preference, *M. dolomieu* does not directly or indirectly alter the habitats of crop species and it does not host pathogens or parasites that could affect crop species.

2.5.3 Effects on domesticated animals

Due to its habitat preference, *M. dolomieu* does not affect domesticated animals or other production animals. *M. dolomieu* could potentially be harmful if it accessed fish farms due to its predatory nature.

2.5.4 Effects on public health

Fish pathogens and parasites are not in general considered harmful to humans. No information could be found regarding the pathogens and parasites of *M. dolomieu* and threats to human health. Indirect effects of *M. dolomieu* introduction may be an increase in the occurrence of algal and/or bacterial blooms (see above). Some species (e.g., cyanobacteria) are harmful to humans.

2.5.5 Socio-economic effects

Positive effects

M. dolomieu is a popular game fish, one of the most popular in North America (Carey et al. 2011). A survey in 2001 in the USA indicated that there were 34.1 million anglers who generated $35.6 billion for the USA economy, of which 11.3 million were bass fishermen (or 33% of the freshwater anglers) (Brown et al. 2009). Angling is also a popular leisure activity in Europe, and of reasonable economic value. Exploitable populations of *M. dolomieu* will certainly be appreciated by anglers and will have a positive economic and social impact to the angling society and business. Large bass species are edible. Populations of reasonable size would be profitable for commercial fisheries, comparable with, for example, the pike perch (*Sander lucioperca*). A small positive economic and social impact to the fisheries industry may occur in the event of *M. dolomieu* establishment (Soes et al. 2011).

Table 2.5: Potential methods for the control of invasive smallmouth bass (*Micropterus dolomieu*) and their pros and cons (adapted from Loppnow et al. 2013).

Method	Description	Pros	Cons
Biological control (pathogens)	Introduction of a parasite or disease that targets bass	Inexpensive (application), not labour intensive, effective in all waterbodies and habitats	Expensive (development), unconventional, controversial, risk to non-target species, resistance
Biological control (predators)	Introduction of organisms that prey on young bass	Inexpensive, not labour intensive, effective in all waterbodies and habitats,	Controversial, unexpected ecological effects
Biological control (sterilization)	Limit reproductive success (e.g., sterile males)	species specific, effective in all water bodies and habitats	Expensive, labour-intensive, unconventional
Chemical	Use of piscicides to kill bass	Not labour intensive, effective in all waterbodies and habitats	Unconventional, controversial, expensive, affects non-target species, destructive
Environmental manipulation (water level)	Complete or partial dewatering to affect survival/reproduction	Effective, inexpensive, not labour intensive	Affects non-target species, controversial, limited applicability
Environmental manipulation (winterkill)	Encouragement of a low-oxygen environment that cannot support bass	Effective, inexpensive, not labour intensive	Unconventional, affects non-target species, limited applicability
Removal (angling)	Use of angling to remove bass	Conventional, uncontroversial, species and size selective, applicable to all depths	Labour intensive, inefficient, impractical in large waterbodies
Removal (electrofishing)	Use of electrofishing to remove bass	Conventional, uncontroversial, effective in small water bodies	Labour intensive, inefficient, affects non-target species, ineffective in deep/complex habitat or large waterbodies, overcompensation
Removal (explosives)	Use of explosives to kill bass	Cost effective and efficient in small water bodies and in all habitats	Unconventional, controversial, affects non-target species, destructive, dangerous, ineffective in large waterbodies
Removal (netting)	Use of nets and traps to remove bass	Conventional, uncontroversial, species and size-selective, applicable to all depths	Labour intensive, mot always effective, affects non-target species

Economic losses and costs

Since *M. dolomieu* does not currently occur in Europe and the species is not present in the pet trade or aquaculture, economic losses and actual management costs are not applicable. Potential management costs relate to measures aimed at the prevention of entry of the species to the EU and prevention of introduction to European water bodies, for example through the adoption and enforcement of EU and national legislation. Potential economic losses depend on the success of these preventive measures. In countries where exotic species have established populations, a set of measures have been applied to eradicate or reduce those populations (Table 2.5). Eradication has been applied in different situations. In a South African stream total removal was accomplished with rotenone, a broad-spectrum piscicide (Jordaan & Weyl 2013). Partial (90%) removal was accomplished in a 257 ha Canadian lake through intensive electrofishing (Lepak et al. 2006).

2.5.6 Effects on ecosystem services

Potential negative effects on ecosystem services mainly result from competition with and predation on capture fishery species and and game fish (Table 2.6). Potential positive effects are those related to recreation by anglers.

Table 2.6: Effects of smallmouth bass (*Micropterus dolomieu*) on the ecosystem services of aquatic systems.

Services		Positive effect	Negative effect
Provisioning Services			
Food	capture fisheries		Smallmouth bass has negative effects on populations of commercially interesting capture fishery species and game fish, like Atlantic salmon, Canadian lake trout and Pacific salmon (Brown et al. 2009; Loppnow et al. 2013; Brewer & Orth 2014).
	aquaculture	Smallmouth bass could in theory be appreciated for human consumption and play a future role in aquaculture (Soes et al. 2011).	
Cultural services			
Recreation and ecotourism		Smallmouth bass is a popular game fish in North America and could also play this role in Europe if it were to become established on a large scale.	

2.5.7 Influence of climate change on impacts

Recently, the spread and establishment of *M. dolomieu* in North America has been facilitated by climate change. The establishment of *M. dolomieu* is dependent on temperature as their range is limited by the severity of overwintering stress in cold water lakes. Suitable habitat for *M. dolomieu* is expanding because of warming of lakes and streams that is attributed to climate change. Climate change can also facilitate the spread of *M. dolomieu* to uninvaded systems through flooding associated with an increase in extreme weather events (Loppnow et al. 2013). This facilitates transfer between previously unconnected water systems. The effects of climate change seen in North America may also occur in the EU if the species is introduced and establishes here.

At current temperatures, 6% of Ontario lakes are predicted to be at high risk of *M. dolomieu* introduction, establishment, and subsequent impacts on native fauna. If the effects of climate change are factored in, this number could increase to 20% by the year 2100. A conservative estimate is that at least 50% of Canada will become thermally suitable *M. dolomieu* habitat, including some arctic locations (Loppnow et al. 2013).

Conclusion

Since *M. dolomieu* does not currently occur in Europe, the review of impacts relating to the invasion of this species is based on situations elsewhere in the world (mainly North America). The described negative effects are expected to occur in the endangered area in the EU in the event that *M. dolomieu* establishes here. The species mainly affects ecosystems through predation on amphibians, smaller fish species and invertebrates, competition with other predatory fish, and as a consequence of alterations to fish communities. This can lead to changes in ecosystems through enhancements to the primary production of algae and plankton as a result of predation on, and a diminishing of, the population size of algae-grazing fish species. To date, Centrarchidae have not been reported to be vectors of parasites or diseases of special concern. The establishment of *M. dolomieu* may have a small, positive social and economic impact on commercial fisheries, the angling community and related businesses. Actual socio-economic effects and impacts on ecosystem services are currently non-existent. If *M. dolomieu* actually establish populations in Europe, fisheries will be negatively influenced because of direct predation on and competition with economically valuable fish species like trout, salmon and possibly eel.

3. Risk assessment

3.1 Risk assessment and classification with the Harmonia+ protocol

3.1.1 Classification for current situation

Table 3.1 presents an overview of the risk assessment of *M. dolomieu* using the Harmonia+ protocol. The expert team exchanged arguments for the risk scores and came to a consensus. The rationale for this risk classification is explained in more detail in the following paragraphs.

Species introduction

The probability that individuals of *M. dolomieu* enter the EU's wild from outside through natural pathways within the time span of a decade is scored as low with a high confidence level because the native and introduced ranges of this species are found in North America, southern Africa and East Asia. The probability that the species will be introduced into the EU's wild by unintentional and intentional human actions is also scored as low (≤ 1 event expected per decade), with a medium confidence level. It is unknown whether the species is currently being held in captivity in Europe. There has been an increase in interest in exotic game fish species in Europe, which has already stimulated the import and keeping of several centrarchid species. If *M. dolomieu* became also a popular game fish in EU countries, as in North America, the same pathways and vectors that occur in North America will apply here.

