Risk analysis of exotic fish species included in the Dutch Fisheries Act and their hybrids

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Nederlands Expertise Centrum Exoten

Risk analysis of exotic fish species included in the Dutch Fisheries Act and their hybrids

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Commisioned by the Bureau for Risk Assessment & Research Programming (Bureau Risicobeoordeling & Onderzoeksprogrammering, BuRO) of the Netherlands Food and Consumer Product Safety Authority (Nederlandse Voedsel- en Warenautoriteit, NVWA)

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PREFACE

Dutch legislation prohibits the introduction of animal species in the wild. Exceptions are species included in the Fisheries Act. This allows the stocking of a number of exotic fish species, without analysing their potential risks in relation to biodiversity or genetic pollution. Therefore the Bureau for Risk Assessment & Research Programming (Bureau Risicobeoordeling & Onderzoeksprogrammering, BuRO) of the Netherlands Food and Consumer Product Safety Authority (Nederlandse Voedsel- en Warenautoriteit, NVWA) commissioned a risk analysis for the exotic fish species included in the Fisheries Act.

The risk analyses was carried out by a project group formed from the following partners:

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SUMMARY

This report describes a risk analysis of exotic fish species which are included in the Dutch Fisheries Act and their hybrids. A literature research and database analysis provided information that is contained in the following sections: a species description; risk analysis; risk classification and management options. The risk analysis was carried out for the following species and a single hybrid: Arctic char (*Salvelinus alpinus*); asp (*Leuciscus aspius*); common carp (*Cyprinus carpio*); eastern mudminnow (*Umbra pygmaea*); grass carp (*Ctenopharyngodon idella*); hybrid 'cross carp' (*Cyprinus carpio* X *Carassius* spp.); pike-perch (*Sander lucioperca*); Prussian carp (*Carassius gibelio*) and vendace (*Coregonus albula*). Although, even though the sea trout (*Salmo trutta trutta*) was present in the initial selection of exotic species, it was decided by expert consensus to treat it as a native species. Therefore, a risk assessment was not carried out in this case.

Of the analysed species, asp, common carp, pike-perch and Prussian carp have the highest invasiveness based on dispersion and reproduction potential. As a result of their relatively long invasion history, these species already occur widely. Also grass carp, a species with a medium invasiveness due to its inability to reproduce, occurs widely as a result of intensive stocking and dispersion. The eastern mudminnow has a relatively long introduction history but a lower invasiveness, it therefore occurs in a restricted range only. The stocked hybrid 'cross carp' is probably able to reproduce, but it's invasiveness is unknown. It currently occurs in isolated populations. Vendace and Arctic char are still absent from the Netherlands and have a limited invasiveness.

A number of the featured species often colonise high conservation value habitats. These are either protected areas or areas featuring habitat suitable for endangered native species. Asp and pike-perch predominantly colonise river habitats; grass carp, Prussian carp and common carp colonise a broad range of vegetated (floodplain) waters and the eastern mudminnow colonises moorland pools and habitats suitable for the wheaterfish (*Misgurnus fossilis*). Furthermore, some exotic species have a large impact on native species. Grass carp can have a large negative impact on different native aquatic plant species. Pike-perch can adversely impact cyprinid and salmonid species. Prussian carp can outcompete tench (*Tinca tinca*) and the endangered crucian carp (*Carassius carassius*). Moreover, the genetic integrity of the crucian carp can be compromised by hybridisation with Prussian carp, common carp, exotic goldfish (*Carassius auratus*) and the cross carp hybrid.

Based on the current body of knowledge, assessments of risk were performed for the current Dutch situation and a future scenario (a two degrees temperature rise resulting from climate change) using the Belgian ISEIA-protocol in an expert workshop. In addition to the exotic species analysed in this report, an ISEIA-score has been derived for brook trout (*Salvelinus fontinalis*), rainbow trout (*Oncorhynchus mykiss*) and northern whitefin gudgeon (*Romanogobio belingi*).

A high risk classification score (ISEIA 11-12, black list), was allocated to three species for the current situation in the Netherlands: the common carp, pike-perch and Prussian carp. A moderate risk score (ISEIA 9-10, watch list), was allocated to six species: the asp, brook trout, grass carp, hybrid cross carp, rainbow trout and northern whitefin gudgeon. A low risk score (ISEIA 4-8), was allocated to three species: Arctic char, eastern mudminnow and vendace. It is important to note that the risk classifications for Arctic char, asp, eastern mudminnow, cross carp, vendace and northern whitefin gudgeon contain over 50% of scored risk assessment categories where only expert judgment was applied. The maximum score given according to expert judgement (2) is

lower than the maximum score (3) that can be allocated when judgements are based on evidence from literature. Therefore, the frequent application of expert judgement will lead to the allocation of a lower overall risk score for what is perceived to be a high risk species. Based on the expert's opinion, this situation applies to the assessment of the cross carp hybrid.

In the future scenario the grass carp received a higher risk classification score (ISEIA 11-12, black list), due to an increased probability of successful reproduction. The risk classifications for the other species remained unchanged.

Once introduced, it is difficult to eliminate unwanted populations of an exotic fish species. Only populations in relatively small isolated water bodies can be eliminated while, at the same time, limiting collateral impacts on native species. Currently, the complete drainage of a water body and humane euthanization by physical means is the only legal method for the elimination of exotic fish species in the Netherlands. Management of established populations has proven to be very difficult or even impossible for species with populations existing in large water bodies.

Based on the results of the risk analyses we recommend the following:

- The stocking of exotic fish species, in particular Prussian carp, pike-perch, grass carp and fertile hybrids (cross carp), should be prevented or controlled to prevent further spread and new introductions of these species.
- The screening of national and international transports and the taking of measures to prevent the spread of diseases and the coincidental spread of other exotic species is strongly advised.

To enhance the knowledge of risks that exotic fish species pose in the Netherlands research is recommended on the following topics:

- Determine if the genotype of the native crucian carp has already been compromised by hybridisation with Prussian carp, goldfish and common carp.
- The impact of the asp, eastern mudminnow, northern whitefin gudgeon, brook trout and rainbow trout on native species and ecosystem functioning should be assessed in more detail.
- A risk assessment of the fertile hybrid of brook trout and Arctic char (Elsässer saibling).

SAMENVATTING

In dit rapport worden de risico's geanalyseerd van exotische vissoorten die zijn opgenomen in de Visserijwet en hun hybriden. De volgende onderdelen zijn uitgewerkt aan de hand van literatuurstudie en database analyse: een soortbeschrijving, risico analyse, risico classificatie en management opties. De volgende soorten en één specifieke hybride zijn in de analyse meegenomen: beekridder (*Salvelinus alpinus*); roofblei (*Leuciscus aspius*); karper (*Cyprinus carpio*); Amerikaanse hondsvis (*Umbra pygmaea*); graskarper (*Ctenopharyngodon idella*); hybride 'kruiskarper' (*Cyprinus carpio* X *Carassius* spp.); snoekbaars (*Sander lucioperca*); giebel (*Carassius gibelio*) en kleine marene (*Coregonus albula*). Hoewel zeeforel (*Salmo trutta trutta*) was opgenomen in de initiële selectie van exotische soorten, is in consensus met experts besloten deze soort als inheems te beschouwen.

Van de geanalyseerde soorten hebben roofblei, karper, snoekbaars en giebel de hoogste invasiviteit gebaseerd op dispersie- en reproductiecapaciteit. Gezien de relatief lange invasiegeschiedenis zijn deze soorten momenteel dan ook wijdverspreid aanwezig in Nederland. Ook graskarper heeft dankzij grootschalige uitzettingen en dispersie momenteel een wijde verspreiding. Amerikaanse hondsvis komt al relatief lang in Nederland voor maar heeft een lagere invasiviteit, de soort komt derhalve in een relatief beperkte range voor. De uitgezette kruiskarper heeft een onbekende invasiviteit maar kan zich waarschijnlijk wel voortplanten. Deze hybride komt momenteel in geïsoleerde populaties voor. Kleine marene en beekridder komen momenteel niet in Nederland voor en hebben een lage invasiviteit.

Een aantal van de exotische soorten koloniseert regelmatig gebieden met een beschermde status of waardevolle habitats voor beschermde en bedreigde soorten. Snoekbaars en rooblei koloniseren vaak riviergebonden habitats, graskarper, giebel en karper koloniseren een diversiteit aan begroeide (uiterwaard) wateren, de Amerikaanse hondvis koloniseert vooral vennen en wateren die voor de grote modderkruiper (*Misgurnus fossilis*) van belang zijn. Daarnaast heeft een aantal exoten een grote negative impact op inheemse soorten. Graskarper kan een grote invloed hebben op verschillende soorten inheemse waterplanten. Snoekbaars kan een negatief effect hebben op populaties van karperachtigen en salmoniden. Giebel kan zeelt (*Tinca tinca*) en de bedreigde kroeskarper (*Carassius carassius*) wegconcurreren. Verder kan genetische vervuiling van kroeskarper optreden door hybridisatie met giebel, karper, goudvis (*Carassius auratus*) en kruiskarper.

Gebaseerd op de huidige kennis van de exotische soorten is tijdens een workshop met deskundigen het risico voor de actuele situatie en een toekomstige scenario (twee graden temperatuurstijging door klimaatverandering) geclassificeerd met het Belgische ISEIA-protocol. In aanvulling op de soorten waarvan de risico's in dit rapport worden geanalyseerd, is tevens een ISEIA-score toegekend aan bronforel (*Salvelinus fontinalis*), regenboogforel (*Oncorhynchus mykiss*) en witvingrondel (*Romanogobio belingi*).
Aan drie soorten is een hoge risicoclassificatie (ISEIA 11-12, zwarte lijst) voor de actuele Nederlandse situatie toegewezen; karper, snoekbaars en giebel. Een gemiddelde risico classificatie (ISEIA 9-10, volglijst) is toegewezen aan zes soorten; roofblei, bronforel, graskarper, kruiskarper, regenboogforel en witvingrondel. Een lage risico score (ISEIA 4-8) is toegewezen aan drie soorten; beekridder, Amerikaanse hondsvis en kleine marene. De risico classificatie van beekridder, roofblei, Amerikaanse hondsvis, kruiskarper en kleine marene bevatten voor meer dan 50% deskundigenoordeel op de gescoorde categorieën. De maximale score bij een deskundigenoordeel (2) is lager dan de maximale score op basis van harde bewijzen (3). Een groot

aandeel deskundigenoordeel kan daarom leiden tot het toekennen van een lagere classificatie terwijl de soort door deskundigen als risicovol wordt beschouwd. Gebaseerd op de mening van de deskundigen is dit laatste van toepassing op de kruiskarper.
In het toekomstscenario is een hoge risico classificatie (ISEIA 11-12, zwarte lijst) toegekend aan de graskarper, vanwege de verhoogde kans op succesvolle reproductie. Bij de andere soorten vond geen wijziging plaats van de risico classificatie in de toekomst.

Eenmaal geïntroduceerd is het moeilijk een ongewenste populatie van een exotische vissoort te elimineren. Enkel populaties in relatief kleine geïsoleerd gelegen waterlichamen kunnen geëlimineerd worden, met tegelijkertijd weinig schade aan inheemse soorten. Op dit moment is het compleet droogzetten van een water en het humaan doden op fysieke wijze de enige legale methode voor eliminatie van exotische vissen in Nederland. Het beheren van gevestigde populaties van exotische vissen blijkt lastig, of zelfs onmogelijk, wanneer soorten zich hebben gevestigd in grote waterlichamen.

Op basis van dit rapport worden de volgende maatregelen aanbevolen:

- Het uitzetten van exoten, met name karper, giebel, snoekbaars, graskarper en vruchtbare hybriden (kruiskarper), moet gestopt of gereguleerd worden om verdere verspreiding en nieuwe introducties te voorkomen.
- Het screenen van nationale en international vistransporten en maatregelen te nemen om de verspreiding van ziekten en andere meeliftende exoten te voorkomen.

Voor de kennisverbetering van de risico's van exotische vissen in Nederland, worden op basis van dit rapport de volgende onderwerpen voorgesteld:

- Vaststellen of het genotype van de inheemse kroeskarper is beïnvloed door hybridisatie met karper, giebel en goudvis.
- Het bepalen van de impact van roofblei, witvingrondel, giebel en Amerikaanse hondsvis op inheemse soorten en het ecosysteem functioneren.
- Het opstellen van een risicobeoordeling voor de vruchtbare hybride van bronforel en beekridder (Elzasser saibling).

1. INTRODUCTION

The introduction of invasive exotic species can reduce native biodiversity, disturb ecosystem functions, cause economic damage and jeopardize public health (Ministry of Agriculture, Nature and Food Quality, 2007). Knowledge of (potentially invasive) exotic species facilitates the reduction of impacts, prevention of further spread and the formulation of control measures.

In the Netherlands, the Bureau Risk Assessment & Research Programming (Bureau Risicobeoordeling & Onderzoeksprogrammering, BuRO) of the Netherlands Food and Consumer Product Safety Authority (Nederlandse Voedsel- en Warenautoriteit, NVWA) provides the ministries of Economic Affairs (Ministerie van Economische Zaken, EZ) and Health, Welfare and Sport (Ministerie van Volksgezondheid, Welzijn en Sport, VWS) with knowledge based advise on the measures to be taken concerning (invasive) exotic species. Among other responsibilities, the BuRO carries out risk analyses for exotic species allowing it to make recommendations about the necessity of prevention, control and available options for management of exotic species (Ministry of Agriculture, Nature and Food Quality, 2007).

For exotic fish species which have been introduced in the Netherlands, or are likely to arrive, a number of risk analyses have been performed (Spikmans *et al.*, 2010; Soes *et al.*, 2010; Soes *et al.*, 2011; Soes & Broeckx, 2010). One specific group of exotic fish species has, however, yet to be assessed. This group consists of exotic species included in the Dutch Fisheries Act (Visserijwet). Some of these fish species have been in the Netherlands for a long period of time and have established self sustaining populations. According to the Dutch Species Register, exotic species which have established a self sustaining population are considered naturalized (>100 years) or naturalizing (>10-100 years) (Nederlands Soortenregister, 2013).

In the Netherlands, it is forbidden to introduce (exotic) species in the wild (Dutch Flora & Fauna Act, art. 14). An exception to this are species included in the Dutch Fisheries Act. Therefore, these species can legally be introduced by the holders of fishing rights. Introductions of these exotic fish species may potentially pose a threat to ecosystems and society. Therefore, the BuRO decided to analyse the risks and management options for the following species and their hybrids:

Arctic char (*Salvelinus alpinus*)
Asp (*Leuciscus aspius*)
Common carp (*Cyprinus carpio*)
Eastern mudminnow (*Umbra pygmaea*)
Grass carp (*Ctenopharyngodon idella*)
Pike-perch (*Sander lucioperca*)
Prussian carp (*Carassius gibelio*)
Sea trout (*Salmo trutta trutta*)
Vendace (*Coregonus albula*)

This report includes a species description, risk analysis, risk classification and management options for the above species. The risk classification of the species is scored using the Belgian ISEIA-protocol. In addition to the above list, an ISEIA-score is determined for the following species:

Brook trout (*Salvelinus fontinalis*)
Rainbow trout (*Oncorhynchus mykiss*)
Northern whitefin gudgeon (*Romanogobio belingi*)

2. METHODS

2.1 Components of this report

In this study a risk assessment was carried out and management options were suggested for each of the following species:

Arctic char (*Salvelinus alpinus*)*
Asp (*Leuciscus aspius*)
Common carp (*Cyprinus carpio*)
Eastern mudminnow (*Umbra pygmaea*)
Grass carp (*Ctenopharyngodon idella*)
Hybrid 'cross carp' (*Cyprinus carpio* x *Carassius* spp.)**
Pike-perch (*Sander lucioperca*)
Prussian carp (*Carassius gibelio*)
Sea trout (*Salmo trutta trutta*)***
Vendace (*Coregonus albula*)

*Elsässer saibling, a hybrid of Arctic char and brook trout (*Salvelinus fontinalis*) is discussed in the text of Arctic char, but the risks of this hybrid are not assessed in this report.

**The hybrid, *Cyprinus carpio* x *Carassius* spp. is treated separately in a this riks assessment. This is because the so called 'kruiskarper' (referred to as 'cross carp' in this report) has been stocked in large numbers at many locations in recent years and information about this hybrid is ambiguous.

***Based on a literature review and expert consensus, it was decided not to treat the sea trout (*Salmo trutta trutta*) as an exotic species, but as a native species. Introductions of sea trout should therefore be treated as a repeated introduction or re-stocking of the species. When reintroducing and re-stocking native species the guidelines set by the IUCN/SSC should be respected (IUCN/SSC, 2013).

Throughout this report, common and scientific names were used which were accepted by Fish Base (Pauly & Froese, 2013). For each species the following components are addressed: a general species description, a risk assessment, risk classification and risk management. The risk assessment includes a risk classification using the ISEIA-protocol.

2.2 General species description

The general species description was made to draw up an ecological profile regarding relevant features for the risk assessment and risk classification. The following (sub)topics were addressed (table 2.1).

A literature review was carried out to gather relevant information. ISI Web of Knowledge, Google Scholar, the RAVON and Radboud University library search engines were applied to find relevant information in scientific peer-reviewed articles and books on the different subjects. An additional search was conducted using Google in an effort to find reports and other information from reliable sources.

Table 2.1: (Sub)topics addressed towards a general species description.

Topic	Subtopic
Nomenclature and taxonomical status	
Species characteristics and identification	
Life cycle	Habitat and environmental tolerance Reproduction Diet Predators Parasites and diseases
Distribution	Native range World distribution Distribution in the Netherlands

To gather relevant data on distribution of the different species in the Netherlands, two databases were used. The first was the RAVON-database, the largest and most up to date database of fish records in the Netherlands. The second was the National Database on Flora and Fauna (NDFF), the largest database in the Netherlands including all species groups. Data from both databases originate from different sources, such as historic reports, field observations by volunteer biologists and the data archives of various governmental and non-governmental organisations. The records of both databases have been validated by experts.

2.3 Risk assessment

To inform the risk assessment and to address the information needed for a risk classification by the ISEIA-protocol, the following topics (table 2.2) have been addressed using a literature review and database analyses (Branquart *et al.*, 2007; Verbrugge *et al.*, 2010; Verbrugge *et al.*, 2012).

Table 2.2: (Sub)topics addressed by the risk assessment.

Topic	Subtopic
Probability of entry	Pathways of introduction Pathways of future introduction
Probability of establishment	Habitat suitability Propagule pressure Population development Potential distribution
Probability of spread	Species characteristics that enable spread Spread in climatically similar countries Potential spread in the Netherlands Vulnerable areas
Negative impact of introduction	Ecological impact Economic impact Social impact
Positive impact of introduction	Ecological impact Economic impact Social impact

2.4 Risk classification

To provide context for the Dutch risk assessment process, a literature review was performed to summarize the outcomes of other (foreign) and risk assessments available online.
Risk classifications for the present and future situation in the Netherlands were determined using the ISEIA-protocol. Three additional species which had been previously risk assessed (see below) were scored using the ISEIA-protocol (Spikmans *et al.*, 2010; Soes & Broeckx, 2010).

Brook trout (*Salvelinus fontinalis*)
Rainbow trout (*Oncorhynchus mykiss*)
Northern whitefin gudgeon (*Romanogobio belingi*)

To inform the current risk classification process, an additional quick scan was carried out to update and add information relevant to these species.

The ISEIA-protocol assesses risks associated with dispersion potential, invasiveness and ecological impacts only (Branquart *et al.*, 2007). Scoring of the risk classification of the ISEIA-protocol was carried out by a team which consisted of 11 experts from six organisations (table 2.3).

Table 2.3: Expert team ISEIA-scoring.

Name	Organisation	Expertise
B.H.J.M. Crombaghs	Natuurbalans-Limes Divergens /Nederlands Expertise Centrum Exoten (NEC-E)	Fish ecology, invasive species
O.L.M. Haenen	Central Veterinary Institute of Wageningen University & Research Center	Fish, shellfish and crustacean diseases
N. van Kessel	Natuurbalans-Limes Divergens /NEC-E	Fish ecology, invasive fish species
H.J.R. Lenders	Institute for Water and Wetland Research, Radboud University Nijmegen / NEC-E	Historic ecology, aquatic ecology, risk assessment
R.S.E.W. Leuven (Chairman)	Institute for Water and Wetland Research, Radboud University / NEC-E	Aquatic ecology, invasive species, risk assessment
J. Matthews	Institute for Water and Wetland Research, Radboud University Nijmegen / NEC-E	Invasive species, risk assessment
L.A.J. Nagelkerke	Wageningen University, Aquaculture & Fisheries Group	Fish biology & fisheries, food webs
M.E. Schiphouwer	RAVON / NEC-E	Fish ecology, invasive fish species
F. Spikmans	RAVON / NEC-E	Fish ecology, invasive fish species
G. van der Velde	Institute for Water and Wetland Research, Radboud University Nijmegen / NEC-E	Aquatic ecology, invasive species
H. Verreycken	Instituut voor Natuur en Bosonderzoek, Belgium	Fish ecology, invasive fish species, risk assessment

Each expert completed an assessment form independently, based on the contents of a knowledge document containing the results of the literature review and data analyses of all species. Following this preliminary individual assessment, the entire expert team met, elucidated differences in risk scores, discussed diversity of risk scores and interpretations of key information during a risk assessment workshop. The workshop was chaired by R.S.E.W. Leuven, an expert on risk analysis protocols. The discussion during the workshop led to agreement on consensus scores and the level of risk relating to the four sections contained within the ISEIA-protocol. The ISEIA-protocol contains twelve criteria that match the last steps of the invasion process (i.e., the potential for spread, the potential for establishment and adverse impacts on native species and ecosystems). These criteria are divided over the four risk sections (table 2.4).

Table 2.4: Risk sections and sub-sections of the ISEIA-protocol.

Section		Sub-section
1.	Dispersion potential or invasiveness	
2.	Colonisation of high conservation habitats	
3.	Adverse impacts on native species	a. predation / herbivory b. interference and exploitation competition c. transmission of diseases to native species d. genetic effects such as hybridisation and introgression with native species
4.	Alteration of ecosystem functions	a. modifications in nutrient cycling or resource pools b. physical modifications to habitats c. modifications to natural successions d. disruption to food-webs

Each (sub-) section of the ISEIA-protocol was scored using given criteria (table 2.5). Scores range from 1 (low risk) to 2 (medium risk) and 3 (high risk). 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 to climate change and a 2°C rise in average (water) temperature, which is an average high estimate for the 2050 scenarios and an average low estimate for the 2100 scenarios (KNMI, 2007). Potential changes in future risk score were assessed without considering the effects of future management intervention. 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). It 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. Species environmental impact 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 the invasion stage: (0) absent, (1) isolated populations, (2) restricted range, and (3) widespread.

Table 2.5: Definitions of criteria for risk classifications per section used in the ISEIA-protocol (Branquart, 2007).

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 colonize remote places. Natural dispersal rarely exceeds more than 1km 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 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 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.

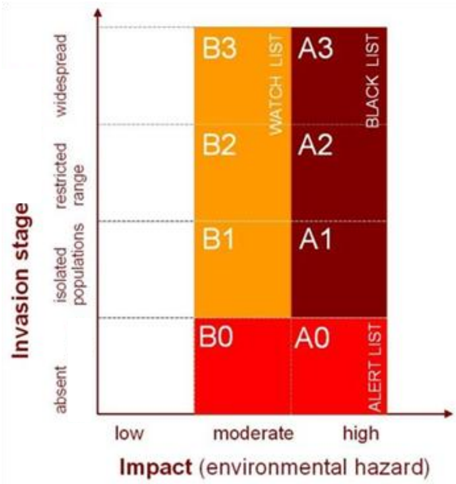

Figure 2.1: BFIS list system to identify species of most concern for preventive and mitigation action (Branquart, 2007; ISELA, 2009).

2.5 Risk management

In the Netherlands, populations have already been recorded for most of the species examined. Therefore, information on how to manage potentially invasive species is important to reduce the occurrence of the species when negative impacts occur. For each species the following three topics were discussed: prevention of introduction, elimination of populations, management of populations. Based on a literature review and the experience of project partners, different management options are discussed which are relevant to the different species examined.

3. ARCTIC CHAR (*Salvelinus alpinus*)

3.1. General species description

3.1.1 Nomenclature and taxonomical status

Order	Salmoniformes
Family	Salmonidae
Genus	*Salvelinus*
Species	*Salvelinus alpinus* Linnaeus, 1758
Common name	Arctic char (Dutch: beekridder)
Synonym	Charr

3.1.2 Species characteristics and identification

Figure 3.1: Arctic char (Salvelinus alpinus) from Eidfjordvatnet, Norway (length, 20cm) (blikonderwater.nl).

The Arctic char (*Salvelinus alpinus*) shows a large variation in phenotypic expression and ecology. Large differences in morphology and coloration exist between populations. The species has hardly any uniquely distinct characteristics that distinguish it from other species within the genus *Salvelinus* (Kottelat & Freyhof, 2007). One of the few external distinguishing features is the presence of 23 to 32 gill rakers (Morrow, 1980). An internal distinguishing feature is the presence of 37 to 75 pyloric caeca (Morrow, 1980). Arctic char has, in general, a dark brown or green back, lighter sides and a pale belly. The sides and back are sprinkled with pink to red spots. The largest spots, that lie along the lateral line, are usually larger than the pupil of the eye (Morrow, 1980). The base colour of the fins is dark in adults and pale in juveniles. The forward edges of pectoral, pelvic and anal fins, and sometimes the caudal fin, have a narrow white margin. Spawning adults, especially males, are brilliant orange-red to bright red in color on the ventral side and pectoral, pelvic and anal fins. The young have about 11 dark parr marks on each side of the body (Morrow, 1980).

3.1.3 Life cycle

Habitat

The Arctic char exhibits a high degree of habitat flexibility and occupies multiple ecological niches in flowing waters, seas, and lakes (Klemetsen *et al.*, 2003; Berg *et al.*, 2010; Eloranta *et al.*, 2013). Arctic char has the most northerly occurrence of any freshwater and anadromous fish species. The species is mainly lacustrine, living in oligotrophic and ultra-oligotrophic lake habitats. Within the northernmost part of its natural distribution range, the fish is anadromous and features numerous populations that migrate between sea and fresh water. In the southern part of its range, it is limited to fresh waters and does not migrate (Maitland *et al.*, 2007). In northern and alpine lakes, Arctic char is often the only fish species present (Klemetsen *et al.*, 2003).

In lakes, Arctic char can live in all major habitats and depth zones (as deep as 280 m) and in all sizes of lake, from very small (e.g., ponds) to very large (Klemetsen *et al.*, 2003). Suitable substrate often consists of fine sand, gravel, and stones; vegetation is scarce (Berg *et al.*, 2010). Juveniles are mainly found in near-shore habitats, due to the lower risk of predation (Byström *et al.*, 2004), and prefer low flow velocities (Sinnatamby *et al.*, 2012).

Water temperature and dissolved oxygen are important habitat characteristics for Arctic char. The species lives in cool or cold, oxygen rich water and can live and feed under ice cover in lakes and streams (Klemetsen *et al.*, 2003). Therefore, in the southern, temperate parts of its distribution range, the species is confined to a selection of deep, cold lakes (Igoe *et al.*, 2013). The species does not occur in shallow, low-altitude lakes because temperatures are too high (Elliott & Elliott, 2010). See table 3.1 for the environmental tolerance values of Arctic char.

Table 3.1: Tolerance of Arctic char (Salvelinus alpines) to different environmental factors.

Environmental factor	Value	Life stage	Remarks	Reference
Stream velocity	0-10cm/s	Juveniles	Preferred range	Sinnatamby *et al.* (2012)
Temperature	6.1 – 9.4°C	General	Mean summer water temperature range in which the species was recorded in Sweden, Canada and Baffin Island	Byström *et al.* (2004); Dick *et al.* (2009); Sinnatamby *et al.* (2012)
	8°C	Eggs	Upper tolerance value	Elliott & Elliott (2010)
	5°C	Eggs	Only few eggs survive water temperatures above this value	Elliott & Elliott (2010)
	27°C	Alevins, parr and smolt	Upper tolerance value	Elliott & Elliott (2010)
	22-23°C	parr and smolt occurs	Stress occurs above this value	Elliott & Elliott (2010)
	14.4 °- 17.2°C	Juveniles and adults	Optimal range for growth	Elliott & Elliott (2010)
	15.1°C	Juveniles and adults	Peak in growth rate	Lyytikäinen *et al.* (1997)
Oxygen	>2.0-3.0mg/l	General	Lower critical value	Elliott & Elliott (2010)
pH	6.4 – 8.9	General	Range in which species was recorded in Sweden, Canada and Baffin Island	Byström *et al.* (2004); Dick *et al.* (2009); Sinnatamby *et al.* (2012)

Reproduction

Generally, the Arctic char spawns in the southern parts of its range in autumn and winter, during late September to December (McCarthy, 2007; Elliott & Elliott, 2010). Moreover, spring-spawning has been recorded at lake Windermere in the UK (Winfield *et al.*, 2008). Spawning occurs every two, three, or even four years (Klemetsen *et al.*, 2003). Fecundity may range from only 13 eggs per small lacustrine female to as many as 9200 eggs per large anadromous female (Klemetsen *et al.*, 2003). However, McCarthy (2007) reported a rather low fecundity in Welsh populations of 100-800 eggs per female and sexual maturation at 3-6 years (Muus & Dahlström, 1968).

Spawning generally takes place in well-oxygenated lakes at shallow depths of less than 5 m, but can also occur in rivers (Klemetsen *et al.*, 2003; Elliott & Elliott, 2010). Research on the spawning habitat of the Arctic char in Irish lakes showed that the fish has a preference for relatively sheltered areas with specific physical characteristics. Spawning habitat was found in long, narrow strips at a maximum depth of 1.24 m, parallel to the shore. Coarse mineral substrate was preferred, with a mean size ranging from 3.5 to 10cm in diameter. Deep, large interstitial spaces are utilised for laying to avoid egg predation by other fish species (Low *et al.*, 2011). Low *et al.* (2011) also summarize the great variety of spawning habitat found in other studies. Spawning habitats feature depths ranging from the very shallow (only 30cm) to the very deep (up to 120 m) and substrate sizes ranging from 1-cm-diameter gravel up to 100-cm-diameter cobbles and boulders (Low *et al.,* 2011). Eggs are laid deep within the substrate and hatch in spring (Muus & Dahlström, 1968).

Arctic char can hybridize with the related brook trout (*Salvelinus fontinalis*) and lake trout (*Salvelinus namaycush*) (Dumas *et al.*, 1992; Wilson & Bernatchez, 1998; Soes & Broeckx, 2010). In aquaculture hybrids between Arctic char and brook trout are often bred and referred to as Sparctic charr or Sparctic trout (Great Britain) and Elsässer Saibling (Germany) (Jansson, 2013). The hybrids grow faster than either parent species, are more robust, and thus popular for sports fisheries (Jansson, 2013). Elsässer saibling are fertile and are able to reproduce and back cross with their parent species leading to introgression (Gross *et al.*, 2004; Soes & Broeckx, 2010). In Germany hatcheries 3 to 100% of the stock of brook trout were hybrids (Gross *et al.* 2004). Hybrids of Arctic char and brown trout (*Salmo trutta*) have been described, but mortality is high and fertility is limited (Buss & Wright, 1958).

Diet

The Arctic char has high dietary flexibility (or plasticity), with a wide and flexible trophic niche (Eloranta *et al.*, 2011). Its feeding strategy also depends on prey types, resource variation, and competition (Jansen *et al.*, 2001; Klemetsen *et al.*, 2003). It changes its diet in response to environmental changes and habitat modification, such as climate change, eutrophication, and population increase of other fish species (Corrigan *et al.*, 2011).

The diet of the Arctic char consists of all major prey types within its habitat including both invertebrates and small vertebrates. It is adapted to feed on all types of prey on the water surface, in the pelagic zone and in the benthic zone (Klemetsen *et al.*, 2003). According to Muus & Dahlström (1968), four different morphs of the Arctic char filling different niches and showing different feeding and spawning strategies live in alpine lakes. One of these strategies is cannibalism (Klemetsen *et al.*, 2003; Finstad *et al.*, 2006; Dick *et al.,* 2009; Berg *et al.*, 2010). The sizes at which Arctic char can become cannibalistic range from 150 mm (Berg *et al.*, 2010), 265 mm (Finstad *et al.*, 2006), to 300 mm (Dick *et al.*, 2009), and predilection to cannibalism increases with size (Dick *et al.*, 2009) and latitude (Klemetsen *et al.*, 2003). Small Arctic chars mainly eat invertebrates, including zooplankton, chironomids, and caddisflies (Finstad *et al.*, 2006; Berg *et al.*, 2010). Chironomids and microcrustaceans are the main prey items of juveniles (Klemetsen *et al.*, 2003).

Predators

Known predators of the Arctic char are cannibalistic conspecifics (Klemetsen *et al.*, 2003; Finstad *et al.*, 2006; Dick *et al.* 2009; Berg *et al.*, 2010) other fish species and diving birds (Klemetsen *et al.*, 2003). Within its Arctic and alpine distribution range, predators are relatively scarce (Klemetsen *et al.*, 2013). In the southern parts of its distribution range, several fish species have been introduced which have a pronounced effect on Arctic char populations due to predation, for example pike (*Esox lucius*) (Winfield *et al.*, 2008). Eggs are predated by several fish species including European eel (*Anguilla anguilla*) and brown trout (*Salmo trutta*) (Low *et al.*, 2011). In the Netherlands, the potential predators of the Arctic char consist of several fish species, such as European eel, pike, perch (*Perca fluviatilis*), pike-perch (*Sander lucioperca*) and (diving) birds, such as the cormorant (*Phalacrocorax carbo*).

Parasites and diseases

Many parasite and diseases have been described for the Arctic char in literature (table 3.2). Much of the available literature is of Scandinavian origin.

Table 3.2: Parasites and diseases described in Arctic char (E = exotic for the Netherlands, N = native for the Netherlands; Effect = disease/mortality in this species, if effect on other fish species is known (OS), this is also mentioned)

Parasite/disease	Location	Reference	Effect
Crepidostomum farionis (E?) *Phyllodistomum conostomum (E?)* *Proteocephalus exiguus (probably N)* *Cyathocephalus truncatus (E?)* *Eubothrium salvelini (E?)* *Diphyllobothrium ditremum (probably N)* *Diphyllobothrium dendriticum (probably N)* *Capillaria salvelini (E?)* *Cystidicola farionis (probably N)* *Philonema oncorhynchi (E?)* *Salmincola edwardsii (E?)*	Norwegian lakes	Kennedy, 1978	Low to medium OS?
Crepidostomum metoecus (E?)	N-Norway	Knudsen *et al.*, 1997	Low to medium OS?
Cryptocotyle lingua Creplin 1825 *(probably N)*	N-Norway, sea water	Kristofferson 1988	Low to medium OS?
Diphyllobothrium ditremum *Eubothrium salvelini* *Proteocephalus exiguus* (see above)	N-Sweden	Hammar, 2000	Low to medium OS?
Tetraonchus alaskensis (Monogenea) (E?) *Proteocephalus longicollis* (Cestoidea) *(probably N)* *Cystidicola cristivomeri* (Nematoda) (E?)	Canada	Beverley-Burton, 1978	Low to medium OS?
Protozoa: *Spironucleus salmonis (E?)* *Apiosoma* sp. (E?) *Capriniana piscium (E?)* *Trichodina* sp. (N, endemic) *Dermocystidium branchiale (E?)* *Chloromyxum truttae (E?)* *Myxidium truttae (E?)* *Myxobolus Arcticus (E?)* *M. cerebralis (probably N)* *M. neurobius (E?)*	Freshwater lakes Iceland	Kristmundsson & Richter, 2009	Low to medium OS?

Sphaerospora truttae (E?) Helminths: *Apatemon gracilis (E?)* *Diplostomum* sp. (N) *Eubothrium crassum* (N)			
Additionally to most of Norway: *Echinorhynchus gadi* (N) *Metechinorhynchus lateralis (E?)* *Bothrimonus sturionis (E?)* *Proteocephalus longicollis (probably N)* *P. tumidocollus (E?)* *Lepeophtheirus salmonis* **(salmon lice)**(E?) *Salmincola carpionis (E?)* *Brachyphallus crenatus (probably N)* *Bunodera luciopercae (probably N)* *Derogenes varicus (E?)* *Lecithaster gibbosus (probably N)* *Neascus* sp. (E?) *Phyllidostomum umblae (E?)* *Phyllodistomum limnosa (E?)* *Gyrodactylus salaris* **(gill worms)**(*E?)* *Tetraonchus alaskensis (E?)* *Anisakis simplex* (N) *Capillaria salvelini (E?)* *Contracaecum sp. (E?)* *C. osculatum/phocae (E?)* *Cystidicola cristivomeri (E?)* *Cystidicoloides tenuissima (E?)* *Hysterothylacium aduncum (E?)* *Philonema agubernaculum (E?)* *Pseudocapillaria salvelini (E?)* *Pseudoterranova decipiens (probably N)*	Finland:	Voutilainen, Ari, 2009 (review)	Low to severe (the latter see the underlined species) Underlined species:OS: severe effect on salmon
Tetracapsuloides bryosalmonae (Proliferative Kidney Disease)(E?)	Scotland	Turnbull, 1992	Low to severe OS: salmonids: may be severe
BACTERIA			
Aeromonas salmonicida subsp. *smithia (E?)*	Austria:	Goldschmidt-Clermont *et al.*, 2009	Low to severe OS: Low to severe
Flavobacterium branchiophilum (the causative agent of bacterial gill disease (BGD) (probably N) Amoebae similar to those responsible for nodular gill disease (NGD) (E?)	Canada	Speare, 1999	Low to severe OS: Low to severe (salmonids)
Renibacterium salmoninarum (Bacterial Kidney Disease (BKD)) (probably N) *Flavobacteriujm columnare* (columnaris disease)(N) *Aeromonas salmonicida* subsp. *salm* (furunculosis)(N)	Canada Finland Sweden & Finland	USGS, 2003/2012; Souter *et al.*, 1987	Low to severe OS: Low to severe (salmonids, carp)
Aeromonas salm.salm. (furunculosis)(N) *Aeromonas salm.* atypical (carp erythrodermatitis)(N) *Vibrio* spp. (N) *Yersinia ruckeri* (enteric redmouth disease) (endemic) *Renibacterium salmoninarum* (Bacterial Kidney Disease (BKD)) (probably N)	Scotland	Turnbull, 1992	Low to severe OS: Low to severe (salmonids, carp)
VIRUSES			
IPN: asymptomatic (N) Pancreas Disease (Salmon Alpha Virus, SAV)(E?) Probably sensitive to Viral Haemorrhagic Septicaemia Virus (VHSV) and Infectious Haematopoietic Necrosis Virus (IHNV)(N)	Scotland	Turnbull, 1992	Low Severe OS: Low (IPN) to severe (other viruses, to salmonids)

3.1.4 Distribution

Distribution and habitat in natural range

The Arctic char has a circumpolar distribution in the Holarctic (Klemetsen *et al.*, 2003; Berg *et al.*, 2010) and is found throughout arctic, sub Arctic, boreal, and temperate climate regions. The largest populations occur in Scandinavia (mainly Sweden and Norway), followed by Canada, Russia, Iceland, Greenland, USA, UK and Ireland. Furthermore, the species lives in pre-alpine and high-altitude lakes in the Alps (Klemetsen *et al.*, 2003; Maitland *et al.*, 2007; Achleitner *et al.*, 2009).

