Risk analysis of the non-native Monkeyflower (Mimulus guttatus) in the Netherlands

By J. Matthews, R. Beringen, F.P.L. Collas, K.R. Koopman, B. Odé, R. Pot, L.B. Sparrius, J.L.C.H. van Valkenburg, L.N.H. Verbrugge & R.S.E.W. Leuven

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Contents

Summary

The Monkeyflower (*Mimulus guttatus*) is a semi-aquatic plant, non-native to the Netherlands. Previously, there was a lack of knowledge regarding the probability of arrival, establishment and spread, (potential) impacts and options for management of *M. guttatus* in the Netherlands. This report is the synthesis of results obtained from a literature study, field observations and expert consultation that address this knowledge gap in the form of a knowledge document. The knowledge document was used to assess the ecological risk using the Belgian Invasive Species Environmental Impact Assessment (ISEIA) protocol. Socio-economic and public health risks were assessed separately as these do not form part of the ISEIA protocol. Recommendations were then made regarding management options relevant to the situation found in the Netherlands.

The availability of *M. guttatus* via the plant trade increases the probability of arrival in the Netherlands and increases the risk of further introductions within the Netherlands. We predict that without management intervention, *M. guttatus* introductions will continue leading to further increases in its distribution. The probability of arrival of *M. guttatus* to and within the Netherlands was judged to be high.

M. guttatus was first recorded in the Netherlands in 1836 in the vicinity of Haarlem. The species has established in small numbers along riverbanks and at sites that are inundated in winter. The number of records of *M. guttatus* in the Netherlands has increased rapidly since the 1980s. After the year 2000, the rate of new records has been relatively consistent. The cumulative number of kilometre squares with records of *M. guttatus* shows a more or less linear increase, suggesting that the species continues to establish. Currently, *M. guttatus* displays a widespread recorded distribution in the Netherlands. The probability of establishment was judged to be high.

After *M. guttatus* has been introduced it spreads via two mechanisms: seed setting and regeneration of fragmented parts. Water only facilitates downstream spread, but seeds can also be spread upstream by wind and animals. Fragments can occur year round and survive for up to 6 weeks which, in combination with high flow velocities, means that *M. guttatus* is able to spread over very large distances throughout the year. The probability of spread was judged to be high.

Four factors are considered as part of the ISEIA protocol: dispersion potential and invasiveness, colonisation of high conservation habitats, adverse impacts on native species and alteration of ecosystem functions.

- Dispersion potential and invasiveness: *M. guttatus* is widely distributed throughout the Netherlands. The species shows a high dispersion potential. *M. guttatus* appears to be highly fecund and is able to disperse through active and passive means employing a number of vectors over distances > 1 km per year. It is most likely that *M. guttatus* has been introduced to non-native habitats via horticulture and the ornamental plant trade and via wildflower seeds mixtures, e.g. on banks of ditches in The Hague.

- Colonisation of high conservation habitats: *M. guttatus* occurs in many areas of high conservation value in the Netherlands defined according to Annex 1 of 92/43/EEC directive (i.e. Natura 2000 sites).

- Adverse impacts to native species: *M. guttatus* is able to establish itself on disturbed riparian habitats. It has been seen to outcompete ruderal or other non-native plants of a low conservation value in Scotland but there is no evidence of impacts on native Dutch species. Due its relatively high light demand, *M. guttatus* is outcompeted by other (early) colonisers during subsequent succession stages (e.g. when growth of taller perennial or woody plants occurs like Reed *Phragmites australis* and Willows *Salix* sp.). It therefore poses a low risk to native species within and outside areas of high conservation value in the Netherlands.

- Alteration to ecosystem functions: *M. guttatus* displays a relatively high soil nitrogen acquisition in laboratory experiments. However, reduced soil nitrogen is beneficial to ecosystems in the Netherlands due to the excess nitrogen enrichment. No negative impacts on ecosystem function were found during the literature study or during discussions with project partners.

M. guttatus was rated as a low risk species for ecological impacts according to the ISEIA protocol and accorded a rating of C3 in the BFIS list classification. A C3 classification is defined as a species that is widespread but demonstrating low environmental hazard.

M. guttatus was rated as a low risk species for ecological impacts according to the ISEIA protocol and accorded a rating of C3 in the BFIS list classification. Future changes in precipitation as a result of climate change will not alter the BFIS list defined invasion stage of *M. guttatus* in the Netherlands. A similar distribution of *M. guttatus* in the future means that impacts on native species and ecosystem function will remain unchanged and *M. guttatus* will remain classified as a C3 species.

There was no information found concerning the socio-economic or human health impacts of *M. guttatus* in the Netherlands during the literature study or in communications with project partners.

M. guttatus features a low environmental hazard due to its limited competitive ability. Socio-economic and public health effects have not been recorded for *M. guttatus* in the Netherlands. Based on the results of the risk analyses, management measures for the elimination and control of *M. guttatus* are not necessary as it has a limited ecological impact in the Netherlands. Moreover, the local introduction of management measures may have a limited effect as *M. guttatus* is already widely distributed.

1. Introduction

The non-native Monkeyflower (*Mimulus guttatus*) originated from the western part of North-America and was first recorded in the Netherlands in 1836 (Mennema *et al*., 1985). Over the past decade, this plant species showed a rapid range extension. Previously, there was a lack of knowledge regarding the probability of arrival, establishment and spread, (potential) impacts and options for management of *M. guttatus* in the Netherlands.

To support decision making with regard to the design of measures to prevent ecological, socio-economical and public health effects, the Invasive Alien Species Team of the Netherlands Food and Consumer Product Safety Authority (Ministry of Economic Affairs, Agriculture and Innovation) has asked to carry out a risk analysis of *M. guttatus.* The present report assesses relevant available knowledge and data which is subsequently used to perform a risk analysis of this species.

1.1 Research goals

The major goals of this study are:

- To perform a risk analysis based on the probability of arrival, establishment and spread, endangered areas, the (potential) ecological, socio-economic and public health impacts of *M. guttatus* in the Netherlands.

- To assess the dispersion, invasiveness and (potential) ecological effects of *M. guttatus* in the Netherlands using the Belgian Invasive Species Environmental Impact Assessment protocol.