Establishment

The current EU climate is considered optimal for the establishment of the species, with high confidence. This is because of the climate match that exists between member states in the southern half of Europe and the native and introduced distribution ranges of the species (it should be noted that since some early unsuccessful stockings the average temperature increased with some degrees and it is not certain whether these introductions were in fact *M. dolomieu* and were made in suitable habitats). Only the climate in alpine regions in Norway, Switzerland and Austria and the cold Atlantic region of Scotland are unsuitable (§2.3.4). The habitat within the EU is also considered optimal for the establishment of the species. Suitable habitat is available in relatively large, clear lakes and rivers in the regions of Europe with suitable climate. However, this score is allocated with medium confidence because reported introductions in the wild or in aquaculture in EU member states have not been successful. Successful reproduction is not documented for the EU, and a review of available literature suggests that the species is currently absent from Europe. It is unknown whether the environmental conditions at these introduction locations prevented the establishment of *M. dolomieu*.

Table 3.1: Consensus risk scores for smallmouth bass (*Micropterus dolomieu*) with confidence levels for the current situation in the European Union and effects of climate change derived using the Harmonia+ protocol.

Context		
A01. Assessor(s)	**Consensus scores of five experts**	
A02. Species name	**Smallmouth bass (*Micropterus dolomieu*)**	
A03. Area under assessment	**European Union**	
A04. Status of species in area	**Alien and not established within the area's wild**	
A05. Potential impact domain	**Environmental domain**	
Risk category	**Risk**	**Confidence**
Introduction		
A06. Probability of introduction by natural means	Low	High
A07. Probability of introduction by unintentional human actions	Low	Medium
A08. Probability of introduction by intentional human actions	Low	Medium
Establishment		
A09. Climate for establishment	Optimal	High
A10. Habitat for establishment	Optimal	Medium
Spread		
A11. Dispersal capacity within the area by natural means	Very high	High
A12. Dispersal capacity within the area by human actions	Medium	Medium
Impacts: environmental targets		
A13. Effects on native species through predation, parasitism or herbivory	High	High
A14. Effects on native species through competition	High	High
A15. Effects on native species through interbreeding	No	High
A16. Effects on native species by hosting harmful parasites or pathogens	Low	Medium
A17. Effects on integrity of ecosystems by affecting abiotic properties	Medium	Medium
A18. Effects on integrity of ecosystems by affecting biotic properties	High	Medium
Impacts: plant targets		
A19. Effects on plant targets through herbivory or predation	Inapplicable	High
A20. Effects on plant targets through competition	Inapplicable	High
A21. Effects on plant targets through interbreeding	Inapplicable	High
A22. Effects on integrity of cultivation systems	Very low	High
A23. Effects on plant targets by hosting harmful parasites or pathogens	Inapplicable	High
Impacts: animal targets		
A24. Effects on animal health or production through parasitism or predation	Low	Medium
A25. Effects on animal health or production by properties hazardous upon contact	Very low	High
A26. Effects on animal health or production by parasites or pathogens	Low	Medium
Impacts: human health		
A27. Effects on human health through parasitism	Inapplicable	High
A28. Effects on human health by properties hazardous upon contact	Very low	High
A29. Effects on human health by parasites or pathogens	Very low	Medium
Impacts: other targets		
A30. Effects by causing damage to infrastructure	Very low	High
Ecosystem services		
A31. Effects on provisioning services	Neutral	Medium
A32. Effects on regulation and maintenance services	Neutral	Medium
A33. Effects on cultural services	Neutral	Medium
Effects of climate change		
A34. Introduction	Increase moderately	Medium
A35. Establishment	Increase moderately	Medium
A36. Spread	Increase moderately	Medium
A37. Impacts: environmental targets	No change	Medium
A38. Impacts: plant targets	No change	High
A39. Impacts: animal targets	No change	Medium
A40. Impacts: human health	No change	High
A41. Impacts: other targets	No change	High

Spread

The capacity of *M. dolomieu* to disperse within the EU by natural means is very high, because it can easily disperse over large distances through the interconnected rivers, canals, and lakes of the European waterways network. The risk of spread within the EU by human actions is scored as medium, with medium confidence. The species is not a successful aquaculture or game fish species in Europe, contrary to North America. However, current information on the frequency with which the species is held in captivity and introductions is scarce, and new intentional introductions for the creation of more fishing opportunities or unintentional introductions by bait bucket transfers may occur.

Environment

The risks of effects of *M. dolomieu* on native species through predation and competition are high. In North America and South Africa the species is a voracious predator that can decrease the abundance of small prey fish. The species has been described as the "world's most disastrous invasive species" and reduction or elimination of indigenous fishes, crustaceans or frogs may follow the establishment, rapid increase in abundance and dominance of this species (§2.4.1). *M. dolomieu* can hybridize with *M. salmoides*, but the latter is an introduced alien species in the EU. Since there are no closely related species native to Europe, there is no risk of hybridization with native species in the EU.

The risk of effects on native species through the hosting of harmful parasites or pathogens is scored as low, with medium confidence. Although a wide variety of parasites and diseases affect the species, most of these have not spread from its native range in eastern North America to its introduced range in western North America. Reports of parasites or diseases that are infectious to native species introduced outside North America due to the introduction of centrarchid fishes could not be found (§2.4.1).

M. dolomieu is expected to have a medium and high effect on ecosystem integrity by affecting abiotic and biotic properties, respectively. As a voracious predator, the species may have a high direct effect on the species composition of fish and other prey species and thus on the aquatic food web. As a result, the species may indirectly affect primary producers and nutrient fluxes in ecosystems.

Plant crops

Establishment of *M. dolomieu* has no consequences for plant crops, pastures and horticultural stock through herbivory, parasitism and interbreeding.

Domestic animals

The effects of the species on domestic animals through parasitism or predation and by parasites or pathogens are scored low in relation to possible effects on aquaculture. This score is allocated with medium confidence. This score and confidence level correspond with the score of criterion A16 (effects on native species by parasites or pathogens).

Human health

Effects on human health through parasitism are not applicable. In general, fish pathogens and parasites are considered not to be harmful to humans. The risk of effects through properties of *M. dolomieu* that are hazardous upon contact is very low with a high level of confidence, similar to the score for criterion A25 (effects on animal health upon contact). Effects of the parasites or pathogens of *M. dolomieu* are expected to be very low. Theoretically, the indirect effects of introduction of *M. dolomieu* can be algal and/or bacterial bloom of which some species (e.g., Cyanobacteria) may be potentially harmful to humans. However, as no records of these effects have been found in scientific literature, it is likely that the risk is low and this score is allocated with medium confidence.

Infrastructure

The risk of damage to infrastructure is scored as very low with a high confidence. No information describing any negative effects of *M. dolomieu* on infrastructure was found in the available literature.

Ecosystem services

Effects on ecosystem services are scored neutral, with a medium level of confidence. Negative effects may result from competition with and predation on capture fishery species and other game fish. If the species establish in Europe, fisheries will be negatively influenced because of direct predation on and competition with economically valuable fish species like trout, salmon and possibly eel. Positive effects are those related to recreation by anglers.

Table 3.2: Risk classification and maximum risk scores per risk category for smallmouth bass (*Micropterus dolomieu*) with confidence levels for the current situation in the European Union derived using the calculation method of the Harmonia+ protocol.