Distribution outside natural range

The Arctic char has been introduced into many lakes in central Europe (Brunner *et al.*, 1998; Klemetsen *et al.*, 2003) and the UK (Maitland *et al.*, 2007; McCarthy, 2007), mainly within its natural distribution range. Introductions occurred for commercial reasons or as part of conservation actions (Englbrecht *et al.*, 2002; Maitland *et al.*, 2007). The consequences of the stocking practices, often with distant genetic material, are diverse. In Lake Königssee (Germany), stocking did not influence genetic integrity of the native population. However, an example from lake Starnberger See (Germany) shows that the entire native population can be substituted by the stocking population, which may result in individuals that are less capable of dealing with stochastic events such as pollution (Englbrecht *et al.*, 2002).

Besides introductions aimed at stocking and conservation within its natural distribution range, Arctic char has been introduced in areas outside of its natural range, namely in France, former Yugoslavia (now Serbia), and on the Kerguelen Islands (Jamet, 1995; Machino, 1995; Klemetsen *et al.*, 2003; Lenhardt *et al.*, 2011; Lécomte *et al.*, 2013). Introduced populations in the Pyrenees are considered to be the southernmost occurrences of the species (Machino 1995; Klemetsen *et al.*, 2003). Introduced populations in Lake Pavin (France) date back to 1860 and the species currently occurs in several lakes in the region (Jamet, 1995; Machino, 1995). Introduction to former Yugoslavia took place in 1943 for sport fishing and to fill a perceived vacant niche. The species acclimatized relatively well and was able to expand through natural reproduction. However, the species is recorded in only two reservoirs, which comprise about 1.3% of the total area of Serbia. In one reservoir a stable population exists and in the other reservoir only a single record exists (Lenhardt *et al.*, 2011). In 1991, introductions occurred at two locations on the Kerguelen Islands in the Southern Ocean. A total of 2808 parr were released. At one location a population established, at the other the introduction failed. Currently, two established populations are known, the second resulting from natural colonization originating from the first established population (Lecomte *et al.*, 2013).

Distribution in the Netherlands

According to "A risk analysis of exotic trout in the Netherlands" (Soes & Broeckx, 2010), Arctic char does not occur in the Netherlands. However, Elsässer saibling does occur here. Elsässer saibling is the result of hybridization between Arctic char (*Salvelinus alpinus*) and brook trout (*Salvelinus fontinalis*) (Reiter, 2006). This hybrid is known to exist at several Dutch trout farms and also occurs in the wild in the Netherlands. In 2010, an Elsässer saibling was caught in the river Roer near Roermond, which probably originated from a trout farm in the upstream German sections of the river Roer (Soes & Broeckx, 2010). The hybrid Elsässer saibling also occurs in the Oostvoornse Meer near Rotterdam. The Oostvoornse Meer is a lake popular for diving and fishing. Since 1984, several trout species have been introduced here yearly (Sportvisserij Zuidwest Nederland, 2012). Introductions to this lake consisted of the hybrid Elsässer saibling rather than the Arctic char (Haarsma, 2012). The species spawns in the Oostvoornse meer, however, reproduction is not successful due to high salinity (Moquette, 2012). There are reports of Elsässer saibling stocking in other Dutch trout fishing lakes; e.g. de Blauwe Hoef (near Tilburg) and Flevonice (near Biddinghuizen) (Vis-gids.nl, 2013; VNV, 2010).

3.2 Risk assessment

3.2.1 Probability of entry

Pathways of introduction
Not applicable to Arctic char, as it does not occur in the Netherlands. The hybrid Elsässer saibling is associated with Dutch trout farms and fishing ponds (Soes & Broeckx, 2010). The hybrid has been introduced in lakes for recreational purposes, for example in the Oostvoornse meer (Sportvisserij Zuidwest Nederland, 2012).

Pathways of future introduction
The potential for introduction of the Arctic char to the Netherlands is considered to be relatively low. Soes & Broeckx (2010) examined the presence of trout and char species in farms and fishing ponds. Five out of a total of 55 farms reported the stocking of Arctic char. However, these were probably all examples of Elsässer saibling, as stocking of Arctic char in the Netherlands is very unlikely due to the low temperature and high oxygen requirement of the fish (Soes & Broeckx, 2010).

Another possible pathway of introduction is for the purpose of recreation, as is the case with Elsässer saibling and other trout species in the Oostvoornse Meer (Sportvisserij Zuidwest Nederland, 2012). Although it seems that other trout species and hybrids are preferred over the Arctic char, it is not unlikely that Arctic char may become a target species for such introductions in the near future.

3.2.2 Probability of establishment

Habitat suitability
Arctic char is considered a habitat generalist and can easily switch from one niche to another (Klemetsen *et al.*, 2003; Berg *et al.*, 2010; Eloranta *et al.*, 2013). However, there are several aspects of Dutch aquatic habitats that will seriously limit the establishment chances of this species.

Firstly, cold and oxygen-rich water is a strict requirement of the species. In the southern, temperate parts of its distribution range, the Arctic char is confined to deep, cold lakes (Igoe *et al.*, 2013). Due to relatively high temperatures, the species does not occur in shallow, low-altitude lakes (Elliott & Elliott, 2010). Several studies indicate that the species is already struggling for survival at the southern edge of its range (Elliott & Elliott, 2010; Low *et al.*, 2011; Hein *et al.*, 2012) due to climate change (Maitland *et al.*, 2007; Winfield *et al.*, 2010; Hein *et al.*, 2012) and eutrophication in warmer climates (Klemetsen *et al.*, 2003).

Besides cold and oxygen-rich water, the absence of large fish communities containing certain other species is important for the survival of Arctic char as it is vulnerable to predation and competition (Hein *et al.,* 2012). Reductions in Arctic char abundance have been associated with roach (*Rutilus rutilus*), brown trout (*Salmo trutta*), and pike (*Esox lucius*) (Maitland *et al.*, 2007; Winfield *et al.*, 2011). Moreover, eutrophication and pollution have a large impact on Arctic char at the southern end of its distribution (Maitland *et al.*, 2007; Winfield *et al.*, 2008).

These aspects led Soes & Broeckx (2010) to conclude that "the […], Arctic char, […] are not expected to be able to establish in the Netherlands". However, another area in the temperate climate, Lake Pavin in France, seems to be suitable for Arctic char colonisation due to its large mean depth (54.9 m; Jamet, 1995). A large mean depth enables the species to exploit the low temperatures that exist there. Also, Sportvisserij Zuidwest Nederland (2012) states that the Oostvoornse meer is suitable for certain trout species due to its 43 m depth featuring cool, oxygen-rich water.

In conclusion, the probability of establishment of Arctic char in large parts of the Netherlands is relatively low. This is because most aquatic habitats feature unsuitably high temperatures and/or low oxygen levels. A small selection of deep lakes without large fish communities may be suitable for the Arctic char.

The hybrid Elsässer saibling is more tolerant to higher water temperatures and is known to survive the Dutch climate. Attempted spawning has been recorded in the Oostvoornse meer, but egg development failed due to the high salinity (Moquette, 2012). Survival of this hybrid and successful spawning could occur in deep, cold, oxygen rich lakes with a lower salinity.

Propagule pressure

The only available evidence for the effect of propagule pressure on the Arctic char is from the Kerguelen Islands where a total of 2808 parr were released at two locations. One of the two introduced populations established successfully (Lecomte *et al.*, 2013).

Population development

The category population development is not applicable to Arctic char in the Netherlands as it has not been recorded here. Introduction into former Yugoslavia resulted in a single stable population (Lenhardt *et al.*, 2011). On the Kerguelen Islands, natural colonization enabled an introduced population to successfully colonize a second watershed (Lecomte *et al.*, 2013). Introduction of the species to Lake Pavin, France, resulted in the occurrence of the species in several lakes in the region (Jamet, 1995; Machino, 1995). However, little is known about the population development and colonization at these introduction sites. According to the cited literature, the species does not appear to be invasive at these locations.

Potential distribution range

Only deep lakes without large fish communities may be suitable for Arctic char colonisation. With ongoing climate change, it is expected that the species will have a limited chance of survival at the edge of its southernmost distribution (Maitland *et al.*, 2007; Winfield *et al.*, 2010; Hein *et al.*, 2012). Therefore, climate change which leads to a higher water temperature will probably reduce the suitability of aquatic habitats in the Netherlands for the Arctic char and decrease the chances that the species will establish.

3.2.3 Probability of spread

Species features that encourage spread

The Arctic char is anadromous within the northern part of its natural distribution range, migrating between sea and fresh water (Maitland *et al.*, 2007). Yearly migration is very common, even within lakes and river systems (Klemetsen *et al.*, 2003). This demonstrates the ability of the species to migrate large distances. The Arctic char generally migrates about 25km, but distances of up to 940km are also possible (Klemetsen *et al.*, 2013).

Nevertheless, the rate of Dutch colonisation is expected to be inhibited by the specific water temperature and oxygen requirements of the species , which are not often met in the Netherlands. Moreover, the species is very vulnerable to a variety of anthropogenic pressures. Maitland *et al.* (2007) list pollution, eutrophication (e.g., by reduction of oxygen levels), acidification (failure of recruitment of new age classes), afforestation, engineering (e.g., hydroelectric schemes), exploitation, aquaculture, introduction of alien species (e.g., roach *Rutilus rutilus*), and climate change as factors that will limit the colonisation of the Arctic char. However, the characteristics of the hybrid Elsässer Saibling are more suitable for Dutch environmental conditions. Therefore, the hybrid displays a higher potential for spread through the Dutch water system.

Spread in climatically similar countries
Only a few introductions of Arctic char have been recorded worldwide. Colonization has been successful in one watershed in the Kerguelen Islands (Lecomte *et al.*, 2013). After introduction to the French Lake Pavin, Arctic char spread to several lakes in the region (Jamet, 1995; Machino, 1995). However, underlying mechanisms of spread were not discussed in these articles.

Potential spread in Netherlands
The potential for spread in the Netherlands cannot be determined on the basis of the few recorded foreign introductions. Suitable habitat is limited in the Netherlands and the species is vulnerable to anthropogenic influences. Therefore, the colonization rate of Arctic char is expected to be limited and the potential spread is low. However, the colonization rate of the hybrid Elsässer saibling could be higher due to its greater tolerance to Dutch environmental conditions.

3.2.4 Vulnerable areas

The only potentially suitable habitat type for the Arctic char in the Netherlands are deep lakes, where the fishes habitat requirements of cold and oxygen rich water may be met. However, as the species is not a strong competitor (see 2.5.1), it is doubtful that any area containing protected species will be suitable for Arctic char establishment. Cold, deep, oxygen rich lakes could be suitable for the introduction and establishment of the hybrid Elsässer saibling.

3.2.5 Negative impact of introduction

Ecological impact
To date, no occurrences of ecological impact following the introduction of Arctic char have been recorded. Moreover, no indications of the invasiveness of this species were found in literature. Lenhardt *et al.* (2011) state that the fishes suspected impact on native species, based on its introduction to Serbia, was categorized as "established existence without apparent impact". Moreover, no negative effects on fish populations native to the Netherlands have been recorded (Lenhardt *et al.*, 2011).

The Arctic char is considered to be a generalist feeder (Eloranta *et al.*, 2013). It is able to switch between different prey types and feeding strategies, depending on competition and resource availability. n its natural range it is able to alter zooplankton communities, affecting the size range of prey populations and eliminating certain plankton species (Jansen *et al.*, 2001; Klemetsen *et al.*, 2003). Therefore, it is not expected that Arctic char will feed specifically on endangered species. Moreover, such effects have not been recorded at its introduction sites.

Within its natural range, habitat and niche segregation due to competition occurs between the Arctic char and other species such as brown trout (Jansen *et al.*, 2001; Klemetsen *et al.*, 2003;

Eloranta *et al.*, 2013). Arctic char show high niche flexibility in competition with other species and are known to be poor resource competitors against sympatric fish, showing little aggression (Klemetsen *et al.*, 2003; Eloranta *et al.*, 2011). Moreover, Arctic char are strongly impacted by the introduction of new fish species, especially in the southernmost parts of its natural distribution (Winfield *et al.*, 2010). Therefore, it is not expected that the Arctic char, a fish exhibiting a high vulnerability to species interactions (Hein *et al.*, 2012), causes significant ecological damage due to competition with native species.

Hybridisation and introgression of Arctic char occurs in association with brook trout (*S. fontinalis*) (Hammar *et al.*, 1991; Dumas *et al.*, 1992; Gross *et al.*, 2004; Lecomte *et al.*, 2013) and lake trout (*S. namaycush*) (Wilson & Hebert, 1993; Wilson & Bernatchez, 1998). Hybrids of brook trout and Arctic char are also known as Elsässer saibling (Reiter, 2006). Arctic char have been crossed with brook trout for use in northern aquaculture (Dumas *et al.*, 1992) and there is also evidence of natural hybridisation between these species (Hammar *et al.*, 1991). Natural hybridisation also occurs between Arctic char and lake trout (Wilson & Hebert, 1993). Gross *et al.* (2004) advise that 'release or escape of introgressed individuals from hatcheries into natural water bodies should be avoided in order to protect the biological diversity and genetic integrity of native fish populations'. Hybridisation with native Dutch fish could occur with the native brown trout (*Salmo trutta*) (Jansson, 2013), but introgression is unlikely as mortality among hybrids is high and fertility limited (Buss & Wright, 1958; Jansson, 2013).

Amundsen *et al.* (2012) describe the introduction of Arctic char to a sub Arctic lake and concluded that new parasites, in particular trophically transmitted species were introduced and had a prominent role in the structure and function of the changed food web. The species causes local changes (< 80%) in population abundance, growth or distribution of one or more native species and transmits sub-lethal diseases. The Arctic char carries the salmon lice *Lepeophtheirus salmonis* (Exotic? =E?) and trematode gill worm *Gyrodactylus salaris* (E?), present in Scandinavia, which are internationally important threats causing big economic losses in the aquaculture of Atlantic salmon (*Salmo salar*). These two parasites cause severe declines (> 80%) of local salmonid populations. These declines are irreversible, especially in the case of salmon. Therefore, the impact of the Arctic char on aquaculture and local salmonid populations may be high.

Economic impact
No negative economic impacts related to the introduction of the Arctic char have been recorded in any country. However, two parasites may have a severe impact on aquaculture and local (cultivated) salmonid populations. Economic impacts are not expected following possible introduction of this species to the Netherlands.

Social impact
No negative social impacts resulting from the introduction of the Arctic char have been recorded in any country or are expected if the species were to be introduced to the Netherlands.

3.2.6 Positive impact of introduction

Ecological impact
Ecological impacts will probably not occur as the Arctic char is a weak competitor and the effects of predation by the Arctic char on native species is expected to be limited.

Social and economic impact
Several authors associate Arctic char with economic benefits. Arctic char may be important as a commercially exploitable species (Achleitner *et al.*, 2009; Berg *et al.*, 2010; Elliott & Elliott, 2010). The species may become a valuable sport fish (Klemetsen *et al.*, 2003; Berg *et al.*, 2010; Elliott & Elliott, 2010). Furthermore, the species can attract divers, thereby boosting diving tourism at certain sites (e.g., see Haarsma, 2012). Arctic char are an important species for scientific research on morphometric heterochrony and comparative behaviour involving both field studies and experimental work (Klemetsen *et al.*, 2003).

3.3 Risk classification

3.3.1 Available risk classifications

Simonovic *et al.* (2013) gives an overview of FISK scores for multiple fish species in Serbia. The risk of Arctic char is classified as low (table 3.3). However, Simonovic *et al.* (2013) gives no rationale for the allocation of this risk classification.

Table 3.3: Overview of risk classifications previously performed for the Arctic char (Salvelinus alpinus).

	Serbia
Scope	Risk assessment
Method	FISK
Risk classification	0 (Low)
Source	Simonovic *et al.* (2013)
Additional information	Classified as non-invasive

3.3.2 Current situation

Expert consensus scores
The total risk score attributed to Arctic char was 6 out of a maximum risk score of 12 (table 3.4). This results in an overall classification of low risk for this species.

Table 3.4: Consensus scores and risk classifications for Arctic char (Salvelinus alpinus) in the current situation in the Netherlands.

ISEIA sections	Risk classification	Consensus score
Dispersion potential or invasiveness	medium	2
Colonization of high value conservation habitats	low	1
Adverse impacts on native species	likely	2
Alteration of ecosystem functions	unlikely	1
Global environmental risk	C - list category	6

Dispersion potential or invasiveness

The Arctic char has poor reproduction potential in the Netherlands due to a requirement for low temperatures (Klemetsen *et al.,* 2003). It is therefore unable to reproduce under current climatic conditions. However, sports fishing clubs in the Netherlands may release Arctic char which makes the low reproduction potential of this fish less relevant. Stocking of Arctic char in the Netherlands is very unlikely due to the fishes requirement for low temperatures and high oxygen levels (Soes & Broeckx, 2010). Arctic char successfully invaded a few locations outside its native range. Even though the potential reproduction of this species in the Netherlands is low, it was concluded that the dispersal potential and invasiveness of Arctic char in the Netherlands is medium.

Colonisation of high conservation value habitats

The Arctic char is not present in the Netherlands and is therefore absent from Dutch high conservation value habitats. Most habitats are not suitable for Arctic char colonisation due to cold water requirement of this species. The only possible habitat where the species may occur in the Netherlands are deep artificial lakes, for example gravel pits. However, these are not examples of high conservation value habitats. Therefore, it was concluded that the potential for Arctic char to colonise high conservation value habitats is low.

Adverse impacts on native species

No evidence of impact of predation or herbivory, interference and exploitation competition or genetic effects is available for the Netherlands. No negative effects on fish populations native to the Netherlands have been recorded (Lenhardt *et al.,* 2011). Information from comparable countries with a similar climate is also limited. However, according to expert judgement, if the species is released in high numbers resulting in high densities, then it is likely that effects related to predation and interference and exploitation competition will occur. Evidence from Scandinavia suggests that the Arctic char is able to transmit sub-lethal diseases to native fish (Kennedy, 1978; Knudsen *et al.,* 1997; Kristofferson, 1988; Hammar, 2000). It was concluded that transmission of diseases and parasites by Arctic char could potentially cause local (<80%) changes in population abundance, growth or distribution of one or more native species in the Netherlands. Hybridisation occurs with brook trout (Hammar *et al.,* 1991; Dumas *et al.,* 1992; Lecomte *et al.,* 2013) and lake trout (*Salvelinus namaycush*) (Wilson & Hebert, 1993; Wilson & Bernatchez, 1998). Hybridisation may occur however there is no evidence of this with respect to native species in the Netherlands. Therefore it was concluded that Arctic char pose a low risk to native species in the Netherlands through hybridisation. Overall, it was concluded that the potential risk for Arctic char to impact Dutch native species negatively is medium.

Alteration of ecosystem functions

There is no evidence in literature of negative ecosystem effects occurring within the Netherlands or from climatically similar countries. Therefore, expert judgement was applied to assess potential negative impacts for all subcategories (modification of nutrient cycling or resource pools, physical modifications of the habitat, modifications of natural succession and disruptions of food webs). Potential ecosystem impacts will likely be limited to food web alteration as a result of the predatory behaviour of the Arctic char. The only impact related to predation by Arctic char has been recorded in its natural range, where it is able to alter zooplankton communities (Klemetsen *et al.,* 2003). However, this evidence may not be relevant to the Netherlands due to the colder Scandinavian climate. Arctic char are generalist feeders and predation may impact macroinvertebrate and zooplankton populations, however, the level of impact is unlikely to be significant. Overall, it was concluded that it is unlikely that the Arctic char will severely alter ecosystem functions in the Netherlands.

Species classification

The species classification corresponds to the global environmental risk score of the ISEIA (table 3.4) combined with the current distribution of the non-native species within the country in question. The Arctic char is not categorised in the list of the BFIS list system (Figure 3.2). This indicates a non-native species that is absent from the Netherlands and features low environmental hazard (i.e. ecological risk: ISEIA score 6: C category).

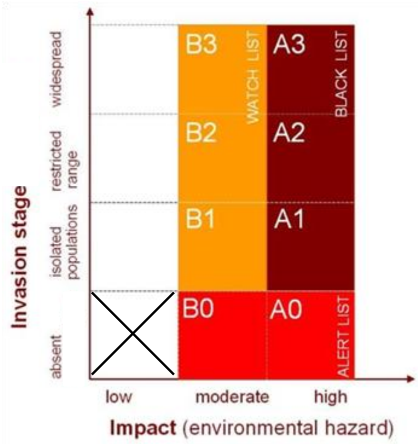

Figure 3.2: Arctic char (Salvelinus alpinus) classification according to the BFIS list system.

3.3.3 Future situation

Water temperature is an important habitat requirement for Arctic char. It lives in cool or cold water and can live and feed under ice cover in lakes and streams (Klemetsen *et al.,* 2003). In the southern, temperate parts of its distribution range, the species is confined to a selection of deep, cold lakes (Igoe *et al.,* 2013). Studies in Canada (Sinnatamby *et al.,* 2012), Sweden (Byström *et al.,* 2004), and on Baffin Island (Dick *et al.,* 2009) measured mean summer water temperatures within a range of 6.1-9.4°C where Arctic char were recorded, significantly lower than current average summer water temperatures in the majority of water bodies in Netherlands. Because of its requirement of cold water habitats, increasing water temperature as result of climate change will have a negative effect on the possibility of reproduction and colonisation of Arctic char in the Netherlands. When only temperature is considered, the overall risk score of Arctic char in the Netherlands is expected to reduce from an eight to a five and the species will likely remain absent in the Netherlands. This decrease is due to a reduction in risk associated with dispersal potential and invasiveness (table 3.5). The global risk score for Arctic char is reduced and the species will remain uncategorised in the BFIS list system.

Table 3.5: Arctic char (Salvelinus alpinus) theoretical classification according to a potential future habitat scenario.

ISEIA sections	Risk classification	Consensus score
Dispersion potential or invasiveness	low	1
Colonization of high value conservation habitats	low	1
Adverse impacts on native species	likely	2
Alteration of ecosystem functions	unlikely	1
Global environmental risk	C - list category	5

3.4 Risk management

3.4.1 Prevention of introduction

The Arctic char is absent in the Netherlands, the hybrid Elsässer saibling rarely occurs. Legal restrictions with regard to breeding and stocking of the species can prevent future introductions. Legal restrictions can also prevent further introductions and spread of the hybrid Elsässer saibling.

3.4.2 Elimination of populations

At this time, the introduction and stocking of Arctic char and the hybrid Elsässer saibling could be prevented. To eliminate populations in the wild, the release of fish after capture could be forbidden. As only the hybrid occurs at isolated locations and successful reproduction has not been observed, both measures will likely result in the elimination of the species in the near future and the costs of implementation of the measures would be minimal. Please refer to appendix 4 for general methods aimed at the elimination of populations of exotic fish.

3.4.3 Management of populations

Management of Arctic char populations in the Netherlands is currently not required. Only a hybrid of the species is present in the wild in isolated populations. This hybrid is fertile and spawning in the Oostvoornse meer has been observed but proved to be unsuccessful. Succesful reproduction could, however, occur at other locations. For locations where the Arctic char or its hybrid is unable to reproduce, a suitable management option would be to prevent stocking and to remove fish from the waterbody.

4. ASP (*Leuciscus aspius*)

4.1 General species description

4.1.1 Nomenclature and taxonomy

Order	Cypriniformes
Family	Cyprinidae
Genus	*Leuciscus*
Species	*Leuciscus aspius* Linnaeus, 1758
Common name	Asp (Dutch: Roofblei)
Synonyms	*Aspius aspius* (Linnaeus, 1758) (Kottelat & Freyhof, 2007)

4.1.2 Species characteristics and identification

Figure 4.1: Asp (Leuciscus aspius) from the Waal river (length 35cm) (digitalnature.org)

Asp have an elongated laterally compressed, streamlined body (figure 4.1). The mouth is large and superior, with a maxilla reaching beyond the front margin of the eye (Kottelat & Freyhof, 2007). The species has a silvery body with silvery grey flanks and a dark grey to green back. The large fins are grey and angular and the caudal fin is deeply forked (Spikmans & Kranenbarg, 2010). Asp have relatively small scales, 67-76 of which are situated on the lateral line (Kottelat & Freyhof, 2007). Asp can grow to a maximum size of about 80-120cm in length and 9kg in weight (Kottelat & Freyhof, 2007; Froese & Pauly, 2011). The highest reported age of asp is 16 years (Trzebiatowski & Leszczewecz, 1976).

Asp, particularly smaller specimens, are often misidentified with other cyprinid species. The most distinct feature of asp is the large superior mouth, where the maxilla reaches beyond the front margin of the eye (Kottelat & Freyhof, 2007). Small belica (*Leucaspius delineatus*) can be distinguished from the asp due to its incomplete lateral line (Spikmans & Kranenbarg, 2010). Bleak (*Alburnus alburnus*) can be distinguished from asp due to its larger scales; 45-51 on the lateral line (Kottelat & Freyhof, 2007). In contrast to asp, ide (*Leuciscus idus*) have a terminal mouth and a relatively short anal fin (Spikmans & Kranenbarg, 2010).

4.1.3 Life cycle

Habitat

Asp inhabit the open waters of large and mid-sized lowland rivers and large lakes (Kottelat & Freyhof, 2007). Asp prefer habitat near river banks, in turbulent waters, fast flows and eddies (Mann, 1996; Fredrich, 2003). The largest adults (3 to 6kg) occur in the centre of the river where flows are locally accelerated. In rivers a small fraction of asp leave the main channel to overwinter in more sheltered areas (Fredrich, 2003).

Spawning sites occur in rivers with fast flowing water at locations with a gravel substrate or submerged vegetation (Mann, 1996; Kottelat & Freyhof, 2007). Long migrations (>100km) are often made to reach spawning sites (Hladik & Kubecka, 2003; Fredrich, 2003).

Larval and juvenile asp live in more sheltered waters, (e.g. floodplains), with a slow to moderate flow velocity (Pennanen, 1991 Cfm. Mann, 1996; Scharbert & Borcherding, 2013). In a floodplain of the Danube 0+ juveniles were observed in waters where current was almost entirely absent (Copp, 1994).

There is limited literature available on the tolerance of asp for different environmental factors (table 4.1).

Reproduction

Asp reach maturity at around 38cm at the age of 3 to 7 years (Kompowski & Neja 2004; Kottelat & Freyhof, 2007; Scharbert & Borcherding, 2013). The fecundity of asp is high, a female can produce over 100,000 eggs (Scharbert & Borcherding, 2013). Kompowski & Neja (2004) found that absolute fecundity ranges between 63,044 and 324,833 eggs per female, with a positive, nearly linear relationship with the length and weight of the fish. Relative fecundity lies within the range of 35 to 107 eggs per gram of body weight. There is no significant correlation between relative fecundity and age, length or body weight (Kompowski & Neja 2004).

Spawning occurs once a year in spring, from March to May, at water temperatures ranging from 8 to 17°C (Alabaster & Lloyd, 1980 Cfm. Van Beek, 2000; Alabaster & Lloyd, 1980 Cfm. Otto & Zahn, 2008; Kottelat & Freyhof, 2007). Asp spawn in fast flowing waters on gravel and large boulders just downstream of shallow riffle areas (Mann, 1996). The species also spawns on submerged plants (Kottelat & Freyhof, 2007). Eggs are adhesive and stick to the substratum.

Diet

In Europe, asp is the only specialized piscivorous species in the family Cyprinidae (Krpo-Cetkovic *et al.*, 2010) and its mouth is adapted to inhale prey fish (Van Wassenbergh & De Rechter, 2011). Larvae of asp feed predominantly on zooplankton (Kujawa *et al.*, 1998; Specziar & Rezsu, 2009). In its early juvenile phase, asp feed on crustaceans, bottom fauna, terrestrial insects that have fallen into the water, and fish larvae (Specziar & Rezsu, 2009; Krpo-Cetkovic *et al.*, 2010). Later juvenile stages and adults feed predominantly on other fish (Specziar & Rezsu, 2009; Krpo-Cetkovic *et al.*, 2010).

The feeding behaviour of asp is opportunistic and prey-density dependent (Krpo-Cetkovic *et al.*, 2010). Prey species often found in the stomachs of asp are bleak (*Alburnus alburnus*), roach (*Rutilus rutilus*) and European smelt (*Osmerus eperlanus*) (Trzebiatowski & Leszczewecz, 1976; Kottelat &

Freyhof, 2007; Krpo-Cetkovic *et al.*, 2010). Moreover, small birds and mammals are sometimes consumed (Ruting, 1958).

Table 4.1: Tolerance of asp (Leuciscus aspius) to different environmental factors.

Environmental factor	Value	Life stage	Remarks	Reference
Stream velocity	10-20cm/s	Larvae	Rarely found outside this range	Pennanen (1991 Cfm. Mann 1996)
	0-<5cm/s	Larvae	Majority of larvae occurred in this range	Grift (2001)
	0-14cm/s	Larvae	Observed in this range	Grift (2001)
	0-30cm/s	Juvenile	Majority of juveniles occurred in this range	Grift (2001)
	0-49cm/s	Juvenile	Observed in this range	Grift (2001)
Temperature	0-10°C	Adult	Inactive	Schreckenbach (2001 Cfm. Otto & Zahn, 2008)
	18-28°C	Adult	Optimum range	Schreckenbach (2001 Cfm. Otto & Zahn, 2008)
	30-35°C	Adult	Stress	Schreckenbach (2001 Cfm. Otto & Zahn, 2008)
	30°C	Adult	Upper critical limit	Wolter *et* al. (2003 Cfm. Otto & Zahn, 2008)
	32-40°C	Adult	Upper critical limit	Schreckenbach (2001 Cfm. Otto & Zahn, 2008)
Oxygen	7.9-8.0mg/l	Adult	Optimum range (20°C)	Wolter *et* al. (2003 Cfm. Otto & Zahn, 2008)
	2.0mg/l	Adult	Lower critical limit (20°C)	Wolter *et* al. (2003 Cfm. Otto & Zahn, 2008)
Salinity			Considered an euryhaline species	Sandu *et* al. (2013)

Predators

Asp are the prey species of a variety of predators. Asp have been found in the stomachs of different predatory fish species i.e., perch, pike and European catfish (Adámek *et al.*, 1999; Rudzianskiené, 2001), otters (Lanski, & Molnár, 2003) and cormorants (Keller, 1995). Virtually no predators are capable of preying on large asp.

Parasites and diseases

Asp are susceptible to many parasites and some diseases that are similar to common carp. Table 4.2 gives an overview of reported diseases.

Table 4.2: Parasites and diseases described in asp (Leuciscus aspius) (E = exotic for the Netherlands, N = native for the Netherlands; Effect = disease/mortality in this species, if effect on other fish species is known (OS), this is also mentioned).

Parasite/disease	Location	Reference	Effect
Trichodina, Chilodonella, Ichthyobodo, Glossatella, Ichthyophthirius multifiliis (white spot), Dactylogyrus/Gyrodactylus spp., *Argulus* spp., *Ligula intestinalis,* a.o. (N)	Netherlands	Haenen, own experience	Low to medium OS: idem (various fish species)
Dactylogyrus cornu (E?)	Czech Republic	Moravec, 2012	Low to medium OS?
Myxobilatus legeri (E?)	Hungary	Molnár, 1988	Low to medium OS?
Ergasilus sieboldi (E?)	Latvia	Kirjušina & Vismanis, 2007	Low to medium OS: idem (various fish species)
Bacteria			
Aeromonas salmonicida atypical (carp erythrodermatitis) *Aer. hydrophila* *Edwardsiella tarda* *Pseudomonas fluorescens* *Flavobacterium columnare* (columnaris disease) *Flavobacterium branchiophilum* *Streptococcus* sp. *Mycobacterium* sp. (e.g. fish tuberculosis)	>Europe (N) (extrapolation of bacteria of common carp)	Jeney & Jeney, 1995 (review)	Medium to severe OS: idem (various fish species)
Viruses			
SVCV (Spring Viremia of Carp Virus) (probably) (N)	Central and Western Europe (not in UK)	Fijan *et al.*, 1971	Severe OS: severe impact on many cyprinids. Extrapolation of data from other cyprinids

4.1.4 Distribution

The native distribution of asp stretches from the Ponto-Caspian region towards central Europe and covers southern Scandinavia, the Danube drainage basin and the north western tip of Turkey. The asp was originally absent from the Rhine river basin. The asp is locally threatened by river alterations in its native range (Kottelat & Freyhof, 2007).
Asp have been introduced in the Rhine, Northern Dvina and Lake Balkhash (Asia) (Kottelat & Freyhof, 2007). Reportedly, asp have been stocked in the German Rhine since the late 1970s (Anonymous a). In Germany, asp have been introduced in fish ponds within the Roer basin, a tributary of the river Meuse (De Nie, 1996). Due to a flooding event, some asp escaped from these ponds. In 1984 the first record of asp was made in a Dutch stretch of the river Roer (De Nie, 1996; FAO, 2013). After 1990, more observations of asp were made in the Dutch as well as the German Rhine basin (De Nie, 1996; NDFF/RAVON Data, 2013; Pawlowski *et al.*, 2012). In Belgium, asp have spread through the Meuse, but are still only rarely observed here (Verreycken *et al.*, 2007).

In the early years of the 1990s, asp observations in the Netherlands were limited to the main rivers. In the period from 1995 to 2004 the number of observations quickly increased and many observations were made in Dutch canals, regional rivers and other waterways (De Nie, 1996; Gaethofs, 2004; Schiphouwer, 2013) (Figure 4.2). Currently, asp are found in many different water types, including polder ditches and closed stagnant waters (Figure 4.3). Asp spread was probably encouraged by the presence of water inlets in polder systems and (illegal) introductions. In the major rivers asp are now an abundant fish species.

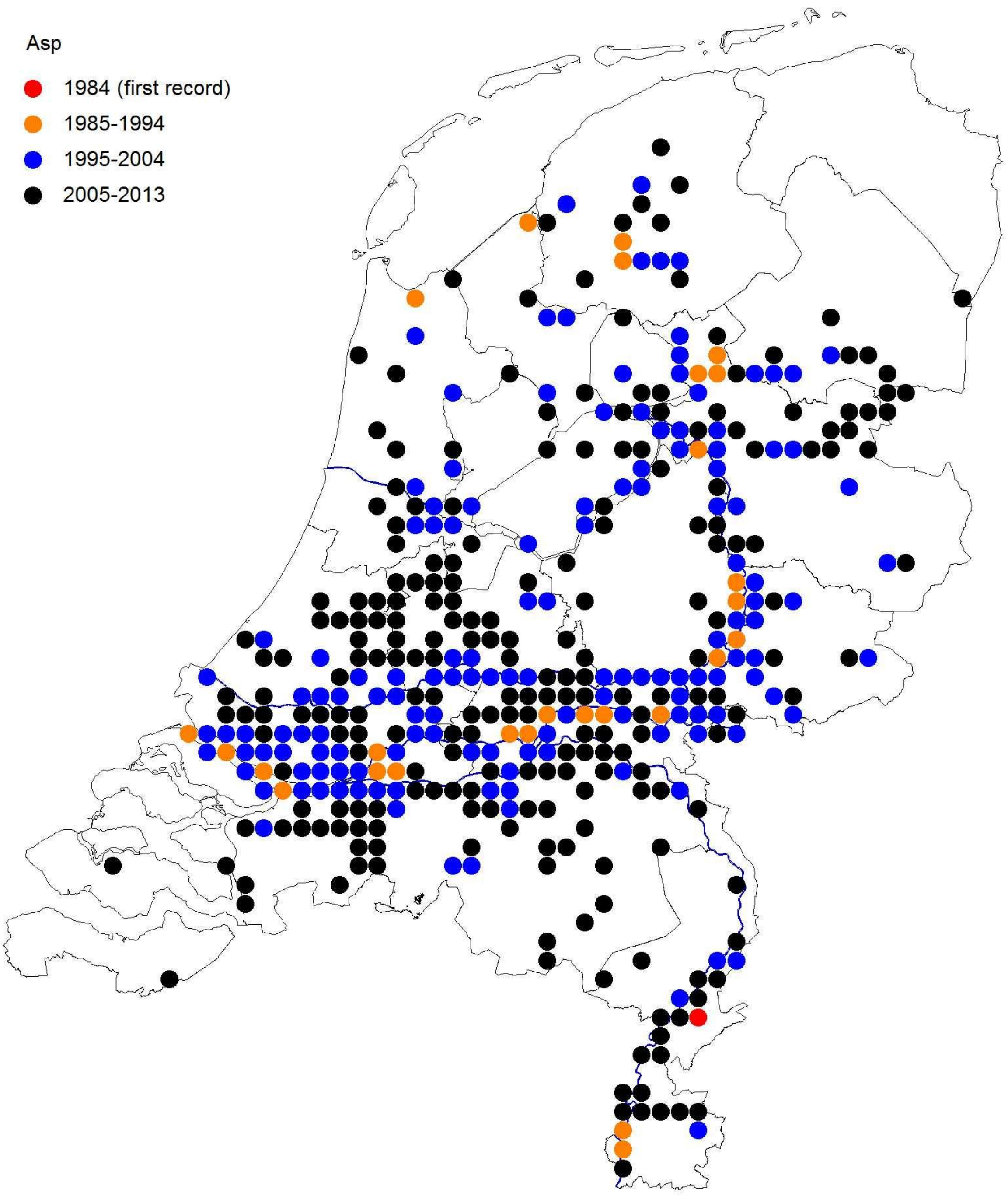

Figure 4.2: Asp (Leuciscus aspius) distribution history in the Netherlands from 1984 to 2013 (older records are plotted on top of more recent records) (RAVON/NDFF data).