- To describe effective risk management options for control of spread, establishment and negative effects of *M. guttatus* into and within the Netherlands.

1.2 Outline and coherence of research

The present chapter describes the problem statement, goals and research questions in order to undertake a risk analysis of *M. guttatus* in the Netherlands (described above). Chapter 2 gives the methodological framework of the project, describes the Belgian Invasive Species Environmental Impact Assessment (ISEIA, 2009) protocol and approaches used to assess socio-economic risks, public health risks and management approaches applicable in the Netherlands. Chapter 3 describes the results of the risk assessment, assesses the probability of arrival, establishment and spread, summarises the results of the literature study of socio-economic and public health risks and analyses risk management options. Chapter 4 discusses gaps in knowledge and uncertainties, other available risk analyses and explains differences between risk classifications.

Chapter 5 draws conclusions and gives recommendations for further research. An appendix containing background information in the form of a knowledge document completes this report. The coherence between various research activities and outcomes of the study are visualised in a flow chart (Figure 1.1).

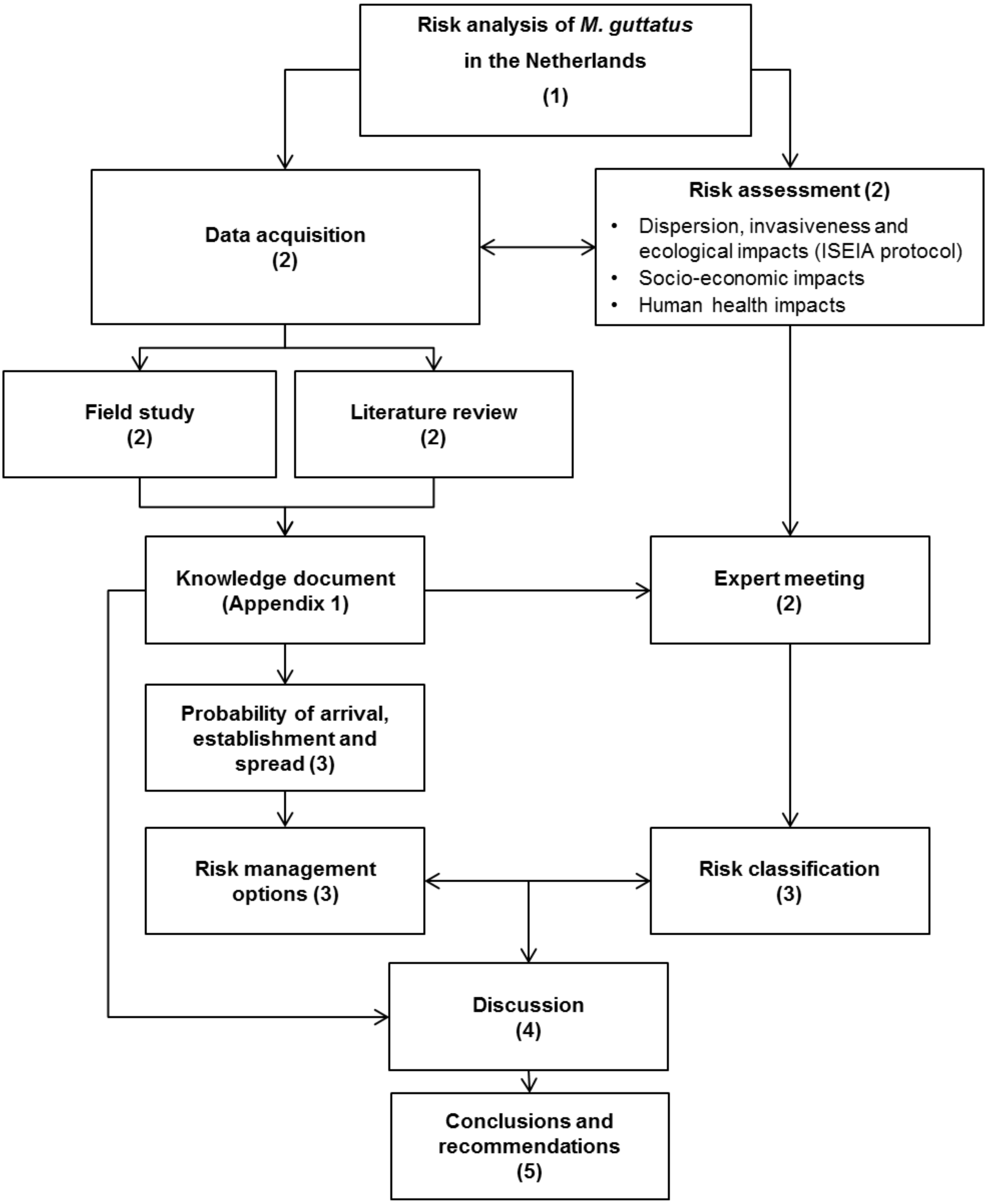

Figure 1.1: Flowchart visualising the coherence of various components of the risk analysis of the Monkeyflower (*Mimulus guttatus*) in the Netherlands. Chapter numbers are indicated in brackets.

2. Methods

2.1 Components of risk analysis

The risk analysis of the Monkeyflower (*Mimulus guttatus*) in the Netherlands was comprised of analyses of probability of introductions into and within the Netherlands, establishment and spread within the Netherlands and an ecological risk assessment using the Belgian Invasive Species Environmental Impact Assessment (ISEIA), developed by the Belgian Biodiversity Platform (Branquart, 2007; ISEIA, 2009). Separate assessments of socio-economic, public health impacts and risk management options were made. Background information and data used for the risk analysis was summarised in the form of a separate knowledge document (Section 2.2).

2.2 Knowledge document

A literature search and data analysis describing the current body of knowledge with regard to taxonomy, habitat preference, dispersal mechanisms, current distribution, ecological and socio-economic impacts and management options for *M. guttatus* was undertaken. The results of the literature search were presented in the form of a knowledge document (Koopman *et al*., 2012; Appendix 1) and distributed to an expert team in preparation for the risk assessment.