Risk category	Risk classification	Risk score	Confidence	Confidence score
Introduction[1]	Low	0.00	High	1.00
Establishment[1]	High	1.00	High	1.00
Spread[1]	High	1.00	High	1.00
Impacts: environmental targets[1]	High	1.00	High	1.00
Impacts: plant targets[1]	Low	0.00	High	1.00
Impacts: animal targets[1]	Low	0.25	Medium	0.50
Impacts: human health[1]	Low	0.00	High	1.00
Impacts: other targets[1]	Low	0.00	High	1.00
Invasion score[2]	NA	NA	NA	NA
Impact score	High	1.00	NA	NA
Risk score (Invasion x impact)	High	1.00	NA	NA

1: maximum score per risk category; 2: introduction x establishment x spread; NA: not applicable.

Risk classification

The calculated invasion score (introduction x establishment x spread) is regarded as not applicable. This is because the present risk of introduction is valued low which results in a 0 score (Table 3.2). However, it should be noted that the risks of establishment and spread are both scored high. The impact score is classified high due to the high impact score for environmental targets. As a consequence, *M. dolomieu* receives a high risk score.

3.1.2 Classification for future situation

The risk of introduction is expected to increase moderately if no preventive measures are taken and rivers and lakes in the northern parts of the EU become suitable for the establishment of this game fish. The risks of establishment of *M. dolomieu* is already scored 1 and is not expected to change in the near future (Table 3.1). However, the potential number of established populations may moderately increase as suitable habitat expands as a result of warming of lakes and streams following climate change, especially in northern countries. Climate change may also facilitate the spread of *M. dolomieu* to uninvaded systems through flooding associated with an increase in extreme weather events. Increase in flooding will connect otherwise isolated water bodies. However, impacts will not change.

3.2 Risk assessment and classification with the ISEIA protocol

3.2.1 Classification for current situation

The expert team discussed the risk scores of *M. dolomieu* and came to a consensus. The experts allocated a maximum “high” risk score to all sections (Table 3.3). The total score for the environmental risk of this species is 12, which is the maximum score.

The species is currently absent in the EU. Therefore, the species is classified as an A0 species for the current situation according to the list system proposed by the Belgian Forum on Invasive Species (BFIS; Figure 3.1). According to the BFIS system, *M. dolomieu* qualifies for the alert list. The rationale for this risk classification is explained in more detail in the following paragraphs.

Dispersion potential or invasiveness

Risk score 3 (**high**). The species has the capacity to easily disperse over large distances in rivers, lakes and canals.

Colonization of high value conservation habitats

Risk score 3 (**high**). The species is able to easily spread via interconnected water courses, including streams and lakes with high conservation value.

Adverse impacts on native species

Risk score 3 (**high**). *M. dolomieu* is a voracious predator that can significantly decrease the abundance of small prey fish and even eliminate indigenous fishes, crustaceans or frogs (§2.4.1). Direct predation on and competition with native and economically valuable fish species like trout, salmon and possibly eel may occur upon invasion of *M. dolomieu* in EU member states. Transmission of parasites and diseases is likely to occur, although most parasites and diseases affecting the species have not spread from *M. dolomieu*'s native range in eastern North America to its introduced range in western North America. Reports of parasites or diseases introduced outside North America due to the introduction of centrarchid fishes that are infectious to native species could not be found (§2.4.1). There is no risk of genetic effects by hybridization since there are no closely related native species occurring in Europe. *M. dolomieu* may successfully hybridize with some other species of the genus, but all of these species are alien to the EU.

Table 3.3: Consensus risk scores and risk assessment for smallmouth bass (*Micropterus dolomieu*) for both the current and future situations in the European Union derived using the ISEIA protocol.

Risk category		Consensus scores
Dispersion potential and invasiveness		**3**
Colonisation of high conservation value habitats		**3**
Direct or indirect adverse impacts on native species		**3**
1. Predation/herbivory	3	
2. Interference, exploitation competition	3	
3. Transmission of parasites and diseases	Likely (= 2)*	
4. Genetic effects (hybridisation / introgression with natives)	1	
Direct or indirect alteration of ecosystem functions		**3**
1. Modification of nutrient cycling or resource pools	Likely (= 2)*	
2. Physical modifications of habitat	Likely (= 2)*	
3. Modification to natural succession	Likely (= 2)*	
4. Disruption to food webs	3	
Total score		**12**
Range of spread		**Absent**
Risk classification		**A0**

***: Best professional judgement (limited data availability)**

Alteration of ecosystem functions

Risk score 3 (**high**). The species can significantly decrease the abundance of small prey fish, crustaceans or frogs through voracious predation, and thus disrupt food webs. It is likely that this impact of the species will indirectly change primary production by altering abundance and species composition cyanobacteria, algae and macrophytes. Thus, the species will likely indirectly affect nutrient cycling, cause physical modifications of habitat and modify natural succession.

3.2.2 Classification for future situation

The expert team expects that climate change will have no effects on the ecological risks of the species in the EU. Only the potential distribution within the EU will increase due to increased suitability of thermal conditions in northern countries, making establishment more likely. The risk assessment for the different sections of the ISEIA protocol will therefore remain unchanged compared to the assessment of the risks for the current situation (Table 3.3). As a consequence, the species is also classified as an A0 species in the EU for the future situation (Figure 3.1). However, the species may become regional distributed or wide spread if no management measures will be taken to prevent future entry in the EU and introductions of the species occur in suitable habitat.

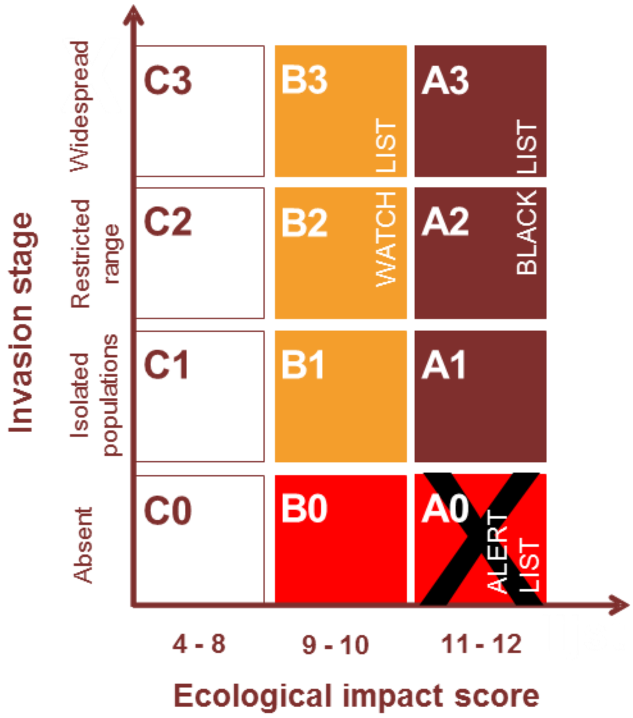


Figure 3.1: The risk classification of smallmouth bass (*Micropterus dolomieu*) for the current and future situations in the European Union according to the BFIS list system.

3.3 Other available risk assessments

Table 3.5 summarizes the available risk classifications of *M. dolomieu* for two EU member states (Germany and the Netherlands) and other regions (i.e., Canada). The outcomes of these risk classifications are consistent in all but one case, and indicate that the introduction and establishment of *M. dolomieu* will pose a high risk of negative effects on native biodiversity and ecosystems.

EU member states

Soes et al. (2011) performed an assessment of risks posed to aquatic ecosystems in the Netherlands by *M. dolomieu,* using the Fish Invasiveness Scoring Kit (FISK). This risk assessment scheme mainly focusses on ecological impacts but also includes some questions for assessing socioeconomic effects (e.g., the effects on angling or commercial species, aquaculture and amenity values). Soes et al. (2011) concludes that *M. dolomieu* is a species that is likely to establish in the Netherlands. The overall risk score is 23 (out of 49) indicating a species with high risk for negative effects on biodiversity and ecosystems (“reject” introduction). Recently, Verbrugge et al. (2015) used best professional expert judgement to assess the potential impacts of a number of alien species in the Netherlands and also classified *M. dolomieu* as a species with a high ecological impact.