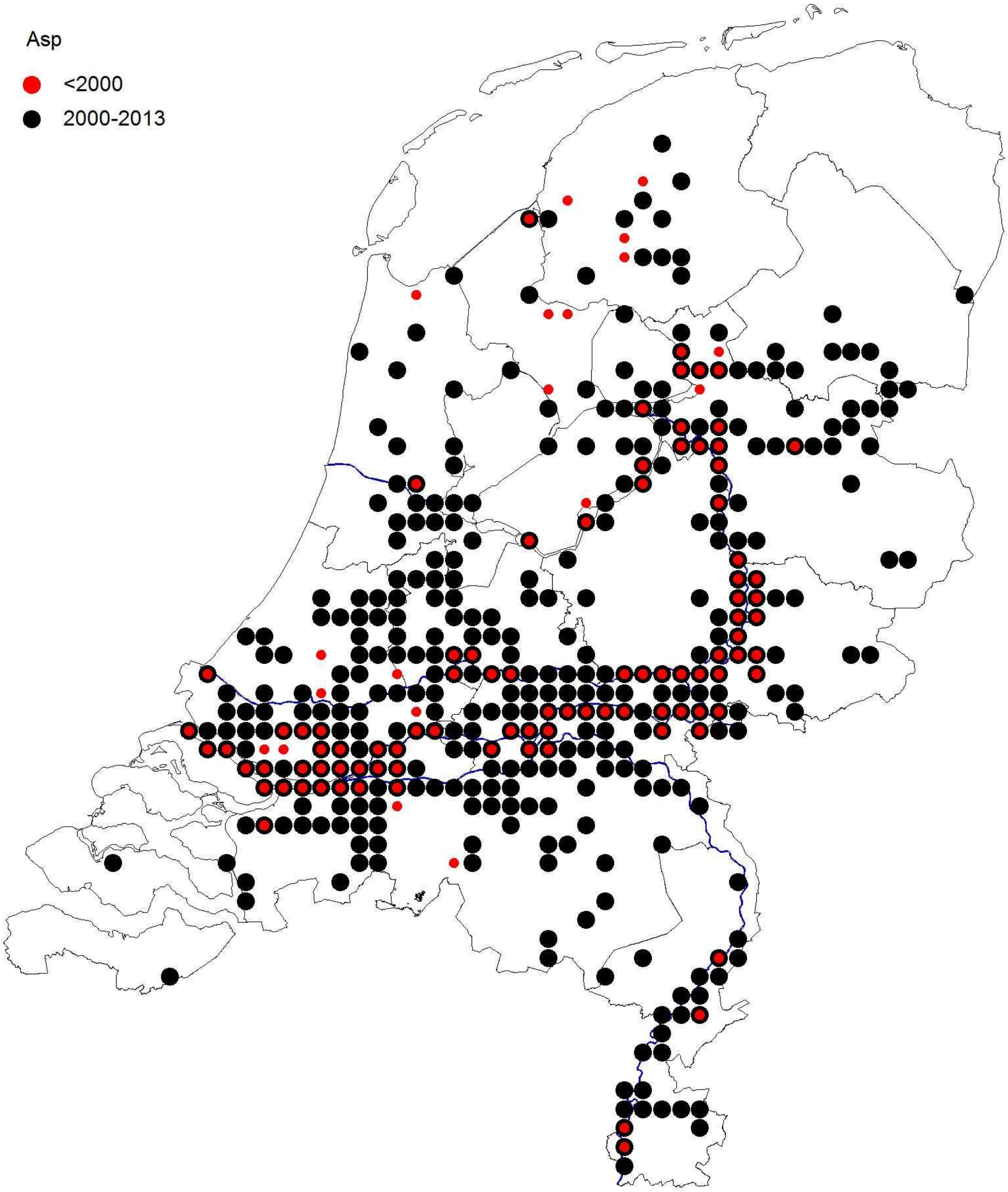

Figure 4.3: Asp distribution (Leuciscus aspius) in the Netherlands before and after the year 2000 (combined black and red dots indicate presence in both periods) (RAVON/NDFF data).

4.2 Risk assessment

4.2.1 Probability of entry

Pathways of introduction

The first observed specimen of asp in the Netherlands (1984) was imported from Scandinavia to the German drainage area of the Roer river. Asp were introduced into a fish pond at this location and subsequently escaped to the river during a flood. From here, asp were able to spread to the Dutch sections of the river system.

The second pathway used by asp to enter the Netherlands is the river Rhine. Asp of East European origin were introduced to the Rhine at the end of the 1970s (Anonymous a). Asp were rarely found in the German Rhine (at Ludwigshafen) between 1980 and 1990 (Pawlowski *et al.*, 2012). The first natural reproduction of asp in the lower Rhine was observed in the 1990s (Anonymous a). The asp became an abundant fish species in the German Rhine after 1990 (Pawlowski *et al.*, 2012). From the German Lower Rhine asp spread easily to the Dutch Rhine branches. Distribution data confirm that asp spread rapidly through the Dutch Rhine river branches in the 1990s.

Connection of the Danube drainage area to the Rhine drainage area by the Main-Danube Canal could have been a secondary pathway of introduction to the river Rhine for the asp (Schiphouwer, 2013). Like many other species (e.g. Gobiidae), this canal provided an easy pathway for asp to access the Rhine system (Leuven *et al.*, 2009). The distribution data shows a rapid increase of asp observations in the years following the opening of the Main-Danube Canal in 1992. Due to prior introductions it is uncertain if this pathway contributed to the successful introduction of asp to the Netherlands.

Pathways of future introduction
The asp is listed in the Dutch Fisheries Act. Therefore, the transport and introduction of this species to the Netherlands can occur legally. Stocking materials can be obtained from different areas (also other countries) and can be transported to many different water bodies where fishing rights apply.

The Main-Danube Canal will probably continue to be a route through which the asp travels between the Rhine and Danube river systems.

4.2.2 Probability of establishment

Habitat suitability
Adult asp can live in fresh to brackish and both standing and running waters. Asp rely on fast flowing waters for reproduction where they spawn on vegetation and gravel substrates. Larval and juvenile asp live in slow flowing waters such as floodplains and the littoral zones of rivers.

In the Netherlands, many water bodies, such as rivers, canals, lakes and larger polder ditches provide suitable habitat for adult asp. Flowing waters are required for reproduction. Water bodies suitable for reproduction are all medium to large rivers with a constant water discharge in spring. Successful reproduction is known to occur in several rivers, e.g.; the Rhine distributaries, the Meuse and tributaries of the river Mark. Other rivers with suitable conditions for successful reproduction are for example the Roer, Niers, Overijsselse Vecht, Dommel and Drentsche Aa.

Propagule pressure
After the first asp observation in 1984, it took several years before the second and third observation were made. In the beginning of the '90s there was a sharp increase in observations. At that time enough adult asp (probably originating from different populations / regions) were available in the system to establish a self sustaining population.

Population development
As shown in figure 4.2, populations of asp spread from locations in the main river branches to connected water ways such as smaller rivers and canals and subsequently further land inward. A large and widespread population of asp has developed in the Netherlands and the species is now abundant, particularly in the major rivers. Besides water bodies that are connected to the major rivers, asp are also found in a number of isolated waters. Here asp are most likely introduced due to stocking practices.

Potential distribution range
The river systems and connected water bodies in the Netherlands offer suitable habitat for asp with a connection to spawning areas. The potential distribution range will most likely be limited by gradients of salt water and migration barriers. Therefore, the potential distribution range where asp can establish through natural reproduction and migration is widespread. This range will include the northern provinces Groningen and Drenthe, but will exclude the Wadden Islands and Zeeland. When active stocking is included in the analysis, the potential distribution of the asp will include the entire inland aquatic area of the Netherlands.

4.2.3 Probability of spread

Species features that encourage spread
The asp is a fast swimmer with a high migration capacity. Distances travelled by asp can exceed 50km/day in the Elbe (Fredrich, 2003). Habitat use is variable and asp often migrate to different habitats, exploring the water system (Fredrich, 2003). Asp produce many offspring and early life stages migrate downstream with the water flow in search of slow flowing waters.

Spread in climatically similar countries
Expansion of asp distribution has occurred relatively recently. Distribution has expanded in both Germany and Belgium. In Germany, a trend of increasing observations in the Rhine occurred in the 1990s where records spread throughout the main river branch (Anonymous b; Pawlowski *et al.*, 2012). In Belgium, spread is still limited to the Meuse drainage area (Verreycken *et al.*, 2007).

Potential spread in Netherlands
Asp have already spread over a vast area in the Netherlands (Figure 4.2). Further broadening of asp distribution has, and probably will, occur facilitated by natural and manmade connections between waterways. Asp (most likely small specimens) have entered polder systems through water inlets and a further increase in distribution in polders can be expected. The potential for further spread is therefore high. Moreover, asp could easily spread throughout the entire country facilitated by stocking practices.

4.2.4 Vulnerable areas

During the past decades, many river restoration and fish migration projects have been carried out (Raat, 2001; Simons *et al.*, 2001). Migration corridors and restored habitats (e.g. river banks and floodplains) play an important role in the life cycle of native fish for feeding and reproduction. Among these are fish species of the Dutch Red List, e.g. belica (*Leucaspius delineatus*), schneider (*Alburnus bipunctatus)*, ide (*Leuciscus idus*), common dace (*Leuciscus leuciscus*), chub (*Squalius cephalus*) and nase (*Chondostroma nasus*). Many fluvial and floodplain habitats are protected under the European Habitats Directive. From data analysis (appendix 1) it is clear that asp occur in Natura 2000 protected areas very often. Asp is known to use floodplain waters bodies and other fluvial habitats (Fredrich *et al.*, 2003; Dorenbosch *et al.*, 2011), also using migration corridors to reach other areas in the river system. Therefore, many vulnerable areas not yet occupied by asp may still be colonised.

4.2.5 Negative impact of introduction

Ecological impact
No scientific research has addressed the potential negative ecological impact of asp, however, due to their piscivory, this species is likely to negatively affect populations of prey fish. These effects could be felt by threatened river fishes that share habitat with asp that could become potential prey species, e.g. nase (*Chondrostoma nasus*) and ide (*Leuciscus idus*).

Habitat and food competition between asp and native predators could occur. The asp has a visual pelagic feeding strategy and prefers areas with turbulent water for foraging. Two predators native to the Netherlands feed in different areas to the asp. The pike (*Esox lucius*) feeds in the littoral zone near vegetation and prefers more stagnant waters. The European catfish (*Silurus glanis*) has a more benthic feeding strategy and prefers deeper waters. Large specimens of perch, however, show habitat overlap with asp due to a shared pelagic and visual feeding strategy, although perch prefer stagnant to moderate flowing waters where asp can endure higher currents. Food competition between asp and the exotic pike-perch (*Sander lucioperca*) was described as negligible by Trzebiatowski (1976) in Poland. Additionally, because there is a large overlap between prey species, food competition between asp and perch, pike and European catfish could occur.

In its early life stages the asp displays a food overlap with a number of native fish species, that all feed on zooplankton and small crustaceans. Research in the Hungarian Lake Balaton has shown that the early life stages of asp are highly flexible in feeding strategy and display a dietary overlap with many species native to the Netherlands (Specziar & Rezsu, 2009). In the Netherlands the abundance of juvenile asp can be very high near river banks and in secondary channels, highly valuable habitats for the juveniles of native species (Grift, 2001; Dorenbosch *et al.*, 2011). Competition between asp and native species may therefore occur. Dorenbosch *et al.* (2011) found a strong habitat overlap between asp and ide, but no indications for direct competition between these species.

There is no literature available referring to the impact of asp introductions with regard to fish diseases. However, given the disease data contained in table 4.2, there are no indications that impacts on native fish populations will occur now or in the future.

Hybridization of asp occasionally occurs with the related ide (Berinkey, 1976; Kottelat & Freyhof, 2007). Hybridization with ide is known to take place in the asp's native range where both species co-occur (Kottelat & Freyhof, 2007). Reports by anglers confirm that hybrids regularly occur in the Netherlands. It is unknown if hybridization has an adverse impact on the ide (e.g. through introgression).

Although negative ecological impacts of the asp have not (yet) been addressed in literature, the ecological impact of this species could be relatively high because the asp is a top predator. For example, another exotic top predator, the pike-perch, exerts a high impact on other species (Chapter 10). High abundance of asp may result in the reduction of both native predator and prey species populations.

Economic impact
The European Water Framework Directive (WFD) sets ecological targets for surface water bodies. In the Dutch WFD policy goals, one criterion is related to fish stock assemblages in natural and manmade waters. If the goals of the WFD are not met before 2027, penalties from the European Union will apply.
In the Dutch WFD assessment of fish stock assemblage, asp is only considered during the scoring of natural water bodies. The asp is regarded as a eurytopic, migratory and habitat sensitive species in small rivers and a eurytopic species in freshwater lakes. In small rivers, the occurrence of asp will have a positive effect on the score, as a higher number of migratory and habitat sensitive species will result in a higher score. On the other hand, asp could influence the score by affecting the abundance of other score-relevant species. In freshwater lakes, asp will have a negative effect, as a higher biomass fraction of eurytopic fish will negatively influence the score. Overall the effect of asp on the WFD score can be regarded negligible.

Social impact
There is no available literature on the negative social impact of asp and negative impacts are not expected in the Netherlands.

4.2.6 Positive impact of introduction

Ecological impact
There is no literature available referring to the positive ecological impact of asp. Therefore the effect of positive ecological impacts in the Netherlands is regarded as negligible.

Economic impact
The asp has a high nutritional value, but is not preferred as a table fish (Trzebiatowski, 1976; Zmijewski, 2006). It is expected that there is no market for asp as an item of consumption in the Netherlands. Asp is highly appreciated by anglers (Trzebiatowski, 1976). The species is therefore of economic importance for the fishing tackle industry. In the Netherlands the asp is being targeted by a growing number of Dutch anglers measured in the growing enthusiasm for asp fishing in (digital) angling magazines and fishing tackle stores.

Social impact
The asp has a recreational value in the Netherlands because many anglers target the species.

4.3 Risk classification

4.3.1 Available risk classifications

Table 4.3: Overview of risk classifications previously performed for the asp (Leuciscus aspius).

	United Kingdom
Scope	Risk assessment
Method	FISK
Risk classification	29 (High)
Source	Copp *et al.* (2009)
Additional information	≥19 = High risk

Rationale for risk classification

Copp *et al.* (2009) give an overview of Fish Invasiveness Scoring Kit (FISK) scores for multiple fish species but give no rationale for the allocation of risk classifications.

4.3.2 Current situation

Expert consensus scores

The total risk score attributed to asp (*Leuciscus aspius*) was 9 out of a maximum risk score of 12 (table 4.4). This results in an overall classification of moderate risk for this species.

Table 4.4: Consensus scores and risk classifications for asp (Leuciscus aspius) in the current situation in the Netherlands.

ISEIA sections	Risk classification	Consensus score
Dispersion potential or invasiveness	high	3
Colonization of high value conservation habitats	high	3
Adverse impacts on native species	likely	2
Alteration of ecosystem functions	unlikely	1
Global environmental risk	B - list category	9

Dispersion potential or invasiveness

The asp is able to spread rapidly through the freshwater network in the Netherlands. The fecundity of asp is high: a female can produce over 100,000 eggs (Scharbert & Borcherding, 2013). The species is already widely spread in the Netherlands. In the first years of the 1990s, asp observations in the Netherlands were limited to the major rivers: Rhine, Meuse and tributaries. In the period from 1995 to 2004 the number of observations quickly increased and many observations were made in canals, regional rivers and other waterways (De Nie, 1996; Gaethofs, 2004). In the major rivers it is now an abundant predator fish species. Therefore, based on a high fecundity together with its recent rapid spread, it was concluded that the dispersal potential and invasiveness of asp in the Netherlands is high.

Colonisation of high conservation value habitats

68% of asp distribution occurs in areas designated under Natura 2000 in the Netherlands (appendix 1). The asp is present in high densities in groyne fields in the major rivers of the Netherlands: Rhine, Meuse and tributaries. These habitats border a number of Natura 2000 areas. Therefore, it was concluded that asp often colonises and poses a high risk to high conservation value habitats in the Netherlands.

Adverse impacts on native species

There is no evidence in literature referring to the adverse impacts of asp on native species in the Netherlands or countries that are climatically similar. Therefore, judgements made were based on expert knowledge. Impacts relating to predation are likely to occur due to the predatory behaviour of asp and their widespread occurrence at high densities in the freshwaters of the Netherlands. Predation by asp may reduce the abundance of threatened river fishes that have an overlap in habitat with the asp, e.g. nase (*Chondrostoma nasus*) and vulnerable species such as ide. There is insufficient information to conclude whether asp will impact native species through interference and exploitation competition. Research in the Hungarian Lake Balaton has shown that early life stages of asp are highly flexible in feeding strategy and show diet overlap with many species native to the Netherlands (Specziar & Rezsu, 2009). The occurrence of impacts relating to disease transmission by asp to native species in the Netherlands is unlikely as asp are not known to carry diseases that are not already present. Hybridization of asp occasionally occurs with the related ide (Berinkey, 1976; Kottelat & Freyhof, 2007). However, it is unlikely that hybridisation with ide results in a significant impact on the native population in the Netherlands, although impacts on a local scale cannot be excluded. Overall, it was concluded that it is likely that asp will have an impact on native species in the Netherlands based on possible negative impacts related to predation.

Alteration of ecosystem functions

There is no evidence in literature referring to the adverse impacts of asp on ecosystem functions in the Netherlands or countries that are climatically similar. Expert judgement was applied to assess potential disruption to food webs only. There was insufficient data to assess the likelihood of effects relating to the other subcategories of this section of the risk assessment (modification of nutrient cycling or resource pools, physical modifications of the habitat and modifications of natural succession).

Potential ecosystem impacts will likely be limited to food web alteration as a result of the predatory behaviour of the asp. The species likely impacts on prey species in the Netherlands, however, it is unclear if this can be classified as a disruption of the food web. No extinctions of prey species are expected. In this category a pragmatic approach was applied. Risk assessors concluded that the effect would likely be greater than those classified under low risk. However, there is no known reason why this species should be classified under medium risk. Overall, it was concluded that it is unlikely that asp will have an impact on ecosystem functions in the Netherlands.

Species classification

The species classification corresponds to the global environmental risk score of the ISEIA (table 4.4) combined with the current distribution of the non-native species within the country in question. The species classification for asp is B3 (Figure 4.4). This indicates a non-native species that is widespread and displays a moderate environmental hazard (i.e. ecological risk) that should be placed on the watch list of the BFIS list system. (i.e. ecological risk: ISEIA score 9: B category).

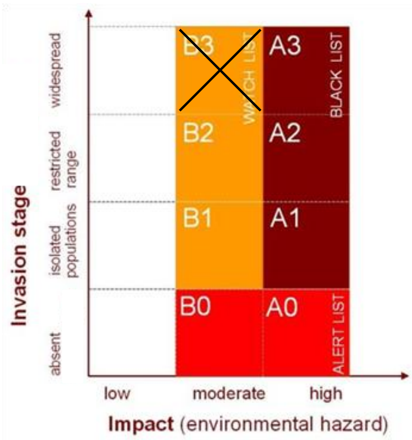

Figure 4.4: Asp (Leuciscus aspius) classification according to the BFIS list system.

4.3.3 Future situation

Future increase in water temperature due to climate change will be unlikely to affect the reproduction of asp and its ability to colonise freshwaters in the Netherlands. The optimum temperature range for adult asp is 18-28°C (Schreckenbach, 2001 Cfm. Otto & Zahn, 2008). In the case of a two degree Celsius temperature rise, average summer water temperatures in the Netherlands will likely remain within this range in the majority of water bodies. When only temperature is considered, the overall risk score and distribution of the asp in the Netherlands is expected to remain unchanged (table 4.5). Therefore, the B3 classification under the BFIS list system will remain the same.

Table 4.5: Asp (Leuciscus aspius) theoretical classification according to a potential future habitat scenario.

ISEIA sections	Risk classification	Consensus score
Dispersion potential or invasiveness	high	3
Colonization of high value conservation habitats	high	3
Adverse impacts on native species	likely	2
Alteration of ecosystem functions	unlikely	1
Global environmental risk	B - list category	9

4.4 Risk management

4.4.1 Prevention of introduction

The asp is already widespread in the Netherlands. Natural dispersion through fish migration corridors and hydrological connections of water ways is virtually impossible to prevent. Nevertheless, further spread to new water bodies and river systems, isolated from the current asp distribution range, can be stopped by the prevention of asp stocking.

4.4.2 Elimination of populations

The current population of asp in the Netherlands is large and widespread. Only populations in relatively small, isolated waters may be eliminated cost efficiently. Internationally, there is no information available that describes how to eliminate asp. See appendix 4 for general methods that may be used to eliminate fish populations.

4.4.3 Management of populations

Internationally, there are no examples of measures available aimed at managing asp populations. For other species a previously implemented measure features the eradication of the species from waters where it occurs (e.g. Roberts & Tilzey, 1996; Chadderton *et al.*, 2003). This management strategy is only feasible when the rate of removal exceeds the rate of increase (recruitment), there is a low probability of reinvasion, it is able to target all individuals in a population and the strategy is supported by society and politics (Chadderton, 2003). When not all individuals can be removed, the management efforts can have an adverse impact. For example intensive removal of pike-perch in the UK led to a lower biomass and a decrease of mean length, but increased abundance (Smith *et al.*, 1995). It was suggested that the removal of pike-perch led to an increased predation intensity on prey fish populations, when in fact the opposite was intended (Smith *et al.*, 1995).

Taking this information into consideration, asp eradication cannot be seen as a feasible measure for the management of asp which are widespread in a large river system.

In some cases the invasion success of exotic species might be mitigated by altering or rehabilitating the water system (Van Kessel *et al.*, 2013). Ideally, as a result of these interventions, completion of the exotic species life cycle is disturbed and that of the native species enhanced. Asp, however, rely on natural river processes which are valuable for many native species. Therefore system alteration or rehabilitation is not a suitable measure to manage asp.

5. BROOK TROUT (*Salvelinus fontinalis*)

The information presented in this chapter is the result of a literature and database quickscan and serves as input for the determination of risk scores using the ISEIA risk protocol. More information about brook trout is addressed by Soes & Broeckx (2010); "A risk analysis of exotic trout in the Netherlands".

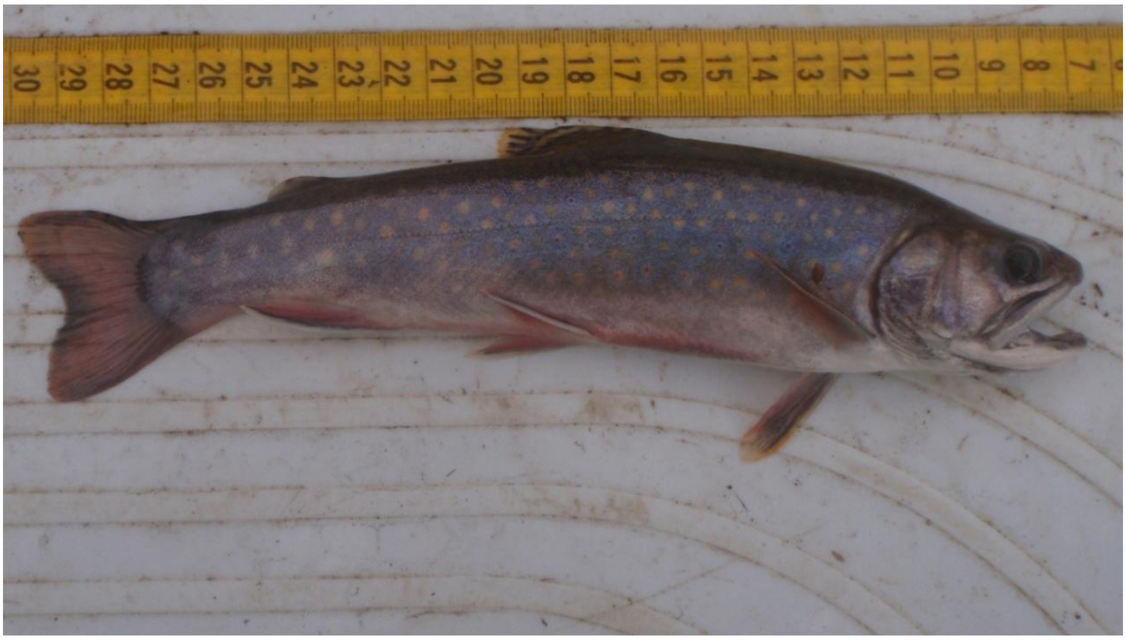

Figure 5.1: Brook trout (Salvelinus fontinalis) from the Geelmolense Beek (length 23cm) (Frank Spikmans).

5.1 Distribution in the Netherlands

Brook trout are very rare in the Netherlands (figure 5.2). Apart from a few (questionable) records in western Netherlands, the species is regularly recorded only in the Geelmolense beek in the Province of Gelderland and the Voer, Geul and Swalm, tributaries of the river Meuse in the Province of Limburg (Soes *et al.*, 2009; Soes & Broeckx, 2010). These brooks and small rivers harbour a rare and vulnerable fish fauna and can therefore be considered as high conservation value habitats (Natura 2000).

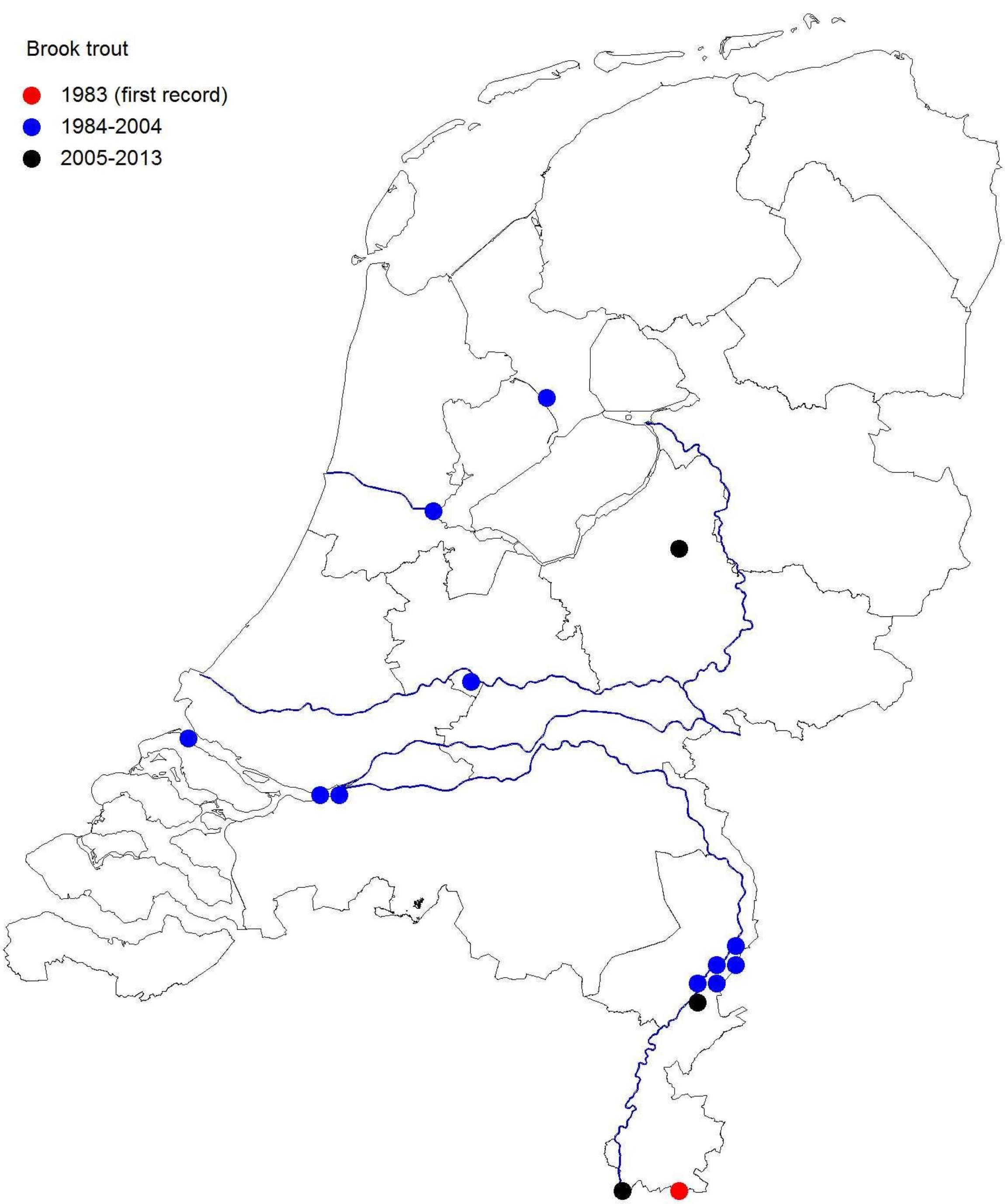

Figure 5.2: Distribution history of brook trout (Salvelinus fontinalis) in the Netherlands (older records are plotted on top of more recent records) (RAVON/NDFF data).

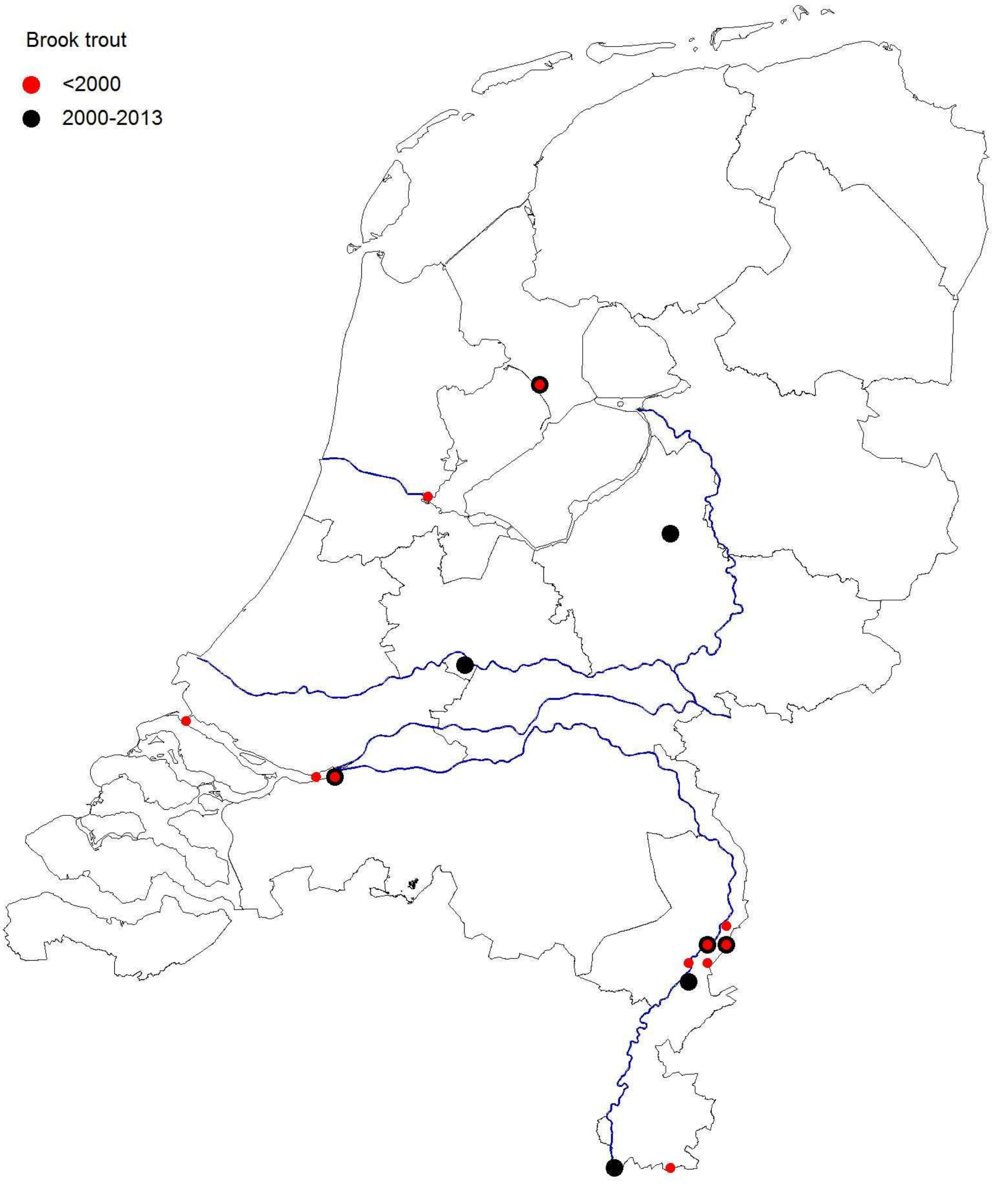

Figure 5.3: Geographical distribution of brook trout (Salvelinus fontinalis) in the Netherlands before and after 2000 (combined black and red dots indicate presence in both periods) (RAVON/NDFF data).

5.2 Potential spread in the Netherlands

Brook trout is a species with a high dispersal capacity (Adams *et al.*, 2000; Korsu & Huusko, 2009) and is characterised by anadromous populations (Curry *et al.*, 2010). The species is able to disperse up to 5km/year from release sites in a Finnish stream (Korsu & Huusko, 2009). It spawns for the first time at 1 to 2 years old in Southern and Central Europe and in Northern Europe at 3 to 4 years old (Kottelat & Freyhof, 2007). The number of mature eggs of brook trout of age 2+ is 210-

681 (mean 461), 3+ 634-1251 (mean 461) and 4+ 1,277-2,376 (mean 1826) in the Dunk river, Canada (Johnston & McKenna, 1977). The absolute fecundity (number of eggs per fish) of cultivated brook trout is 723±320 while relative fecundity (number of eggs/g) is 2.5 ±1.5 (Serezli *et al.*, 2010).

Successful spawning of brook trout in the Netherlands has been recorded in the Geelmolense beek (Soes & Broeckx, 2010). The temperature range of the Geelmolense brook fits within the optimal temperature range of brook trout (Raleigh, 1982). This type of brook is found in the Province of Limburg and Gelderland (the Veluwe and Achterhoek). Suitable spawning sites featuring large gravel beds are very rare (Schouten, 1995 cited in: Soes & Broeckx, 2010). The species is recorded in various special areas of conservation in the Netherlands listed under the Habitats Directive, for example the Biesbosch, Geuldal, Haringvliet, Hollandsch Diep, Ijsselmeer, Roerdal, Swalmdal, Veluwe and Voordelta. The removal of fish migratory barriers in the Netherlands will favour the spread of brook trout, as will the intentional release of brook trout. Due to the low densities and scarcity of available spawning sites, it is not likely that the species will become invasive in the Netherlands.

5.3 Ecological impact

Non-native salmonids may impact negatively on native fish species (Korsu *et al.*, 2010; Morita *et al.*, 2004). In Italy in alpine lakes, brook trout negatively affect the common frog (*Rana temporaria*) most likely as a result of larval predation or selective avoidance by the common frog of lakes stocked with brook trout (Tiberti & von Harderberg, 2012). Moreover, introduced trout can have severe effects on populations of montane amphibians, such as the mountain yellow-legged frog (*Rana muscosa*) in southern California, USA (Vredeburg, 2004) and endemic Iberian frog (*Rana iberica*) in central Spain in Europe (Bosch *et al.*, 2006). The survival of juvenile chinook salmon (*Oncorhynchus tsawytscha*) in the Colombia River Basin in streams without non-native brook trout was nearly twice the survival rate of juveniles in streams with non-native brook trout (Levin *et al.*, 2002). (In)direct severe impacts of introduced brook trout include top-down trophic interactions resulting in modifications to benthic zooplankton, macroinvertebrates, and algal communities (Bechera *et al.*, 1992; Bechera *et al.*, 1993).

In Sweden, the introduction of brook trout coincided with the decrease or extinction of native brown trout populations in boreal lakes (Spens *et al.*, 2007). Kitano (2004) describes the significant negative impact of brook trout on several native fish species in Japan. Moreover, competitive interactions with brook trout are an important factor regulating the presence of bull char (*Salvelinus confluentus*) and cutthroat trout (*Oncorhynchus clarkii*) in the USA (Nakano *et al.*, 1998; Peterson *et al.*, 2004; Rieman *et al.*, 2006).
Brook trout can be affected by a variety of (lethal) diseases and parasites (Soes & Broeckx, 2010). They are resistant to and carriers of viral hemorrhagic syndrome and infectious haematopoietic necrosis (Haffray, 2008 and Roberts & Sheperd, 1997 cited in: Soes & Broeckx, 2010).