2.3 Risk assessment

2.3.1 Dispersal potential, Invasiveness and ecological impacts

The ISEIA protocol assesses risks associated with dispersion potential, invasiveness and ecological impacts only (Branquart, 2007). The *M. guttatus* risk assessment was carried out by an expert team. This team consists of five individuals. One from the Netherlands Food and Consumer Product Safety Authority; one from the Dutch plant research and conservation organisation FLORON; one from the Roelf Pot Research and Consultancy firm and two from the Radboud University, Nijmegen. Each expert completed an assessment form independently, based on the contents of the knowledge documents. Following this preliminary individual assessment, the entire project team met, elucidated differences in risk scores, discussed diversity of risk scores and interpretations of key information. The results of these discussions were presented in an earlier draft of this report. Following the submission of this draft version to the expert team, further discussion led to agreement on consensus scores and the level of risks relating to the four sections contained within the ISEIA protocol (Table 2.1).

Table 2.1: Definitions of criteria for risk classifications per section used in the ecological risk assessment protocol (Branquart, 2007; ISEIA, 2009).

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 non-native species are restricted to man-made habitats (low conservation value).
Medium	Populations of the non-native species are usually confined to habitats with a low or a medium conservation value and may occasionally colonise high conservation habitats.
High	The non-native 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 non-native 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 non-native species <u>often</u> causes local <u>severe</u> (>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 non-native 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 physico-chemical 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.

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 hybridisation and introgression with 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.

Each criterion of the ISEIA protocol was scored. 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 2.1. If knowledge obtained from the literature review was insufficient, then the assessment was based on expert judgement and 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 no score was given (DD - deficient data). Finally, the highest score within each section was used to calculate the total score for the species.

Consensus on the risk score of each section was reached using a hierarchical method where evidence from within the Netherlands was given priority over evidence derived from impacts occurring outside the Netherlands. It was also considered that the suitability of habitats in the Netherlands may change due to e.g. water temperature rise due to climate change. Moreover, consideration was given to the future application or non-application of management measures that will affect the invasiveness and impacts of this invasive plant in the Netherlands.

Subsequently, the Belgian Forum Invasive Species (BFIS) list system for preventive and management actions was used to categorise the species of concern (Branquart, 2007; ISEIA, 2009). This list system was designed as a two dimensional ordination (Environmental impact * Invasion stage; Figure 2.1). This list system is based on guidelines proposed by the Convention on Biological Diversity (CBD decision VI/7) and the European Union strategy on invasive non-native species. Environmental impact of the species was classified based on the total risk score (global environmental risk) which is converted to a letter / list: score 4-8 (C), 9-10 (B - watch list) and 11-12 (A - black list). This letter is then combined with a number representing invasion stage: (0) absent, (1) isolated populations, (2) restricted range, and (3) widespread.

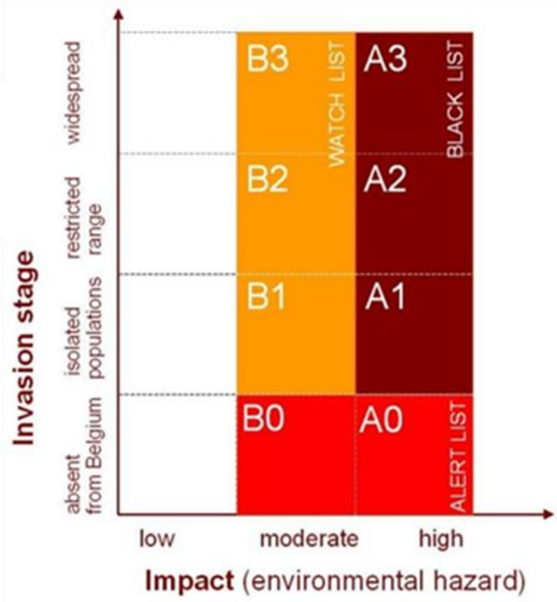

Figure 2.1: BFIS list system to identify species of most concern for preventive and mitigation action (Branquart, 2007; ISEIA, 2009).

2.3.2 Socio-economic and public health impacts

Potential socio-economic and public health impacts did not form a part in the risk analysis according to the ISEIA protocol. However, these potential risks should be considered in an integrated risk analysis. Socio-economic risks were examined as part of the literature study (Koopman *et al.*, 2012) and in discussions with project partners. Socio-economic risks occurring at present or in the future dependent on alterations in habitat suitability and management interventions were considered.

2.4 Risk management options

Management options were examined as part of the literature study and extensively described in the knowledge document (Appendix 1) and in discussions with project partners. A description of effective management options is given. These are specifically relevant to, and therefore recommended for, the Netherlands.

3. Risk analysis

3.1 Probability of arrival

M. guttatus is mainly used as an ornamental plant and therefore it is most likely that the species has been introduced to non-native habitats via horticulture and the ornamental plant trade (Tokarska-Guzik & Dajdok, 2010; Often *et al.*, 2003).

It is also introduced via wildflower seeds mixtures, e.g. on banks of ditches in The Hague (R. Pot, unpublished observation in 2001). *M. guttatus* species was listed as a suitable species for wet and nutrient rich banks (CUR, 1994). Seed mixtures containing *M. guttatus* are still available on the Dutch market and can be ordered via internet.

A Google search (search terms: 'gele maskerbloem kopen') for the availability of *M. guttatus* in the Netherlands revealed several sites that advertised the plant with prices ranging around €2. Some retailers mentioned that the plant was for ornamental use only and should not be introduced into nature.

The potential for introduction of a species repeatedly and on a large scale into a new area is one of the most important factors that lead to invasiveness (Riis *et al.,* 2010). The availability of *M. guttatus* via the plant trade has contributed greatly to its widespread distribution in the Netherlands. We predict that without management intervention, *M. guttatus* introductions will continue leading to further introductions within the Netherlands. However, *M. guttatus* is already widespread in the Netherlands and further introductions will not increase its overall ISEIA distribution classification.

After considering the above information the probability of arrival was judged to be high.

3.2 Probability of establishment

In the Netherlands *M. guttatus* was first recorded in 1836 in the vicinity of Haarlem on a swampy bank of a canal (Mennema *et al.*, 1985). The geographical distribution of the species in the Netherlands is presented in figure 3.1.