Nehring et al. (2010) conducted a risk assessment for listing alien species in Germany using 11 criteria for negative effects on biodiversity and ecosystems, and a matrix for assigning these species to a black, grey or white list. *M. dolomieu* classified for the White list, indicating no actual risk. However, their low risk classification was mainly related to the absence of the species and a lack of evidence for negative effects in Germany.

Table 3.5: Other available risk classifications of smallmouth bass (*Micropterus dolomieu*).

	European Union			**Other regions**	
	the Netherlands	**the Netherlands**	**Germany and Austria**	**British Columbia (Canada)**	**British Columbia, Southwest Miramichi River and Gulf Region (Canada)**
Scope	Risk assessment	Prioritizing alien species for listing as IAS of EU concern	Risk classification for management	Qualitative risk assessment	Qualitative risk assessment
Method	FISK	Questionnaire and expert panel meeting	List classification	Matrix	Matrix
Risk classification	High; score 23	High ecological impact	White list (no actual risk)	High to very high (for 5 of 8 regions)	Overall risk: high with moderate uncertainty; Moderate (riverine) to high (lakes)
Source	Soes et al. (2011)	Verbrugge et al. (2015)	Nehring et al. (2010)	Tovey et al. (2008)	DFO (2009, 2011); Chaput & Caissie (2010)
Additional information		Best professional expert judgement of potential impacts	Aggregated method	Assessment matrix based on national guidelines for assessing the biological risk of aquatic invasive species in Canada	Assessment matrix based on national guidelines for assessing the biological risk of aquatic invasive species in Canada

Other regions

Several risk assessments have been published which evaluate the risk posed by *M. dolomieu* to rivers and lakes in British Columbia, Canada (Chaput & Caissie 2010, DFO 2009, 2011, Tovey et al. 2008). These assessments evaluated all invasion stages including the probability of introduction, survival and reproduction, spread, and widespread establishment. Next, the ecological consequences of widespread establishment were characterized and combined with the likelihood to determine the overall risk. The overall risk posed by *M. dolomieu* was determined to be high with a moderate uncertainty. Areas predicted to be most impacted are the Vancouver Island, lower mainland, upper Fraser, Thompson and Columbia regions. The Arctic, central coast and north coast regions were less likely to be impacted. Risk was considered higher in small lakes compared to larger lakes, although individual bodies of water within each region will vary in the potential risk posed.

4. Discussion

4.1 Classification and rating of risks

The expert team classified *M. dolomieu* as an alien species with a high risk of environmental impact. Although the species is currently absent from Europe, according to literature and alien species databases, the species has the potential to become a problematic invasive predator, like it currently is in its introduced ranges in North America and South Africa. The species is described as the “world’s most disastrous invasive species” (Brown et al. 2009). It is a voracious predator that can decrease the abundance of small prey fish, frogs and invertebrates and can even eliminate native species. *M. dolomieu* has a high fecundity and exhibits parental care, likely favouring the species’ population growth. Although some criteria in the Harmonia$^+$ protocol were scored with a lower level of confidence, all available information collected during the risk inventory indicates that the species poses a high risk in the EU.

4.2 Knowledge gaps and uncertainties

All criteria in the Harmonia$^+$ protocol were scored with high or medium confidence. Medium confidence was applied to risk scores concerning the role of humans in the introduction and spread of the species. The species is not a successful aquaculture or game fish species in Europe. *M. dolomieu* is a popular species for anglers in North America. There has been an increase in interest in more exotic fish species in Europe, which has stimulated the import and keeping of several centrarchid species. It is unknown whether *M. dolomieu* is currently being held in captivity in Europe. Intentional introductions or unintentional introductions resulting from bait bucket transfers may occur if the species becomes a popular game fish in European countries. In addition, little information is available on harmful parasites spread by the species, but according to available information the consensus risk score of the expert team for this criterion is low. However, these knowledge gaps do not significantly influence the classification of *M. dolomieu* as an alien species with high environmental risks.

The current absence of *M. dolomieu* in Europe despite several past introductions in different European countries, together with a lack of reports of successful reproduction results in some uncertainty concerning the degree of habitat match. Large clear water lakes and rivers are optimal habitats for the species. These habitats are present in EU member states that display a climate match with the species’ native and introduced ranges. This raises doubts with regards to whether the species was previously introduced to habitat with suitable thermal conditions. Otherwise, some unknown habitat requirements that enable the species to successfully establish populations may not be met in European clear water lakes and streams, in contrast with rivers and lakes in its current native and introduced range.

The medium level of confidence allocated to scores relating to the future effects of climate change is partly related to the uncertainty concerning the species' habitat requirements. Increased temperature might result in an increase of suitable habitat with suitable thermal conditions in northern Europe. However, uncertainty relating to the availability of habitats that fully meet the species' requirements still apply to this potential future situation.

4.3 Management

Several methods for the eradication or reduction of populations of *M. dolomieu* have been applied outside Europe (for an overview of available measures see §2.5.5). All of these measures have their pros and cons. Some measures are inexpensive, but controversial, e.g., due to their effects on non-target species, whereas other measures are expensive, labour intensive and/or inefficient. Therefore, measures to prevent the introduction of *M. dolomieu* to EU member states are likely to be the most cost effective.

5. Conclusions

Current presence in the EU

- Smallmouth bass (*Micropterus dolomieu*) is considered to be currently absent in Europe. Introduction of the species has occurred in several EU member states, but these introductions were not successful and there are no recent observations of the species. No information or data could be found on the keeping of this species by fish farmers or hobbyists within the EU, which suggests that this species is not or is hardly being kept in this way.

Probability of entry

- The probability that individuals of *M. dolomieu* enter the EU's wild from outside through natural pathways is low, because the native and introduced ranges of this species are found in North America, southern Africa and eastern Asia.

- The probability of the species being introduced into the EU's wild by unintentional and intentional human actions is currently low. To date, the species has not been successfully applied in aquaculture or as a game fish species. However, in Europe there has been an increase in interest in more exotic fish species which has stimulated the import and keeping of several centrarchid fish species and could increase the risk of introduction of *M. dolomieu*.

Probability of establishment

- The climatic requirements of *M. dolomieu* are met in the EU as indicated by the match in climate zones between the species' native and introduced ranges and all EU member states. Temperature requirements are not met in northern countries and high altitude regions.

- The habitat requirements of *M. dolomieu* are expected to be fully met in the EU. This is because suitable habitat is available in relatively large, clear lakes and rivers. However, some uncertainty exists because reported introductions in Europe have not been successful and it is unknown whether the environmental conditions at these introduction locations presented a barrier for the establishment of *M. dolomieu*.

- The risk of establishment of *M. dolomieu* is expected to increase moderately in future as suitable habitat is expanding as a result of the warming of lakes and streams due to climate change, especially in northern countries.

- Based on current climatic conditions and habitat requirements, *M. dolomieu* could establish in the several EU member states. The endangered areas are all clear water lakes and rivers in Austria, Bulgaria, Croatia, Cyprus, Czech Republic, France, Germany, Greece, Hungary, Italy, Poland, Portugal, Romania, Slovakia, Slovenia, and Spain. Currently, Belgium, the Netherlands, Latvia and Lithuania are on the limit of the area of potential establishment according to climate. When temperature increases due to climate change, the potential area of establishment will expand northward. In future, the species could potentially establish in clear water lakes and rivers of Denmark, the United Kingdom, Sweden and Estonia.

Probability of spread

- The capacity of *M. dolomieu* to disperse within the EU by natural means is very high because the species can easily disperse over large distances through the interconnected rivers, lakes and canals of the European waterways network.

- There is a medium risk of spread within the EU as a result of other human vectors such as introductions with respect to fisheries and related unintentional introductions by transfers via the bait buckets of anglers.

- Climate change can facilitate the spread of the species to uninvaded systems by increasing the area of available climate matched habitat, and through an increase in flooded areas, associated with more extreme weather events, that connects otherwise isolated water bodies.