Brook trout hybridize with brown trout resulting in the sterile 'tiger trout' hybrid (Kottelat & Freyhof, 2007). Brook trout is known to hybridize with Arctic char, producing the hybrid Elsässer saibling, which is also present in the Netherlands (Hammar *et al.*, 1991; Dumas *et al.*, 1992; Reiter, 2006; Lecomte *et al.*, 2013).

The brook trout will probably exert an impact on native species as it is proven to be able to establish in the Netherlands. Furthermore a high introduction rate may increase this impact and may cause irreversible alterations to ecosystem functions.

5.4. Risk Classification

5.4.1 Available risk classifications

Table 5.1: Overview of risk classifications previously performed for brook trout (Salvelinus fontinalis).

	Germany, Austria	Norway	Bulgaria, Macedonia, Serbia	United Kingdom	Ireland
Scope	Risk assessment	Risk assessment	Risk assessment	Risk assessment	Species prioritised for more detailed risk assessment
Method	The German-Austrian Black List Information System (GABLIS)	2012 Norwegian Black List	FISK	FISK	Invasive Species Ireland Risk Assessment
Risk classification	Grey list (action list)	Low impact	4 (Medium)	14 (High)	18/24 (High)
Source	Nehring *et al.* (2010)	Gederaas *et al.* (2012)	Simonovic *et al.* (2013)	Copp *et al.* (2005)	Kelly *et al.* (2013)
Additional information	Invasiveness not proven but suspicion is high enough to introduce measures	Alien species with a low impact are not documented as having any substantial impact upon Norwegian nature	Classified as invasive	Any positive score was considered high risk	Scores ≥ 18 are classified as high risk

Rationale for risk classification

Nehring *et al.* (2010) suggest that it is a reasonable assumption that brook trout displaces brown trout (*Salmo trutta*) and impacts on the spawning of native salmonids in Germany and Austria (Honsig-Erlenburg & Petutschnig, 2002; Wiesner *et al.*, 2010). Brook trout does not form a threat to native German or Austrian species due to hybridisation and there is an absence of other ecosystem effects. Hybridisation between brook trout and the Arctic char (*Salvelinus alpinus*) and brown trout may occur but these hybrids are unable to reproduce (Waterstraat *et al.*, 2002). It is not known if impacts relating to predation and herbivory exist. However, at high abundances brook trout is expected to impact on the benthic macroinvertebrate population (Bechara *et al.*, 1992). It is not known if diseases or parasites carried by brook trout impact on German and Austrian native species. brook trout is a widespread species in Germany and Austria and occurs in valuable trout stocking habitats. Reproduction potential is low (Johnston & McKenna, 1977; Serezli *et al.*, 2010). Potential spread is classified as high, however, the population distribution appears to be stable. It is unknown if the species is able to monopolise natural resources. It is unknown if climate change will have an effect on this species in Austria or Germany. Brook trout does not impact human health in Austria or Germany. There are no known negative impacts of brook trout on the social-economy however brook trout is beneficial to fisheries and recreational fishing.

Gederaas *et al.* (2012) gave brook trout a low impact rating despite potential interaction with other native species which was rated 2 out of a maximum of 4 on the Norwegian risk scale. Multiple species were assessed as a part of the risk assessment and no other rationale was given for the classification of individual species.

Simonovic *et al.* (2013) gives an overview of FISK scores for multiple fish species in Bulgaria, Macedonia and Serbia, but gives no rationale for the allocation of risk classifications.

Copp *et al.* (2005) gives an overview of FISK scores for fish species for the United Kingdom, but gives no rationale for the allocation of risk classifications.
Kelly *et al.* (2013) gives an overview of prioritization risk assessment scores for multiple fish species in Ireland, but gives no rationale for the allocation of risk classifications.

5.4.2 Current situation

Expert consensus scores
The total risk score attributed to brook trout was 9 out of a maximum risk score of 12 (table 5.2). This results in an overall classification of moderate risk for this species.

Table 5.2: Consensus scores and risk classifications for brook trout (Salvelinus fontinalis) in the current situation in the Netherlands.

ISEIA sections	Risk classification	Consensus score
Dispersion potential or invasiveness	medium	2
Colonization of high value conservation habitats	high	3
Adverse impacts on native species	medium	2
Alteration of ecosystem functions	likely	2
Global environmental risk	B - list category	9

Dispersion potential or invasiveness
The brook trout is able to disperse over great distances but has a low reproductive capacity (Johnston & McKenna, 1977; Adams *et al.,* 2000; Korsu & Huusko, 2009; Serezli *et al.,* 2010). In the Netherlands, the brook trout's current distribution is characterised by isolated populations but it is able to reproduce (Soes & Broeckx, 2010; Section 4.3.5), although suitable spawning sites featuring large gravel beds are very rare (Schouten, 1995 cited in: Soes & Broeckx, 2010). Therefore, based on the high dispersal potential of brook trout but limited distribution, it was concluded that the dispersal potential and invasiveness of brook trout in the Netherlands is medium.

Colonisation of high conservation value habitats
47% of the current distribution of brook trout occurs in Natura 2000 areas (16 of 34km-squares). The species is present in Geelmolense beek, an example of a valuable habitat type in the Netherlands (Soes & Broeckx, 2010). This type of brook is found in the Province of Limburg and Gelderland (the Veluwe and Achterhoek). Suitable spawning grounds are rare and may therefore be considered high conservation value habitats. It was concluded that brook trout often colonise and pose a high risk to high conservation value habitats in the Netherlands.

Adverse impacts on native species
Evidence from countries that are climatically similar to the Netherlands suggests that brook trout negatively impact brown trout. Nehring *et al.* (2010) state that it is a reasonable assumption that brook trout displace brown trout and impact the spawning of native salmonids in Germany and Austria by overlaying and destroying the eggs of the native species. Moreover, brook trout introduction was followed by the decrease or extinction of native brown trout populations in boreal lakes in Sweden (Spens *et al.,* 2007). Brook trout are able to hybridise with brown trout, however the offspring are unable to reproduce (Waterstraat *et al.,* 2002). It was concluded that brook trout pose a medium risk of impact on native species as a result of predation, interference

and exploitation competition and genetic effects in the Netherlands. Brook trout carry a number of diseases and parasites that are likely to infect native species in the Netherlands (O. Haenen, pers. comm.). Overall, It was concluded that brook trout pose a medium risk of impact on native species in the Netherlands.

Alteration of ecosystem functions
No information is available with regard to the impact of brook trout on ecosystem functions in the Netherlands. However, in Germany and Austria there is no evidence of ecosystem effects resulting from the presence of this species (Nehring *et al.,* 2010). In other countries brook trout impact amphibian species through predation (Vredeburg, 2004; Bosch *et al.,* 2006; Tiberti & von Harderberg, 2012) and the survival of salmon species (Levin *et al.,* 2002). (In)direct severe impacts of introduced brook trout include top-down trophic interactions resulting in modifications of benthic zooplankton, macroinvertebrates, and algal communities (Bechera *et al.,* 1992; Bechera *et al.,* 1993). It is likely that negative impacts relating to alterations of ecosystem functions will occur in the Netherlands. This judgement is based on literature from countries with with some climatic dissimilarity to the Netherlands. However, some of the species affected by the brook trout in these countries, are also present in Dutch freshwaters. There was insufficient information (deficient data) to judge the impact of brook trout on the other subcategories in this section (modification of nutrient cycling or resource pools, physical modification of habitat or modifications of natural succession).

Species classification
The species classification corresponds to the global environmental risk score of the ISEIA (table 5.2) combined with the current distribution of the non-native species within the country in question. The species classification for brook trout is B1 (Figure 5.4). This indicates a non-native species distributed in isolated populations and displaying a medium environmental hazard (i.e. ecological risk) that should be placed on the watch list of the BFIS list system (i.e. ecological risk: ISEIA score 9: B category).

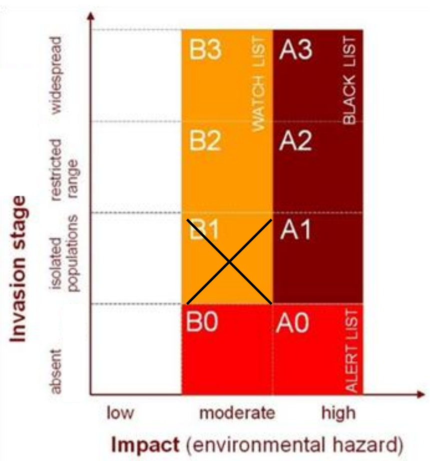

Figure 5.4: Brook trout (Salvelinus fontinalis) classification according to the BFIS list system.

5.4.3 Future situation

It is expected on the basis of expert judgement that there will be no change in the future risk classification and distribution of brook trout when only a potential two degrees Celsius rise in temperature is considered (table 5.3). Therefore, the B1 classification under the BFIS list system would remain the same.

Table 5.3: Brook trout (Salvelinus fontinalis) theoretical classification according to a potential future habitat scenario.

ISEIA sections	Risk classification	Consensus score
Dispersion potential or invasiveness	medium	2
Colonization of high value conservation habitats	high	3
Adverse impacts on native species	medium	2
Alteration of ecosystem functions	likely	2
Global environmental risk	B - list category	9

6. COMMON CARP (*Cyprinus carpio*)

6.1 General species description

6.1.1 Nomenclature and taxonomy

Order	Cypriniformes
Family	Cyprinidae
Genus	*Cyprinus*
Species	*Cyprinus carpio* Linnaeus 1758
Common name	Common carp (Dutch: Karper)
Synonyms	*Cyprinus carpio* Linnaeus 1758

6.1.2 Species characteristics and identification

Figure 6.1: Juvenile common carp (Cyprinus carpio) (length 12cm) (digitalnature.org).

The common carp has an elongated fully scaled body with a bronze to brown base colour. Due to aquaculture selection there are lineages featuring a higher back, different colours and fewer scales. Carp breeds featuring different colours are often referred to as 'koi carp', which can display colours including yellow, white, orange and black. Specimens with fewer scales are referred to as mirror carp (few large scales) or leather carp (no scales).

Figure 6.2: Adult mirror carp (Cyprinus carpio)(length 60cm) (digitalnature.org).

The common carp has two pairs of barbels attached to its mouth. Early juvenile carp have a weak dark spot on their caudal peduncle. Juvenile tench (*Tinca tinca*) and juvenile crucian carp (*Carassius carassius*) share this feature, although the spot is very dark in crucian carp. Juvenile tench are distinguished by the very small, virtually invisible, scales. See table 11.1 in chapter 11 for an overview of other distinguishing features contrasting with *Carassius* spp. Note: common carp can hybridize with *Carassius* spp. resulting in hybrids that exhibit intermediate features (see also chapter 9 & 11). Common carp can grow to a length of 110cm, weigh over 40kg and can live to a maximum of 47 years (Flower, 1935; Barus *et al.*, 2001).

6.1.3 Life cycle

Habitat

Common carp can live in a wide variety of still and slow flowing water bodies and even in slightly brackish waters. They are tolerant of low oxygen concentrations. In The Netherlands, the species lives in rivers, lakes, canals and deeper polder ditches. They prefer warm shallows with submerged vegetation or roots for spawning (Kottelat & Freyhof, 2007) which is then used as a nursery area. Table 6.1 gives an overview of the tolerances of common carp to different environmental factors.

*Table 6.1: Tolerances of common carp (*Cyprinus carpio*) to different environmental factors.*

Environmental factor	Value	Life stage	Remarks	Reference
Stream velocity	0-20cm/s	Adult	Optimum range	De Wilt & Van Emmerik, 2008
Temperature	0-8°C	Adult	Inactive	De Wilt & Van Emmerik, 2008
	14-28°C	Adult	Optimum range	De Wilt & Van Emmerik, 2008
	32.5-34.8°C	Adult	Stress	Alabaster & Loyd, 1980
	40.6-40.9°C	Adult	Lethal temperature range	Alabaster & Loyd, 1980
	32.5°C	Eggs	Upper critical limit	Schäperclaus, 1961; Steffens, 1962
	10°C	Eggs	Lower critical limit	Schäperclaus, 1961; Steffens, 1962
pH	4-4.5	Adult	Lower critical limit	Leuven *et al.*, 1987
	10-10.5	Adult	Upper critical limit	Alabaster & Lloyd, 1982
	5-5.5	Eggs	Lower critical limit	Leuven *et al.*, 1987
	6-7.5	Adult	Optimum range	Alabaster & Lloyd, 1982
Oxygen	6.0-7.0mg/l	Adult	Optimum range	De Wilt & Van Emmerik, 2008
	2.0mg/l	Adult	Lower critical limit	De Wilt & Van Emmerik, 2008
	9.0mg/l	Eggs	Optimum range	De Wilt & Van Emmerik, 2008
Salinity	5‰	Eggs	Upper critical limit	Bath *et al.*, 1994
	6.6‰	Larvae	Upper critical limit	De Wilt & Van Emmerik, 2008
	12‰	Juveniles	Upper critical limit	De Wilt & Van Emmerik, 2008
	17-18.5‰	Adult	Upper critical limit	Hynes, 1970

Reproduction

In Europe, common carp males reproduce for the first time at 3 to 5 years old, females one year later. They usually spawn once every year from May to July in waters where temperatures lie above 18°C. In river systems common carp can migrate over long distances to reach suitable spawning habitat (Kottelat & Freyhof, 2007). The relative fecundity of common carp is high, a female can produce 100 to 200 eggs/g body weight (Steffens, 1958). The water temperature is of great importance for reproduction success. The duration of egg hatching is only 1-2 days at 30°C and 9 days at 15°C (De Wilt & Van Emmerik, 2008). Common carp can hybridize with many cyprinid species and produce fertile hybrid offspring with *Carassius* species (e.g. Crunkilton, 1977; Barus *et al.*, 2001; Hänfling *et al.*, 2005).

Diet

The common carp is an omnivorous species. The fish can eat water plants, but prefers insect larvae, crustaceans (including zooplankton) and benthic worms (De Wilt & Van Emmerik, 2008). Larvae of common carp feed predominantly on zooplankton.

Predators

Juvenile common carp are preyed upon by perch, pike, European catfish, otters and cormorants. There are virtually no predators that are capable of preying on large (> 30cm) common carp (Raat, 1986; Sarig, 1966).

Parasites and diseases
Research from aquaculture and of common carp in their natural habitat has discovered many parasites and diseases that are associated with them (table 6.2).

Table 6.2: Parasites and diseases described in common carp (Cyprinus carpio) (E = exotic for the Netherlands, N = native for the Netherlands; Effect = disease/mortality in this species, if effect on other fish species is known (OS), this is also mentioned)

Parasite/disease	Location	Reference	Effect
Trichodina, Chilodonella, Ichthyobodo, Glossatella, Ichthyophthirius multifiliis (white spot), *Dactylogyrus/Gyrodactylus* spp., *Argulus* spp., a.o. (N)	Netherlands	Haenen, own experience	Low to medium OS: idem
Acolpenteron sp. (E?) *Dactylogyrus achmerowi (E?)* *Dactylogyrus amphibothrium (E?)* *Dactylogyrus anchoratus (E?)* *Dactylogyrus auriculatus (E?)* *Trypanoplasma borreli (probably N)*	*Czech Republic*	*Moravec, 2012*	*Low to medium* *OS?*
Ichthyobodo spp. *Cryptobia spp.* *Eimeria spp.* *Ichthyophthirius multifiliis (white spot)* *Chilodonella spp.* *Trichodina spp.* *Myxidium spp.* *Shaerospora spp.* *Myxobolus spp.* *Henneguya spp.* *Dactylogyrus/Gyrodactylus spp.,* *Diplostomum spp.* *Posthodiplostomum spp.* *Sanguinicola spp.* *Clonorchis sinensis (Asia)* *Opistorchis felineus(Asia)* *Caryophyllaeus spp.* *Ligula intestinalis* *Bothriocephalus acheilognathi* *Khwaia sinensis* *Triaenophorus spp.* *Philometroides spp.* *Anisakis spp.* *Contracaecum spp.* *Camallanus spp.* *Philometra spp.* *Acantocephala spp.* *Hirudinae* *Glochidia* *Ergasilus spp.* *Lernea spp.* *Tracheliastes spp.* *Argulus spp.*	World (N) except for 2 species (Asia)	Jeney & Jeney, 1995 (review)	Low to medium OS: idem
Fungi			
Achlya spp. *Saprolegnia spp.* *Branchiomyces sanguinis*	>Europe	Jeney & Jeney, 1995 (review)	Low to medium OS: idem
Bacteria			
Aeromonas salmonicida atypical (carp erythrodermatitis) *Aer. hydrophila* *Edwardsiella tarda* *Pseudomonas fluorescens* *Flavobacterium columnare (columnaris disease)*	>Europe (N)	Jeney & Jeney, 1995 (review)	Low to severe OS: idem (cyprinids, eel, a.o.)

Flavobacterium branchiophilum (cold water disease) *Streptococcus sp.* *Mycobacterium sp. (e.g. fish tuberculosis)*			
Viruses			
SVCV (Spring Viremia of Carp Virus) (N)	Central & W-Europe	Fijan *et al.*, 1971:	Severe OS: severe (cyprinids)
Herpesvirus (carp pox) (N?) (CyHV-1)	Central Europe	Waltzek *et al.*, 2005	Medium to severe OS: low (species specific)
Koi Herpes Virus (N)	Worldwide, including NL	Hedrick *et al.*, 2000; OIE, 2013a	Severe OS: low (species specific)
Koi sleepy disease (KSD) (probably E)	Japan, Netherlands	Miyazaki *et al.*, 2005 Haenen *et al.*, 2013	Medium to severe OS: low (species specific)
Iridovirus (single finding) (E?)	Russia (1981)	Jeney & Jeney, 1995 (review)	Medium OS: unknown, probably low

6.1.4 Distribution

The native distribution of the common carp extends from Eastern Europe to Central Asia in the basins of the Black, Caspian and Aral Seas (Barus *et al.*, 2001; Kottelat & Freyhof, 2007). The common carp is farmed in large quantities, has been introduced throughout the world, is produced in aquaculture for human food and stocked for sport fishing. In Europe the species has been domesticated since the Middle Ages. Archaeological research indicates that common carp probably already lived in the Netherlands in the 14th century (De Wilt & Van Emmerik, 2008). Numerous historic references state that carp occurred widely throughout the Netherlands for several centuries and were locally abundant due to successful natural reproduction (e.g. Houttuyn, 1765; Van Bemmelen, 1866; Hoek, 1893; Redeke, 1941).

Today common carp are still widespread in the Netherlands and are present in the majority of fresh to brackish water bodies (figure 6.3).

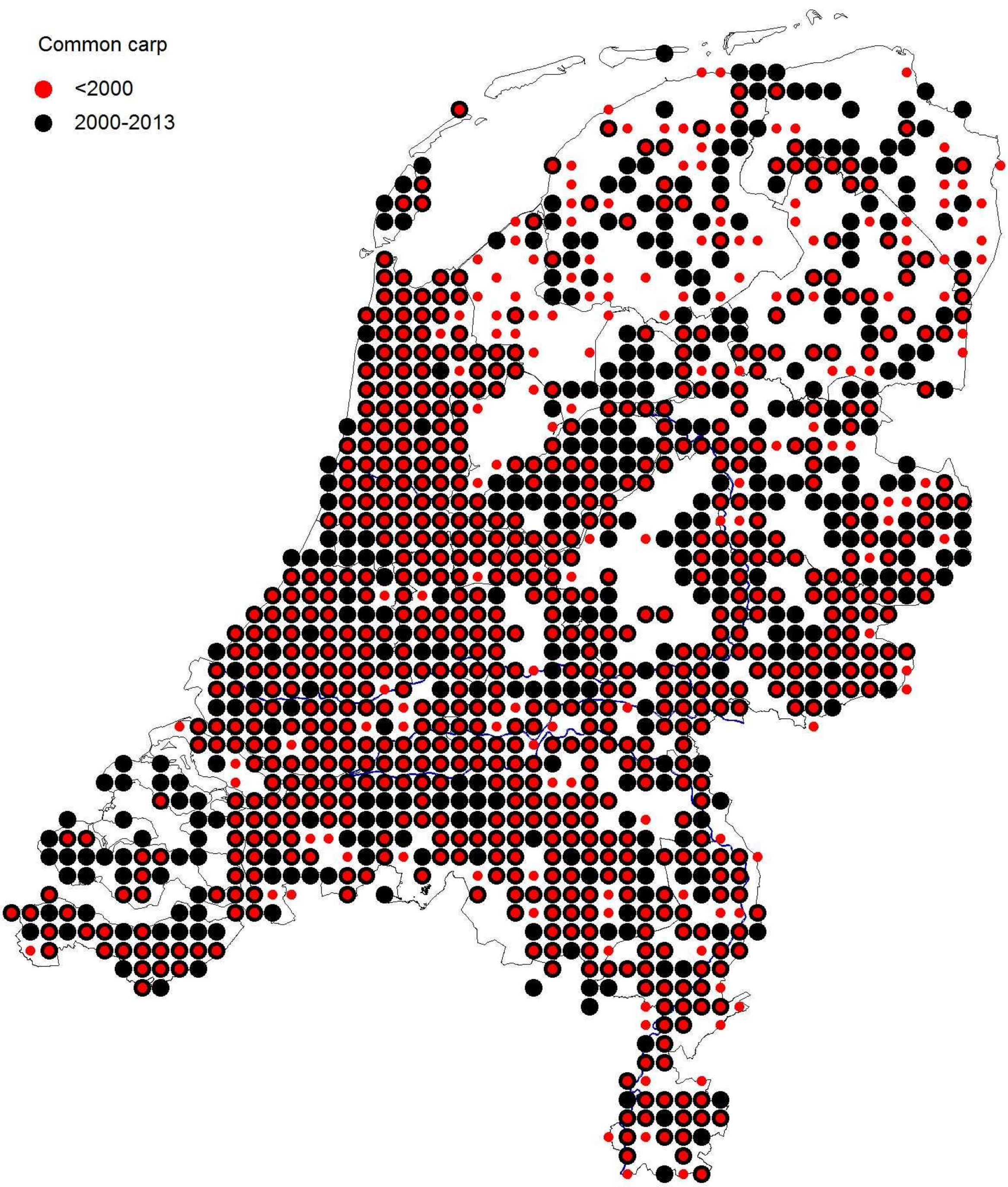

Figure 6.3: Common carp (Cyprinus carpio) distribution in the Netherlands before and after 2000 (combined black and red dots indicate presence in both periods) (RAVON/NDFF data).

6.2 Risk assessment

6.2.1 Probability of entry

Pathways of introduction

It is not known exactly when and how the common carp arrived in the Netherlands. The species has been cultivated and stocked here to provide human food for centuries. The species was already present in the 14^{th} century in areas like Friesland, Noord-Holland and Zuid-Holland (De Wilt & Van Emmerik, 2008). A common carp strain that has been living and reproducing in the Netherlands for centuries is called the wild common carp (Dutch: boerenkarper). It is not clear if the common carp was directly introduced within the Netherlands or if it escaped from ponds more upstream and migrated from other countries through rivers like the Rhine (in Germany the species was stocked in high numbers).

Pathways of future introduction

The common carp is one of the exotic species included in the Dutch Fisheries Act. It can be transported and introduced legally by people or organisations who own the fishing rights to a certain water body. Stocking materials can be obtained from different locations (also other countries) and transported to many different water bodies in the Netherlands where fishing rights apply. Because common carp is a very popular sport fish, a lot of stocking was carried out by the former Heidemij and the OVB (organisation to improve freshwater fisheries). Nowadays, stocking by various sport fishing organisations continues. Therefore the probability of future introductions through different pathways is high.

6.2.2 Probability of establishment

Habitat suitability

The current climatic conditions in the Netherlands are not optimal for the reproduction of common carp. Here, reproduction success is relatively low compared to other, warmer climatic zones (e.g. France, Spain, Australia) (Smith, 2004). Under average conditions, the number of eggs, larvae and juveniles that survive the first year in Dutch waters is very low compared to cyprinids like bream (*Abramis brama*) and roach (*Rutilus rutilus*) that spawn earlier in the year at lower water temperatures. Common carp is able to maintain large populations with successful reproduction in waters with shallow, warm, vegetated areas and areas with a low abundance of predatory fish species. These locations are commonly situated in the lower parts of the Netherlands, especially in waters with an elevated salinity. Suitable habitat is present for adult and sub-adult common carp in the majority of water types in the Netherlands.

Propagule pressure

Since the 14th century, it is likely that millions of common carp have been released in the Netherlands, subsequently becoming established in many water bodies due to natural reproduction and restocking.

Population development

Because the common carp has been in the Netherlands since the 14^{th} century, it is not clear how the population developed over the centuries. From historic information it is known that the species was quite common in certain lakes and deeper polder ditches in areas like Friesland, Noord-Holland and Zuid-Holland (De Wilt & Van Emmerik, 2008). Common carp still occur frequently in these places. The species is also common in the province of Zeeland where most polder waters are brackish. In other parts of the Netherlands high abundances are found in isolated waters that are stocked with common carp by sport fishery organisations. In most of these water bodies, reproduction success is low due to poor spawning and juvenile habitat quality in combination with presence of predatory fish.

Habitat quality in most water bodies has decreased since the 1950s probably because of intensive agricultural land use in the Netherlands. During the 1970s, similarly to most other freshwater fishes, a population decline due to bad water quality was reported. The artificially maintained, low water levels that occur in spring and summer in the Netherlands, do not encourage spawning and reproduction success in common carp. On the other hand, there are some minor indications that natural reproduction success increases due to warmer spring and summer temperatures as a result of climate change.

Potential distribution range

The potential distribution range of the common carp will likely be the same as the current distribution range. This is because only a minor shift in the distribution of this species has been observed in recent years. Currently, the common carp is widespread in the Netherlands. Due to its long life span, the common carp will probably maintain its wide spread distribution even without stocking. In the future, the distribution of this species may increase due to climate change and higher temperatures (higher salinities in some areas may also encourage further spread). As a result of this, the species will be able to successfully reproduce in a higher number of waterbodies throughout the entire country.

6.2.3 Probability of spread

Species features that encourage spread

The common carp is able to live in different water types, is tolerant of low oxygen levels and higher salinities and can migrate over long distances. Therefore, the species has a high potential for spread.

Spread in climatically similar countries

In all Western European countries common carp spread through introductions and natural dispersion to various water systems. It therefore is one of the most widely distributed fish species in Europe.

Potential spread in Netherlands

Common carp have already spread to most water bodies in the Netherlands. It could potentially spread to isolated water bodies as a result of stocking and to water bodies connected to the river system which have so far not been occupied.

6.2.4 Vulnerable areas

Common carp often occur in habitats protected under Natura 2000 in the Netherlands (Appendix 1). Water bodies featuring submersed vegetation may be vulnerable to high densities of common carp. Habitat directive species such as wheaterfish (*Misgurnus fossilis*), bitterling (*Rhodeus amarus*) and spined loach (*Cobitis taenia*) exist at these locations. Moreover, water bodies featuring crucian carp (*Carassius carassius*) are vulnerable because this Dutch Red List species is sensitive to competition from other fish species and hybridizes with common carp (genetic pollution).

6.2.5 Negative impact of introduction

Ecological impact

High densities of common carp can have a great impact on submerged vegetation and turbidity due to the disturbance of bottom sediments that results from foraging and the consumption of aquatic macrophytes (Bajer & Sorensen, 2009; Breukelaar, 1992; Breukelaar *et al.*, 1994; Roberts *et al.*, 1995; Scheffer, 1998; Weber & Brown, 2009). Vegetated lakes can become turbid and algal blooms may occur resulting in changes to the species composition of vegetation, fish and birds. The common carp is considered as invasive in the U.S., Australia and Canada (Bajer & Sorensen, 2009; Khoen, 2004; McCrimmon, 1968).

The densities of common carp that can cause changes in ecosystems vary between studies from 30kg/ha (Scheffer 1998), 100 to 250kg/ha (Breukelaar, 1992; Breukelaar *et al.*, 1994; Bajer & Sorensen, 2009; Barthelmes, 2003; Smith 1999) to 450kg/ha (Roberts *et al.*, 1995). Other factors in association with carp density such as soil type, water depth, nutrient input, predators of common carp and climate will influence ecosystem effects.

Common carp provided for stocking often originate from outside the Netherlands (Middle and Eastern Europe). Placing hosts in new environments might lead to the introduction of new viral infections. Global warming and changed management practices (such as practices that lead to overcrowding) might also play a part in disease transmission (Dixon, 2006). Examples of viruses spread over the globe that result in high common carp mortalities are Koi Herpes Virus (KHV) and Spring Viremia of Carp Virus (SVCV) (Haenen *et al.*, 2004; CEFAS, 2009). Effects resulting in severe non-reversible declines of local common carp populations have been reported (> 80%). A temperature increase related to climate change will enhance the KHV. However, SVCV will not be affected by an increase in temperature as this disease only occurs at water temperatures of less than 16°C. Parasites and bacteria will not have the same impact as the above viruses. Most parasites and bacteria described for the common carp are already globally present.

Common carp hybridizes with *Carassius* species, a genus that includes the native crucian carp (e.g. Hänfling *et al.*, 2005). Furthermore, common carp competes with crucian carp (e.g. Knytl *et al.*, 2013). Hybridization and competition have negative impacts on the crucian carp population which is native and threatened in the Netherlands (Dutch Red List).

Economic impact

The European Water Framework Directive (WFD) sets ecological targets for surface water bodies. In the Dutch version of the WFD policy goals, fish stock assemblages in natural and manmade waters are included in the assessment criteria. If the WFD goals are not met before 2027, penalties from the European Union will apply. Common carp is classified as a eurytopic fish in the fish stock assemblage score of the WFD. Water bodies where the abundance of eurytopic fish is too high are scored insufficiently according to the criteria of the WFD. A high abundance of common carp could result in a lower score attributed to some water types, leading to a negative economic impact as a result of European financial penalties.

Social impact

In Australia, the carp is an invasive species. Social impacts of carp are felt by Australian communities through "a loss of environmental quality and amenity" (Anonymous c, 2012) meaning that "communities are not proud of the condition of many of their waterways because of the presence of carp" (anonymous c, 2012). In Europe, no negative social impacts have been described in available literature. Here, carp are often highly appreciated, contributing to recreation and are either eaten or kept as pets.

6.2.6 Positive impact of introduction

Ecological impact
There was no literature found on the positive ecological impact of common carp.

Economic impact
Common carp have a high nutritional value, but are not preferred as table fish in the Netherlands. The species is highly appreciated by anglers and are therefore of great economic importance. The total turnover of the fresh water angling industry in the Netherlands (including indirect turnover that includes for example travel expenses) is estimated to be in the order of 360 million to 600 million €/year generated from 1.6 million recreational anglers (Smit *et al.*, 2004). Anglers targeting carp make up about 9% of the angling community, but spend a relatively high amount of money on their hobby compared with other anglers (Steyn, 2010; Smit *et al.*, 2004).

Social impact
In the Netherlands the common carp is a very popular and important species for sport fishing. There are about 1.6 million people that fish in the Netherlands, 9% of which mainly fish for carp (Smit *et al.*, 2004). In the past century, many books have been written about carp fishing in the Netherlands. Large common carp often have a high intrinsic value, as they are individually recognized by anglers and, in some cases, individually named. Common carp are treated with much respect by anglers, who put them on thick soft sheets to remove the (often barbless) hook. Virtually all common carp are released after being caught by recreational anglers.

6.3 Risk classification

6.3.1 Available risk classifications

No formal risk assessments were found for the common carp.

6.3.2 Current situation

Expert consensus scores
The total risk score attributed to the common carp was 11 out of a maximum risk score of 12 (table 4.3). This results in an overall classification of high risk for this species.

Table 4.3: Consensus scores and risk classifications for common carp (Cyprinus carpio) in the current situation in the Netherlands.

ISEIA sections	Risk classification	Consensus score
Dispersion potential or invasiveness	high	3
Colonization of high value conservation habitats	high	3
Adverse impacts on native species	medium	2
Alteration of ecosystem functions	high	3
Global environmental risk	A - list category	11

Dispersion potential or invasiveness
The common carp has a high dispersal and reproduction capacity in the Netherlands. This high reproduction capacity is predominantly expressed in the western parts of the country where habitat is suitable for reproduction. In the eastern part of the Netherlands the common carp's reproduction success is often not high enough to maintain populations. The relative fecundity of the common carp is high, with females producing 100,000 to 200,000 eggs/kg body weight (Steffens, 1958). The species can migrate over long distances to reach suitable spawning habitat (Kottelat & Freyhof, 2007). Common carp are already widespread in the Dutch freshwater network and were probably already present in the Netherland in the 14th century. The combination of high fecundity, regional high reproduction success, large migration capacity and widespread distribution suggest that common carp have a high dispersal potential and invasiveness in the Netherlands.

Colonisation of high conservation value habitats
37% of common carp distribution occurs in areas designated under Natura 2000 and, therefore, often occurs in high conservation value habitats in the Netherlands (appendix 1). For example, common carp are often present in fens (Dutch: veenweide) and floodplain lakes, both of which are classified as high conservation value habitats. It was concluded that the common carp poses a high risk to high conservation value habitats in the Netherlands due to its current widespread distribution and more than occasional occurrence in these areas. However, common carp reach only low abundances in most high conservation habitats in the Netherlands due to less than ideal habitat conditions. Common carp reach their highest abundance in man-made waters, often with elevated salinity levels.

Adverse impacts on native species
There is no information available from literature that describes the impact of common carp on native species in the Netherlands. Evidence from climatically similar countries suggests that common carp may impact the crucian carp (*Carassius carassius*) population through dietary competition and hybridization (Hänfling & Harley, 2003; Knytl *et al.,* 2013). Hybridization between common carp and crucian carp has occurred in the United Kingdom (Hänfling & Harley, 2003), however it is not clear what proportion of the crucian carp population disappeared as a result of this. The crucian carp is a native species and threatened in the Netherlands (Dutch Red List). However, it is improbable that hybridization has led to a decrease of more than 80% of crucian carp. Aquatic vegetation is negatively affected by the presence of common carp. Removal of vegetation has a negative impact on many native species, for example the European weatherfish (*Misgurnus fossilis*), a protected and vulnerable red-list species in the Netherlands. Based on evidence derived from countries that are climatically similar to the Netherlands, it was concluded that common carp pose a medium risk to native species related to the subcategories predation and herbivory, interference and exploitation competition and genetic effects.

The common carp carries a range of diseases that, according to expert judgement, will likely affect various cyprinid native species, an example of this is SVCV (OIE, 2013b). The threat of infection increases following the release of common carp from isolated ponds. Moreover, common carp may carry the Herpes virus (KHVD). However, this disease is specific to carp and will not affect other fish species native to the Netherlands (OIE, 2013a). No evidence of any disease transmission between common carp and native species in the Netherlands has been recorded in literature. Therefore, expert judgment determined that it was likely that the diseases and parasites of common carp will have a negative impact on Dutch native species.

Overall, it was concluded that common carp pose a medium risk to native species in the Netherlands based on negative impacts related to the subcategories predation and herbivory, interference and exploitation competition and genetic effects.

Alteration of ecosystem functions

High densities of common carp can have a strong impact on submerged vegetation that is utilised as a food source by many species, and turbidity because they often grub through bottom sediments during feeding (Bajer & Sorensen, 2009; Breukelaar, 1992; Breukelaar *et al.,* 1994; Roberts *et al.,* 1995; Weber & Brown, 2009). Vegetated lakes can turn into turbid waters featuring algal blooms resulting in changes to the species composition of vegetation, fish and birds. Based on the evidence available it was concluded that common carp pose a high risk for negative impacts relating to the modification of nutrient cycling or resource pools, the physical modifications of habitats, the modifications of natural succession and the disruptions of food webs in the Netherlands.

Species classification

The species classification corresponds to the global environmental risk score of the ISEIA (table 6.3) combined with the current distribution of the non-native species within the country in question. The species classification for common carp is A3 (Figure 6.4). This indicates a non-native species exhibiting a wide distribution and high environmental hazard (i.e. ecological risk) that should be placed on the black list of the BFIS list system (i.e. ecological risk: ISEIA score 11: A category).

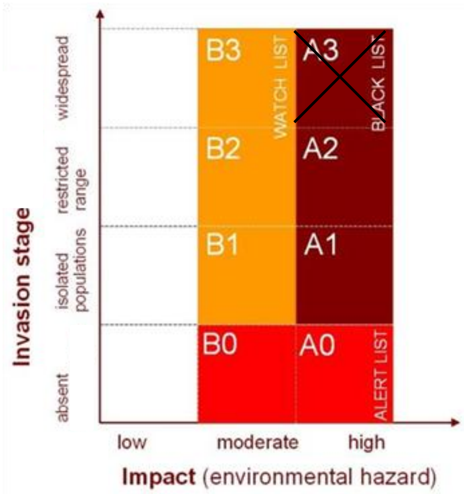

Figure 6.4: Common carp (Cyprinus carpio) classification according to the BFIS list system.

6.3.3 Future situation

The optimum temperature range for adult common carp is 14-28°C (De Wilt & Van Emmerik, 2008). In the event of a two degrees Celsius temperature rise, average summer water temperatures in the Netherlands will likely remain within this range in the majority of water bodies. Current climate conditions in the Netherlands are not optimal for the species. In warmer climates, common carp have been observed to reproduce highly successfully (Smith, 2004). Therefore, in a worst case scenario, it is possible that the reproduction success of common carp in the Netherlands will increase. Temperature increases will likely also encourage diseases (e.g. KHVD) and parasites of common carp (O. Haenen, pers. comm.; OIE, 2013a). However, these diseases and parasites will not affect native species in the Netherlands. When only temperature is considered, the overall risk score of common carp in the Netherlands could rise due to a possible worsening negative impact on native species as a result of increases in common carp abundance (table 6.4). However, in this scenario the A3 classification under the BFIS list system would remain the same.