In the past century, *M. guttatus* mainly occurred ephemerally in parts of floodplains that are susceptible to flooding during winter and in urban areas. Currently, the species occurs in small numbers along riverbanks and at sites that are inundated in winter. Although the number of individuals is only specified in a limited number of records, it seems that the larger populations that occur over several years are found in kilometre squares located outside the river district. Although these locations are less dynamic, mesotrophic, moist habitats, the vegetation still appears to be in an early succession stage (possibly due to inundation or recent soil excavation).

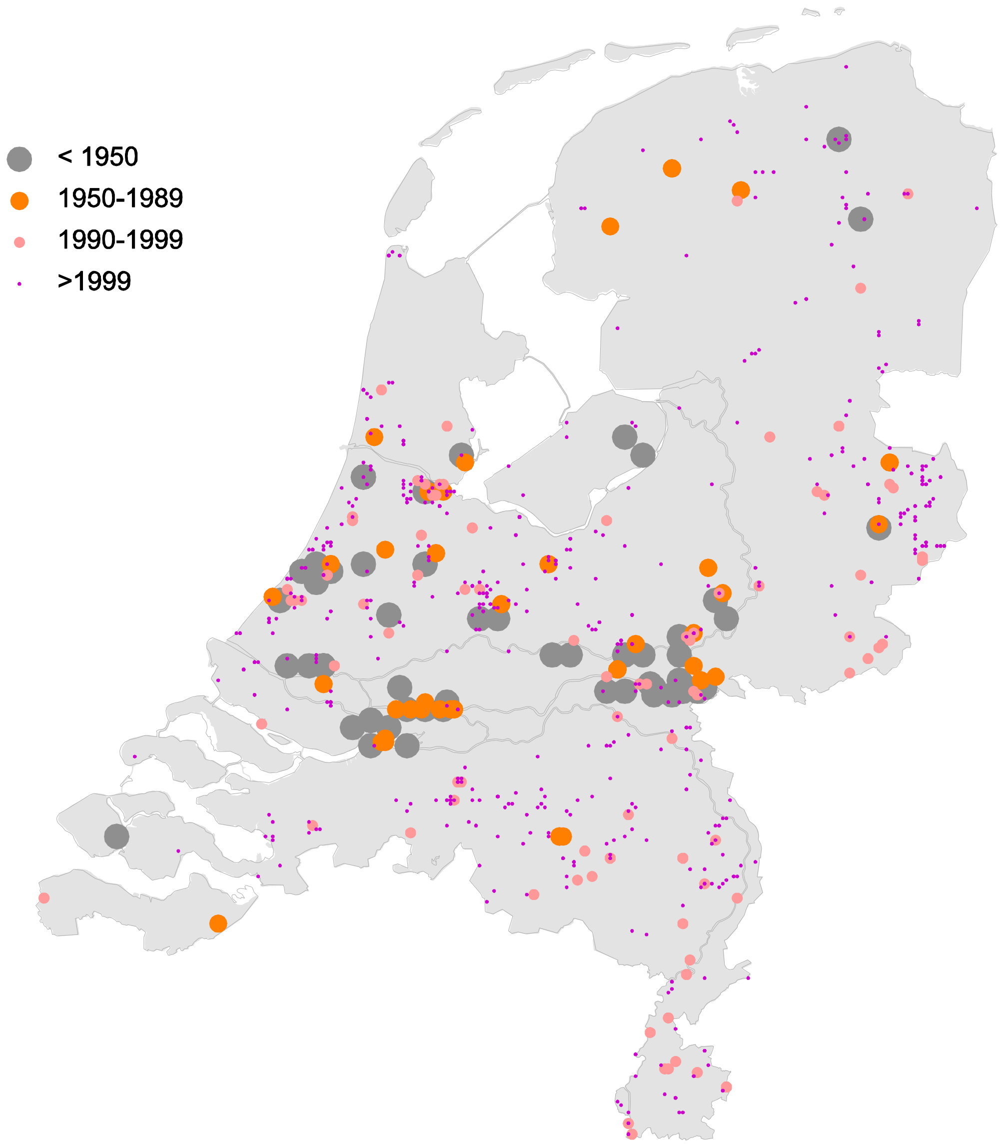

Figure 3.1: Distribution of the Monkeyflower (*Mimulus guttatus*) in the Netherlands (Data: National Database Flora en Fauna, complemented with data sources mentioned in Koopman *et al*., 2012).

It is still unknown whether annual or perennial types of *M. guttatus* occur in the Netherlands. However, during the field surveys of a claypit near Udenhout (Province Noord Brabant) and a small river valley near Renkum (Province Gelderland) creeping stolons of *M. guttatus* remaining from last year were recorded (Figure 3.2). These creeping stolons are characteristic of the perennial form of the plant. These plants also exhibited poor seed setting. The plants observed at Udenhout were seen only in the riparian zone that inundates periodically. Our observations may be biased for perennial plants because locations for our field surveys were selected using high density and occurrence during several years as a selection criteria.

Figure 3.2: The Monkeyflower (*Mimulus guttatus*) with creeping stolons sampled a claypit near Udenhout (Province Noord Brabant, the Netherlands) (Photo: R. Beringen, 12 July 2012).

A trend analysis was carried out to gain an impression of the colonization history and spread rate of *M. guttatus* in the Netherlands. *M. guttatus* was recorded in the Netherlands in the 19th century, but the number of records has increased rapidly since 1980s. After the year 2000, the rate of new records has been relatively consistent. The cumulative number of kilometre squares with records of *M. guttatus* shows a more or less linear increase, suggesting that the spread of the species is still in progress.