Probability of impact

- The impact of *M. dolomieu* on native species is classified as very high. This is because the species is a voracious predator in both North America and South Africa that can reduce the abundance of small prey fish, frogs and invertebrates. Even the elimination of certain native species is described for some ecosystems. It is expected that these negative effects will also occur in suitable habitats of the endangered area within the EU.

- *M. dolomieu* has a large direct effect on the species composition of fish and other prey species and thus on the aquatic food web. As a result, the species may indirectly affect primary producers and nutrient fluxes in the ecosystem.

- The impact of *M. dolomieu* on ecosystem functions is expected to be neutral overall. If the species establishes in Europe, direct predation on and competition with economically valuable fish species will negatively affect fisheries. Positive effects are those related to recreation by anglers.

Risk classification

- The expert team allocated *M. dolomieu* a “**high**” total risk score for ecological risks in the EU using the Harmonia$^+$ protocol. The classification of *M. dolomieu* by experts based on available knowledge resulted in the following risk scores derived using the Harmonia$^+$ protocol:
  - Introductions risk: **Low** (Confidence: High);
  - Establishment risk: **High** (Confidence: High);
  - Spread risk: **High** (Confidence: High);

- Environmental impact risk: **High** (Confidence: High);
- Risk effects plant cultivation: **Low** (Confidence: High);
- Risk effects domesticated animals and livestock: **Low** (Confidence: Moderate);
- Risk effects public health: **Low** (Confidence: High);
- Other risk effects: **Low** (Confidence: High).

- The expert team allocated a "**high**" total risk score for the ecological risks of *M. dolomieu* in the EU using the ISEIA protocol. This species is currently absent in the EU, therefore, it is classified as an A0-species in the BFIS-system and qualifies for the **alert list** in the current and future situations.

- Climate change is expected to have no effect on the ecological risks of *M. dolomieu*, but the potential risks of introduction and establishment within the EU will increase due to more favourable thermal conditions in northern countries. Climate change may also facilitate the spread of *M. dolomieu* to uninvaded systems through flooding associated with an increase in extreme weather events that connects otherwise isolated waterbodies.

Knowledge gaps

- Relevant gaps in knowledge mainly concern the potential establishment of populations of *M. dolomieu* in relation to the current climate and habitat conditions in north-western European countries. The unsuccessful introductions in Europe increase uncertainty relating to the habitat match in the EU. It is not clear whether the species was introduced in habitat with suitable thermal conditions, or whether there may be other environmental variables or threshold values which limit the establishment of the species in European clear water lakes and streams.

- There is some uncertainty relating to the role of humans in the introduction and spread of *M. dolomieu*, on the future appreciation of the species by anglers, and the risk of spread of harmful parasites by the species. However, these knowledge gaps do not significantly influence the classification of *M. dolomieu* as an invasive alien species with high environmental risks.

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Appendix 1 – Materials and methods

A1.1 Risk analysis components

The present risk assessment of the smallmouth bass (*Micropterus dolomieu*) in the EU includes analyses of the probability of introduction, establishment and secondary spread within the EU. The literature on the ecological and socio-economic effects, impact on public health and availability of cost-effective options for risk management were analysed. The background information and data collected in the risk inventory are presented in chapter 2 and used as basis for the risk assessments and classification in chapter 3.

Subsequently, an ecological risk assessment and risk classification of the species in the EU was made using the Harmonia$^+$ protocol (D'hondt et al. 2014, 2015). The novel internet version of this protocol includes criteria for an ecological risk assessment as well as modules for the assessment of (potential) impacts on human health, infrastructure and ecosystem services, and a module to assess effects of climate change on the risks posed by alien species. The earlier version of Harmonia$^+$ was nearly compliant with criteria for risk assessment of IAS of EU-concern derived from Regulation 1143/2014 on the prevention and management of the introduction and spread of IAS (Roy et al. 2014b). We assumed that the current internet version of Harmonia$^+$ is compliant with these criteria due to the addition of modules concerning the impacts of ecosystem services and the potential effects of climate change on future impacts of alien species.

In addition, a risk assessment was performed using the Invasive Species Environmental Impact Assessment (ISEIA) protocol (Branquart 2009a, b; Vanderhoeven et al. 2015). This protocol was used to allow comparisons of our risk classification of *M. dolomieu* with those of other alien species assessed for the Netherlands. In the past the ISEIA protocol was often used to assess ecological risks of alien species.

A1.2 Risk inventory

An extensive literature review was carried out to compile a science based overview of the current knowledge on taxonomy, habitat preference, introduction and dispersal mechanisms, current distribution, ecological impact, socio-economic impact and consequences for public health of the species. In addition, data on the current distribution in EU member states were acquired. In this risk inventory internationally published knowledge in scientific journals and reports was described. If relevant issues mentioned in the format for this risk inventory could not sufficiently be supported by knowledge published in international scientific literature, 'grey literature' or 'best professional judgement' was used. In the latter case, this has been indicated in the report to clearly identify which arguments may be open to discussion. Uncertainties and knowledge gaps are also addressed in the discussion.

A1.2.1 Literature review

The web of science, Google and Google scholar search engines were used to find general information on *M. dolomieu* and more specific information on its distribution, tolerances, habitat characteristics and other aspects indicated by the search terms given in Table A1.1. A quick-scan of the title or summary of the first 25 results was made to estimate their relevance.

Table A1.1. Literature search strategy.

Search engine	Search terms	Search date
Web of Science / Google Scholar	*Micropterus dolomieu* / black bass / smallmouth bass + habitat Preference, pH tolerance, oxygen tolerance, temperature tolerance, salinity, distribution range, introductions, Japan, South Africa, Tanzania, Belgium, Vietnam, global distribution, native range, Italy, Spain, Sweden, Czech Republic, climate, average July temperature Europe, Average July temperature Netherlands, genetic diversity, genetic bottleneck, predators, pathogens, competition, management, facilitation;	24-2-2016/3-3-2016
Google	*Micropterus dolomieu* / black bass / smallmouth bass + Spain, France, UK, Italy, Belgium, management, facilitation	24-2-2016/3-3-2016
Fish Base	*Micropterus dolomieu*	24-2-2016/3-3-2016
Database on Introductions of Aquatic Species - FAO	*Micropterus dolomieu*	24-2-2016/3-3-2016

A1.2.2 Data acquisition on current distribution

Several online databases (Table A1.1) and scientific publications were used to acquire data on the current distribution of *M. dolomieu*.

A1.3 Risk assessment and classification

A1.3.1 Selection of risk assessment methods

One of the aims of this project is to provide insight into the risks of *M. dolomieu* to biodiversity and ecosystems in the EU. Assessments of ecological risks were therefore required and it was decided to apply both the Harmonia$^+$ and the ISEIA protocols for this purpose. In the current study, the Harmonia$^+$ protocol was used as it includes the assessment of impacts on socio-economic aspects, public health, infrastructure and ecosystem services, as well as the effects of climate change on the establishment, spread, and impacts of alien species. Moreover, the Harmonia$^+$ protocol complies with the criteria of the EU regulation 1143/2014. The ISEIA protocol requires less detailed information on impacts to obtain a risk classification than Harmonia$^+$ and focuses on ecological impacts only. Additionally, this protocol was used to allow comparisons of our risk classification of *M. dolomieu* with those of other alien species assessed for the Netherlands. In the Netherlands, the ISEIA protocol has been most frequently used for the risk classification of alien species.

Harmonia$^+$ and ISEIA are protocols for risk screening and are primarily developed for assessing the negative effects of alien species. They do not consider positive effects, except the module on ecosystem services in the Harmonia$^+$ protocol. However, available information on positive effects of alien species has been included in the risk inventory (Chapter 2).