Table 6.4: Common carp (Cyprinus carpio) theoretical classification according to a potential future habitat scenario.

ISEIA sections	Risk classification	Consensus score
Dispersion potential or invasiveness	high	3
Colonization of high value conservation habitats	high	3
Adverse impacts on native species	high	3
Alteration of ecosystem functions	high	3
Global environmental risk	A - list category	12

6.4 Risk management

6.4.1 Prevention of introduction

The common carp is widespread in the Netherlands. Natural dispersion through fish migration corridors and connected waterways is virtually impossible to prevent. Nevertheless, prevention of the further spread of fish to isolated water bodies currently unoccupied by common carp, and the removal of populations with unsuccessful reproduction can be achieved through the banning of stocking practices.

6.4.2 Elimination of populations

The common carp is widespread in the Netherlands. Only populations in relatively small isolated water bodies may be eliminated cost efficiently. Internationally, most literature available on the elimination of carp populations features examples from Australia (Roberts & Tilzey, 1996). In Tasmania in the 1970s, common carp were eradicated with rotenone poison. In this example, about 20 populations in dam reservoirs were eradicated. The reservoirs remained free of the species for over 20 years (Roberts & Tilzey, 1996). However, complete eradication of carp in large water bodies has proven to be very difficult, as a few surviving specimens always remain (Diggle *et al.*, 2004). For elimination methods applicable to fish species in general, see Appendix 4.

6.4.3 Management of populations

The common carp has been present for centuries in the Netherlands and many populations are managed by re-stocking in many water bodies. When carp are not re-stocked, it is expected that numbers will decrease in waters with unsuitable conditions for reproduction and juvenile life stages. These waters are particularly situated in the eastern half of the Netherlands.

Carp removal as a population management method has not been implemented in the Netherlands. Biomanipulation measures (*'actief biologisch beheer'*) aimed at reducing stocks of 'turbidity increasing' fish species have been suggested as a method to enhance the clarity of stagnant waters (e.g. Jaarsma 2008). However, plans to remove carp and other species (predominantly native bream, *Abramis brama*) from several water systems were halted because of public opposition (e.g. Visblad, 2010).

In Australia much research has addressed management options for the control of common carp (e.g. Roberts & Tilzey, 1996; Gilligan *et al.*, 2005). Also, involvement of the Australian public has been encouraged, leading to the organisation of carp killing events by recreational anglers (Smith, 2011). However, the effectiveness of both the chemical and physical control options are limited in large water systems (Gilligan *et al.*, 2005). Therefore, other management options are suggested, for example biological controls like the daughterless carp program which introduces physical barriers to carp reproduction (Gilligan *et al.*, 2005).

In some cases, the invasion success of exotic species might be mitigated by altering or rehabilitating the water system (Van Kessel *et al.*, 2013). Ideally these measures disrupt the completion of exotic species' life cycle and enhance native species. In Australia, adult carp are excluded from spawning areas using 'fish screens', that prevent reproduction (Gilligan *et al.*, 2005). However, this measure would also negatively affect native species if introduced to the Netherlands.

As common carp are a widespread species in the Netherlands, eradication and active control of the population will be difficult and costly. Furthermore, efforts to reduce the carp population will suffer high societal resistance because the species features a high intrinsic value for many anglers.

7. EASTERN MUDMINNOW (*Umbra pygmaea*)

7.1 General species description

7.1.1 Nomenclature and taxonomical status

Order	Salmoniformes
Family	Umbridae
Genus	*Umbra**
Species	*Umbra pygmaea* De Kay, 1842
Common name	Eastern mudminnow (Dutch: Amerikaanse hondsvis)
Synonyms	*Leuciscus pygmaeus*

*The eastern mudminnow (*Umbra pygmaea*) is one of three members in the genus *Umbra*, in the family Umbridae. *Umbra* is monophyletic with the European mudminnow (*U. krameri*), this being the sister species to the two North American species (Schmidt & Daniels, 2006). However, the relationships between these esocoid fishes are controversial (López *et al.*, 2004).

7.1.2 Species characteristics and identification

Figure 7.1: The eastern mudminnow (Umbra pygmaea) from a North-Brabant moorland pool (length 8cm) (digitalnature.org)

The eastern mudminnow has an elongated shape and it is rather small in size: its length ranges from 3.4 to 13.7cm (Verreycken *et al.*, 2010). Its body is robust, thick and somewhat compressed. The species has generally a green-brown colour which is darker and more pronounced on the animal's back than on the flanks (Froese & Pauly, 2011; Bouyssou, 2012). The colour pattern of the eastern mudminnow is its most distinctive feature; it has 8 to 12 dark, longitudinal stripes separated by lighter stripes of equal or slightly greater depth (Figure 7.1) (Riehl & Baensch, 1991; Schmidt & Daniels, 2006). When observed in section, the body seems nearly circular (Bouyssou, 2012). The fish has a dark stripe through its eye, a black basicaudal bar, a pale lower jaw and pale and plain fins (Riehl & Baensch, 1991). The head is bluntly conic and the snout is short and equal to the diameter of the eye. The mouth is moderate with short jaws and the mandible protrudes slightly beyond the tip of the upper jaw, the premaxillaries are not protractile (Froese & Pauly, 2011). The caudal fin is composed of a single lobe and is rounded, with 18-20 rays (Spillman, 1961; Guido & Keith, 2002). The dorsal fin has a rounded form and is located very close to the back of the body, almost directly above the anal fin and features 14-15 soft rays (Froese & Pauly, 2011; Bouyssou, 2012). The pelvic fins start from a position situated clearly ahead of the dorsal fin (Bouyssou, 2012). The maximum age that could be established for the eastern mudminnow is 8 years (Den Hartog & Wendelaar Bonga, 1990). In the Netherlands, the males reach a length of 8.4cm, while the females may reach a size of 13.4cm.

The eastern mudminnow and central mudminnow (*Umbra limi*) are very similar in appearance (Schmidt & Daniels, 2006). However, a search of the Dutch species register (Naturalis Biodiversity Center, 2013) revealed no record of central mudminnow existing in the Netherlands.

7.1.3 Life cycle

Habitat characteristics and environmental tolerances

The eastern mudminnow is typical of slow-moving, mud-bottomed, and highly vegetated streams, swamps, and small ponds (Panek & Weis, 2013). Crombaghs *et al.* (2000) were able to define the preferred biotic and abiotic parameters in river systems of the Netherlands. The eastern mudminnow is often found in wider ditches (4 to 5 m) that are deeper than 0.5 m with a sandy or muddy substrate and low water velocity (<0.30 m/s with about 40% of the observations <0.05 m/s). Dense vegetation is often present at these sites. Abundance of the eastern mudminnow is inversely related to the abundance of other fish species (Leuven & Oyen, 1987).

The eastern mudminnow has a great potential to colonise a broad range of habitats (Crombaghs *et al.*, 2000; Verreycken *et al.*, 2010; Van Emmerik, 2003), which allows this species to extend its distribution range into extreme habitats (Dederen *et al.*, 1986). It can also tolerate large fluctuations in water temperature, low pH, low dissolved oxygen levels and also temporary desiccation of its environment (Den Hartog & Wendelaar Bonga, 1990; Rieger *et al.*, 2004). Table 7.1 gives an overview of the physiological tolerances of the eastern mudminnow.

Reproduction

The eastern mudminnow matures within one to two years after hatching (Dederen *et al.*, 1986; Den Hartog & Wendelaar Bonga, 1990; Guido & Keith, 2002). The fecundity estimates for the eastern mudminnow range from 250 eggs/female at age-1 to 2,168 eggs/female at age 5 in the United States (Panek & Weis, 2012) and 100-1,200 eggs/female (size 1.8-1.9 mm) in the Netherlands (Dederen *et al.*, 1986; Den Hartog & Wendelaar Bonga, 1990). In the Netherlands, the maturation of the gonads of the eastern mudminnow takes place from October to April. The female deposits the eggs in April and May (Dederen *et al.*, 1986; Den Hartog & Wendelaar Bonga, 1990). In the United States, peak spawning occurs in mid-April at temperatures of 9-12°C, and all females have spawned by late April (13-15°C) (Panek & Weis, 2012). Eggs are deposited in vegetation near the banks of water bodies. The incubation period is five to ten days. At a temperature of 10°C, hatching takes place after 14 days. The larvae are then 5 mm and still have a yolk sac. When they have grown to 7 mm, the yolk has been used up completely. Both parent fish may take care of the fry, since the fish live in pairs during the entire reproduction season (Dederen *et al.*, 1986; Den Hartog & Wendelaar Bonga, 1990).

Table 7.1: Physiological conditions tolerated by eastern mudminnow (Umbra pygmaea).

Parameter	Tolerance	Remarks	References
pH	3.1-8.43	Tolerated range	Leuven *et al.* (1984); Dederen *et al.* (1986); Den Hartog & Wendelaar Bonga (1990); Wendelaar Bonga *et al.* (1990); Verreycken *et al.* (2010)
pH	3.5-6.0	Optimal range	Leuven *et al.* (1984); Leuven & Oyen (1987); Den Hartog & Wendelaar Bonga, (1990); Wendelaar Bonga *et al.* (1990)
pH	4.5	Higher growth observed than at neutral pH	(Wendelaar Bonga, 1990)
pH	3.5-8	Normal gonadal maturation and fertilization, development and hatching of eggs have been observed	Dederen *et al.* (1986); Leuven & Oyen (1987); Leuven *et al.* (1987)
Alkalinity	<0.1 meq/l	Lower critical value	Dederen *et al.* (1986); Den Hartog & Wendelaar Bonga, (1990)
Oxygen	3.3-20.4mg/l	Present at range	Verreycken *et al.* (2010)
Oxygen	hypoxia	Air-breathing and use of swim bladder as an accessory respiratory organ at high water temperatures, or under other hypoxic conditions.	Gee (1980); Rahn *et al.* (1971); Den Hartog & Wendelaar Bonga (1990)
Temperature	0.1-23°C	Present at this range	Riehl & Baensch (1991); Verreycken *et al.* (2010)
Spawning temperature	9–12°C		Panek & Weis (2012)
Depth range	>0.5 m	Present at this range	Crombaghs *et al.* (2000)
Mean depth	0.15-1.20 m	Present at this range	Verreycken *et al.* (2010)
Water velocity	<0,6m/s	All observations below value	Crombaghs *et al.* (2000)
Conductivity	0-1245 µS/cm		Dederen *et al.* (1986); Verreycken *et al.* (2010)
Salinity	<5%	Documented for oligohaline waters (<5%)	Wang & Kernehan (1979)
Calcium concentration	15-100 mmol/l	Present at this range	Dederen *et al.* (1986); Den Hartog & Wendelaar Bonga (1990)

Diet

The eastern mudminnow is a bottom-feeding generalist that consumes cladocerans, ostracods, chironomid larvae, coleopteran larvae, and other insects and crustaceans. Declerck *et al.* (2002) examined the diet mass composition of the eastern mudminnow at the "De Maten" nature reserve in Gent, Belgium, where the species was introduced. They found that the diet mainly consisted of larger prey items including chironomid larvae, ephemeropterans, asellid isopods, odonates, and coleopteran larvae. Moreover, the eastern mudminnow predates on the larvae of amphibians (Vooran, 1972; Chalcraft & Resetarits, 2003). The wide variety of prey items of the eastern mudminnow indicates diet flexibility in varying environments (Panek & Weis, 2013).

Predators
In the Netherlands, the eastern mudminnow is a potential prey species of fish eating birds such as grebes and, in less acidic water-bodies, piscivorous fish species such as the European perch (*Perca fluviatilis*) and pike (*Esox lucius*) (Dederen *et al.*, 1986; Den Hartog & Wendelaar Bonga, 1990).

Parasites and diseases
There is very little information available on the parasites and diseases of the eastern mudminnow. Only the parasite species *Lernaea cyprinacea* Linnaeus, 1758 is specifically mentioned in connection with this species (WoRMS, 2013).

7.1.4 Native range and world distribution

The native North American range of the eastern mudminnow includes the Atlantic and Gulf slopes from south-eastern New York (including Long Island) to St. Johns River drainage in Florida and west to Aucilla River drainage in Florida and Georgia, USA (Froese & Pauly, 2009) (Figure 7.1). In Europe, the eastern mudminnow was introduced in six countries namely Germany, Belgium, the Netherlands, France, Poland and Denmark. However, the core of the current distribution of the eastern mudminnow in Europe is the south-eastern part of The Netherlands (provinces Limburg and Noord-Brabant) and the northeast of Flanders (provinces Antwerpen and Limburg) in Belgium. The distribution in the Netherlands completely links up with the distribution range in Flanders and together this forms the largest distribution area of the eastern mudminnow outside its native range (Verreycken *et al.*, 2010).

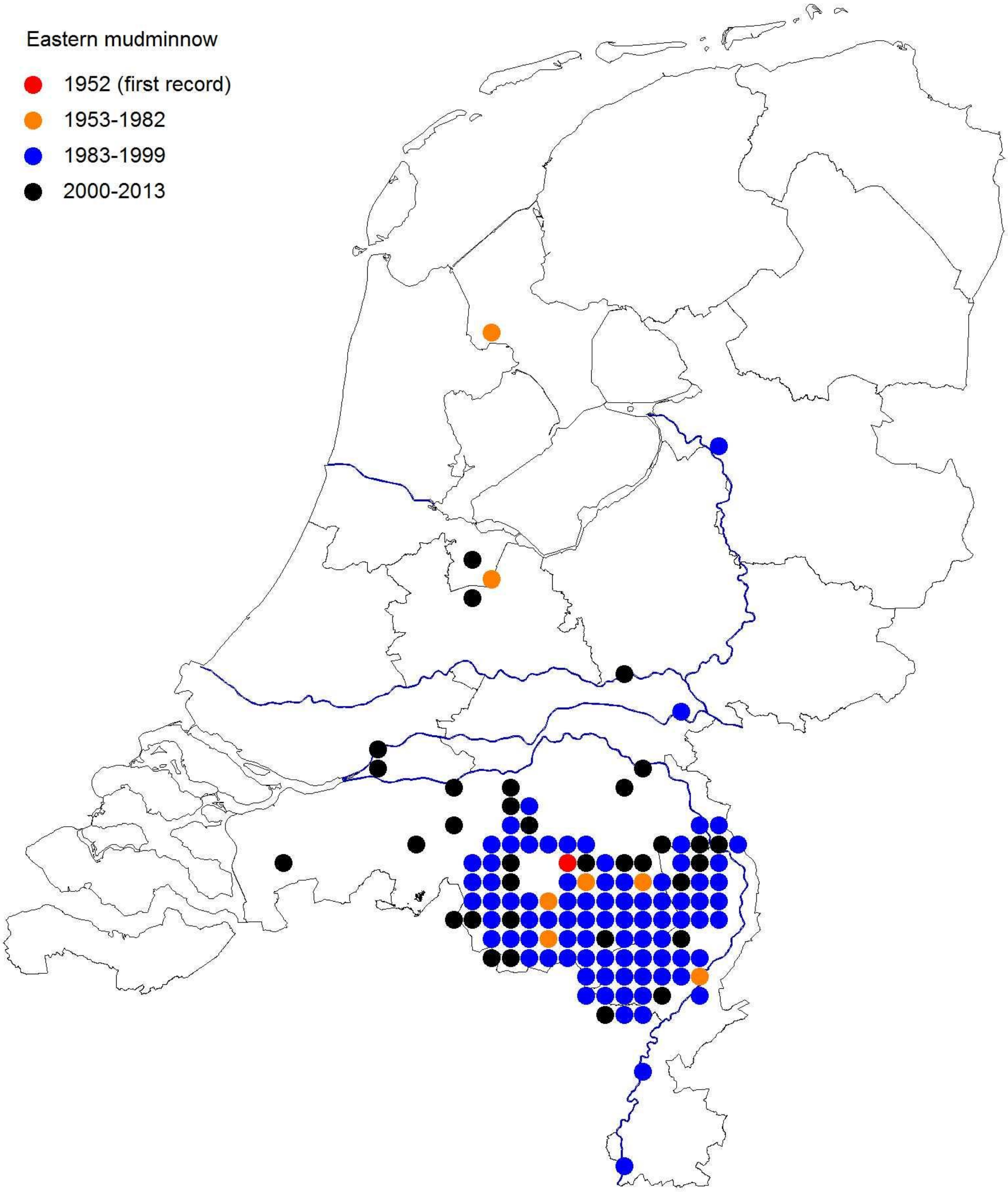

Figure 7.2: Distribution history of the eastern mudminnow (Umbra pygmaea) in the Netherlands (older records are plotted on top of more recent records) (RAVON/NDFF data).

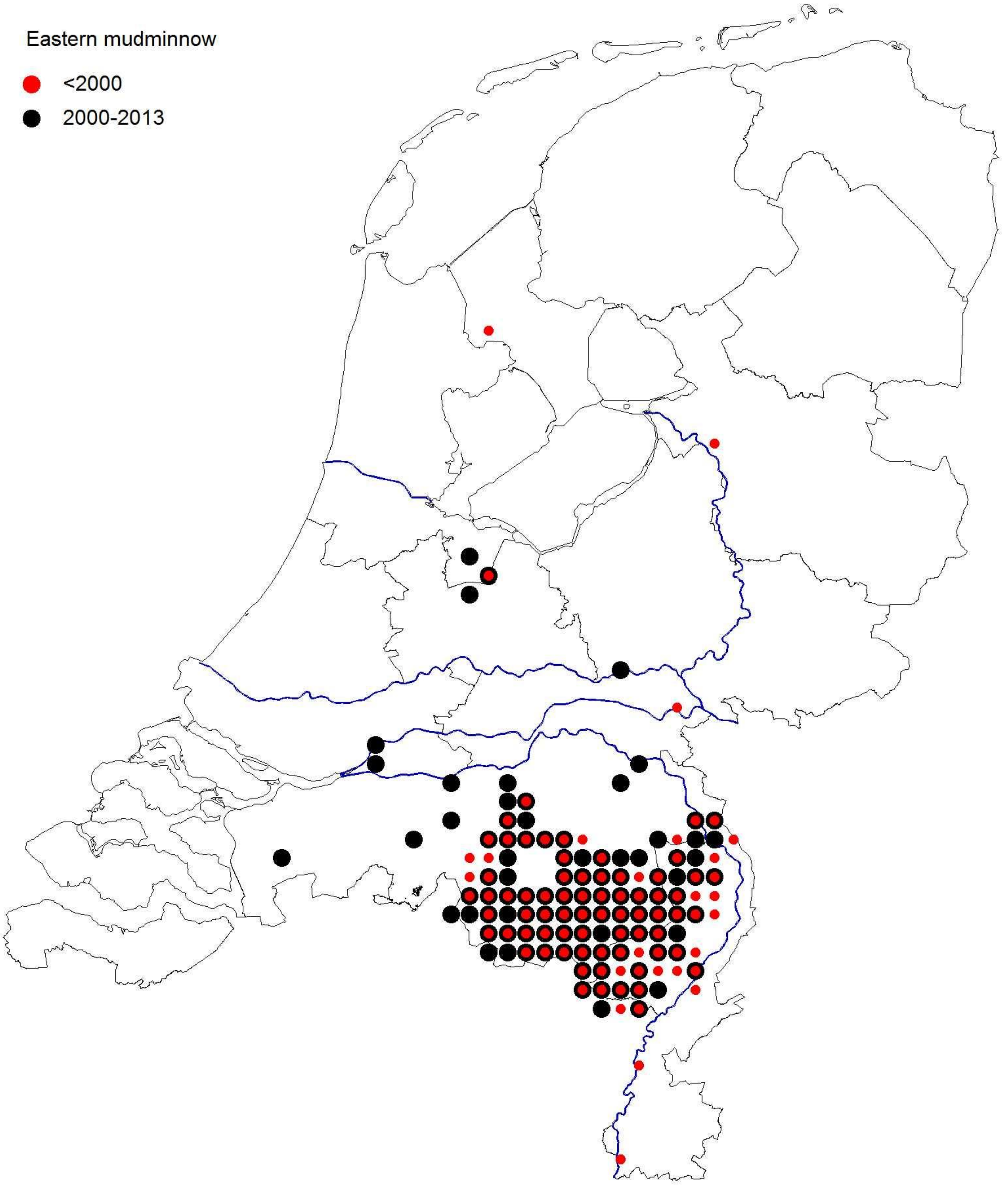

Figure 7.3: Geographical distribution of the eastern mudminnow (Umbra pygmaea) before and after 2000 in the Netherlands (combined black and red dots indicate presence in both periods) (RAVON/NDFF data).

Today, the eastern mudminnow is widespread in the south-eastern part of the Netherlands. In the Netherlands, the species occupies the provinces Limburg and North Brabant (Figure 7.2). Here it is particularly abundant in acidified soft-water ecosystems with a low pH, such as moorland pools ("vennen"), and is usually the only fish species (Leuven & Oyen, 1987; Dederen, 1986). The eastern mudminnow was first introduced to the Netherlands in the 1920s from aquaculture (Den Hartog & Wendelaar Bonga, 1990; Verreycken *et al.*, 2010). The early recorded distribution of the eastern mudminnow in the Netherlands was characterised by isolated populations till the early

1980s. Between 1983 and 1999, a large number of records were collected focussing mainly in the south of the Netherlands in Limburg and North Brabant. Since the year 2000 more recordings have been made outside the initial range.

7.2 Risk assessment

7.2.1 Probability of entry

The eastern mudminnow was first introduced to the Netherlands in the 1920s from aquaculture (Den Hartog & Wendelaar Bonga, 1990; Verreycken *et al.*, 2010). In general, the majority of the initial introductions that have occurred in Europe (the Netherlands, Germany and Poland) were a result of aquaculture and the aquarium trade (Geiter *et al.*, 2002; Wolter, 2009; Verreycken *et al.*, 2010; Crombaghs *et al.*, 2000; de Nie, 1996) or in the case of Denmark and France were released on purpose into water-bodies (Atlas of Danish Freshwater Fish, 2007; Guidou & Keith, 2002; Keith & Allardi, 2001). For example, in the 1970-80s the eastern mudminnow was spread to several ponds in the Argonne (Marne region, France) unintentionally by Belgian pisciculturists (Guidou & Keith, 2002). Moreover, in Belgium, earthen fish culture ponds which are emptied every year, may act as a major source of eastern mudminnow specimens for riverine populations (Verreycken *et al.*, 2010). However, dispersal to Belgium may also have resulted from natural dispersal originating in the Netherlands (Poll, 1949; Philippart, 2007; Verreycken *et al.*, 2007). Based on an internet search it appears that there is limited interest in the eastern mudminnow as an aquarium or garden pond species in the Netherlands and Flanders. No retailers selling 'Amerikaanse hondsvis' could be found online. However, there were examples of interest in the species in Dutch and Belgium hobbyist forums. One particular contributor wanted an example of the eastern mudminnow for their aquarium and requested information on where they could fish for the eastern mudminnow in the Netherlands. The probability of new entries is therefore low.

7.2.2 Probability of establishment

In the Netherlands, the eastern mudminnow occurs in ditches with dense vegetation or in waters without other fish species (e.g. acid moorland pools) where viable and very dense populations can occur (Leuven *et al.*, 1984; Crombaghs *et al.*, 2000). Acidification of shallow and lentic soft waters has had an important impact on fish assemblages and has favoured the distribution and densities of eastern mudminnow (Dederen *et al.*, 1986; Leuven & Oyen, 1987). No temperate fish species other than the eastern mudminnow are known to us that reproduce successfully below pH 4.5, in contrast the eastern mudminnow seems to function optimally under acid conditions in the 3.5 to 4.0 pH range (Den Hartog & Wendelaar Bonga, 1990). In a survey of about 100 lakes and ditches in the Netherlands, with a pH varying from 3.5 to 8.1, strongly acid waters (pH < 5) were generally fishless. However, if fish were present in these waters, the catches mainly consisted of the eastern mudminnow (Leuven & Oyen, 1987).

The eastern mudminnow appears to be able to tolerate a wide range of conditions, including circumneutral waters (Dederen *et al.*, 1986; Crombaghs *et al.* 2000). However, in habitats with less extreme (pH) conditions and in the presence of piscivorous fish species, abundance of the eastern mudminnow is lower. The fish is quite sluggish, making it an easy prey for larger fish and fish-eating birds. In circumneutral waters in the Netherlands, abundance is limited, probably due to predation by large fish (Den Hartog & Wendelaar Bonga, 1990). Crombaghs *et al.* (2000) noticed hardly any juveniles or subadults in Dutch streams and brooks suggesting that the eastern mudminnow does not or barely reproduce successfully in these waters, explained by the presence of predators. In many waters the probability of establishment is therefore low. However, in densely vegetated waters, with a low abundance of predators, the probability of establishment can be high.

7.2.3 Probability of spread

The eastern mudminnow has spread by diffusion after escapes or releases in the lowland waters of Northern Europe (Elvira, 2001). After its initial establishment in the Netherlands in the 1920s, the distribution of the eastern mudminnow in the Netherlands has remained focussed around the Limburg and North Brabant area (Figure 7.2). From here the eastern mudminnow possibly spread to Flanders, where it was first recorded in 1949 (Verreycken *et al.*, 2010). Its recorded distribution, while expanding significantly in the 1980s and 90s, remains focussed in these regions. The spread in the Netherlands is slow, but the distribution is expanding gradually (Figure 7.2).

The distribution of eastern mudminnow in the Netherlands completely links up with the distribution range in Flanders, Belgium (Verreycken *et al.*, 2010). After the initial dispersal following its introduction (Burny, 1984), distribution of the Belgium population of the eastern mudminnow remained relatively unchanged in the 1980s and 1990s and changes to frequency of occurrence and abundance over the last decade have been minimal (Vandelannoote *et al.* 1998; Verreycken *et al.* 2007). Moreover, other authors have concluded that the spread potential of eastern mudminnow seems low and is probably limited by the presence of piscivorous fish species in Flemish lotic waters (Dederen *et al.*, 1986). The (relative) abundance of the eastern mudminnow is inversely related to the number of fish species present (Panek, 1981; Verreycken *et al.*, 2010). Assessment of the eastern mudminnow for its potential invasiveness in Flanders results in a low to medium risk (Verreycken *et al.*, 2010). In general, the slow dispersal of the eastern mudminnow in Europe since its introduction, except for human aided dispersal (e.g. Guidou & Keith 2002), and its confined distribution seem to confirm its low spread potential (Verreycken *et al.*, 2010).

7.2.4 Vulnerable areas

The eastern mudminnow predominantly occurs in internationally protected areas listed under Natura 2000 (Appendix 1) (Schut *et al.*, 2011; Nationaal Park de Groote Peel, 2013). The eastern mudminnow is present virtually everywhere and in high densities in the Deurnese Peel and may predate on the eggs of the palmate newt (*Lissotriton helveticus*) (Schut *et al.*, 2011). Palmate newt is a protected species and has been placed on a red list in the Netherlands (Van Delft *et al.*, 2007). Another area recognised as Natura 2000 that supports populations of the eastern mudminnow is the Beuven within the Strabrechtse Heide in North Brabant. Here, the eastern mudminnow is thought to consume the larvae of amphibians and has a negative influence on species richness as a result (KNNV, 2009). The eastern mudminnow may also have played a role in the reduced abundance of *Dytiscus latissimus* in the Netherlands, a beetle species that is recorded on the IUCN red list (IUCN red list of threatened species, 2013; Ministerie van Landbouw en Economische Zaken, 2013). In northeast Brabant, the eastern mudminnow has spread to habitats occupied by the wheaterfish (*Misgurnus fossilis*), a highly protected and endangered native species (Red List). Here the eastern mudminnow was found to be relatively abundant in pH neutral, stagnant, densely vegetated, low dynamic habitats of the Aa and the Dommel the river systems. Therefore, the eastern mudminnow could possibly colonise other similar habitats that are important to the native wheaterfish.

7.2.5 Negative (ecological) impact

There is a paucity of (peer-reviewed) publications on the introduced range and the ecological impact of the eastern mudminnow. The few publications that refer to the ecological impact (and distribution) of the eastern mudminnow mainly feature extreme habitats where this fish can occur in high densities due to limited predation, and where it is often the only fish species present (Verreycken *et al.*, 2010). Therefore, a review of the potential impacts of the eastern mudminnow should be viewed against factors that may limit its range and local abundance.

Effects on native species through predation and herbivory.
In the four decades preceding 1986, at least 60% of Dutch moorland pools were acidified (Leuven *et al.*, 1986). The pH level within these habitats increased from 4.3 to 4.5 in the 1970s and '80s to 4.8 to 5.0 in the year 2010 (van Dam & Mertens, 2011). This remains within the preferred tolerance range of the eastern mudminnow of pH 3.5 to 6 (Leuven & Oyen, 1987; Den Hartog & Wendelaar Bonga, 1990; Wendelaar Bonga *et al.*, 1990). However, other fish species that would otherwise compete with the eastern mudminnow are unable to tolerate such acidic conditions. In these habitats and in ditches with dense vegetation, the eastern mudminnow may, along with the larvae of Odonata, play an important role as a top predator (Leuven *et al.*, 1984; Dederen *et al.*, 1986; Crombaghs *et al.*, 2000).
The eastern mudminnow predates on the larvae of amphibians (Vooran, 1972; Chalcraft & Resetarits, 2003). Moreover, it has been suggested that the eastern mudminnow may predate on the palmate newt in the Netherlands (Van Kessel *et al.*, 2008; Schut *et al.*, 2010). A study in North Brabant found a negative, but not significant trend between eastern mudminnow abundance and the abundance of the palmate newt. This negative trend could either be a result of predation or that palmate newt chose to reproduce away from waters inhabited by the eastern mudminnow (Schut *et al.*, 2011). The result was not statistically significant due to a sampled water body where both species were observed to coexist. It was suggested that both the eastern mudminnow and palmate newt were able to exist together in this water body due to the presence of vegetation that provided cover for the palmate newt. The eastern mudminnow may also be a potential threat to certain dragonfly species that occur in Dutch water systems where fish do not normally occur due to low pH levels (Berwaerts *et al.*, 2009).

Effects on native species through competition.
In Belgium, the impact of the presence of the eastern mudminnow on other (indigenous) fish species was hard to evaluate. This was because many factors influence the fish species composition and diversity and accurate data of fish assemblages of rivers before the introduction of the eastern mudminnow are very rare (Verreycken *et al.*, 2010).
In the east of North Brabant, the eastern mudminnow has spread to habitats occupied by the European wheaterfish (*Misgurnus fossilis*), a highly protected and endangered native species (Red List). Competition of these species has, however, not yet been examined.
Declerck *et al.* (2002) examined dietary overlap between functional group combinations of fish and found that the analysis comparing the diet of the eastern mudminnow with other species resulted in low to very low overlap values. This suggests that intra-specific competition will probably not occur due to a dissimilarity of the diet of the eastern mudminnow compared to other fish. However, niche overlap indices should be interpreted with caution, as low diet overlaps may in principle also result from competition induced niche shifts (Declerck *et al.*, 2002).

Effects on native species through parasite and disease transmission.
There is very little information available on the parasites and diseases of the eastern mudminnow. Only the parasite species *Lernaea cyprinacea* Linnaeus, 1758 is specifically mentioned in connection with this fish (WoRMS, 2013). In the Netherlands, no investigations have been done on parasites and diseases of the eastern mudminnow. Apart from *Lernaea*, the eastern mudminnow will be sensitive to the endemic fish parasites of the Netherlands, the protozoans (for example *Trichodina*, *Chilodonella*, *Ichthyobodo*, *Glossatella*, *Ichthyophthirius multifiliis* (white spot) and metazoans (for example *Dactylogyrus/Gyrodactylus* spp.). However, the level of harm done will depend on the density of the fish and the parasites in combination with water temperature. It is not known if the other parasite species are harmful to native and other fish species. No investigations have been done in the Netherlands investigating these parasites.
No information specific to pathogenic bacteria relating to the eastern mudminnow is published. The eastern mudminnow will be susceptible to at least the endemic secondary pathogenic bacteria of fish, dependent on their immune status. These include, for example *Aeromonas sobria*, and *A. hydrophila*, *Plesiomonas shigelloides*, and myxobacteria (for example, *Flavobacterium columnare*).
No specific pathogenic viruses were found in relation to this fish species.
Only *Lernaea* is a known parasite of this fish species. This is a common carp parasite in Western Europe, and does not cause severe disease (ADW, 2013). Therefore the ecological impact of introduction of this parasite is low, also in future scenarios. The impact of parasites and diseases of the eastern mudminnow on native species in the Netherlands is negligible, leading to minimal effects that are easily reversibly.

Effects on native species through hybridisation.
A natural hybrid occurs between the eastern mudminnow and the central mudminnow, (*Umbra limi*) in North America. Hybrid individuals have been identified in a supratidal pool in a fresh-tidal marsh in the Hudson River, New York (Schmidt & Daniels, 2006). However, a search of the Dutch species register (Naturalis Biodiversity Center, 2013) revealed no record of central mudminnow existing in the Netherlands. No other information concerning the (magnitude of) effects on native species through hybridisation was found during the literature search or in communication with project partners.

Effect on ecosystem functioning
No information could be found relating the eastern mudminnow with effects on ecosystem functioning in the Netherlands or worldwide.

Modification of nutrient cycling or resource pools
No information could be found relating the eastern mudminnow with the modification of nutrient cycling or resource pools in the Netherlands or worldwide.

Physical modifications of habitat (hydraulic regime, turbidity, light interception, destruction of fish nurseries etc.)
No information could be found relating the eastern mudminnow with the physical modification of habitat in the Netherlands or worldwide.

Modification to natural succession
No information could be found relating the eastern mudminnow with the modification to natural succession in the Netherlands or worldwide.

Disruption to food webs
In the Netherlands, the eastern mudminnow may play an important role as a top predator in acidic moorland pools where it suffers little competition from other fish species (Dederen *et al.*, 1986). In these water systems the eastern mudminnow is a new predator and could reduce prey populations (e.g. insect larvae, water beetles, water bugs and larvae of amphibians). No other information concerning the (magnitude of) effects on ecosystem functioning was found during the literature search or in communication with project partners.

7.2.6 Positive impact of introduction

Nematocera form 84% of the food of the eastern mudminnow (Dederen, 1986), consequently the fish may be applied as a control agent for mosquitoes in acidified water systems such as marshes and slow moving vegetated streams (Slavin *et al.*, 1977; Den Hartog & Wendelaar Bonga, 1990).

In less acid water bodies in the Netherlands, the eastern mudminnow is a potential prey species of European perch (*Perca fluviatilis*) and Pike (*Esox lucius*) suggesting that it may have a positive impact on these species (Dederen *et al.*, 1986). Moreover, in some water-bodies The eastern mudminnow may provide food for grebes (Den Hartog & Wendelaar Bonga, 1990).

The species has no commercial or recreational value.

7.3 Risk classification

7.3.1 Available risk classifications

An overview of available risk classifications for the eastern mudminnow is given in table 7.2.

Table 7.2: Overview of risk classifications previously performed for the eastern mudminnow (Umbra pygmaea).

	Spain	Germany, Austria	Belgium	Belgium	United Kingdom
Scope	Risk assessment	Risk assessment	Risk assessment	Risk assessment	Risk assessment
Method	Iberian risk index	The German-Austrian Black List Information System (GABLIS)	ISIEA protocol	FISK	FISK
Risk classification	14/25 (watch list)	White list (low)	8 /12 (low)	14 (medium)	24 (high)
Source	Clavero (2011)	Nehring *et al.* (2010)	Anseeuw *et al.* (2007)	Verreycken *et al.* (2010)	Copp *et al.* (2009)
Additional information	Species not yet present in Spain	Poses no danger to native species or habitats	Not classified as invasive	≥19 = High risk	≥19 = High risk

Rationale for risk classification
Clavero (2011) gives an overview of Iberian risk index scores for multiple fish species and gives no rationale for the allocation of risk classifications.

Nehring *et al.* (2010) state that the eastern mudminnow has no impact on German and Austrian biodiversity through inter-specific competition, predation and herbivory, introduction of diseases or parasites, hybridisation with native species and no negative ecosystem effects. The distribution of the eastern mudminnow in these countries is limited. However, it is present in valuable habitats such as marshes (Gaumert & Kämmereit, 1993). Reproduction potential and potential spread were classified as high, although the species appears not to be increasing its current distribution (Geiter *et al.*, 2002). The eastern mudminnow does not monopolize resources such as food sources. It is unknown if this species will benefit from climate change. The eastern mudminnow does not impact the socio-economy or human health in Austria and Germany (Nehring *et al.,* 2010).

The geographical distribution range of the eastern mudminnow in Belgium is restricted and its distribution is stable. It is able to reproduce in the wild, displays a medium dispersion potential and its ability in colonising natural habitats is high. Anseeuw *et al.* (2007) judge the eastern mudminnow as a species with limited competitive ability, which finds it difficult to reproduce in the presence of other fish species in Belgium. It rarely occurs in high densities. Impacts on nutrient cycling and natural succession are low. No change to food webs or ecosystems are expected due to the presence of this species. Impacts on native species due to predation and herbivory and genetic effects are limited. However, the effect of competition with native species is medium. The potential for disease transmission by the eastern mudminnow is unknown in Belgium.

The results of the Belgium FISK assessment are mainly based on expert judgement. The few publications that deal with the ecological impact (and distribution) of the eastern mudminnow are mainly about extreme habitats where this fish can occur in high densities and it is often the only fish species present. Answers from the Belgian assessors in the risk assessment were based on their knowledge of the distribution and impact of eastern mudminnow in lotic waters in Flanders with low densities of this fish. In these rivers it seems appropriate that the eastern mudminnow is categorized as a species with "low to medium risk" of becoming invasive (Verreycken *et al.*, 2010).

Copp *et al.* (2009) gives an overview of FISK scores for multiple fish species in the United Kingdom but gives no rationale for the allocation of risk classifications.