Populations of the *M. guttatus* in native areas are widely scattered across moist meadows, along streams and rivers (Grant, 1924 cited in Elderd & Doak, 2006). *M. guttatus* often colonizes these riparian habitats after disturbances by flooding. These disturbances cause population sizes to fluctuate over time through extinction, recolonization, founder effects and inbreeding allowing populations to act as a metapopulation (Vickery Jr., 1999). These metapopulation characteristics are reflected in variations in the mating system of *M. guttatus* which varies from 75% selfing to complete outcrossing (Dudash & Ritland, 1991; Ivey & Carr, 2005; Ritland & Ritland, 1989; Willis, 1993 cited in Ivey & Carr, 2012). Table 3.1 shows the ranges of environmental factors at sites where *M. guttatus* has been recorded. However, in most publications it has not explicitly been stated whether these data relate to annual or perennial types. The species can occur at sites with air temperatures ranging during the day from 4 to 30 ^{o}C and during the night from 4 to 23 ^{o}C (Vickery Jr., 1974). The current distribution indicates that this species tolerates lower as well as higher temperatures. Soil temperatures up to 50 ^{o}C have been recorded for sites with *M. guttatus* (Lekberg *et al*., 2012). Although plants can survive on thermal soils with temperatures ranging from 30 to 50 ^{o}C, they do show heat stress. This stress is translated in decreased total biomass, root length and diameter and early flowering to evade drought (Bunn *et al.*, 2009). Optimal growth often occurs in moderate climates with day temperatures around 17 ^{o}C and night temperatures ranging from 4 to 17 ^{o}C (Vickery Jr., 1974).

Table 3.1: Environmental tolerances of the Monkeyflower (*Mimulus guttatus*).

Parameter	**Physiological tolerance**	**References**
pH	3 – 7.9 6.5 – 6.8	Bunn & Zanbinski (2003); Hani Soliman (1976); Sletten & Larson (1984) This study
Alkalinity (eq l^{-1})	$4.851E^{-4}$ – $8.668E^{-4}$	This study
Conductivity (K25) (Micromhos cm^{-1})	491.15	Sletten & Larson (1984)
Day temperature (^{o}C)[e]	4 - 30	Vickery Jr. (1974)
Night temperature (^{o}C)[e]	4 - 23	Vickery Jr. (1974)
Soil Temperature (^{o}C)	Up to 50	Lekberg *et al.* (2012)
Temperature frost damage (^{o}C)	-6[c]	Bannister (1990)
Ca/Mg ratio	0.16	Murren *et al.* (2006)
Coastal tolerance to Na^{+} (mM)	Up to 100	Lowry *et al.* (2009)
Inland tolerance to Na^{+} (mM)	Up to 50	Lowry *et al.* (2009)
Copper (mg kg^{-1} DS)[a,d]	6549.8	Tilstone *et al.* (1997)
Cadmium (mg kg^{-1} DS)[a,d]	2.35	Tilstone *et al.* (1997)
Copper (ppm)	7020	Allen & Sheppard (1971)
Zinc (ppm)	538	Allen & Sheppard (1971)
Lead (ppm)	<100	Allen & Sheppard (1971)
Nickel (ppm)	135	Allen & Sheppard (1971)
Phosphate (mg kg^{-1} DS)[d]	54	Samecka-Cymerman & Kempers (1999)
Potassium (mg kg^{-1} DS)[d]	100	Samecka-Cymerman & Kempers (1999)
Calcium (mg kg^{-1} DS)[d]	7400	Samecka-Cymerman & Kempers (1999)
Magnesium (mg kg^{-1} DS)[d]	1500	Samecka-Cymerman & Kempers (1999)
Iron (mg kg^{-1} DS)[d]	300	Samecka-Cymerman & Kempers (1999)
Chromium (mg kg^{-1} DS)[d]	12.4	Samecka-Cymerman & Kempers (1999)
Nickel (mg kg^{-1} DS)[d]	11.4	Samecka-Cymerman & Kempers (1999)
Aluminum (mg kg^{-1} DS)[d]	5400	Samecka-Cymerman & Kempers (1999)
Cobalt (mg kg^{-1} DS)[d]	5.9	Samecka-Cymerman & Kempers, (1999)
Lead (mg kg^{-1} DS)[d]	64	Samecka-Cymerman & Kempers (1999)
Zinc (mg kg^{-1} DS)[d]	122	Samecka-Cymerman & Kempers (1999)

a = value for copper tolerant plants; b = value for non copper tolerant plants; c lowest air temperature were no damage to leaves occurs; d = mg kg^{-1} Dry soil; e = temperature range is thought to be wider.

In the native range the perennial plants mostly occur along the coast where persistent fog keeps temperatures relatively low, maintains high soil moisture and reduces plant transpiration (Hall & Willis, 2006; Lowry *et al.*, 2008; Corbin *et al.*, 2005 cited in Lowry *et al.*, 2009). In these coastal areas the plants experience a relatively high amount of salt spray, therefore the perennial plants have developed a high tolerance to salt (Table 3.1; Lowry *et al.*, 2008). The late flowering of perennials compared to annuals makes it impossible for them to survive more inland where drought stress is high due to hot summers that dry out the soil. Therefore, in inland habitats mostly drought tolerant annual plant populations occur. These populations are able to survive hot summers through early flowering and seed setting. Plants die off in the dry period but the seeds survive and germinate in the next growing season. Annual plants are not able to survive in coastal habitats because they are not tolerant to the high salt conditions occurring with salt spray (Table 3.1; Lowry *et al.*, 2008; Wu *et al.*, 2010).

To combat the negative effects of herbivory by Meadow Spittlebug *Philaenus spumarius* (Ivey *et al.*, 2009) and Common Buckeye *Junonia coenia* (Tindle *et al.*, 2004) perennial *M. guttatus* plants form trichomes, hairy like structures that grow from the epidermis. The trichomes are straight and often glandular, they secrete a sticky substance that can be harmful to herbivores. Furthermore, they are also capable of reducing light radiation and transpiration rates. However, these factors are negligible for the perennial plants since they do not experience drought and intense sunlight. The inland annual plants produce none or very few trichomes. This is because of their short life time (6-10 weeks) and exposure to minimal insect herbivory. Moreover, trichome production is costly in these water limited habitats (Holeski, 2007).

After considering the above information the probability of establishment was judged to be high.

3.3 Probability of spread

The species shows sexual as well as vegetative reproduction and auto-fertility. The perennial plants invest more in vegetative reproduction through stolons or rhizomes compared to faster developing annual plants that invest more in sexual reproduction (Van Kleunen, 2007).