A1.3.2 Harmonia+ ecological risk assessment protocol

The Harmonia+ protocol includes procedures for the risk assessment of potentially invasive alien plant and animal species. This protocol stems from a review of the ISEIA protocol and incorporates all stages of invasion and different types of impacts. The online version of the Harmonia+ protocol (D'hondt et al. 2014, 2015) was used for the risk assessment of *M. dolomieu*. All risk scores were calculated with this online version. This risk assessment method comprises 41 questions grouped in the following modules:

A0. Context (assessor, area and organism).
A1. Introduction (probability of the organism to be introduced into the area).
A2. Establishment (does the area provide suitable climate and habitat).
A3. Spread (risks of dispersal within the area).
A4. Potential impact on the following subcategories:
- A4a. Environmental effects: wild animals and plants, habitats and ecosystems.
- A4b. Effects on cultivated plants.
- A4c. Effects on domesticated animals.
- A4d. Effects on human health.
- A4e. Effects on infrastructure.

A5a. Effects on ecosystem services.
A5b. Effects of climate change on the impact of the organism.

Each module contains one or more risk assessment questions and provides options for risk scores in each question. The protocol provides guidance for all questions and includes explanations and examples that serve as a reference for attributing risk scores.

Table A1.2: Concepts and definitions for risk assessments and classifications of alien species with the Harmonia+ protocol (D'hondt et al. 2014).

Conceptual framework **Invasion**= *f*(*Introduction; Establishment; Spread; Impact$_{a-g}$*) **Risk** = *Exposure* x *Likelihood* x *Impact* Invasion = risk? *Exposure* ≡ f_1(*Introduction;Establishment;Spread*) = ***Invasion score*** *Likelihood* x *Impact* ≡ f_2(*Impact$_a$; Impact$_b$; Impact$_c$; Impact$_d$; Impact$_e$; Impact$_f$; Impact$_g$*) = ***Impact score*** a: environment (biodiversity and ecosystems); b: cultivated plants; c. domesticated animals; d. human health; e: other; f: ecosystem services; g: climate change **Total risk** = *Exposure* x *Likelihood* x *Impact* ≡ f_3(*Invasion score*; *Impact score*) = **Invasion** Mathematical framework f_1 : (weighed) geometric mean or product f_2 : (weighed) arithmetic mean or maximum f_3 : product

Table A1.2 shows the formulas used for the calculation of various risk scores. The protocol allows the assignment of various weighing factors to impact categories (i.e., weighing risks within and between categories). In order to prevent averaging of risks and to keep the highest score of each risk category visible, the highest score was always used to calculate final effect scores for a specific impact category. This 'one out all out' principle has also been used in other risk assessments of alien species (e.g., in ISEIA and the EPPO prioritizing schemes) and other policy domains (such as ecological status assessments of water bodies according to the European Water Framework directive). The default value 1 was always used for weighing between various impact categories (i.e., equal weighing). The product of the introduction, establishment and spread was used to calculate the invasion score. The maximum of the different impact scores was used to calculate the aggregated impact score.

The degree of certainty associated with a given risk was scored as a level of confidence. The level of confidence of risk scores has been consistently reported using low, medium and high, in accordance with the framework of Mastrandrea et al. (2010, 2011). Harmonia^{+} attributes values of 0, 0.5 and 1 to low, medium and high confidence, respectively, to calculate confidence levels for various impact categories. The cut-off values for risk scores and confidence levels used for the risk classification of *M. dolomieu* in the EU are summarized in Table A1.3.

Table A1.3: Cut-off values for risk scores and confidence levels used for the risk classification of the smallmouth bass (*Micropterus dolomieu*) in the EU, using the Harmonia^{+} protocol.

Colour code risk	Risk classification	Risk score (RS)*	Colour code confidence	Confidence	Confidence score (CS)*
	Low	<0.33		Low	<0.33
	Medium	0.33 ≤ RS ≤ 0.66		Medium	0.33 ≤ CS ≤ 0.66
	High	>0.66		High	>0.66

*: Arbitrary cut off values for distribution of risk scores between 0 and 1.

A1.3.3 ISEIA ecological risk assessment protocol

The ISEIA protocol assesses risks associated with dispersion potential, invasiveness and ecological impacts only (Branquart 2009a). Definitions for risk classifications relating to the four sections contained within the ISEIA protocol are presented in Table A1.4.

The ISEIA protocol contains twelve criteria that match the last steps of the invasion process (i.e., the potential for spread, establishment, adverse impacts on native species and ecosystems). These criteria are divided over the following four risk sections: (1) dispersion potential or invasiveness, (2) colonisation of high conservation habitats, (3) adverse impacts on native species, and (4) alteration of ecosystem functions. Section 3 contains sub-sections referring to (i) predation / herbivory, (ii) interference and exploitation competition, (iii) transmission of diseases to native species (parasites, pest organisms or pathogens), and (iv) genetic effects such as hybridization and introgression with related native species. Section 4 contains sub-sections referring to (i) modifications in nutrient cycling or resource pools, (ii) physical modifications to habitats (changes to hydrological regimes, increase in water turbidity, light interception, alteration of river banks, destruction of fish nursery areas, etc.), (iii) modifications to natural successions and (iv) disruption to food-webs, i.e., a modification to lower trophic levels through herbivory or predation (top-down regulation) leading to ecosystem imbalance.

Table A1.4: Definitions of criteria for risk classifications per section used in the ecological risk assessment protocol (Branquart 2009a).

1. Dispersion potential or invasiveness risk	
Low	The species does not spread in the environment because of poor dispersal capacities and a low reproduction potential.
Medium	Except when assisted by man, the species doesn't colonise remote places. Natural dispersal rarely exceeds more than 1 km per year. However, the species can become locally invasive because of a strong reproduction potential.
High	The species is highly fecund, can easily disperse through active or passive means over distances > 1km / year and initiate new populations. Are to be considered here plant species that take advantage of anemochory, hydrochory and zoochory, insects like *Harmonia axyridis* or *Cemeraria ohridella* and all bird species.
2. Colonisation of high conservation habitats risk	
Low	Population of the alien species are restricted to man-made habitats (low conservation value).
Medium	Populations of the alien species are usually confined to habitats with a low or a medium conservation value and may occasionally colonise high conservation habitats.
High	The alien species often colonises high conservation value habitats (i.e., most of the sites of a given habitat are likely to be readily colonised by the species when source populations are present in the vicinity) and makes therefore a potential threat for red-listed species.
3. Adverse impacts on native species risk	
Low	Data from invasion histories suggest that the negative impact on native populations is negligible.
Medium	The alien species is known to cause local changes (<80%) in population abundance, growth or distribution of one or several native species, especially amongst common and ruderal species. The effect is usually considered as reversible.
High	The development of the alien species often causes local severe (>80%) population declines and the reduction of local species richness. At a regional scale, it can be considered as a factor for precipitating (rare) species decline. Those alien species form long standing populations and their impacts on native biodiversity are considered as hardly reversible. Examples: strong interspecific competition in plant communities mediated by allelopathic chemicals, intra-guild predation leading to local extinction of native species, transmission of new lethal diseases to native species.
4. Alteration of ecosystem functions risk	
Low	The impact on ecosystem processes and structures is considered negligible.
Medium	The impact on ecosystem processes and structures is moderate and considered as easily reversible.
High	The impact on ecosystem processes and structures is strong and difficult to reverse. Examples: alterations of physicochemical properties of water, facilitation of river bank erosion, prevention of natural regeneration of trees, destruction of river banks, reed beds and / or fish nursery areas and food web disruption.

Each criterion of the ISEIA protocol was scored by five experts (§A1.3.4). The scores range from 1 (low risk) to 2 (medium risk) and 3 (high risk). Definitions for low, medium and high risk, according to the four sections of the ISEIA protocol are given in Table A1.2. If information obtained from the literature review was insufficient for the derivation of a risk score, then the risk score was based on best professional judgement and / or field observation leading to a score of 1 (unlikely) or 2 (likely). If no answer could be given to a particular question (no information) then a score of 1 was given (DD - deficient data). This is the minimum score that can be applied in any risk category. In cases with data or knowledge limitations, periodical review of new literature and updates of risk scores will be recommended. Finally, the highest score within each section was used to calculate the total ISEIA risk score for the species.