7.3.2 Current situation

Expert consensus scores

The total risk score attributed to eastern mudminnow was 8 out of a maximum risk score of 12 (table 7.3). This results in an overall classification of low risk for this species.

Table 7.3: Consensus scores and risk classifications for eastern mudminnow (Umbra pygmaea) in the current situation in the Netherlands.

ISEIA sections	Risk classification	Consensus score
Dispersion potential or invasiveness	moderate	2
Colonization of high value conservation habitats	high	3
Adverse impacts on native species	likely	2
Alteration of ecosystem functions	unlikely	1
Global environmental risk	C - list category	8

Dispersion potential or invasiveness

The eastern mudminnow exhibits a low fecundity with low dispersal ability in the Netherlands. The females deposit 100-1200 eggs (size 1.8-1.9 mm) in April and May during spawning (Dederen *et al.,* 1986; Den Hartog & Wendelaar Bonga, 1990). The eastern mudminnow is highly tolerant of acidic conditions and, in the Netherlands, occurs in high abundances in acidic moorland pools, where it is often the only fish species present (Leuven & Oyen, 1987; Dederen, 1986). In less acidic waters its distribution is limited by piscivorous fish (Dederen *et al.,* 1986; Den Hartog & Wendelaar Bonga, 1990; Crombaghs *et al.,* 2000). However, recent unpublished observations have confirmed that the eastern mudminnow has spread during the last 30 years to habitats with less extreme pH conditions and the species occurs locally in Dutch streams and rivers. Low fecundity and a distribution that has shown some signs of increase in recent years suggest that the eastern mudminnow has a medium dispersal and invasiveness potential in the Netherlands.

Colonisation of high conservation value habitats

The eastern mudminnow favours low pH habitats and colonises valuable moorland habitats in the Netherlands. 58% of eastern mudminnow distribution occurs in areas designated under Natura 2000 in the Netherlands (appendix 1). Moreover, the eastern mudminnow is present in two wetlands that are internationally protected under the RAMSAR convention as well as Natura 2000, the Deurnese Peel and Groote Peel in Limburg (Schut *et al.,* 2011; Nationaal Park de Groote Peel, 2013). Furthermore, the habitat of the eastern mudminnow overlaps with that of the European weatherfish, a species that is protected in the Netherlands and is categorized as vulnerable under the Dutch red list (Naturalis Biodiversity Center, 2013). It was concluded that the eastern mudminnow poses a high risk to high conservation value habitats in the Netherlands.

Adverse impacts on native species

There is no empirical evidence in literature referring to the impact of the eastern mudminnow in the Netherlands or in climatically similar countries. However, in habitats where no other predatory fish species are present, the eastern mudminnow may become a top predator (Leuven *et al.,* 1984; Dederen *et al.,* 1986; Crombaghs *et al.,* 2000). In these habitats it is likely that the macroinvertebrate population will be impacted. Odonata species (dragonflies and damselflies) may be particularly vulnerable. Furthermore, the eastern mudminnow preys on the larvae of amphibians (Vooran, 1972; Chalcraft & Resetarits, 2003) and it has been suggested that it may prey on the palmate newt, a protected species in the Netherlands (Van Delft *et al.,* 2007; Van Kessel *et al.,* 2008). However, the evidence for these impacts is based on expert judgement. There is insufficient data to conclude whether or not diseases and parasites associated with the eastern mudminnow, or if interference and exploitation competition by this species pose a threat to native species in the Netherlands. It is unlikely that hybridisation with native species will occur as there are no similar species present in the Netherlands. Based on probable impacts related to predation, it was concluded that it is likely that the eastern mudminnow will negatively impact native species in the Netherlands.

Alteration of ecosystem functions
There is no literature evidence describing the impacts of the eastern mudminnow on ecosystem functions in the Netherlands. The localised and low density distribution of the eastern mudminnow suggests that any ecosystem effects will be insignificant. It was concluded that it is unlikely that the eastern mudminnow causes negative ecosystem effects in the Netherlands.

Species classification
The species classification corresponds to the global environmental risk score of the ISEIA (table 7.3) combined with the current distribution of the non-native species within the country in question. The eastern mudminnow is not assigned to a specific list in the BFIS list system (Figure 7.4). This indicates a non-native species that is present in a restricted range in the Netherlands and features low environmental hazard (i.e. ecological risk: ISEIA score 8: C category).

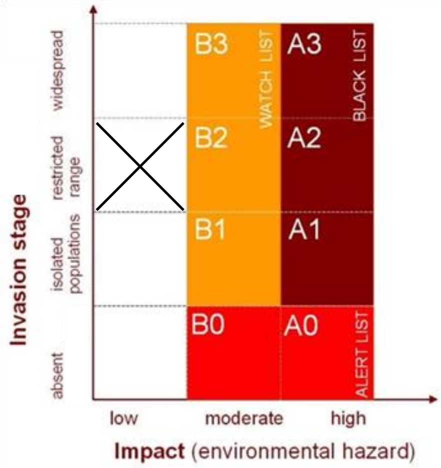

Figure 7.4: Eastern mudminnow (Umbra pygmaea) classification according to the BFIS list system.

7.3.3 Future situation

A future two degrees Celsius increase in water temperature due to climate change will be unlikely to affect the reproduction and ability of the eastern mudminnow to colonise freshwaters in the Netherlands. In Belgium, the eastern mudminnow has been observed in waters in winter and summer ranging in temperature from 0.1-23°C (Riehl & Baensch, 1991; Verreycken *et al.,* 2010). However, the actual temperature tolerance of the eastern mudminnow may extend over a broader range. When only temperature is considered, the overall risk score and distribution of the eastern mudminnow in the Netherlands is expected to remain unchanged (table 7.4) and therefore the species will remain unassigned in the BFIS list system. A possible reduction in atmospheric deposition due to potential improvements in air quality will lead to increased pH in water bodies in the Netherlands which may negatively affect high-density populations of the eastern mudminnow locally. Elsewhere, based on the increased spread of the eastern mudminnow over the last 30 years in the Netherlands, there may be a limited increase in distribution.

Table 7.4: Eastern mudminnow (Umbra pygmaea) theoretical classification according to a potential future habitat scenario.

ISEIA sections	Risk classification	Consensus score
Dispersion potential or invasiveness	moderate	2
Colonization of high value conservation habitats	high	3
Adverse impacts on native species	likely	2
Alteration of ecosystem functions	unlikely	1
Global environmental risk	C - list category	8

7.4 Risk management

7.4.1 Prevention of introduction

The eastern mudminnow is confined to a restricted range in the Netherlands. Natural dispersion through fish migration corridors and hydrologically connected water ways is virtually impossible to prevent. Nevertheless, further spread to currently unoccupied, isolated water bodies and river systems can be stopped by the prevention of stocking.

7.4.2 Elimination of populations

The largest abundances of eastern mudminnow in the Netherlands occur in small isolated water bodies. If desired, populations in these water bodies could be eliminated cost efficiently. There is internationally no information available on methods for the elimination of the eastern mudminnow. General methods for the elimination of populations of exotic fish can be found in Appendix 4. It is however, important to note that eastern mudminnows are extremely resilient and can survive in wet mud and under hypoxic conditions. Therefore, the methods described may not be applicable for this species.

7.4.3 Management of populations

Internationally there are no examples of measures to manage eastern mudminnow populations.

For other species a previously implemented measure features the eradication of the species from waters where it occurs (e.g. Roberts & Tilzey, 1996; Chadderton *et al.*, 2003). This management strategy is only feasible when the rate of removal exceeds the rate of increase (recruitment), there is a low probability of reinvasion, it is able to target all individuals in a population and the strategy is supported by society and politics (Chadderton, 2003). When not all individuals can be removed, the management efforts can have an adverse impact. For example intensive removal of pike-perch in the UK led to a lower biomass and a decrease of mean length, but increased abundance (Smith *et al.*, 1995). It was suggested that the removal of pike-perch led to an increased predation intensity on prey fish populations, when in fact the opposite was intended (Smith *et al.*, 1995).

Partial eradication of eastern mudminnow cannot be considered a feasible management measure as the population will probably recover quickly.

Introduction of a predator could be a suitable measure to reduce numbers of eastern mudminnow in moorland pools as it is susceptible to predation. Recently, introduction of pike in moorland pools was carried out to reduce numbers of pumpkinseed (*Lepomis gibbosus*) (Nijssen & Van Kleef, 2013).

In some cases, the invasion success of exotic species might be mitigated by altering or rehabilitating the water system (Van Kessel *et al.*, 2013). Ideally these measures disrupt the completion of exotic species' life cycle and enhance native species. Often, the eastern mudminnow relies on water acidification that reduces the abundance of predator fish. Therefore, system rehabilitation that reduces the load of acidifying substances and neutralizes acidified waters could be a suitable measure to reduce the fitness of eastern mudminnow populations.

8. GRASS CARP (*Ctenopharyngodon idella*)

8.1 General species description

8.1.1 Nomenclature and taxonomy

Order	Cypriniformes
Family	Cyprinidae
Genus	*Ctenopharyngodon*
Species	*Ctenopharyngodon idella* Valenciennes, 1884
Common name	Grass carp (Dutch: Graskarper)
Synonyms	-

8.1.2 Species characteristics and identification

Figure 8.1: Grass carp (Ctenopharyngodon idella) (Length ca. 25cm) (digitalnature.org)

Grass carp (*Ctenopharyngodon idella*) have an elongated cylindrical body with a large head. The large terminal mouth has no barbels. The body is completely covered with large scales and is olive to brassy green in colour in its upper portions and silvery white to yellow in its lower portions (Kottelat & Freyhof, 2007). The fins are dark grey. The dorsal fin and anal fin are short and normally feature seven branched rays to the dorsal fin and eight branched rays to the anal fin (Bíró, 1999). The grass carp is a large species and can reach a maximum length of 120cm and up to 45.4 kilograms in weight (Bíró, 1999; Kottelat & Freyhof, 2007). Grass carp live approximately 10 to 15 years, the oldest recorded specimen lived 21 years (Shireman & Smith, 1983; Bíró, 1999; Kirk & Socha, 2003). Observations in the Netherlands suggest that the longevity of this species is significantly higher.

Small specimens of grass carp are sometimes misidentified as native chub (*Squalius cephalus*) and vice versa (Spikmans & Kranenbarg, 2010). The species can be distinguished from each other by the position of the dorsal fin, which is situated in front of the pelvic fin in the case of grass carp and behind the pelvic fin in the case of chub. Another distinguishing feature is the shape of the anal fin which is rounded for (sub) adult chub and angular for grass carp. Furthermore chub feature 42 to 46 scales positioned on the lateral line whereas grass carp feature 38 to 45 scales at this location (Spikmans & Kranenbarg, 2010).

8.1.3 Life cycle

Habitat

In its native range of Eastern Asia, grass carp inhabit the middle and lower sections of large rivers and connected floodplains, lakes, reservoirs and backwaters (Bíró, 1999). The rivers are characterized by warm clear water, large water level fluctuations and flooding events twice a year (Bíró, 1999; Kottelat & Freyhof, 2007). In standing waters, grass carp usually inhabit macrophyte-rich littoral zones or form schools in open water (Bíró, 1999). In autumn, grass carp migrate to deep water in the lower sections of the river where they overwinter.

Spawning occurs at riverine locations, for example rapids or at the mouth of tributaries, featuring a strong current and gravel substrates (Bíró, 1999). Larvae and juvenile fish inhabit floodplain lakes and channels with little or no current (Kottelat & Freyhof, 2007).

Grass carp are tolerant of a wide range of extreme environmental conditions including low temperatures and large fluctuations in diurnal oxygen concentration (table 8.1) (Bíró, 1999).

Reproduction

Maturity is reached at 51-60cm (standard length) for males and 58-67cm for females. Spawning first occurs at the age of 1 (recorded in India) to 11 years (Amur River, China). In tropical regions, grass carp mature at earlier ages and smaller sizes (Bíró, 1999).

Female grass carp produce around 110 eggs per gram of body weight and generally produce 600,000 to 1,150,000 eggs each year. Fecundity increases with length, weight and age, but does not seem to be influenced by geographic location (Bíró, 1999).
Spawning takes place in spring or summer from April through September during peaks in the discharge and water level. Grass carp usually spawn once or twice year. For successful spawning a temperature of 22-24°C is required. Grass carp spawn in the pelagic zone or at the surface in small groups. The semi-buoyant eggs drift 50 to 180km downstream and hatching occurs after 16 (at 30°C) to 60 hours (at 17°C) (Bíró, 1999).

Worldwide, sterile triploid specimens of grass carp have been introduced in many instances (e.g. Chilton & Muoneke, 1992). Triploid fish are obtained by either heating, chilling or pressure shocking eggs. Triploid fish are introduced to prevent natural reproduction within populations. Stocks containing only triploid fish are unable to reproduce, however offspring resulting from the crossing of diploid and triploid fish may be fertile (Van Eenennaam *et al.*, 1990).

Table 8.1: Tolerance of grass carp (Ctenopharyngodon idella) to different environmental factors.

Environmental factor	Value	Life stage	Remarks	Reference
Stream velocity	0.8-1.8 m/s	Adult	Optimum range	Bíró (1999)
Temperature	21-25°C	Hatching	Optimum range	Scott & Cross (1973; Cfm. Bíró, 1999)
	18°C	Hatching	Sudden drop to 18°C reduces survival rate	Scott & Cross (1973; Cfm. Bíró, 1999)
	0.0-0.1 and 40°C	Fry	Minimum and maximum lethal temperature	Antalfi & Tölg (1972; Cfm. Bíró, 1999)
	38.5°C	unknown	Maximum lethal temperature	Alabaster & Lloyd (1980; Cfm. Van Beek, 2000)
	16- 40°C	Fry & fingerlings	Tolerated range	Singh *et al.* (1967; Cfm. Bíró, 1999)
pH	5.0-9.0	Fry & fingerlings	Tolerated range	Singh *et al.* (1967 Cfm. Bíró, 1999)
Oxygen	0.22-0.41ppm	Juvenile	Lethal minimum	Opuszynski (1967a; Cfm. Bíró, 1999)
	0.2-0.6mg/l	1.8-78 gram body weight	Lethal range (cessation of respiratory movement) after exposure to declining concentration at 12-18°C	Opuszynski (1967; Cfm. Doudoroff & Shumway, 1970)
	1-28ppm	Fry & fingerlings	Tolerated range	Singh *et al.* (1967; Cfm. Bíró, 1999)
	<3mg/l	Juvenile	Stress	Opuszynski (1967a; Cfm. Bíró, 1999)
	3-7mg/l	Juvenile	No reaction	Opuszynski (1967a; Cfm. Bíró, 1999)
Salinity	14.0‰	Unknown	Upper tolerance limit, LC50 for fish acclimatized to 3‰ and 5‰	Bíró (1999)
	14.2‰	Unknown	Upper tolerance limit, LC50 for fish acclimatized to 7‰	Bíró (1999)
	7.5-12‰	Fry & fingerlings	Tolerated range	Singh *et al.* (1967; Cfm. Bíró, 1999)
Suspended matter	125-215ppm	Fry & fingerlings	Tolerated range	Singh *et al.* (1967; Cfm. Bíró, 1999)
Total alkalinity	88-620ppm	Fry & fingerlings	Tolerated range	Singh *et al.* (1967; Cfm. Bíró, 1999)
	1500ppm	Fry & fingerlings	Maximum in soft waters	Singh *et al.* (1967; Cfm. Bíró, 1999)
Non-ionized ammonia	0-3.8ppm	Fry & fingerlings	Tolerated range	Singh *et al.* (1967; Cfm. Bíró, 1999)

Diet

Grass carp larvae feed mainly on algae, phyto- and zooplankton. juveniles from 25-50 mm and larger feed on aquatic macrophytes. Juveniles show opportunistic feeding behaviour when macro-invertebrates and the larvae of other fish species are an easy accessible food source (Shireman & Smith 1983). Larger juveniles and adults feed on aquatic and, during flooding, terrestrial macrophytes (Shireman & Smith, 1983; Kottelat & Freyhof, 2007). Small grass carp feed mainly on algae and the tender parts of aquatic macrophytes, larger specimens consume more plant species and tougher plant parts.

Predators

In their early life stages, grass carp may be consumed by a variety of invertebrate predators (Shireman & Smith 1983). Juvenile life stages are prey for a number of vertebrates, such as predatory fish, birds and mammals (Shireman & Smith, 1983, Pot & Rosielle, 1988). Virtually no predator species are capable of preying on large adult grass carp.

Parasites and diseases

Grass carp are susceptible to many parasites and some diseases that are similar to common carp (*Cyprinus carpio*). Table 8.2 gives an overview of these parasites and diseases.

Table 8.2: Parasites and diseases described in grass carp (Ctenopharyngodon idella) (E = exotic for the Netherlands, N = native for the Netherlands; Effect = disease/mortality in this species, if effect on other fish species is known (OS), this is also mentioned)

Parasite/disease	Location	Reference	Effect
Trichodina, Chilodonella, Ichthyobodo, Glossatella, Ichthyophthirius multifiliis (white spot), Dactylogyrus/Gyrodactylus spp., *Argulus* spp., *Ligula intestinalis*, a.o. (N)	Netherlands	Haenen, own experience	Low to medium OS: idem
Bothriocephalus gowkongensis (E?)	Czech Republic	Lusk *et al.* (2010)	Low to medium OS?
Dactylogyrus ctenopharyngodonis (E?)	Czech Republic	Moravec (2012)	Low to medium OS?
Lernaea cyprinacea (N*), L. polymorpha, L. oryzophila*, and *L. lophiara* (E?)	Pakistan	Tasawar *et al.* (2009)	Low to medium OS?
Fungi: *Branchiomyces sanguinis (N?);* *Saprolegnia* sp. (endemic); *Ichthyophonus hoferi (N?)*	various	Opuszynski & Shireman (1995) (review)	Low to medium OS: many fish species: idem, as tertiairy pathogen
Apiosoma sp.; *A. cylindriformis; A. magna; A. minimicro nucleate; A. piscicola; Balantidium ctenopharyngodontis; Chilodonella* sp.; *C. cucullulus; C. cyprini; C. hexasticha; Chloromyxum* sp.; *C. cyprini; C. nanum; Costia necatrix* (= *Ichthyobodo necator); Cryptobia* sp.; *C. branchialis; C. cyprini; Dexiostoma campylum; Eimeria carpelli; E. cheni; E. mylopharyngodonis; E. sinensis; Enamoeba ctenopharyngodontis; Epistylis* sp.; *E. lwoffi; Euglenosoma caudate; Frontonia acuminate; F. leucas; Glaucoma pyriformis;* G. *scintillans; Glugea* sp.; *Hemiophrys macrostoma; Hexamita* sp.; *Icthyophthyrius* sp.; *I. multifiliis; Myxidium* sp.; *M. ctenopharyngodonis; Myxobolus dispar; M. ellipsoids; M. drjagini; M. pavlovskii; Sessilia* sp.; *Sphaerospora carassii; Sphaerosporidae lieni; Spiromtcleus* sp.; *Tetrahymena pyriformis; Thelohanellus oculi-leucisci; Trichodina* sp.; *T. bulbosa; T. carasii;*	various	Opuszynski & Shireman (1995) (review); ISSG (2013)	Low to medium OS: idem, as far as is known, many fish species

T. domerguei; T. meridionalis; T. nigra; T. ovaliformis; T. pediculus; T. reticulate; Trichodinella sp.*; T. subtilis; Trichophrya* sp.*; T. piscium; T. sinensis; T. variformis; Tripartiella* sp.*; T. bulbosa, T. lata; Trypanoplasma* sp.*; Zschokkella nova*			
Amurotrema dombrowskajae; Ancryocephalus subaequalis; Apharyngostrigea curnu; Aspidogaster amurensis; Cotylurus communis; C. pileatus; Dactylogyrys sp.; *D. aristichthys; D. ctenopharyngodontis; D. hypophthalmichthys; D. inexpectatus; D. lamellatus; D. magnihamatus, D. nobilis; D. scrjabini; Diplostomum* sp.*; D. indistinctum; D. macrostomum; D. mergi; D. paraspathaceum; D. spathaceum; Siplozoon* sp.*; D. paradoxum; Fasciolata* sp.*; Gyrodactylus* sp.*; G. ctneopharyngodontis; G. elegans;* G. *kathariner*, G. *medius*, G. *wageneri, Metagonimus yokogawai, Opisthorchis* (= *Chlonorchis*)*, sinensis; Posthodiplostomum* sp.; *P. cuticola, Sphaerostoma bramae, Tetracotyle* sp.; *T. percae fluviatilis, T. variegata*	various	Opuszynski & Shireman (1995) (review); ISSG (2013)	Low to medium OS: idem, as far as is known, many fish species
Biacetabulum appendiculatum; Bothriocephalus gowkongensis; (= *acheilognathi*)*; B. opsarichthydis; Diagramma interrupta; Khawia sinensis; Ligula intestinalis; Triaenophorus lucii; T. nodulosus*	various	Opuszynski & Shireman (1995) (review); ISSG (2013)	Low to medium OS?
Capillaria amurensis; C. *pretrushewskii; Capillaria* sp.; *Philometra* sp.; *P. lusiana; Philometroides lusii; Rhabdochona denudata; Skrjabilianus amuri; Spiroxys* sp.	various	Opuszynski & Shireman (1995) (review); ISSG (2013)	Low to medium OS: idem, as far as is known, many fish species
Hemiclepsis marginata; Piscicola geometra	various	Opuszynski & Shireman (1995) (review); ISSG (2013)	Low to medium OS: idem
Argulus sp.*; A.foliaceus; Ergasilus* sp.*; Lernaea* sp.*; L. ctenopharyngodontis; L. cyprinacea; L. elegans; L. piscinae; L. quadrinucifera; Neoergasilus longispinosus; Paraergasilus medius; Sebekia oxycephala; Sinergasilus lieni; S. major*	various	Opuszynski & Shireman (1995) (review); ISSG (2013)	Low to medium OS: idem
Bacteria			
Achromobacter sp.; *A. curydice; A. pestifer; Aeromonas* sp.; *A. punctata; A. salmonicida* var. *achromogenes; Bacillus cereus; B. megaterium; Aeromonas salmonicida* atypical (Carp erythrodennatitis) ; *Citrobacter* sp.; *Flavobacterium aquatile; Flexibacter columnaris* (columnaris disease); *Micrococcus luteus; M. flavus; Myxococcus piscicola; Paracolobactrum aerogenoides; Pseudomonas* sp.; *P. dermoalba; P. fluorescens; P. fragi; P. putida; Staphylococcus aureus (most N)*	Various	Opuszynski & Shireman (1995) (review); ISSG (2013)	Low to severe OS: idem (salmonids, carp, eel, a.o.)
Viruses			
Spring viremia of Carp virus (SVCV) (N) Grass carp rhabdovirus (GRV) (E?)	Various (source GRV not known)	Opuszynski & Shireman (1995) (review)	Medium to severe OS: SVCV: other cyprinids; GRV is specific to grass carp
GCHV (Grass Carp Hemorrhagic Virus) (E)	China	Chen & Jiang (1983)	Single finding. Possibly only severe for grass carp

8.1.4 Distribution

Grass carp originally inhabit the middle and lower sections of East Asian rivers and ponds situated less than 1000 metre above sea level and between 23° and 53° N latitude (Bíró, 1999). This area is dominated by a monsoon climate. The largest and most abundant natural population of grass carp lives in the Yangtze River, the largest river in Asia. This population has severely declined since the 1960s due to a number of factors such as over-fishing, water pollution and hydroelectric facilities (e.g., the Three Gorges Dam) (Zhao *et al.*, 2011).

Over the last century, particularly since 1940, grass carp have been introduced to over 50 countries for aquaculture or weed control, e.g. India, the United States of America (USA) (Bíró, 1999; FAO, 2013). Grass carp were introduced to Western Europe in 1970 approximately (Belgium 1967, Germany 1970 and the Netherlands 1973). In Europe, grass carp became established in many countries due to continuous restocking (FAO, 2013). In South-eastern Europe, grass carp became established as a result of natural reproduction and stocking in Romania, Hungary and the former Yugoslavian area (including the Danube) (Jankovic, 1998; FAO, 2013). Outside Europe, grass carp have established self sustaining populations in three countries: Japan, the USA and Mexico (Bíró, 1999).

In the Netherlands, grass carp were introduced in the 1970s as an alternative for mechanical and chemical weed control (Van der Kruis & Krasowski, 1984). During the 1980s and the 1990s, many experimental introductions were carried out in closed water systems (Van de Kruis & Krasowski, 1984; Pot & Rosielle, 1988). Between 1977 and 1983, 173,700kg of grass carp were introduced in 12.44km^2 of water bodies (140kg/ha)(De Nie, 1996). Between 1983 and 1994 another 350,300kg were introduced in 18.52km^2 of water bodies (189kg/ha). In 1996, the grass carp was already observed in 130 5x5km grids, of these only 23 locations were legally stocked (De Nie, 1996). As a result of escapes, the grass carp is often observed in many (open) waterways and displays a widespread distribution, but generally occurs in low densities (Figure 8.2).

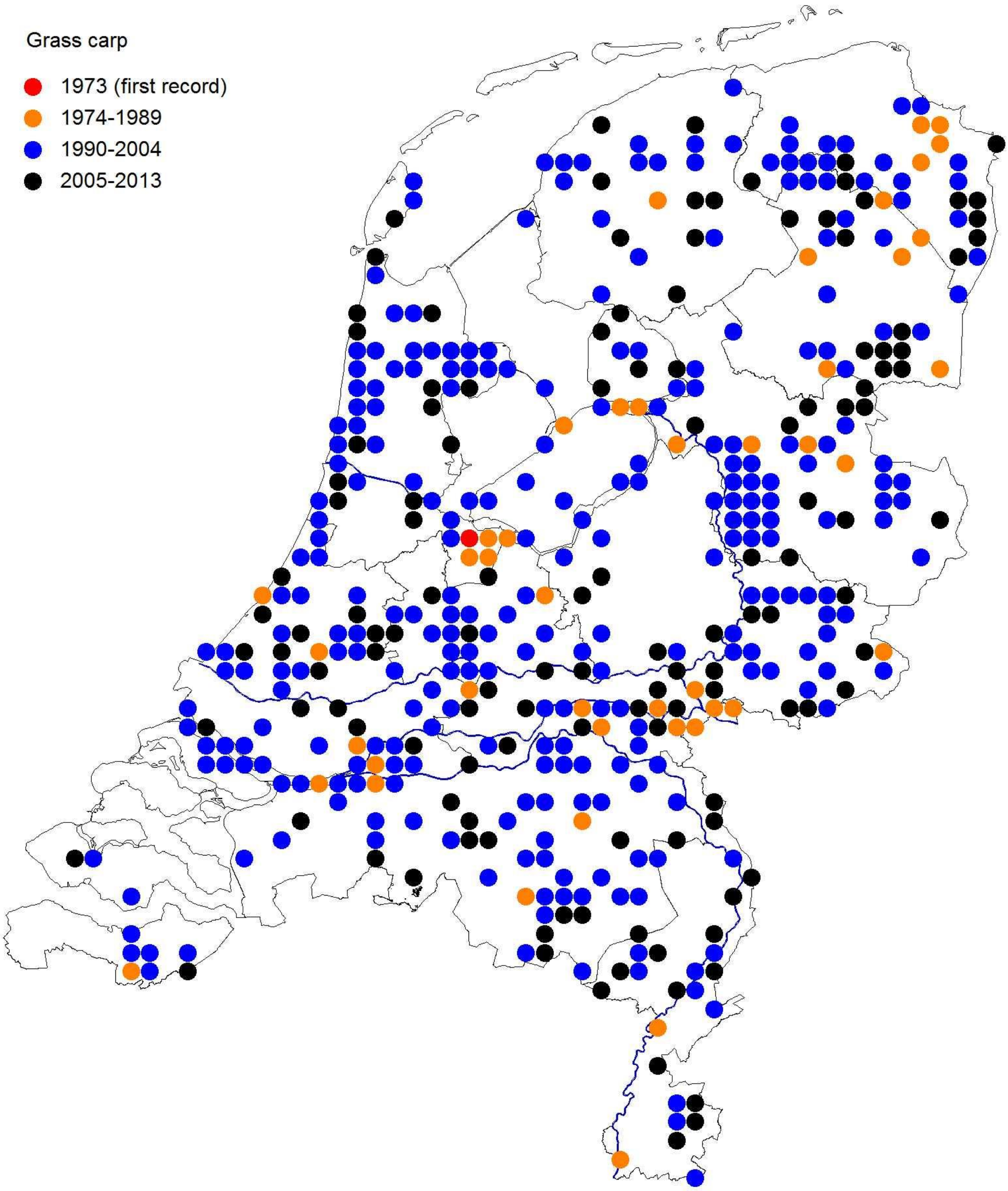

Figure 8.2: Grass carp (Ctenopharyngodon idella) distribution history in the Netherlands from 1973 to 2013 (older records are plotted on top of more recent records) (RAVON/NDFF data).

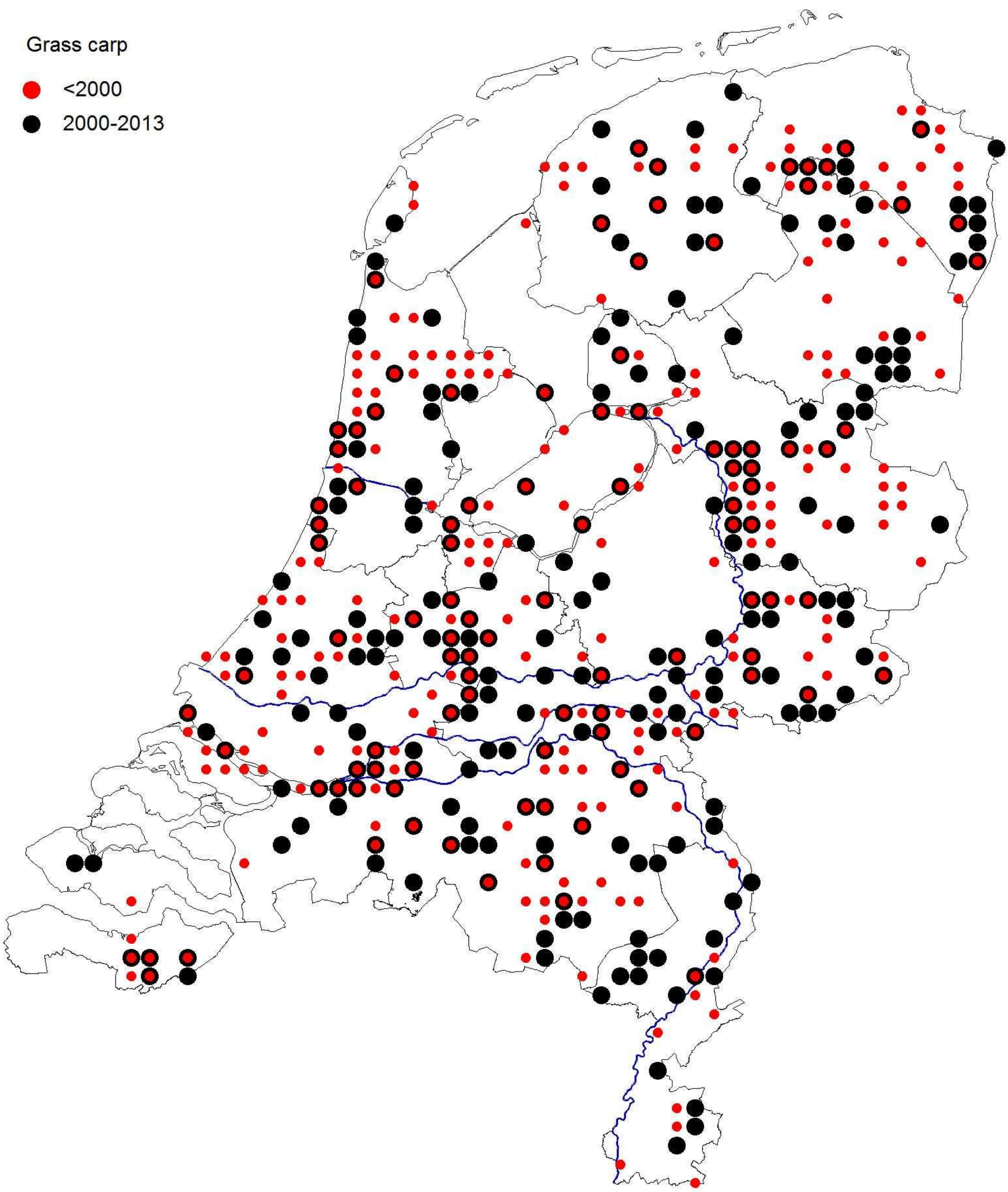

Figure 8.3: Grass carp (Ctenopharyngodon idella) distribution in the Netherlands before and after 2000 (combined black and red dots indicate presence in both periods) (RAVON/NDFF data).

8.2 Risk assessment

8.2.1 Probability of entry

Pathways of introduction
Since the 1970s, 100,000kgs of grass carp have been introduced to the Netherlands for weed control (e.g. De Nie, 1996). The stocked fish were farmed in Western Europe from parent fish originating from the native distribution range in Eastern Asia.

Pathways of future introduction
The grass carp can be introduced legally by people or organisations who own fishing rights to certain water bodies. There are some legal restrictions that apply to the introduction of grass carp. It is forbidden to introduce grass carp in protected and designated nature areas (Uitvoeringsregeling Visserij, art 28). Introduction may only occur in closed water systems (or water systems enclosed by special fencing) and with the consent of the landowner (Uitvoeringsregeling Visserij, art 62). Therefore, within certain limits, it is possible to introduce grass carp. Stocking materials can be obtained from different areas (also other countries) and can be transported to many different water bodies in the Netherlands to which fishing rights apply and with the agreement of landowners.

In the Danube, a naturally reproducing grass carp population exists (Jankovic, 1998). These fish may possibly reach the Rhine river basin via the Main-Danube Canal.

8.2.2 Probability of establishment

Habitat suitability
Adult grass carp are tolerant of a wide spectrum of environmental conditions. Many medium to large stagnant and flowing water types provide suitable habitat for adult grass carp. Grass carp establishment in the Netherlands is restricted due to lack of suitable conditions for successful reproduction. Grass carp need long uninterrupted flowing river trajects with a relatively high water temperature to reproduce. Successful natural reproduction has been observed in several rivers outside the natural range of grass carp, e.g. Illinois River, Elbe River and Danube river (Ladiges & Vogt, 1979; Raibley *et al.*, 1995; Jankovic, 1998). Despite its relatively long existence in the Netherlands, successful reproduction of grass carp has not been observed. But, in theory successful spawning conditions could occur. For example in the Rhine river during a warm summer with a water temperature of >22°C in combination with an elevated discharge. The number of days that water temperatures of the major rivers are suitable increase every year (CBS *et al.*, 2012) and summer peak discharges also occur (e.g. De Bruin & Creemers, 2013) but will likely decrease in occurrence (De Wit *et al.*, 2007). Overall, the chance for successfull reproduction in the future is moderate.

Propagule pressure
100,000s of grass carp have been introduced in the Netherlands since the 1970s, and many of them still survive today. In rivers and other water ways, enough adult individuals occur to potentially build a viable population. In the Netherlands, both triploid (sterile) and diploid (fertile) grass carp have been introduced (Kempenaar *et al.*, 2009).

Population development
Since the mass introductions that occurred at the end of the 20th century, the grass carp population has spread to new habitats, probably due to escapes. Since the introductions, which consisted mainly of juveniles, the fish have grown and nowadays most individuals are large adults. Compared to the initial situation after stocking, the population is now more widespread and consists of fewer, larger specimens.

Potential distribution range
No evidence relating to the effect of climate change on this species is available for the Netherlands specifically. However, in the extremely hot summer of 1976, grass carp individuals survived and reproduced in the Southern Elbe territory of Germany (Ladiges & Vogt, 1979). Climate change is expected to increase successful reproduction of this species in Germany and Austria (Nehring *et al.*, 2010). In slightly warmer climates, the grass carp population survives as a result of natural reproduction. Examples of this are former Yugoslavia and the state of Illinois in the USA (Raibley *et al.*, 1995; Jankovic, 1998). Warmer summers and higher river temperatures could lead to circumstances favourable for successful reproduction of grass carp in the major rivers of the Netherlands. Therefore, the potential future distribution of grass carp in the Netherlands features the major rivers and connected water bodies.

8.2.3 Probability of spread

Species features that encourage spread
The grass carp is a long lived, large migratory species. It is a good swimmer which is known for its ability to jump over large obstacles (e.g. Ellis, 1974). In the United States, it has been described as one of the fastest spreading exotic species (Guillory *et al.*, 1978; Bain, 1993).

Spread in climatically similar countries
Grass carp have also been introduced in Belgium and Germany. In both countries the species is rarely observed (Verreycken, 2007; Anonymous b, 2013). In Flanders, Belgium the grass carp's distribution is restricted to two of five river basins and restricted to manmade habitats (Verreycken, 2007). Large scale spread of this species through the entire river system, as observed in the Netherlands, has not been described in climatically similar countries.

Potential spread in Netherlands
The potential for spread is high. Grass carp can escape to water bodies adjacent to stocking locations. The species may spread to connected waters as it already occurs in the river system.

8.2.4 Vulnerable areas

Although it is forbidden to introduce grass carp to nature areas, the species often occurs in areas protected under Natura 2000 as a result of escapes and subsequent dispersal (appendix 1). Areas vulnerable to the introduction of grass carp are shallow waters in stagnant locations and river habitats with vegetation. This vegetation shelters many (protected) species and functions as a spawning substrate for the majority of native species.

8.2.5 Negative impact of introduction

There are numerous contradictory results reported in the literature concerning grass carp interactions with other species (Shireman & Smith, 1983). The effects of grass carp relate to species density, macrophyte abundance and community structure of the ecosystem (Cudmore & Mandrake, 2004). Grass carp are significant consumers of aquatic vegetation, that comprises up to 95% of their diet, endangering species that require vegetation for habitat and herbivorous species (Booth, 2008; Fedorenko & Fraser, 1978).