After *M. guttatus* has been introduced it disperses via two mechanisms: seed setting and regeneration of fragmented parts. *M. guttatus* releases its seeds from August to September and mean seed numbers are found to be higher in non-native ranges. During our field surveys in the Netherlands seed setting was already recorded in early July.

In dynamic floodplains seeds are dispersed during high flow events after the initial seed setting period (e.g. in winter; Goodson *et al.*, 2002). The seeds of *M. guttatus* are buoyant after release, however, this buoyancy decreases after time. The speed at which buoyancy decreases is strongly determined by the hydrological characteristics of the river. *M. guttatus* seeds show significantly shorter buoyancy with increasing high flows and turbulence. At an average daily flow velocity of 0.28 m s^{-1} seeds can be transported for 1 km. However, some seeds retain buoyancy longer at average daily flow velocities of 0.82 m s^{-1} and were able to disperse over a distance of 3 km (Truscott *et al.*, 2006). Water only facilitates downstream dispersal, but seeds can also be dispersed upstream by wind and animals. Dispersal through wind can only occur over short distances of several meters, whereas dispersal by animals like deer, birds and cattle can disperse seeds over 1 km and possibly even further (Truscott *et al.*, 2006; Vickery Jr. *et al.*, 1986; Waser *et al.*, 1982; Lindsay, 1964 cited in Vickery Jr. *et al.*,1986). The relative importance of seeds in long-distance dispersal is dependent on the environmental conditions in the period of seed setting.

Fragmentation can occur through rough hydrological conditions or herbivory. Fragments can have considerable regenerative capacities. Fragments of any length are capable of root extension along the main stem and from the nodes. Fragments can occur year round and survive up to 6 weeks which, in combination with high flow velocities, means that *M. guttatus* is able to disperse over very large distances throughout the year. However, long distance dispersal is often hampered by the trapping of fragments in vegetation, stones and other obstacles along the river banks (Truscott *et al.*, 2006). The potential dispersal vectors of *M. guttatus* are summarized in table 3.2.

After considering the above information the probability of spread was judged to be high.

Table 3.2: Potential dispersal factors of the Monkeyflower (*Mimulus guttatus*).

Vector / Mechanism	**Mode of transport**	**Examples and relevant information**	**Importance to dispersal into and within the Netherlands**	**References**
Humans	Ornamental plant trade	Introduced/escaped from gardens; wildflower seeds mixtures; multiple introductions	High	Tokarska-Guzik & Dajdok (2010); Often *et al.* (2003); Van Kleunen & Fischer (2008)
Water	Hydrochory	Floating seeds and fragments; short and long distance dispersal	Medium	Truscott *et al.* (2006)
Animals	Zoochory	Seeds in faeces of deer, cattle, birds; long distance dispersal	Medium	Truscott *et al.* (2006); Vickery Jr. *et al.* (1986); Waser *et al.* (1982)
Wind	Anemochory	Short distance dispersal	Low	Vickery Jr. *et al.* (1986)

3.4 Risk classification using the ISEIA protocol

3.4.1 Expert consensus scores

The total risk score attributed to the *M. guttatus* was 8 out of a maximum risk score of 12 (Table 3.3). This results in an overall classification of low risk for this species.

Table 3.3: Consensus scores and risk classifications for Monkeyflower (*Mimulus guttatus*) in the current situation in the Netherlands.

ISEIA Sections	Risk classification	Consensus score
Dispersion potential or invasiveness	high risk	3
Colonization of high value conservation habitats	high risk	3
Adverse impacts on native species	low risk	1
Alteration of ecosystem functions	low risk	1
Global environmental risk	**C - list category**	**8**

3.4.2 Dispersion potential or invasiveness

Classification: **High**. *M. guttatus* is mainly used as an ornamental plant and has been introduced via wildflower seed mixtures, e.g. on banks of ditches in The Hague. It shows a high dispersion potential in the Netherlands. The species appeared to be highly fecund and is able to disperse through active and passive means employing a number of vectors over distances > 1 km per year.

3.4.3 Colonisation of high conservation value habitats

Classification: **High**. Table 3.4 shows that *M. guttatus* occurs in many areas of high conservation value defined according to Annex 1 of 92/43/EEC directive (i.e. Natura 2000 sites).

Table 3.4: Occurrence of the Monkeyflower (*Mimulus guttatus*) in Natura-2000 areas.

Confirmed[1]	Possible[2]
Arkemheen	*Achter de Voort, Agelerbroek & Voltherbroek*
Broekvelden, Vettenbroek & Polder Stein	*Biesbosch*
Duinen Den Helder-Callantsoog	*Deurnsche Peel & Mariapeel*
Gelderse Poort	*Dwingelderveld*
Kampina & Oisterwijkse Vennen	*Haringvliet*
Kennemerland-Zuid	*Lonnekermeer*
Loevestein, Pompveld & Kornsche Boezem	*Maasduinen*
Loonse en Drunense Duinen & Leemkuilen	*Nieuwkoopse Plassen & De Haeck*
Meijendel & Berkheide	*Oude Maas*
Meinweg	*Uiterwaarden Zwarte Water en Vecht*
Noordhollands Duinreservaat	
Oostelijke Vechtplassen	
Polder Westzaan	
Roerdal	
Uiterwaarden Waal	
Veluwe	
Witte Veen	

1: Records with detailed coordinates and growing site within the boundaries of the Natura-2000 area; 2: Observations with a kilometre square record and Natura-2000 area within this kilometre grid.

Although only few records contain detailed information on biotopes, available data show that the species may occur in the following habitat types:

- H2190 Humid dune slacks;
- H3130 Oligotrophic to mesotrophic standing waters with vegetation (Littorelletea uniflorae);
- H3270 Rivers with muddy banks with *Chenopodion rubri* p.p. and *Bidention* p.p. vegetation.

The species may also occur on banks of water courses of plain levels with habitat type H3260 (*Ranunculion fluitantis* and *Callitricho-Batrachion*).