Consideration was given to the future situation assuming no changes in management measures that will affect the invasiveness and impacts of this invasive fish. The risk assessment and classification of *M. dolomieu* for the future situation was performed, with the assumption of a temperature increase of 2 ^{o}C in 2050, which reflects the IPCC scenarios for Climate Change (IPCC 2013) and unchanged policies on exotics in the EU member states.

Subsequently, the Belgian Forum Invasive Species (BFIS) list system for preventive and management actions was used to categorise the species of concern (Branquart 2009a). This list system was designed as a two dimensional ordination (Ecological impact * Invasion stage; Figure A1.1). The BFIS list system is based on guidelines proposed by the Convention on Biological Diversity (CBD decision VI/7) and the EU strategy on invasive alien species.

Ecological impact of the species was classified into a group represented by the letters A, B or C, which was based on the total ISEIA risk score: low ecological risk score 4-8 (C), moderate ecological risk score 9-10 (B - watch list) and high ecological risk score 11-12 (A - black list) (Figure A1.1). This letter was then combined with a number representing the invasion stage: (0) absent, (1) isolated populations, (2) restricted range, and (3) widespread. In the risk assessment section 3.2 a cross was used to indicate the risk classification of the assessed species within the BFIS system (figure 3.2).

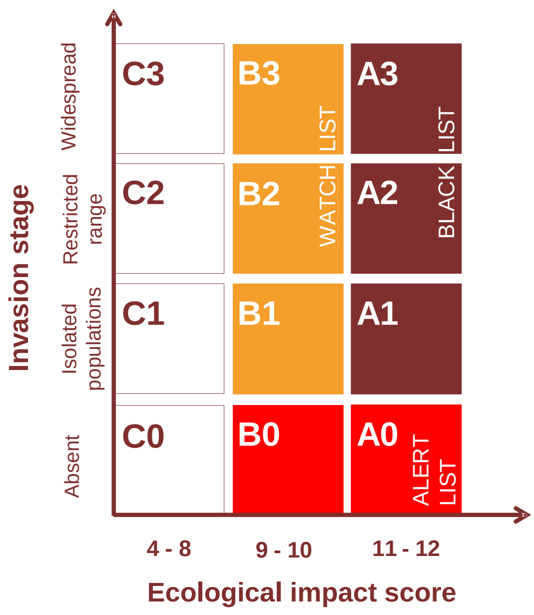

Figure A1.1: BFIS list system to identify species of most concern for preventive and mitigation action (Branquart 2009a; score 4-8: low risk; score 9-10: medium risk; score 11-12: high risk).

A1.3.4 Expert meeting on risk classification

The risk assessments of *M. dolomieu* have been performed by a team of five experts (M.E. Schiphouwer MSc, R.P.W.H. Felix MSc, Dr. G.A. van Duinen, Dr. R.S.E.W. Leuven and Dr. G. van der Velde), using the Harmonia$^+$ and ISEIA protocols. Each expert thoroughly reviewed the risk inventory (knowledge document). Subsequently, experts independently assessed and classified current and future risks of *M. dolomieu*, using both protocols. Future risks were determined with respect to the potential effects of climate change on the introduction, establishment, spread, and impacts of the species.

Following the individual assessment of experts, the entire team met, elucidated differences in risk scores, discussed diversity of risk scores and interpretations of key information during a risk assessment workshop. Discussion during the workshop led to agreement on consensus scores and a risk classification relating to both protocols. The consensus scores, risk classifications and justifications for the scores were described in a draft report that was reviewed by the project team, assuring full agreement with the outcomes of the risk assessments.

A1.3.5 Other available risk assessments and classifications

A specific literature search using the Web of Science and Google (Scholar) was performed to retrieve other available risk assessments and classifications of *M. dolomieu*. Search terms applied were the scientific species name and English name combined with the following terms: risk, risk assessment, risk analyses and risk classification. The outcomes of these risk assessments and classifications were included in this report and compared for consistency with our risk classifications.

A1.4 Peer review by independent experts

The quality of this risk assessment was assured by an external peer review procedure. The final draft of this report was reviewed by two independent experts:

1. Dr. M. Dorenbosch, Bureau Waardenburg. Culemborg, the Netherlands;
2. Dr. H. Verreycken, Research Institute for Nature and Forest (INBO). Brussels, Belgium.

Both experts critically reviewed the available data and information described in the risk inventory as well as the outcomes of the risk assessments. Special attention was focused on the justification of the risk classification and relevant scientific uncertainties. Appendix 4 summarizes how the remarks and suggestions of the reviewers were dealt with.

Appendix 2 – Risk assessment for the Netherlands

Het deskundigenpanel heeft de risico's van de kleinbekbaars (*Micropterus dolomieu*) voor Nederland geclassificeerd met behulp van het ISEIA-protocol (Tabel A2.1 en A2.2). Voor uitleg over dit beoordelingsprotocol wordt verwezen naar Appendix A1.3.3).

Tabel A2.1: Risicobeoordeling van de kleinbekbaars (*Micropterus dolomieu*) voor de huidige situatie in Nederland met behulp van het ISEIA-protocol.

Risicocategorie		Consensus scores
Dispersie potentieel en invasiviteit		**2**
Kolonisatie van waardevolle habitats		**3**
Directe en indirecte negatieve effecten op inheemse soorten		**3**
1. Predatie/begrazing	3	
2. Verstoring en competitie	3	
3. Overdracht van parasieten en ziektes	Aannemelijk (= 2)*	
4. Genetische effecten (hybridisatie / introgressie met inheemse soorten)	1	
Directe of indirecte verandering van ecosysteem functies		**3**
1. Modificatie van nutriëntencycli of hulpbronnenvoorraad	Aannemelijk (= 2)*	
2. Fysieke modificatie van habitat	Aannemelijk (= 2)*	
3. Modificatie van natuurlijke successie	Aannemelijk (= 2)*	
4. Ontwrichting voedselketens	3	
Totaal score		**11**
Verspreiding		**Afwezig**
Risicoclassificatie		**A0**

***: Deskundigenoordeel vanwege gebrek aan informatie.**

Huidige situatie

Het risico op dispersie en invasiviteit is als matig (Score 2, Tabel A2.1) geclassificeerd, vanwege de gemakkelijke verspreiding van deze vis via rivieren, maar het beperkt aanwezig zijn van optimaal habitat voor voortplanting. In Nederland is potentieel voortplantingshabitat aanwezig in grindgaten. Het temperatuurregime van deze wateren is vermoedelijk niet optimaal.

Het risico op kolonisatie van waardevolle habitats wordt als hoog (Score 3) geclassificeerd, omdat de soort in Nederland rivieren en allerlei daarmee verbonden wateren kan bereiken.

De risico's op negatieve effecten op inheemse soorten en op ecosysteemfuncties worden beide als hoog geclassificeerd, vanwege informatie over de sterke predatiedruk die deze soort kan uitoefenen op inheemse vissoorten en aquatische ongewervelden. Voor de beoordeling van verschillende criteria is gebrek aan informatie geconstateerd en zijn de betreffende risico's op basis van deskundigenoordeel al aannemelijk (maximale score is dan 2) geclassificeerd.

De totaalscore van *M. dolomieu* voor de huidige situatie in Nederland is **11**. Dit betekent dat dit een invasieve exoot is met een **hoog** risico voor negatieve effecten op biodiversiteit en ecosystemen. De soort heeft zich nog niet gevestigd in Nederland en komt volgens het BFIS systeem in aanmerking voor plaatsing op een alertheidslijst (Classificatie: **A0**).

Toekomstige situatie

Klimaatverandering zal naar verwachting tot een hoog risico op invasiviteit (score 3) leiden, omdat het temperatuurregime van de oppervlaktewateren daardoor gunstiger wordt voor de vestiging en voortplanting van de soort (Tabel A2.2).

Tabel A2.2: Risicobeoordeling van de kleinbekbaars (*Micropterus dolomieu*) voor de toekomstige situatie in Nederland met behulp van het ISEIA-protocol.