In the Netherlands the grass carp shows very little food type selectivity (Van Zon, 1975). Experiences from other countries demonstrate that grass carp are selective, opportunistic feeders grazing on a number of different species. Grass carp select the most palatable vegetation first i.e. soft-tissue aquatic plants, filamentous algae (e.g., Cladophora and Pithophora) and duckweeds (Lemnaceae), moving to less palatable plants once preferred species become unavailable (Bowers *et al.*, 1987; Pipalova, 2006). Where grass carp have been introduced, large changes occur in the macrophyte population. In experimental ponds grass carp grazing has been found to dramatically alter macrophyte population structure in favour of less palatable species (Fowler & Robson, 1978). Examples from North America and the Iberian peninsula indicate that, depending on species composition, some macrophyte species preferred by the grass carp may be significantly impacted or eradicated e.g. *hydrilla*, *Azolla filiculoides* and *Lemna* sp., whereas other species may be less significantly impacted or avoided e.g. *Potamogeton pectinatus*, *Myriophyllum spicatum, Myriophyllum aquaticum, Egeria densa* and *Eichhornia crassipes* (Bonar *et al.*, 1993; Catarino *et al.*, 1997). In New Zealand, grass carp may feed on all aquatic plant species and, where grass carp have been released, more than 95% of vegetation has been removed (Edwards, 1974; Rowe & Schipper, 1985). In this country, native charophytes are known to be a preferred species (Clayton & Wells, 2009).

Macrophyte beds act as refugia for the prey of benthivorous fish and piscivorous fishes and provide food for many animals such as fish, waterfowl, mammals, reptiles, amphibians and macroinvertebrates (Swanson & Meyer, 1973; Pardue & Nielsen 1979; Gilinsky, 1984; Keast, 1984; Eldridge, 1990; Fredrickson & Laubhan 1996; Crowder & Cooper, 1982; Heck & Wilson, 1987; Savino & Stein, 1989; Lodge *et al.*, 1997). Macrophyte removal may have a great impact on macroinvertebrates because changes in plant biomass have been correlated with the size and species diversity of this species group (Heck & Wetstone, 1977; Stoner, 1980; Wiley *et al.*, 1984; Bell & Westoby, 1986). Direct competition can occur for plant material between grass carp and other herbivorous animals when aquatic macrophytes are eliminated (Cudmore & Mandrake, 2004; Pipalova, 2006; Chilton & Muoneke, 1992).

Consumption of invertebrate species may occur coincidentally during the process of vegetation consumption (Clayton & Wells, 1999; Dorenbosch & Bakker, 2012). Conversely, in an American study, the amount of animal matter consumed (mainly crayfish, cladocerans and gyrinids) in grass carp guts increased greatly following vegetation depletion (Chilton & Muoneke, 1992), suggesting that a dietary switch occurred. Grass carp may also predate on amphibian larvae, salmonid fry and may occasionally consume the young of other small fish (Goodchild, 1999; Ade *et al.*, 2010). However, grass carp influence zoobenthos more through the loss of macrophyte habitat rather than predation (Pipalova, 2006).

Little information could be found regarding interference or exploitation competition involving grass carp in the Netherlands. In Dutch experiments, the quantity of macrofauna and macrobenthos decreased in grass carp plots compared to plots where the fish was absent but diversity did not differ (Van Zon, 1975). Experiences from other countries demonstrate that grass carp can strongly affect native species. Grass carp can significantly alter habitat, biological resources and animal species through the indirect effects of aquatic vegetation removal (Chilton & Muoneke, 1992; Bain, 1993). Removal of vegetation results in the elimination of food sources, refuge and spawning habitat that can have negative effects on native fish (Taylor *et al.,* 1984 cited in Cudmore & Mandrake, 2004). Generally, the abundance of fish species that are dependent on macrophyte beds for spawning and shelter from predation and rest from water flow decreases (Ware & Gasaway, 1978, Klussman *et al.*, 1988, Maceina *et al.*, 1991, Bettoli *et al.*, 1992; Clayton & Wells, 1999; Pipalova, 2006). It has been reported that species such as perch (*Perca fluviatilis*) and pike (*Esox lucius*) may be eradicated following the introduction of grass carp (Stanley *et al.*, 1978) and the abundance of rudd (*Scardinius erythrophthalmus*) roach (*Rutilus rutilus*) and tench (*Tinca tinca*) may be seriously reduced as a result of sustained grass carp stocking (Krzywosz *et al.*, 1980). Other non-native fish species may benefit from the removal of macrophytes. For example rainbow trout (*Oncorhynchus mykiss*) grew better as a result of increases in phytoplankton and zooplankton following vegetation removal by grass carp (Hubert, 1994).

In locations where grass carp reside, there have been reports of considerable losses of snail and crayfish populations (Booth, 2008). The disappearance of aquatic macrophytes reduces the number and size of hiding places leading to a reduction in phytophilous fauna (Opuszynski, 1972; Van Zon, 1977). Grass carp herbivory has been blamed for the greatly decreased abundance of gastropods and the isopod *Asellus aquaticus* in the UK, increases in midges and other benthic invertebrates and a reduction in the average yield of harvestable-sized red swamp crayfish, *Procambarus clarkii* due to competition for plant material (Forester & Avault, 1978; Petridis, 1990; Clayton & Wells, 1999). Zoobenthos became more than twice as abundant than prior to grass carp introduction in Turkmenistan due to the prevention of annual vegetation die off, improved oxygen content and water quality (Aliev, 1976).

No direct effects of grass carp on waterfowl have been reported. However, grass carp may affect waterfowl e.g. ducks and coots, indirectly because of overlapping food requirements (Venter & Schoonbee, 1991; McKnight & Hepp, 1995; Benedict & Hepp; 2000; Chilton & Muoneke, 1992).

Zooplankton (such as Cladocera) avoid predation by seeking refuge in macrophytes and may be affected by their removal (Clayton & Wells, 1999). Moreover, it seems that grass carp faeces or attached bacteria may serve as a food source for zooplankton and zoobenthos. However, based upon existing literature it is difficult to generalize about the effects of grass carp on the zoobenthos / zooplankton communities (Pipalova, 2006).

Grass carp are known to carry over 100 parasitic species and diseases worldwide e.g. the Asian tapeworm (*Bothriocephalus acheilognathi*) of which the grass carp is the main vector (Biro, 1999; ISSG database, 2013). The Asian tapeworm exists in grass carp in Europe and may infect fish species in the families Cyprinidae, Poeciliidae, Cichlidae and Centrarchidae and specifically crucian carp (*Carassius carassius*) and common carp (*Cyprinus carpio*) in the United Kingdom (Marcogliese, 2008; Fisheries Technical Service). It is not known if this parasites exists in the Netherlands.

Two parasites and a single bacterial infection of grass carp occur in the Netherlands. There are no diseases specific to grass carp found here. The tapeworm (*Ligula intestinalis*) and the myxospore parasite are known to infect grass carp. *L. intestinalis* infects members of the Cyprinidae particularly, and may be transferred to fish eating birds (Ergonul & Altindag, 2005). Grass carp may be infected by the bacterium atypical *Aeromonas salmonicida* in the Netherlands. *A. salmonicida* causes severe septicaemia and acute mortality in susceptible salmonid hosts (Cipriano & Bullock, 2001).

In general, turbidity, alkalinity, chlorophyll a, ammonia-nitrogen and phosphorus concentrations can increase after the removal of vegetation by grass carp, while dissolved oxygen levels can decrease (Rose 1972, Lembi *et al.* 1978, NatureServe 2003 cited in Cudmore & Mandrake, 2004).

Macrophyte removal leads to loss of the nutrient absorbing capability of plants, reduced sediment stability and increased turbidity (Lembi *et al.*, 1978; Carpenter & Lodge, 1986, Maceina *et al.*, 1992; Barko & James, 1997). Moreover, additional nutrient enrichment occurs due to sediment resuspension resulting from feeding and faecal deposition by carp (Pipalova, 2006; Dibble & Kovalenko, 2009). It is often impossible to reverse altered water quality, even after herbivorous fish have been removed for some time (Scheffer *et al.*, 2001). However, nutrient levels do not always increase following grass carp introduction (Opuszynski & Shireman, 1995). Either no increase or a minimal short-term increase of phosphorus and nitrogen levels may be found after grass carp stocking (Van Zon *et al.*, 1977).

Grass carp can significantly alter food webs and trophic structures resulting in a decline in the density of organisms that require structured littoral habitats and feed on plant detritus, macrophytes and attached algae (Bain, 1993). Submerged aquatic plants provide surfaces for attachment of periphyton, a major source of food for snails, and detritus which provides food for many other organisms (Clayton & Wells, 1999). Based upon existing literature it is difficult to generalize on the effects of grass carp on the zoobenthos / zooplankton communities (Pipalova, 2006).

No evidence regarding hybridisation of grass carp with native species in the Netherlands was found during the literature review.

Economic impact
No evidence regarding the negative economic impacts of grass carp was discovered for the Netherlands during the literature review. In North America, grass carp grazing may reduce the abundance of invertebrates that feed many sport and forage fish species (Price, 1963; Keast & Webb, 1966; Cherry & Guthrie, 1975; Phillips *et al.*, 1982; Schaeffer & Margraf, 1986 cited in Chilton & Muoneke, 1992).

Social impact
No evidence regarding the negative social impacts of grass carp was discovered for the Netherlands during the literature review. The removal of aquatic plants results in an increase in midges that can become a nuisance to the public (Clayton & Wells, 1999).

No evidence regarding the public health effects of grass carp was discovered for the Netherlands during the literature review.

8.2.6 Positive impact of introduction

Ecological impact
In the Netherlands, it was observed that the disappearance of filamentous algae after grass carp stocking reduced fluctuations in oxygen concentration (Van Zon, 1977). Moreover, in an experimental pond treated with grass carp, filamentous algae could not suppress other aquatic macrophytes as they did in a control pond without grass carp (Pipalova, 2002). In general, grass carp can accumulate nutrients which may inhibit eutrophication (Pipalova, 2006). On the other hand, fish faeces increase the nutrient load in water leading to an increase in phytoplankton levels which may in turn benefit zooplankton and zoobenthos, from which planktivorous fish can profit (Bettoli *et al.*, 1990). Moreover, some fish species may benefit by directly feeding on grass carp faeces (Takamura *et al.*, 1993).

Economical impact
Grass carp have been introduced in a number of European countries including the Netherlands as a management tool for aquatic weed control. Van Zon (1977) concluded, after reviewing experiences in Europe, that the efficiency of the grass carp for weed control is high, that costs are low and that no severe side-effects are observed. It should be emphasised, however, that this conclusion refers to managed situations where the number of fish introduced is calculated to gain a desired effect and that reproduction between the introduced strains is not possible. These conclusions do not refer to diploid grass carp that are able to reproduce naturally.

Social impact
In various Western European countries grass carp are favoured in sport fishing (West Germany: Bohl, 1971; The Netherlands: Lagerwey, 1971).

8.3 Risk classification

8.3.1 Available risk classifications

Table 8.3 Overview of risk classifications previously performed for grass carp (Ctenopharyngodon idella).

	Bulgaria, Macedonia, Montenegro, Serbia	Germany, Austria	United Kingdom
Scope	Risk assessment	Risk assessment	Risk assessment
Method	FISK	The German-Austrian Black List Information System (GABLIS)	FISK
Risk classification	Moderately high	Black list (management list)	High
Source	Simonovic *et al.* (2013)	Nehring *et al.* (2010)	Copp *et al.* (2009)
Additional information		Species requires management to reduce ecological impacts	≥19 = High risk

Rationale for risk classification
Simonovic *et al.* (2013) gives an overview of FISK scores for multiple fish species but gives no rationale for the allocation of risk classifications of the grass carp.

Nehring *et al.* (2010) state that grass carp impact on German and Austrian biodiversity in a number of ways. Grass carp strongly impact aquatic and possibly riparian vegetation, and cause other negative ecosystem effects (For Germany see: Scharf & Dilewski, 1988; Wüstemann & Kammerad, 1994; For Austria: Mikschi *et al.*, 1996; Worldwide: Dibble & Kovalenko, 2009). Moreover, the species can strongly impact nutrient dynamics, soil chemistry, water turbidity, food webs and succession (Germany: Scharf & Dilewski, 1988; Wüstemann & Kammerad, 1994; Austria: Mikschi *et al.*, 1996; Worldwide: Dibble & Kovalenko, 2009). It is unknown if grass carp introduce diseases or parasites to German and Austrian native species, however, the species is known to carry over 100 parasites and diseases (Biro, 1999). No impacts relating to inter-specific competition and hybridisation with native German and Austrian species are expected. The distribution of grass carp in these countries is widespread. Reproduction potential is limited as the species reaches sexual maturity after 7 to 10 years (Kottelat & Freyhof, 2007). However, potential spread is classified as high but the population appears to be aging in German rivers (Wolter *et al.*, 2003). Grass carp monopolize macrophyte food sources leading to their complete destruction in some isolated water bodies (Germany: Scharf & Dilewski, 1988; Wüstemann & Kammerad, 1994;

Austria: Mikschi *et al.*, 1996; Worldwide, Dibble & Kovalenko, 2009). Climate change is expected to increase successful reproduction in this species. Grass carp impact the social-economy negatively through reductions in water quality as a result of macrophyte destruction and the cost implications of removal from sensitive areas (Austria: Wiesner *et al.*, 2010). Grass carp do not impact human health in Austria or Germany.

Copp *et al.* (2009) gives an overview of FISK scores for multiple fish species but gives no rationale for the allocation of risk classifications.

8.3.2 Present situation

Expert consensus scores
The total risk score attributed to grass carp was 10 out of a maximum risk score of 12 (table 8.4). This results in an overall classification of moderate risk for this species.

Table 8.4: Consensus scores and risk classifications for grass carp (Ctenopharyngodon idella) in the current situation in the Netherlands.

ISEIA sections	Risk classification	Consensus score
Dispersion potential or invasiveness	low	1
Colonization of high value conservation habitats	high	3
Adverse impacts on native species	high	3
Alteration of ecosystem functions	high	3
Global environmental risk	B - list category	10

Dispersion potential or invasiveness
Spawning of grass carp in the Netherlands has not been recorded due to circumstances that prevent spawning. Grass carp distribution is not a reflection of natural reproduction in the Netherlands but is the result of escapes and releases facilitated by people. Many individuals are used for the management of macrophyte density in domestic ponds. Only adult fish can be successfully used for the control of macrophytes, and ponds are often overstocked early in the management process. Overstocking and changed feeding habits following maturation lead to the disposal of many specimens to other water bodies. The grass carp is often observed in many (open) waterways and displays a widespread distribution, although it generally occurs in low densities. Due to its low capacity for reproduction and its inability to disperse unaided by people in the Netherlands, it was concluded that the grass carp displays a low potential dispersal and invasiveness in the Netherlands.

Colonisation of high conservation value habitats
The grass carp is widely spread in the Netherlands, occurring in many rivers and other water bodies. 41% of grass carp distribution occurs in areas designated under Natura 2000 in the Netherlands (appendix 1). Outside areas where the species was stocked, it is generally observed in low numbers. The grass carp occurs in Natura 2000 areas often, suggesting that this species poses a high risk to high conservation habitats in the Netherlands according to the ISEIA protocol.

Adverse impacts on native species
The grass carp is an opportunistic feeder, grazing on a number of different macrophyte species. Therefore, impacts on native species are mostly related to the direct and indirect consequences of

macrophyte consumption. Little information could be found regarding the feeding preferences of the grass carp in the Netherlands. Here, the grass carp shows very little selectivity in type of food eaten (Van Zon, 1975). However, evidence from other countries demonstrates that the grass carp has major impacts on macrophyte and associated faunal communities through herbivory, predation and competition (Edwards, 1974; Rowe & Schipper, 1985; Maceina *et al.,* 1992; Cudmore & Mandrake, 2004; Pipalova, 2006; Chilton & Muoneke, 1992; Clayton & Wells, 1999). During feeding, grass carp remove macrophytes and any organisms attached to them such as macroinvertebrates and insect eggs. It was concluded following discussions during the risk analysis that if densities are high, grass carp will negatively impact native species resulting in a reduction of local species richness in the Netherlands. However, impacts are expected to be less severe at the lower fish densities currently observed in the Netherlands. As the grass carp is unable to reproduce in the Netherlands, species density and the level of impact will depend on how and where the species is stocked. A high level of stocking in isolated water-bodies, from where the species cannot disperse, will result in high local impacts on native species. In situations where densities are high it was concluded that the grass carp has a high impact on native species in the Netherlands as a result of herbivory and interference and exploitation competition.

The grass carp does not reproduce in the Netherlands and therefore will not hybridise with native species. Impacts related to hybridisation with native species in Germany and Austria are not expected (Nehring *et al.,* 2010). On the basis of this it was concluded that impacts relating to genetic effects of grass carp in the Netherlands are negligible.

The grass carp is a known carrier of Asian tapeworms which are known to infect several fish species in Canada: common carp, golden shiner (*Notemigonus crysoleucas*), fathead minnow (*Pimephales promelas*) and channel catfish (*Ictalurus punctatus*) (ISSG database, 2013). However, there is no literature evidence that establishes a link between these parasites and diseases and increased risk to Dutch native species. Therefore expert knowledge was used to assess this risk subcategory. It was concluded that the parasites and diseases of the grass carp are likely to negatively impact native species in the Netherlands because no monitoring of parasite species is undertaken and the grass carp carries many disease and parasites identified in other countries.

Overall it was concluded that the grass carp poses a high risk to native species in the Netherlands based on negative impacts relating to herbivory, predation and interference and exploitation competition in situations where their density is high.

Alteration of ecosystem functions

In areas where densities of the grass carp are high, the impact on ecosystem processes and structures in the Netherlands is strong, difficult to reverse and mostly related to the removal of macrophytes through herbivory. There is a wide body of evidence, that demonstrates the impact of the grass carp on ecosystem functions. This evidence is primarily from foreign studies including some from countries with a similar climate to the Netherlands. Submerged macrophytes are important for water quality, nutrient dynamics, and invertebrate-fish interactions (Jeppesen *et al.,* 1997). The removal of vegetation by the grass carp is followed by possible increases in turbidity, alkalinity, chlorophyll a, ammonia-nitrogen and phosphorus concentrations while dissolved oxygen levels can decrease (Rose, 1972; Lembi *et al.,* 1978; NatureServe, 2003). Nutrient enrichment results from sediment re-suspension during feeding and faecal matter deposition by the grass carp. These mechanisms are further enhanced by the fact that vegetation often does not recover once macrophytes are removed (Scheffer, 1998; Dibble & Kovalenko, 2009). Water quality changes are often irreversible over relatively long time scales, even after herbivorous fish are removed (Scheffer *et al.,* 2001). Physical modifications of habitat will also occur dependent on grass carp density. Macrophytes provide food, cover and reproductive habitat for animal species. Changes in plant biomass are strongly correlated with the diversity of associated aquatic invertebrate species (Heck & Wetstone, 1977; Stoner, 1980; Wiley *et al.,* 1984; Bell & Westoby, 1986). Also food webs are strongly affected by macrophyte removal as vegetated habitats provide abundant food sources for mammals, waterfowl, amphibians, reptiles, fish, and invertebrates (Swanson & Meyer, 1973; Pardue & Nielsen, 1979; Gilinsky, 1984; Keast, 1984; Eldridge, 1990; Fredrickson & Laubhan, 1996).

It was concluded that, at high densities, the grass carp poses a high risk to ecosystem functions in the Netherlands due to impacts relating to all subcategories (modification of nutrient cycling or resource pools, physical modifications of the habitat, modifications of natural succession and disruptions of food webs).

Species classification

The species classification corresponds to the global environmental risk score of the ISEIA (table 8.4) combined with the current distribution of the non-native species within the country in question. The species classification for grass carp is B3 (Figure 8.4). This indicates a non-native species that is widespread, displaying a high environmental hazard (i.e. ecological risk) that should be placed on the watch list of the BFIS list system (i.e. ecological risk: ISEIA score 10: B category).

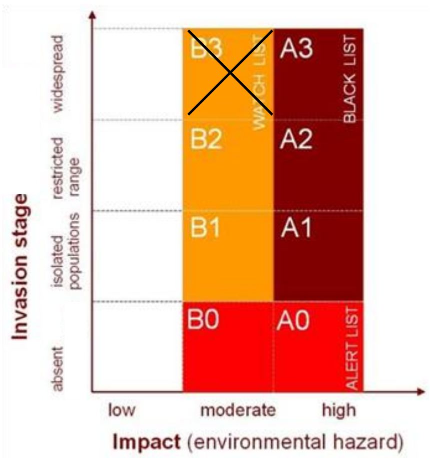

Figure 8.4: Grass carp (Ctenopharyngodon idella) classification according to the BFIS list system.

8.3.3 Future situation

A future two degrees Celsius increase in temperature in the Netherlands may be enough to stimulate spawning and reproduction in grass carp. The optimum range for the hatching of grass carp eggs is 21 to 25°C, whilst fry and fingerlings can tolerate temperatures ranging from 16 to 40°C (Scott & Cross, 1973, Cfm. Bíró, 1999; Singh *et al.,* 1967, Cfm. Bíró, 1999). The yearly minimum and maximum river temperatures at Lobith, the point at which the Rhine enters the Netherlands, have increased by circa 4 ^{0}C over the period 1908 to 2010 (Leuven *et al.,* 2011). Summer water temperatures in many water bodies in the Netherlands may have already reached an acceptable temperature range for grass carp reproduction. However, successful reproduction of carp species also requires an increase of flow velocity because spawning is triggered by increasing current velocity and rising water levels (Chang, 1966; Holcik, 1976; Krykhtin & Gorbach, 1981). The presence of spawning habitat in the Danube and sections of the upper Rhine in Germany combined with possible temperature increases may provide suitable conditions for reproduction there. This may result in an increased migration of grass carp into the Netherlands through the Rhine via the Main-Danube Canal. In slightly warmer climates, grass carp populations survive through natural reproduction, e.g. former Yugoslavia and Illinois, USA (Raibley *et al.,* 1995; Jankovic, 1998). However, this scenario would have to be investigated further to assess the likelihood of its occurring. In a worst case future scenario, the dispersal and invasiveness potential of the grass carp is increased from low to high risk (table 8.5). The species would remain widespread but occur in higher densities and colonise more high conservation value habitats than in the present situation. The B3 classification under the BFIS list system would also increase to A3. The A3 classification indicates a non-native species exhibiting a wide distribution and high environmental hazard (i.e. ecological risk) that should be placed on the black list of the BFIS list system.

Table 8.5: Grass carp (Ctenopharyngodon idella) theoretical classification according to a potential future habitat scenario.

ISEIA sections	Risk classification	Consensus score
Dispersion potential or invasiveness	high	3
Colonization of high value conservation habitats	high	3
Adverse impacts on native species	high	3
Alteration of ecosystem functions	high	3
Global environmental risk	A - list category	12

8.4 Risk management

8.4.1 Prevention of introduction

The grass carp is currently widespread in the Netherlands. Natural dispersal through fish migration corridors and hydrologically connected water ways is virtually impossible to prevent. Nevertheless, potential spread to currently unoccupied isolated water bodies and the practice of fish stocking can be prevented. It is currently lawful for fishing right owners to stock grass carp in unoccupied water bodies with the permission of the landowner, if the water body is not protected and if it is isolated or enclosed by fencing. Additional legal restrictions could prevent the further spread and introduction of grass carp to isolated water systems and prevent the maintenance of populations by re-stocking.

8.4.2 Elimination of populations

The current recorded distribution of grass carp in the Netherlands is widespread, but the species often occurs in large waterways at low abundance. Only populations in relatively small, isolated waters may be eliminated cost efficiently. In Austria removel of the species from sensitive areas has been reported expensive (Wiesner *et al.*, 2010). Eradication of the current Dutch population is impossible as the species is widespread, occurring in low densities. Furthermore, the species is intrinsically valuable to many anglers. Appendix 4 describes general measures for the elimination of exotic fish populations.

8.4.3 Management of populations

In the Netherlands, grass carp populations are maintained by re-stocking and the species does not reproduce. If stocking were not to be continued, the species would likely disappear within a few decades. The discontinuation of stocking practices may be the most effective management measure. However, future successful grass carp reproduction in the Netherlands cannot be ruled out.

In the USA, it is unlawful to introduce diploid (fertile) grass carp. Only sterile triploid grass carp may be used (e.g. Chilton & Muoneke, 1992). Because of this, grass carp populations are unable to reproduce and populations are kept under control, but are still sustained for long periods due to the species' longevity. Therefore, it is highly recommended that triploid specimens are used to avoid possible reproduction if stocking is to continue in the Netherlands.

An additional management option applied abroad is the implantation of an erodible poison capsule into stocked grass carp that shortens the fishes lifespan (Thomas *et al.*, 2006). The shortened lifespan allows easier control of population size. This option is, however, controversial and would probably result in public opposition in the Netherlands. Poisoned pellets have also been used to reduce the size of fish populations (Mallison *et al.*, 1994). However, this method can lead to unwanted casualties among native species (Gehrke, 2001).

9. HYBRID 'CROSS CARP' (*Cyprinus carpio* X *Carassius* spp.)

9.1 General species description

9.1.1 Nomenclature and taxonomy

Order	Cypriniformes
Family	Cyprinidae
Genus	*Cyprinus* X *Carassius*
Species	Hybrid of *Cyprinus carpio* X *Carassius gibelio* or *Carassius carassius* or *Carassius auratus** Bloch, 1782
Common name	Hybrid (Dutch: Kruiskarper or Kruiskroeskarper)
Synonyms	-

* The correct taxonomy of the 'cross carp' hybrid in the Netherlands remains unclear due to ambiguous information. Kamman (2011) and Sportvisserij Nederland (2013) do not clearly define the origin of the hybrid and it may either result from a cross between *Cyprinus carpio* X *Carassius auratus* or *Cyprinus carpio* X *Carassius gibelio*. De Laak (2010) states that the hybrid originates from a male *Cyprinus carpio* X female *Carassius auratus*. The cross carp has also been regarded as a hybrid of *Cyprinus carpio* X *Carassius carassius* by Kamman (in Bal, 2009). Stocking fish have mainly been obtained at a Belgian fish farm, who refer to the species as a hybrid between *Cyprinus carpio* X *Carassius carassius* (Vandeput, accessed 2013).

9.1.2 Characteristics and identification

Figure 9.1: Hybrid 'cross carp' (Cyprinus carpio X Carassius spp.) stocked in the Netherlands (length 40cm) (Sportvisserij Nederland).

Hybrids between *Cyprinus carpio* and *Carassius* spp. express intermediate features of both parent fish species (Masai & Sato, 1969; Taylor & Mahon, 1977; Crunkilton, 1977; Hume *et al.*, 1983;

Pullan & Smith, 1987; Szczerbowski, 2001; Hänfling & Harley, 2003; Papousek *et al.*, 2008; Haynes *et al.*, 2012). For distinguishing features of the parent species see chapters 6 & 11. In general, the cross carp stocked in the Netherlands are often characterized by a similar body shape to the Prussian carp (*Carassius gibelio*), featuring small barbels and a brown base colour (Kamman, 2011)(Figure 9.1). Compared to common carp (*Cyprinus carpio*), the growth of some hybrids can be faster but they do not reach the high maximum length of this species (Szczerbowski, 2001). The cross carp lives to about 7 years (Szczerbowski, 2001).

9.1.3 Life cycle

Habitat and tolerance toward environmental factors

The preferred habitat of the cross carp is probably intermediate to the habitats of common carp and Prussian carp, goldfish (*Carassius auratus*) or crucian carp (*Carassius carassius*). The habitats of these species show much overlap, although compared to common carp, Prussian carp and goldfish habitat displays more aquatic vegetation while the habitat of crucian carp is usually largely overgrown with vegetation. See chapter 6 for a description of common carp habitat and chapter 11 for that of the Prussian carp.

In the Netherlands it has been observed that cross carp tend to seek the cover of reed beds, overhanging trees and shallow vegetated areas (Kamman, 2011).

Common carp and *Carassius* spp. are described as very tolerant fish species. Compared to the common carp, hybrids of crucian carp x common carp and of Prussian carp x common carp are more tolerant of diseases and poor environmental conditions (Szczerbowski, 2001; Balashov & Recoubratsky, 2011). Crucian carp remain the most tolerant of the species to low oxygen concentrations in winter. Wheeler (2000) describes a completely ice covered pond where crucian carp were unaffected but numerous common carp and common carp x crucian carp hybrids died. See chapter 6 for an overview of the environmental tolerances of common carp and chapter 11 for those of Prussian carp.

Reproduction

Cross carp are considered a non-fertile hybrid (Kamman, 2011; Sportvisserij Nederland, 2013). However, in literature multiple generations of fertile hybrids of *Carassius* spp. x *Cyprinus carpio* are described, with occurrences of backcrossing and introgression (gene flow between two species) by a number of authors.

It has been described that hybrids and backcrosses of goldfish and common carp are abundant in the North American wild (Taylor & Mahon, 1977). Masai & Sato (1969) state that only female hybrids of goldfish and common carp are fertile and can be backcrossed with both parental species. Crunkilton (1977), however, proves that both male and female hybrids of goldfish and common carp are fully fertile and that backcrossing is possible. Genetic research in Western Europe reveals that first generation and second generation goldfish x common carp and crucian carp x common carp hybrids exist in the wild, as do first generation back-crosses (Hänfling & Harley, 2003; Hänfling *et al.*, 2005, Maes *et al.*, 2007). Moreover, in Australia, second-generation goldfish x common carp hybrids and backcrossed individuals were detected, indicating that gene flow between common carp and goldfish is ongoing in Australia (Hume *et al.*, 1983; Haynes *et al.*, 2012). Research by Liu *et al.* (2001) shows that goldfish (female) and common carp (male) produce a viable diploid hybrid, of which 4.7% male F1 (first generation) hybrids and 44.3% female F1 hybrids were found to be fertile. Furthermore, these authors were able to produce ten more generations by artificial breeding of these hybrids during the research period.

Hybrids between crucian carp and common carp can occur, producing mainly fertile females (Crunkilton, 1977). Nikoluikin (1952 Cfm. Szczerbowski, 2001) backcrossed hybrids between common carp and crucian carp with both parental species and obtained numerous progeny. Also Skora (1968 Cfm. Szczerbowski, 2001) reports backcrossing of hybrids of crucian carp x common carp with both parental species. Gomel'ski *et al.* (1985 Cfm. Szczerbowski, 2001) report that fertile crucian carp x common carp hybrids reach sexual maturity in the second or third year, but that most males are sterile and females feature strongly reduced gonads.

Fertile hybrids and subsequent generations are also produced by hybridisation of Prussian carp and common carp (Cherfas *et al.,* 1994). Furthermore, pure Prussian carp progeny resulting from reproduction between triploid female Prussian carp and male common carp, can occur due to gynogenetic reproduction (also see reproduction of Prussian carp, chapter 11).

The production of fertile first and second generation hybrids between the above mentioned species leads to introgression between *Carassius* spp. and common carp (Crunkilton 1977; Hänfling & Harley, 2003; Hänfling *et al.*, 2005; Maes *et al.*, 2007; Haynes *et al.*, 2012). Therefore the assertion that cross carp are a non-fertile hybrid is questionable.

Diet

The diet of cross carp will likely show a great deal of resemblance to that of common carp and Prussian carp (Chapter 6 & 11).

Predators

Predators of cross carp will likely show a great deal of resemblance to those of common carp and Prussian carp (Chapter 6 & 11). Cross carp were thought to be a less palatable prey species and were introduced to the Netherlands to reduce cormorant predation problems occurring in recreational fishing ponds. However, it has been observed that cross carp are still attacked by cormorants, leading to mortality (Kamman, 2011).

Parasites and diseases

Diseases of the cross carp are probably similar to those described for common carp and Prussian carp (Chapter 6 & 11). However, the hybrid is more tolerant to some diseases (Szczerbowski, 2001).

9.1.4 Distribution

Common carp and *Carassius* spp. hybrids are farmed in the entire Eurasian continent in aquaculture. Moreover, common carp and *Carassius* spp. are reported to hybridize naturally in Europe, Asia, North America and Australia (Crunkilton, 1977, Barus *et al.*, 2001; Hänfling *et al.*, 2005, Maes *et al.*, 2007; Haynes *et al.*, 2012). In the Netherlands, hybrids of common carp and *Carassius* spp. have occasionally been observed over several centuries (Redeke, 1941; Nijssen & De Groot 1987). However, in recent years (2006 to 2013), hybrids of common carp and *Carassius* spp. have been deliberately stocked in hydrologically isolated recreational fishing ponds. Publications by Sportvisserij Nederland (2010, 2011 & 2014) and the report of Kamman (2011) show that these hybrids ('kruiskarper' & 'kruiskroeskarper') have been stocked in 96 water bodies in the Netherlands (see also Figure 9.2). However, the number of stocking locations presented here could be underestimated, because of undocumented stockings. The current recorded distribution of stocked hybrids is spread over a large area of the Netherlands, but still consists of isolated populations.

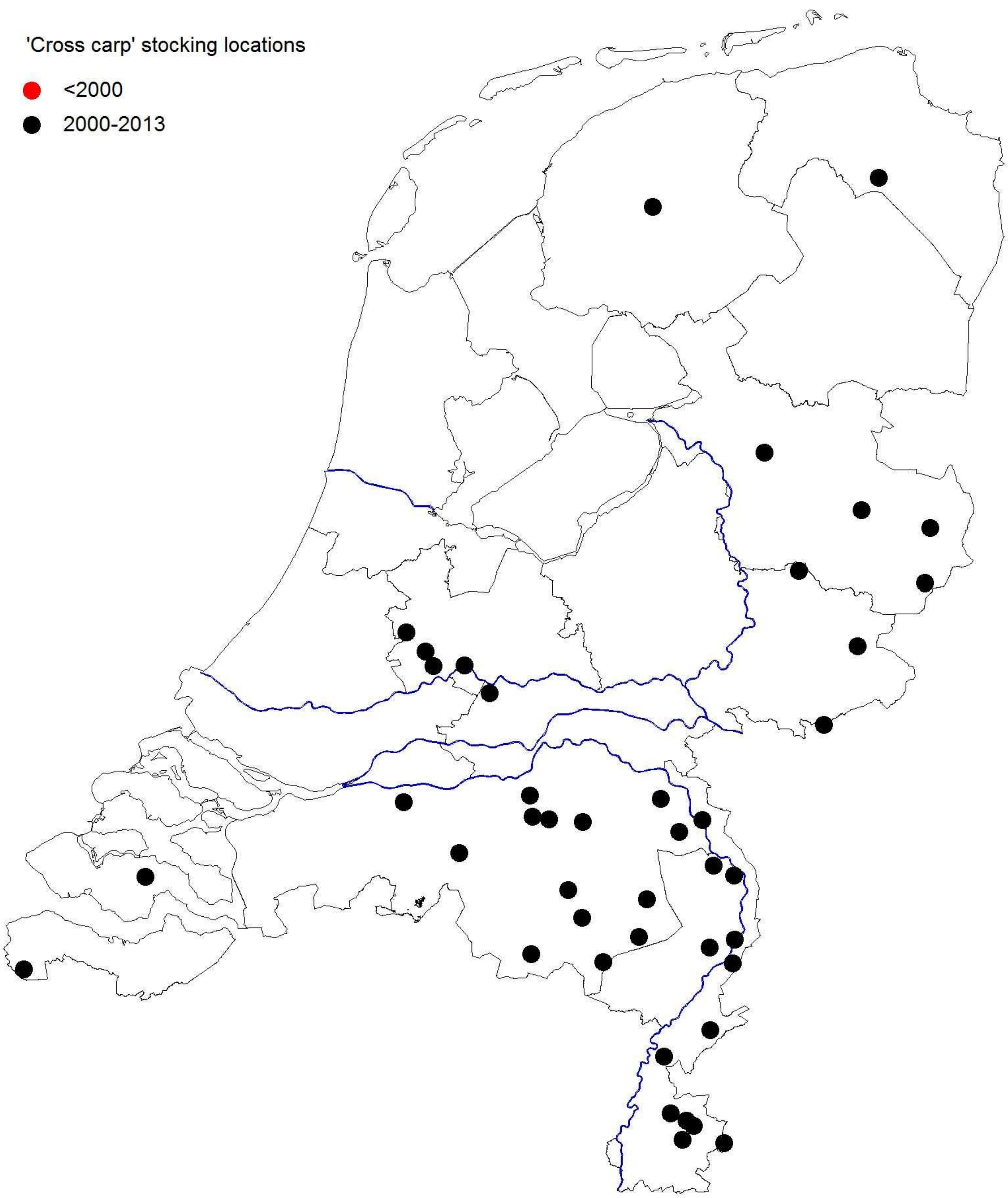

Figure 9.2: Cross carp (Cyprinus carpio X Carassius spp.) distribution of 48 stocking locations in the Netherlands (Data from Kamman (2011) and internet search).

9.2 Risk assessment

9.2.1 Probability of entry

Pathways of introduction

Two introduction pathways have been described for the Netherlands by Kamman (2011). The first pathway, used to stock nine water bodies, was road transport originating at a Belgian fish farm (Zonhoven). The second pathway, used to stock one water body, was the importation of fish by a commercial fishing company from the Czech republic (Kamman, 2011). No other occurrences of stocking using these pathways or occurrences of other pathways has been described in the literature.

Pathways of future introduction

Prussian carp, common carp, crucian carp and their hybrids are among the listed species in the Dutch Fisheries Act and their shipping and introduction can legally occur. Stocking materials can be obtained from different areas (including other countries) and can be transported to different water bodies in the Netherlands to which fishing rights apply. However, if the cross carp is a product of common carp and goldfish, stocking into the wild is not allowed because goldfish is an exotic species which is not included in the Fisheries Act.