3.4.4 Adverse impacts on native species

Classification: **Low.** Herbivory and predation are not relevant impact criteria for this plant species. No negative effects resulting from the influence of *M. guttatus* on native species due to parasites and diseases were discovered during the literature study. *M. guttatus* is related to a number of hybrids as part of a species complex, however, there was no evidence found that *M. guttatus* hybridises with native species in the Netherlands. Therefore, the risk classification is based on the competition sub-section. While *M. guttatus* displays a wide distribution in the Netherlands and has colonised many areas of high conservation value, the impact on native species within these habitats is expected to be low. Until now, no impacts on native species within protected habitats in the Netherlands have been recorded. During our field surveys in the Netherlands it has been observed that *M. guttatus* is able to establish itself on disturbed riparian habitats but is eventually overgrown, through the course of vegetation succession, by taller perennial or woody plants like Reed (*Phragmites australis*) and Willows (*Salix* sp.). Evidence from other countries supports these observations. *M. guttatus* establishes quickly in disturbed habitats at an early successional stage. In Scotland, *M. guttatus* has been shown to induce local species replacement. Here, it impacts widespread ruderal or other non-native plants of a low conservation value but due its relatively high light demand is outcompeted by species that establish in later successional stages (Truscott *et al.,* 2008a; Truscott *et al.,* 2008b; Hejda *et al.,* 2009). However, this example is not relevant to the Netherlands due to climatic differences (R. Pot, unpublished results). *M. guttatus* poses no threat to national species richness and does not have a serious impact on the plant community in the Czech republic (Hejda *et al.,* 2009).

3.4.5 Alteration of ecosystem functions

Classification: **Low.** No information on modification of natural succession and direct disruption to food webs by *M. guttatus* in the Netherlands or in other countries was found during the literature study. Moreover no evidence of physical modifications to habitats occurring in the Netherlands was found during the literature study. Therefore, the risk classification is based on the modifications in nutrient cycling and resource pools sub-section. In laboratory experimentation, *M. guttatus* has a higher soil nitrogen acquisition than *Lamium amplexicaule*. Reduced availability of nitrogen to *L. amplexicaule* may reduce its floral display and the attractiveness of its nectar to pollinators (Baude *et al*., 2011). However, reduced soil nitrogen is beneficial to ecosystems in the Netherlands due to the excess nitrogen enrichment that has occurred through the fertilization of agricultural land.

3.4.6 Species classification

The species classification corresponds to the global environmental risk score of the ISEIA (Table 3.3) combined with the current distribution of the non-native species within the country in question. The species classification for *M. guttatus* is C3 (Figure 3.3). This indicates a non-native species that is widespread but features a low environmental hazard (ecological risk).

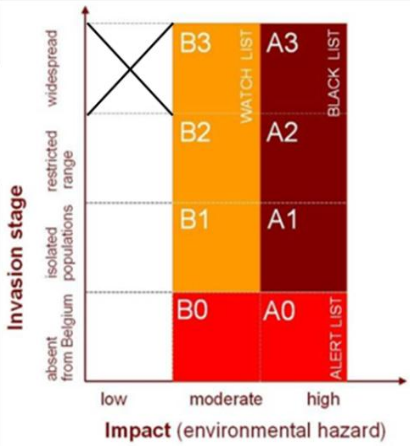

Figure 3.3: Monkeyflower (*Mimulus guttatus*) species classification according to the BFIS list system.

However, habitat alteration resulting from climate change may result in a future re-grading of risk. Future changes in precipitation pattern due to climate change may cause a reduced river water level and desiccation in summer that will have a negative impact on *M. guttatus* distribution. On the other hand, an increase in the area of floodplain could result in increased habitat availability. However, *M. guttatus* is already widely distributed in the Netherlands and poses a low risk to native species and has a low impact on ecosystem functions. It is expected, therefore, that impacts on native species and alterations to ecosystem functions will not alter from the present situation. This would lead to the same low global environmental risk classification as is seen today (Table 3.5). In this theoretical scenario *M. guttatus* would remain in the C3 classification within the BFIS list system.

Table 3.5: The Monkeyflower (*Mimulus guttatus*) species theoretical classification according to potential future habitat scenario.

ISEIA Sections	Risk classification	Consensus score
Dispersion potential or invasiveness	high risk	3
Colonization of high value conservation habitats	high risk	3
Adverse impacts on native species	low risk	1
Alteration of ecosystem functions	low risk	1
Global environmental risk	**C - list category**	**8**

3.5 Socio-economic impacts

No economic effects are reported from Central or Northern Europe (e.g. Poland, Germany, Denmark and Norway). However, *M. guttatus* is able to invade drainage ditches, which can lead to economic problems (Gudžinskas, personal observation cited in Tokarska-Guzik & Dajdok, 2010). Further details on these economic problems are not given by the authors. However, due to its habitat preferences, it is expected that *M. guttatus* can only colonize ephemeral ditches and therefore does not increase management costs. In this type of ditch frequent vegetation removal by land owners is carried out already because of rapid establishment of terrestrial plants species.

3.6 Public health effects

There was no information found concerning the public health impacts of *M. guttatus* during the literature study or in communications with project partners.

3.7 Risk management options

3.7.1 Prevention

Public awareness is an important component in a strategy aimed at controlling or removing an invasive species from a catchment area. This is especially true of species such as *M. guttatus* where the sale of plants and seeds is a major factor in the extension of its non-native range. Awareness leaflets, press releases, calendars, lakeside notifications and an information website, warning of the environmental, economic and social hazards posed by this plant will contribute to public awareness (Caffrey & O'Callaghan, 2007).

3.7.2 Elimination and control

There is no experience with species-specific elimination or control measures in the Netherlands. The best option for elimination or control is mowing before the ripening of the seeds. In the Netherlands the ripening of seeds has already been observed in early July. Therefore, mowing before July is advised. However, it is expected that mowing will not be an effective measure for perennial plants. If the plants appear to be perennial or hybrids then no management at all is recommended. This will allow vegetation succession to overgrow the plants and is the next best option to reduce the population size.

4. Discussion

4.1 Gaps in knowledge and uncertainties

A lack of information in the literature on the (potential) impact of the Monkeyflower (*Mimulus guttatus*) in the Netherlands has resulted in a reliance on expert knowledge and field observations to judge the level of certain impacts.