Risicocategorie	Consensus scores	
Dispersie potentieel en invasiviteit		**3**
Kolonisatie van waardevolle habitats		**3**
Directe en indirecte negatieve effecten op inheemse soorten		**3**
1. Predatie/begrazing	3	
2. Verstoring en competitie	3	
3. Overdracht van parasieten en ziektes	Aannemelijk (= 2)*	
4. Genetische effecten (hybridisatie / introgressie met inheemse soorten)	1	
Directe of indirecte verandering van ecosysteem functies		**3**
1. Modificatie van nutriëntencycli of hulpbronnenvoorraad	Aannemelijk (= 2)*	
2. Fysieke modificatie van habitat (hydraulisch regiem, turbiditeit, licht interceptie, vernietiging kraamkamers vis etc.)	Aannemelijk (= 2)*	
3. Modificatie van natuurlijke successie	Aannemelijk (= 2)*	
4. Ontwrichting voedselketens	3	
Totaal score		**12**
Verspreiding		**Absent**
Risicoclassificatie		**A0**

***: Deskundigenoordeel vanwege gebrek aan informatie.**

De totaalscore van *M. dolomieu* voor de toekomstige situatie in Nederland is **12**. Dit betekent dat dit een invasieve exoot is met een **hoog** risico voor negatieve effecten op biodiversiteit en ecosystemen. Als de soort dan nog niet is geïntroduceerd in Nederland blijft de risicoclassificatie volgens het BFIS systeem **A0** (Alertheidslijst).

Vergelijking met risicoclassificatie voor EU

De risicoclassificatie van *M. dolomieu* voor de Nederlandse situatie wijkt slechts op een onderdeel af van de classificatie met het ISEIA-protocol voor de gehele EU, namelijk het risico van dispersie en invasiviteit. Voor de EU is dit risico als hoog (Score 3, Tabel 3.3) geclassificeerd, maar voor huidige situatie in Nederland als matig (Score 2, Tabel A2.1), vanwege het beperkt aanwezig zijn van optimaal habitat in Nederland. Potentieel habitat voor voortplanting is in Nederland aanwezig in grindgaten maar het temperatuurregime van deze wateren is onder de huidige klimatologische omstandigheden vermoedelijk niet optimaal. In Nederland kan de soort zich wel gemakkelijk verspreiden via rivieren. De risicoclassificatie voor de toekomstige situatie komt overeen met die voor de gehele EU.

Appendix 3 – Identification key

Key for the identification of smallmouth bass, Largemouth bass and some other related species, modified from Hubbs & Bailey (1940), Hubbs & Lagler (2004) and Freeman et al. (2015).

1a. Mouth large. Upper jaw extending beyond eye in adults. Spinous and soft dorsal fins separated by a deep notch, sometimes a small membrane may be present. 58-69 scales in lateral line. Lateral stripe usually present, but without blotches[a] … .... **Largemouth bass (*M. salmoides*)**

1b. Mouth moderate. Upper jaw extending little or not at all beyond eye in adult. Spinous and soft dorsal fins separated by a shallow notch with a well-connected membrane. Lateral stripe, if present, with vertically expanded blotches or sides uniformly pigmented with vertical bars **2**

2a. Sides without a prominent lateral stripe **3**

2b. Sides with a prominent lateral stripe that may or may not be partially fused **4**

3a. Sides with horizontal rows of spots below the lateral line. Juveniles and adults with anal, soft dorsal, and caudal fins suffused with red pigment............................ .... **Redeye bass (*M. coosae*)**

3b. Sides without horizontal rows of spots below the lateral line, 68-81 scales in lateral line and uniformly coloured with vertically elongated blotches………………. .... **Smallmouth bass (*M. dolomieu*)**

4a. Lateral stripe fused on the caudal peduncle. Dorsolateral blotches touch origin of spinous dorsal fin. Lateral line scale count modally 65... ....**Spotted bass (*M. punctulatus*)**

4b. Lateral stripe not fused on caudal peduncle, but a series of closely spaced blotches. Dorsolateral blotches do not touch origin of spinous dorsal fin. Lateral line scale count modally 75 ....**Alabama bass (*M. henshalli*)**

[a]: According to Köttelat & Freyhof (2007): one prominent lateral stripe or series of closely set blotches.

Appendix 4 – Quality assurance by peer review

In addition to internal quality assurance, the quality of this risk assessment was assured by an external peer review procedure. The independent experts Dr. M. Dorenbosch (Bureau Waardenburg. Culemborg, the Netherlands) and Dr. H. Verreycken (Research Institute for Nature and Forest, Brussels, Belgium) reviewed the final draft of this report. They assessed the available information used for the risk assessments and the outcome of the assessments, including the justifications for the risk classifications and scientific uncertainties.

The external reviewers stated that a thorough study with respect to the establishment and effects of smallmouth bass (*Micropterus dolomieu*) in the EU has been performed. The report is regarded as a valuable document that can help decision makers with the management of this species. The risk inventory is an extensive overview of the available literature. The reviewers generally agreed with the methodology, risk classification results and main conclusions of the risk assessment. The conclusions are soundly based on the evidence presented. Both reviewers agree that this species should be categorized as a high impact species which is currently absent in the EU. According to the reviewers, the report complies with criteria for risk assessments that are used for decision making on listing IAS of EU concern.

The remarks of both reviewers mainly concerned the risk inventory and a few comments were related to the risk assessment. They delivered useful comments and suggestions for improvements to the risk inventory and assessment. This mainly concerned the biology, distribution and environmental conditions in the native range.

Nearly all remarks and suggestions of the reviewers are implemented in the present version of this report. A new map on the native and introduced range is now included. For this map only data with verifiable documentation has been used. Information on hybridization with related species in the native and introduced geographical ranges has been included. Textual inconsistency or indistinctness has been corrected and clarified. Textual repetition in the risk assessment has been reduced where possible but is functions for risk classifications in order to avoid misinterpretations by differences in wording. The English language of the final version was improved by a native speaker. Several additional references to primary scientific literature have been added. Moreover, the references have been checked and correctly cited in the main text and reference list.

The main concern of one reviewer is focussed on the current climate range of the EU with respect to establishment of smallmouth bass. To date, there are no populations present, despite various introduction attempts. Water temperature may be a controlling factor, especially in north-western European countries. Moreover, several other environmental conditions may limit habitat suitability (e.g., nutrient characteristics). This reviewer considered the EU climate to be suboptimal for *M. dolomieu* because the average water temperature is too low and earlier introductions appear not to be successful. Global warming may result in an optimal climate over time. The reviewer suggested detailed analyses of temperature regimes and habitat conditions in lakes and rivers within the EU in comparison with native ranges. These comments are valued as meaningful but detailed analyses of habitat suitability of individual lakes and rivers in various EU member states and native ranges are out of the scope and the budget of our broad scale risk assessment at EU level. According to the remarks and suggestions of the reviewer, we improved and extended descriptions of several sections concerning climate and habitat match and added the potential mismatch in north-western European countries as a gap in knowledge. Our optimal habitat score is based on the current climate matches between native areas, some introduced ranges and the southern half of the EU. The temperature in the EU has increased by a number of degrees since the earlier failed introductions. Moreover, it is not certain whether earlier reported introductions were records that accurately referred to *M. dolomieu* and if these stockings were made in suitable habitats.

This reviewer also remarked that establishment of the species may result in cyanobacterial blooms if it affects aquatic food webs by influencing nutrient fluxes and predating on herbivores or piscivores. According to our knowledge, there is no literature confirming that this phenomenon occurred in native or introduced ranges.

According to the second reviewer, risk assessments with the ISEIA and Harmonia$^+$ protocol are likely to have a similar outcome since ISEIA has been used to develop Harmonia$^+$. A.1.3.1 explains why both risk assessments were chosen but maybe a different protocol (e.g., FISK) would have been a valuable addition. In our opinion application of other protocols may have added value from a comparative and scientific point of view but is not required for the goals of the present risk assessment.