There is lack of experience in managing *M. guttatus* in the Netherlands therefore recommendations had to be made on expert knowledge and experience with other similar species.

The ISEIA protocol is limited to an assessment of invasiveness and ecological impacts. No assessment of socio-economic impacts or impacts to human health are considered and are not considered in the calculation of global environmental risk score. Socio-economic impacts or impacts to human health were therefore considered separately.

Risk criteria in the ISEIA protocol were sometimes restrictive, as there was an absence of quantitative data that allowed the criteria to be assessed e.g. 1 km per year dispersal criterion for the 'dispersion or invasiveness' section.

4.2 Comparison of available risk classifications

Formal risk assessments have been conducted in two countries: Belgium and Ireland.

In Belgium an ecological risk assessment according to the ISEIA method was performed, resulting in placing *M. guttatus* on a watch list (B2 species; score 10 out of 12). The higher risk obtained for *M. guttatus* in Belgium maybe a function of a greater habitat suitability and resultant higher level of invasiveness (Baus *et al.,* 2010).

In Ireland a stage 1 risk assessment for *M. guttatus* was performed according to the IS Ireland Risk Assessment method, which resulted in a medium risk score of 13 (Anonymous, 2007). According to this method, stage 1 risk assessments are reserved for established species. The hybrid *M. x robertsii* was also assessed, resulting in a medium risk score of 10. In these assessments low risk species score 0-12, medium risk species 13-19 and high risk species greater than 19.

In the United Kingdom, Natural England carried out an assessment using a rapid screening process designed to be applicable to larger numbers of plants (Horizon scanning). *Mimulus cupreus* x *guttatus* (*M.* x *burnetii*), a hybrid of *M. guttatus*, was characterised as low risk requiring no further assessment (Natural England, 2011).

4.3 Risk management

Banning of sale of plants and seeds via the plant trade continues to be potentially the most effective method of controlling the spread of invasive plant species. However, *M.*

guttatus is already widely distributed in the Netherlands, reducing the relevance of measures that prevent further introductions to the wider environment. *M. guttatus* features a low environmental hazard due to its limited competitive ability. The introduction of management measures to eliminate and control *M. guttatus* is not necessary as *M. guttatus* has a limited ecological and socio-economic impact in the Netherlands. Moreover, *M. guttatus* will, in many locations, be outcompeted by the greater competiveness for light of other (early) colonisers during subsequent succession stages (e.g. when growth of taller perennial or woody plants occurs like Reed *Phragmites australis* and Willows *Salix* sp.). Due to its current wide distribution, the local introduction of management measures may have a limited effect on the total population of *M. guttatus* in the Netherlands.

M. guttatus is classified in the low risk category of the ISEIA protocol. The species is widely distributed in the Netherlands and poses a low risk to native species and has a low impact on ecosystem functions. Future changes in precipitation as a result of climate change will not alter the invasion stage of the species in the Netherlands. A similar distribution of *M. guttatus* in the future means that impacts on native species and ecosystem functions will remain unchanged. Therefore, no management measures are recommended for the control of *M. guttatus* in the Netherlands.

5. Conclusions and recommendations

The main conclusions and recommendations of the risk analysis of non-native Monkeyflower (*Mimulus guttatus)* in the Netherlands are as follows:

- It is most likely that *M. guttatus* arrived in the Netherlands via horticulture and the ornamental plant trade and via wildflower seeds mixtures. *M. guttatus* is now widely distributed throughout the Netherlands. Therefore, the probability of arrival of *M. guttatus* to and within the Netherlands was judged to be high.

- The number of records of *M. guttatus* in the Netherlands has increased rapidly since the 1980s. After the year 2000, the rate of new records has been relatively consistent. The cumulative number of kilometre squares with records of *M. guttatus* shows a more or less linear increase, suggesting that the species continues to establish. Currently, *M. guttatus* displays a widespread recorded distribution in the Netherlands. The probability of establishment within the Netherlands was judged to be high.

- *M. guttatus* shows a high probability of spread. *M. guttatus* appears to be highly fecund and is able to spread through active and passive means employing a number of vectors over distances > 1 km per year. We predict that without management intervention, *M. guttatus* introductions will continue leading to further increases in its distribution within the Netherlands. The probability of spread of *M. guttatus* within the Netherlands was judged to be high.

- *M. guttatus* occurs in many areas of high conservation value in the Netherlands defined according to Annex 1 of 92/43/EEC Habitats directive (i.e. Natura 2000 sites).

- *M. guttatus* is able to establish on disturbed riparian habitats. It has been observed to outcompete ruderal or other non-native plants of a low conservation value in Scotland. Due its relatively high light demand, at several locations in the Netherlands it is outcompeted by taller perennial or woody plants like Reed (*Phragmites australis*) and Willows (*Salix* sp.) at a later successional stage. There is no evidence of impacts on native plants in the Netherlands.

- *M. guttatus* displays a relatively high soil nitrogen acquisition in laboratory experiments. However, reduced soil nitrogen is beneficial to ecosystems in the Netherlands due to the excess nitrogen enrichment.

- *M. guttatus* was rated as a low risk species for ecological impacts according to the ISEIA protocol and accorded a rating of C3 in the BFIS list classification.

- There was no information found concerning the socio-economic or human health impacts of *M. guttatus* in the Netherlands during the literature study or in communications with project partners. Socio-economic impacts observed abroad are not relevant for the Netherlands due to differing habitat conditions and management procedures.

- The introduction of management measures to eliminate and control *M. guttatus* is not required as *M. guttatus* has a limited ecological and socio-economic impact in the Netherlands. The occurrence of *M. guttatus* will, in many locations, be limited by the greater competitiveness of other (early) colonisers during vegetation succession. Due to its current wide distribution, the local introduction of management measures may have a limited effect on the total population of *M. guttatus* in the Netherlands.

- Future changes in precipitation as a result of climate change will not alter the BFIS list defined invasion stage of *M. guttatus* in the Netherlands. A similar distribution of *M. guttatus* in the future means that impacts on native species and ecosystem function will remain unchanged and *M. guttatus* will remain classified as a C3 species.

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8. Appendices

Appendix 1. Knowledge document used for the risk analysis