Additionally to stocking, natural dispersion of the hybrids can be a pathway for future introductions.

9.2.2 Probability of establishment

Habitat suitability

Many Dutch water bodies provide suitable habitat for both common carp and *Carassius* spp., these habitats will also be suitable for hybrids of these species.

Propagule pressure

It can be concluded from the reports of Kamman (2011) and other reports that a minimal estimated number of 30,000 cross carp have been introduced in at least 96 ponds in the Netherlands during the past seven years (Sportvisserij Nederland, 2010; Sportvisserij Nederland, 2011; Wijmans, 2011; Sportvisserij Nederland, 2014). The exact number of waters in which cross carp have been introduced could be higher, because of undocumented stockings. The reproductive success of cross carp in the Netherlands is unknown. Active stocking of cross carp is promoted and often financially supported by Sportvisserij Nederland, which advises that ponds are stocked with 200 to 400kg/ha of the hybrid (Kamman, 2011; Wijmans, 2011; Sportvisserij Nederland, 2014).

Population development

The population development of the cross carp is unknown in the Netherlands. Mortality as a result of cormorant predation has been observed (Kamman, 2011). In relatively recent history, there have been no reports of establishment of the cross carp through natural reproduction.

Potential distribution range

Aided by stocking, illegal transport and escapes, the distribution of stocked hybrids could expand to virtually all stagnant fresh to light brackish waters in the Netherlands. When the cross carp reproduces it can establish hybrid populations with other hybrids, with the common carp or *Carassius* spp..

9.2.3 Probability of spread

Species features that encourage spread
Carassius species are considered non-migratory, common carp on the other hand can migrate over long distances (Szczerbowski, 2001). It is therefore likely that at least some hybrids will display migratory behaviour.

Spread in climatically similar countries
The spread of the hybrid in similar countries to the Netherlands has not been described in available literature.

Potential spread in Netherlands
A number of fishing ponds which were stocked with cross carp are situated next to rivers or have a hydrological connection with other water systems. Cross carp are likely to escape from these ponds during flooding events. With the aid of stocking, transport, escapes and migration, cross carp could spread to numerous water bodies throughout the entire country.

9.2.4 Vulnerable areas

Water bodies in the vicinity of stocked fishing ponds are likely to receive escaped (or intentionally released) specimens of cross carp. Therefore, cross carp are likely to occur in a number of N2000 areas. Areas inhabited by the native and endangered crucian carp are especially vulnerable for the introduction of cross carp because of hybridisaton.

9.2.5 Negative impact of introduction

Ecological impact
Huxel (1999) states that native species (including fish) can be rapidly displaced by invasive species as a result of hybridization. Therefore, the cross carp, if fertile, poses a serious threat to the native endangered (Red List) crucian carp as a result of hybridization and introgression (fertile hybrids and back-crossing). Many authors report that the endemic genotype of the crucian carp may be lost due to hybridization (Crunkilton, 1977; Wheeler *et al.*, 2000; Hänfling *et al.*, 2005; Maes *et al.*, 2007; Papousek *et al.*, 2008; Wouters *et al.*, 2012; Knytl *et al.*, 2013).

Eutrophication may occur in the presence of cross carp (as described for common carp and Prussian carp, chapter 6 & 11), especially if the advice to stock at high densities (>200kg/ha) is followed (Sportvisserij Nederland, 2013). Furthermore, interspecific competition with native species for resources may occur (also described for Prussian carp, chapter 11). In the Netherlands, Kamman (2011) reported that starvation of native bream (*Abramis brama*) and tench (*Tinca tinca*) occurred in a pond which was heavily stocked with cross carp (500kg/ha).

Economic impact
A high abundance of cross carp may positively influence the total phosphorus concentration in water (a known effect of both common carp and Prussian carp). According to the Dutch Water Framework Directive policy goals, an elevated phosphorus concentration results in a lower score for water quality in natural water bodies. When the scores are too low, European Union penalties will be incurred.

Social impact

There is no literature available that describes the negative social impact of cross carp and a negative impact is not expected.

9.2.6 Positive impact of introduction

Ecological impact

There is no literature on positive ecological impact of cross carp and a positive impact is not expected.

Social and economic impact

Carassius spp., common carp and their hybrids are of economic importance to aquaculture in Asia and a few East European countries (Szczerbowski, 2001). In the Netherlands, cross carp are of economic significance, but are still not one of the main target species, of recreational anglers. Kamman (2011) reports that the membership of fish clubs who stocked cross carp increased compared to other fishing clubs because the species is attractive to recreational anglers.

9.3 Risk classification

9.3.1 Available risk classifications

No formal risk classifications are available for cross carp.

9.3.2 Current situation

Expert consensus scores

The total risk score attributed to the cross carp was 9 out of a maximum risk score of 12 (table 9.2). This results in an overall classification of moderate risk for this species. However, this score is heavily influenced by expert judgment. Expert judgment is applied to nine out of 10 categories, limiting the score given. Most of the ecological risks associated with this species were judged using expert judgement which limits the maximum possible score in each category to a two rather than a three resulting in a lower overall score.

Table 9.2: Consensus scores and risk classifications for cross carp (Cyprinus carpio X Carassius spp.) in the current situation in the Netherlands.

ISEIA sections	Risk classification	Consensus score
Dispersion potential or invasiveness	likely	2
Colonization of high value conservation habitats	likely	2
Adverse impacts on native species	High	3
Alteration of ecosystem functions	likely	2
Global environmental risk	B - list category	9

Dispersion potential or invasiveness

Limited and conflicting evidence is available from literature that describes the dispersion potential or invasiveness of the cross carp in the Netherlands or from climatically similar countries (Kamman, 2011; Sportvisserij Nederland, 2013; Hänfling *et al.,* 2005). The cross carp is considered a non-fertile hybrid in the Netherlands (Kamman, 2011; Sportvisserij Nederland, 2013). However, in literature there is evidence that multiple generations of fertile hybrids of cross carp have been produced resulting in backcrossing and introgression (Hänfling *et al.,* 2005). *Carassius* species are considered non-migratory, while common carp can migrate over long distances (Szczerbowski, 2001), therefore the dispersion potential of the cross carp may be high. The current distribution of the cross carp consists of isolated populations that are spread relatively evenly throughout the Netherlands. However, this distribution pattern is the result of recent stocking for recreational fishing (Kamman, 2011). It was concluded using expert judgement that the dispersion potential and invasiveness of the cross carp is likely to be significant due to the high dispersal ability of the parent species.

Colonisation of high conservation value habitats
There is no evidence available from literature that describes the presence of the cross carp in high conservation value habitats in the Netherlands. However, it is likely that the cross carp is able to inhabit the same areas as the native and endangered crucian carp, which is especially vulnerable to introduction of this hybrid. Since crucian carp inhabit areas of high conservation value, it is likely that the cross carp will colonise high conservation value habitats in the Netherlands.

Adverse impacts on native species
There is limited evidence concerning the impacts of the cross carp in relation to predation and herbivory and interference and exploitation competition on native species in the Netherlands and elsewhere. In a single example, starvation of native bream (*Abramis brama*) and tench (*Tinca tinca*) occurred in a Dutch pond which was heavily stocked with the hybrid (500kg/ha) (Kamman, 2011). It was concluded that, depending on fish density, the cross carp is likely to impact on Dutch native species in a similar way to the common carp.

In other countries, some of which are climatically similar to the Netherlands, hybridization of common carp with *Carassius* spp. has a high genetic impact. Interbreeding with native crucian carp, a species which is threatened in the Netherlands, may result in the loss of its endemic genotype (Crunkilton, 1977; Wheeler *et al.,* 2000; Hänfling *et al.,* 2005; Maes *et al.,* 2007; Papousek *et al.,* 2008; Wouters *et al.,* 2012; Knytl *et al.,* 2013). Moreover, it is possible following a number of generations that genetic material related to crucian carp disappears. From the literature evidence it was concluded that it is more than likely that the cross carp can breed with crucian carp in the Netherlands and therefore has a high impact on native species as a result of genetic effects.

Large impacts relating to diseases and parasites carried by the cross carp are unlikely to occur as these are already carried by fish species native to the Netherlands. However, the transportation of cross carp could introduce new pathoghens to isolated waters.

Overall it was concluded that, dependent on fish density, the cross carp will have a likely impact on native species in the Netherlands.

Alteration of ecosystem functions
There is no evidence available in literature that directly links the cross carp with alterations in ecosystem functioning from the Netherlands or from climatically similar countries. However, based on expert judgement it is considered likely that effects similar to those felt by the common carp will occur in all subcategories categorised under alteration of ecosystem functions (modification of nutrient cycling or resource pools, physical modifications of the habitat, modifications of natural succession, disruptions of food webs).

Species classification

The species classification corresponds to the global environmental risk score of the ISEIA (table 9.2) combined with the current distribution of the non-native species within the country in question. The cross carp received a B1 score and is categorised in the watch list of the BFIS list system (Figure 9.3). B1 indicates a non-native species that is present in isolated populations in the Netherlands and features a moderate environmental hazard (i.e. ecological risk: ISEIA score 9: B category). The authors would like to emphasise that a score of 9 (moderate risk) does not reflect the expert opinion that this hybrid species may impact native species and alter ecosystem functions in the Netherlands in a similar way to the common carp and Prussian carp which received an 11 (high risk) score and appear on the black list.

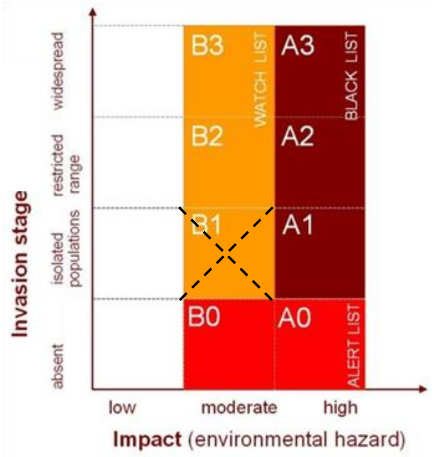

Figure 9.3: Cross carp (Cyprinus carpio X Carassius spp.) classification according to the BFIS list system. Dashed cross indicates a reliance on expert judgment when assessing this species.

9.3.3 Future situation

The temperature tolerance range of common carp and *Carassius* spp. is broad (e.g. Van Beek, 2000; De Wilt & Van Emmerik, 2008). This suggests that future temperature changes relating to climate change will have no impact on the cross carp. Risk assessment scores and distribution of this species are expected to remain the same if only temperature is considered (table 9.3). Therefore, the cross carp will remain on the watch list of the BFIS list system. However, a potential increase in precipitation in connection with climate change may result in increased flooding in ponds and streams which could result in a higher number of escapes. Moreover, natural selection may result in the production of more highly fecund individuals that will result in an increase in propagule pressure in the future. However, these scenarios are pure speculation and would have to be investigated further to assess the likelihood of them occurring. The authors would like to emphasise that a score of 9 (moderate risk) does not reflect the expert opinion that this hybrid species may impact native species and alter ecosystem functions in the Netherlands in a similar way to the common carp which received a 12 (high risk) score in the future scenario and appears on the black list. Most of the ecological risks associated with this species were judged using expert judgement which limits the maximum possible score to a two rather than a three resulting in a lower overall score.

Table 9.3: Cross carp (Cyprinus carpio X Carassius spp.) theoretical classification according to a potential future habitat scenario.

ISEIA sections	Risk classification	Consensus score
Dispersion potential or invasiveness	likely	2
Colonization of high value conservation habitats	likely	2
Adverse impacts on native species	high	3
Alteration of ecosystem functions	likely	2
Global environmental risk	B - list category	9

9.4 Risk management

9.4.1 Prevention of introduction

The stocked hybrid 'cross carp' exists in isolated populations throughout the Netherlands. Natural dispersal following escapes, through fish migration corridors and hydrologically connected water ways is virtually impossible to prevent. Nevertheless, dispersal to currently unoccupied isolated water bodies and the maintenance of populations by stocking can be prevented. It is currently lawful for fishing right owners to stock different variations of cross carp in unoccupied water bodies. It is, however, unlawful to stock cross carp with goldfish genes, because goldfish is an exotic species which has not been included in the Fisheries Act. Additional restrictions limiting the stocking could prevent the further spread and introduction of cross carp to isolated water systems and prevent the maintenance of populations through re-stocking practices.

9.4.2 Elimination of populations

The current population of cross carp in the Netherlands is relatively small and occurs, in many instances, in closed or isolated water bodies. Only populations in relatively small, isolated water bodies may be eliminated cost efficiently. See Appendix 4 for a description of general elimination options for exotic fish species.

9.4.3 Management of populations

It was the intention that cross carp populations in the Netherlands were non-reproductive due to the stocking of what were perceived to be sterile specimens. However, as discussed earlier in this report, the sterility of the cross carp cannot be confirmed. Therefore, prevention of cross carp stocking is the most reliable management option for the control of this hybrid species. Currently, stocked populations of cross carp can still be managed by elimination methods.

10. PIKE-PERCH (*Sander lucioperca*)

10.1 General species description

10.1.1 Nomenclature and taxonomy

Order	Perciformes
Family	Percidae
Genus	*Sander*
Species	*Sander lucioperca* Linnaeus, 1758
Common name	Pike-perch (Dutch: Snoekbaars)
Synonyms	*Stizostedion lucioperca*

10.1.2 Species characteristics and identification

Figure 10.1: Pike-perch (Sander lucioperca) obtained from the river Meuse (length 30cm) (digitalnature.org).

The pike-perch (*Sander lucioperca*) has an elongated body, a pointed head and large mouth with large teeth (Spikmans & Kranenbarg, 2010)(Figure 10.1). The species has two freestanding dorsal fins, the front one featuring sharp spines (Kottelat & Freyhof, 2007). The skin feels rough when rubbed from back to front. Pike-perch have silvery grey flanks featuring weak dark vertical stripes. The fishes back is brown to grey in colour and the belly is light grey to white. In the spawning season males turn darker with a dark grey belly. Pike-perch can grow to up to 120-130cm and weigh up to 20kg, reaching a maximum age of 17 years (Froese & Pauly, 2013; Aarts, 2007).

10.1.3 Life cycle

Habitat

Pike-perch inhabit large turbid rivers, eutrophic lakes and brackish coastal lakes and estuaries (Kottelat & Freyhof, 2007). The species lives near the bottom of water bodies in places where light conditions are poor.

Spawning occurs in water from 1 to 3 metres deep, with a sand or gravel bottom or among plant roots. Pike-perch usually undertake short spawning migrations, but migrations up to 250km have been observed for individuals foraging in brackish waters (Kottelat & Freyhof, 2007). Spawning sites can be situated in open lakes, the lower reaches of rivers and river inlets (Lappalainen *et al.*, 2003). Juveniles are photophobic, preferring deep turbid waters with poor light conditions (Luchiari *et al.*, 2006). There is only limited literature available on the tolerance of pike-perch toward different environmental factors, see table 10.1 for an overview.

Table 10.1: Tolerance of pike-perch (Sander lucioperca) to different environmental factors.

Environmental factor	Value	Life stage	Remarks	Reference
Temperature	33-37.2°C	Unknown	Lethal range	Alabaster & Lloyd (1980 Cfm. Van Beek, 2000)
	31.6-33°C	Unknown	Stress	Alabaster & Lloyd (1980 Cfm. Van Beek, 2000)
	27.3°C	Unknown	Physiological optimum	Hokanson (1977 cfm. Buijse & Houthuijzen, 1992)
	28-30°C	Unknown	Growth optimum	Hokanson (1977 cfm. Buijse & Houthuijzen, 1992)
	23°C	larvae to sub-adult	Significantly higher growth and condition compared to lower temperatures	Hermelink *et* al. (2011)
	11.5-20°C	Egg	Optimal incubation temperature	Muntyan (1977 Cfm. Lappalainen, 2003)
Oxygen	5.0-6.5mg/l	Larvae (0.3mg)	Declining concentration, LC50 at 18-20°C	Doudoroff & Shumway (1970)
	3.2-4.8mg/l	Larvae (0.7-11mg)	Declining concentration, LC50 at 20-25°C	Doudoroff & Shumway (1970)
	1.4-1.9mg/l	Larvae (358-370mg)	Declining concentration, LC50 at 22-26°C	Doudoroff & Shumway (1970)
	1.3-1.4mg/l	Juvenile (1.1-1.7 g)	Declining concentration, LC50 at 25-26°C	Doudoroff & Shumway (1970)
	0.5-0.8	Unknown	LC100 at 0-20°C	Doudoroff & Shumway (1970)
Salinity	0.7‰	Egg	Survival is highest	Klinkhardt & Winkler (1989 Cfm. Lappalainen *et* al., 2003)
	6.7‰	Egg	No survival	Klinkhardt & Winkler (1989 Cfm. Lappalainen *et* al., 2003)
	12 psu (ppt)	Adult	Tolerated at 10°C	Sadoka (2004)
	15‰	Adult	Upper tolerance level	Thiel *et* al. (1995 Cfm.Van Beek, 2000)
	20‰	Adult	Upper tolerance level	Hynes (1970 Cfm. Van Beek, 2000)

Reproduction

Pike-perch reach maturity at 3 to 10 years and a length of 31 to 46cm (Lappalainen *et al.*, 2003). The relative fecundity of the pike-perch is high for a predatory fish and ranges on average between 150 and 400 eggs/gram of female body weight. The absolute fecundity of pike-perch is around 1,000,000 eggs, but can be as high as 2,000,000 eggs from a single female (Lappalainen *et al.*, 2003). Absolute fecundity is positively correlated with fish length. Larger fish that have repeatedly spawned produce the highest quality eggs.

Spawning occurs once a year from late February until June at water temperatures ranging from 8 to 16°C. Spawning sites are situated at depths of 1 to 3 meters in water bodies with a sand or gravel bottom and rarely on submerged plants (Lappalainen *et al.*, 2003). Prior to spawning, the male excavates a nest with a diameter of 50cm and a depth of 5 to 10cm. Pike-perch spawn in pairs. The male guards the nest until the eggs hatch. He displays parental care by transporting oxygenated water to the nest and removing silt from the nest (Lappalainen *et al.*, 2003; Poulet *et al.*, 2005; Aarts, 2007; Kottelat & Freyhof, 2007).

Diet

Juvenile pike-perch initially predate on zooplankton and small crustaceans. After growing to a length of 10cm, they switch to a diet dominated by fish (Buijse & Houthuijzen, 1992). If the switch to piscivory is not made in the first year, condition decreases which leads to a weak year class with high mortality (Buijse & Houthuijzen, 1992).

Adult pike-perch feed predominantly on fish, and also display cannibalism (e.g. Kottelat & Freyhof, 2007; Kopp *et al.*, 2009). Prey species often mentioned in literature are smelt (*Osmerus eperlanus*), roach (*Rutilus rutilus*), bleak (*Alburnus alburnus*) and perch (*Perca fluviatilis*), this last species being a preferred prey item (Schulze *et al.*, 2006). It has been observed that pike-perch ingest prey of up to 50 to 66% of their own length (Sutela & Hyvärinen, 2002).

Predators

Larval and juvenile pike-perch are preyed on by a variety of predatory fish (including larger pike-perch), and a number of fish eating birds (e.g. Froese & Pauly, 2011). There are virtually no predators able to prey on large adult pike-perch.

Parasites and diseases

Pike-perch may be infected with standard non-specific parasites and bacteria. Sportvisserij Nederland (2013) highlights an intermediate stage of the worm *Bucephalus polymorphus* that may occur in the pike-perch and inhabits slow flowing waters. The pike-perch does not suffer morbidity due to this parasite.

20 species of parasites were found in pike-perch of the Baltic Coast of eastern Germany by Walter (1988): "Protozoa (1), Monogenea (1), Cestoda (2), Trematoda (8), Nematoda (3), Acanthocephala (2), Hirudinea (1) and Crustacea (2). The high extent and intensity of the parasitisation of *Bunodera luciopercae* in the pike-perch of the Oder Bay is striking. Here, the presence of *B. luciopercae* in pike-perch may inhibit their growth and development. Parasitological investigation (infestation of pike-perch with *Brachyphallus crenatus* and *Anisakis* spec. larv.) has proven that about 75% of pike-perch individuals migrate between the Peenestrom and Bay of Greifswald areas. The high occurrence of *Achtheres percarum* infestation in fish causes serious damage to the gill filaments in a number of cases. Studies carried out to date have shown that parasitic infestation of pike-perch has no negative effect on its edibility.

Bacterial infections are seldom. In France, it has been reported that the pike-perch rhabovirus has caused disease problems (Nougayrede *et al.*, 1992). Diseases described for pike-perch are shown in table 10.2.

Table 10.2: Parasites and diseases described for pike-perch (Sander lucioperca) (E = exotic for the Netherlands, N = Native for the Netherlands; Effect = disease/mortality in this species, if effect on other fish species is known (OS), this is also mentioned)

Parasite/disease	Location	Reference	Effect
Trichodina, Chilodonella, Ichthyobodo, Glossatella, Ichthyophthirius multifiliis (white spot), Dactylogyrus/Gyrodactylus spp., a.o. (N)	Europe	Haenen, expert knowledge	Low to medium OS: idem (various fish species)
Anisakis spp. (N)	East Sea	Feiler & Winkler, (1981)	Low to medium OS: idem (various fish species)
Ancyrocephalus paradoxus (E?)	E-Europe	Starovoitov (1988)	Low to medium OS?
Corynosoma strumosum (E?)	Poland	Rolbiecki & Rokicki (1996)	Low to medium OS?
Bucephalus polymorphus (N)	Netherlands	Sportvisserij Nederland (2013)	Low to medium OS?
Bunodera luciopercae (E?) *Brachyphallus crenatus* (E?) *Anisakis* spp. (N) *Achtheres percarum (E?)*	Baltic coast E-Germany	Walter (1988)	Low to medium OS? *Anisakis* spp.: Low to medium effect on various other fish species.
Bacteria			
Aeromonas salmonicida atypical (carp erythrodermatitis *Aer. hydrophila* *Edwardsiella tarda* *Pseudomonas fluorescens* *Flavobacterium columnare* (columnaris disease) *Streptococcus* sp., a.o.	>Europe (N) (extrapolation of bacteria of common carp)	Based on Jeney & Jeney, 1995 (review) based on probability and experience	Medium to severe OS: idem (various fish species)
Viruses			
Pike-perch rhabdovirus	France	Nougayrede *et al.*, 1992	Medium to severe OS: low (fish species specific)
Ranaviruses: o.a. pike-perch iridovirus (PPIV)	Finland	Bang Jensen *et al.*, 2011	Low OS (trout, catfish): low

10.1.4 Distribution

The native range of the pike-perch covers a number of drainage areas in Western Asia and Northern and Eastern Europe including the Danube river basin (Kottelat & Freyhof, 2007). Pike-perch have been introduced for fishery purposes and have become established in Western Europe, including the UK, the Iberian Peninsula and Italy (Kottelat & Freyhof, 2007).

The first introductions of pike-perch in the UK occurred from 1878 onwards with material originating from Germany and Sweden (Kottelat & Freyhof, 2007; FAO, 2013). In the German

Rhine basin, pike-perch were stocked with material from Eastern Europe in the late 1800s (FAO, 2013).

The first observation of pike-perch in the Netherlands was made in 1888 in the Rhine close to the border of Germany. Subsequently, natural reproduction was observed in the Dutch Rhine distributaries in 1901. In the Early 1900s, thousands of pike-perch were reared and stocked in a large variety of Dutch water bodies (De Nie, 1996). Pike-perch became established, colonizing the major rivers and larger connected water bodies. Currently, pike-perch are distributed virtually throughout the entire Netherlands, including the Wadden Island, Texel (figure 10.2).

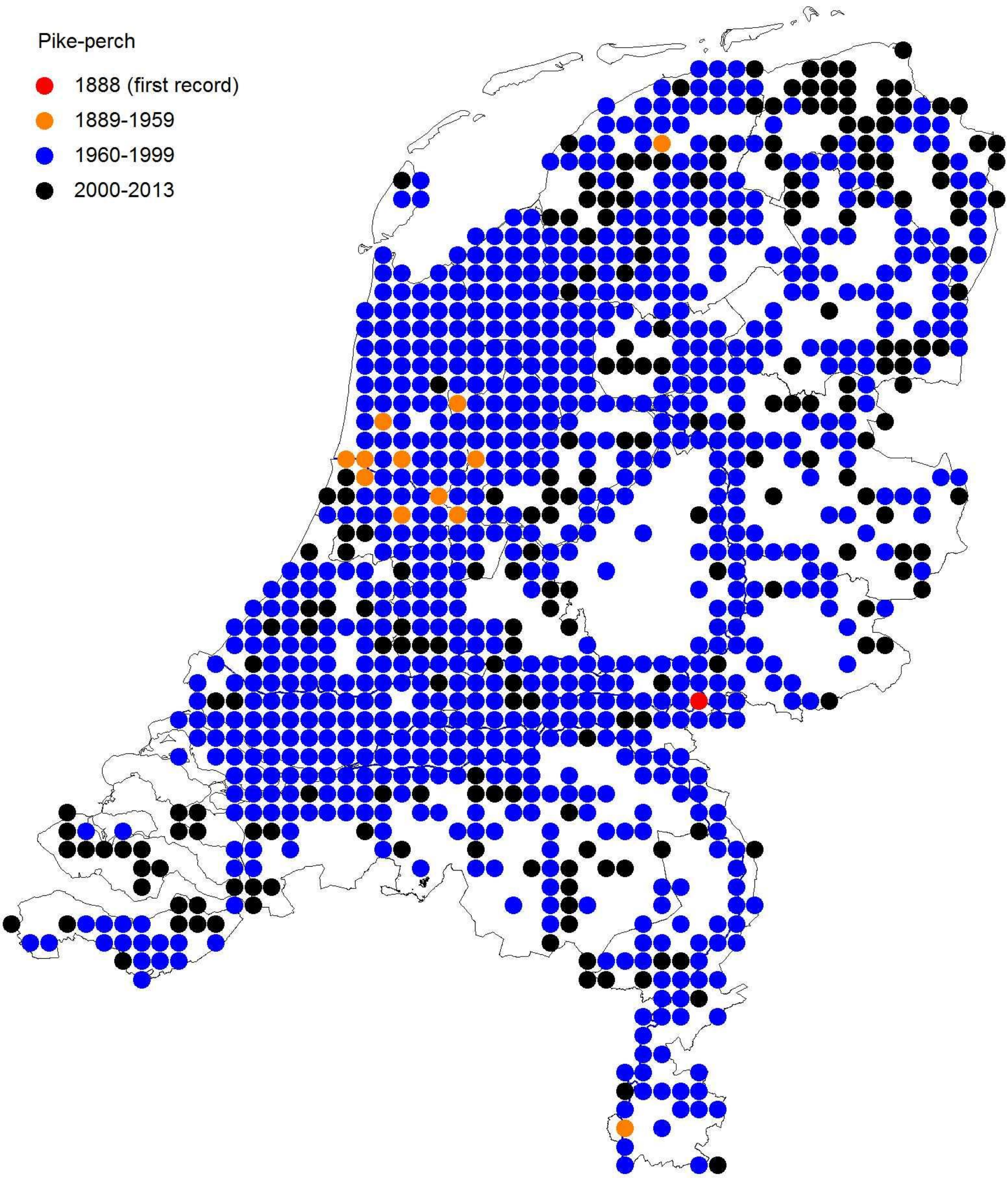

Figure 10.2: Pike-perch (Sander lucioperca) distribution history in the Netherlands from 1984 to 2013 (older records are plotted on top of more recent records) (RAVON/NDFF data).

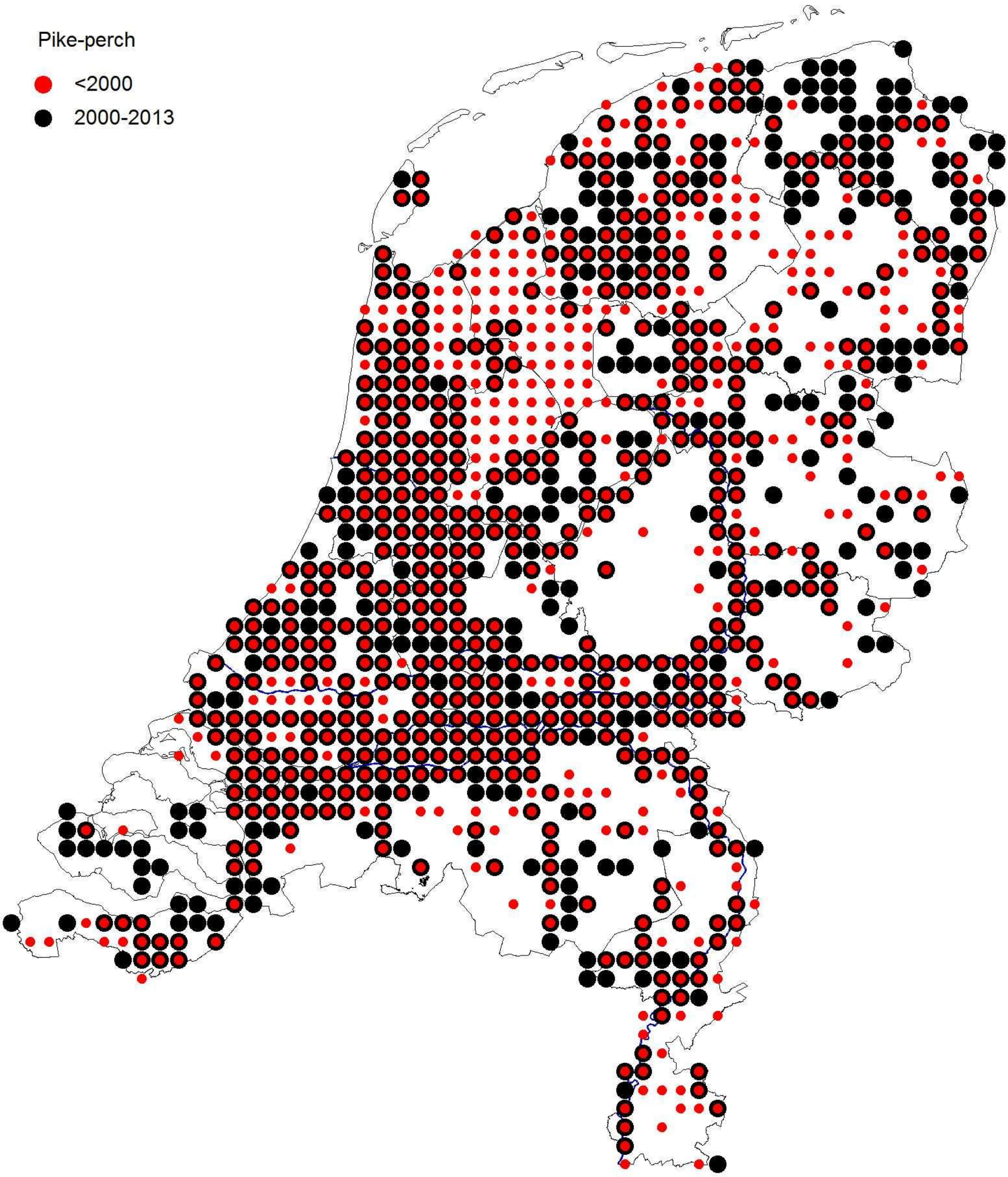

Figure 10.3: Pike-perch (Sander lucioperca) distribution in the Netherlands before and after 2000 (combined black and red dots indicate presence in both periods) (RAVON/NDFF data).

10.2 Risk assessment

10.2.1 Probability of entry

Pathways of introduction

The pike-perch was introduced to western parts of Germany with stocking materials from Eastern Europe. Subsequently pike-perch dispersed through the river Rhine to the Netherlands.

Moreover, pike-perch were (and still are) actively transported by humans throughout the Netherlands for recreational and commercial fishing purposes.

Pathways of future introduction
The pike-perch is listed in the Dutch Fisheries Act. Therefore, the transport and introduction of this species to the Netherlands can occur legally. Stocking materials can be obtained from different areas (also other countries) and can be transported to many different water bodies where fishing rights apply.

Pike-perch are native to the Danube. Therefore, the species can easily use the Main-Danube Canal as a pathway to disperse to the Rhine river system, like many other species from Eastern Europe (Leuven *et al.*, 2009).

10.2.2 Probability of establishment

Habitat suitability
In the Netherlands, the large river Rhine delta and many freshwater and brackish mesotrophic to eutrophic lakes provide suitable habitat for pike-perch.

Propagule pressure
Natural reproduction occurred in the major rivers within a few years of the first observation of pike-perch in 1888. Subsequently, very high numbers of pike-perch were stocked in various waters (De Nie, 1996). Therefore, it was relatively easy for a high fecundity fish such as the pike-perch to build a large population in the Netherlands in only a few decades.

Population development
Evidence from historical records suggests that population development was relatively limited in the period between 1889 and 1959. However, reports from fisheries in Lake IJssel show that annual landings of pike-perch increased rapidly since 1934. Redeke (1941) states that pike-perch rapidly became common in the major rivers in the first half of the 20th century. Currently, over a century after its first introduction and after gradual population development, the pike-perch is now widespread and present in virtually all larger water bodies connected to the Dutch freshwater network. It has become the most abundant predatory fish species in the deeper (>2m) water layers of most fresh and brackish water bodies. The pike-perch population could decrease due to increase of the water quality and clarity.

Potential distribution range
Pike-perch are distributed throughout the entire Netherlands. Distribution data show that in recent years (2000-2013), a relatively small number of new records were made in 5x5 grids where no previous records existed. This recent expansion could have occurred either by natural dispersal, stocking in isolated waters or as a result of higher monitoring effort and improved data collection. In the future, the pike-perch may expand its range to more isolated water bodies as a result of stocking. Pike-perch will definitely maintain its establishment in the Netherlands in the near future.

10.2.3 Probability of spread

Species features that encourage spread
Pike-perch are benthic fish that usually exhibits a limited home range (Aarts, 2007). Spawning migrations of up to 250km do occur (Lappalainen *et al.*, 2003). Adult pike-perch also show non-spawning migrations of up to 30km in a period of only a few months (Aarts, 2007). The high migratory capacity and high fecundity of the pike-perch result in a species that can easily spread.

Spread in climatically similar countries
In Germany, pike-perch have spread through the Rhine basin. Here, the distribution seems limited to the main river branches (Anonymous b). In Belgium, a similar introduction history as the Netherlands applies. Here, pike-perch distribution is limited to larger, linear waterways such as rivers and canals. According to Louette *et al.* (2001), pike-perch are spreading in a westerly direction due to improved water quality. In the United Kingdom, pike-perch steadily spread through the water system after introduction and stocking increases the rate of dispersal (Copp *et al.*, 2003).

Potential spread in Netherlands
Aided by stocking and by dispersion the pike-perch could easily spread to unoccupied water bodies in the Netherlands. The potential for further spread is therefore high.

10.2.4 Vulnerable areas

Pike-perch has predominantly been recorded in large water bodies protected under Natura 2000 in the Netherlands (Appendix 1). The Dutch rivers and large lakes function as important habitats and migration routes for a high number of native species. Many fluvial habitats are protected under the European Habitats Directive. These areas are vulnerable to the presence of pike-perch. Other areas vulnerable to pike-perch spread are waters where it has not been introduced to date, especially if these waters hold threatened / protected fish species or feature protected habitats.

10.2.5 Negative impact of introduction

Ecological impact
Pike-perch can be categorized as a top-predator and occupy a higher trophic position in comparison to other predatory fish species (Kopp *et al.*, 2009). In its role as top-predator, pike-perch greatly impact prey species populations and populations of other predatory fish.

In Turkey, after the introduction of pike-perch to the Beysehir Lake and Egredir Lake, the number of native fish species and population sizes drastically decreased, and three endemic species became extinct (Innal & Erk'akan, 2006; Crivelli 1995; Kücük *et al.*, 2009).

In our climatic region, many authors describe the adverse effects of pike-perch introduction. Cowx (1997 Cfm. Larsen & Berg 2011) found that the introduction of pike-perch to English rivers created a crash in the cyprinid fish community. Moreover, in the Danish lake Skanderborg, declining abundance of planktivorous fish was attributed to the presence of pike-perch (Jeppesen *et al.*, 2000).
In north-east Germany, Holker *et al.* (2007) found that the avoidance of pike-perch by prey species (predator avoidance) varied greatly between species, ranging from reduced activity in roach (*Rutilus rutilus*) and small perch (*Perca fluviatilis*), to a shift in habitat use by roach, to no

change in the habitat use and activity of rudd (*Scardinius erythrophthalmus*). These differences in response effected the population density of the prey species. The most profound effect was felt by rudd whose density dramatically decreased by more than 80% (Hölker *et al.*, 2007). Roach density declined only slightly and small perch density increased (Hölker *et al.*, 2007). Brabrand & Faafeng (1993) demonstrated how young roach shifted from pelagic to littoral habitats as a result of pike-perch introduction in a Norwegian lake. An indirect effect of this changed behaviour was an increased infection rate by the ectoparasite *Ichthyophthirius multifiliis*. Roach were more often exposed to the parasite when living in shallow water near the substrate (Braband *et al.*, 1994).
In Lake Grosser Vätersee, a shallow, mesotrophic lake in north-east Germany, introduction of pike-perch negatively affected the perch population (*Perca fluviatilis*). According to Schulze *et al.* 2006 "perch was forced away from its preferred habitat, the pelagic zone, by pike-perch, and as the littoral zone was already occupied by pike (*Esox lucius*), the perch population was "sandwiched" between pike and the introduced pike-perch". Furthermore, pike-perch have shown a preference for perch as a prey item (Schulze *et al.*, 2006). Jensen (pers. comm. Cfm. Larsen & Berg, 2011) states 'as perch have been found to be the most important predator to control the density of zooplanktivorous 0+ cyprinids in Danish lakes, the introduction of pike-perch must be considered as negative and indeed has been observed to result in reduced environmental conditions compared to those expected in eutrophic Danish lakes".
In Denmark, a high occurrence of predation by pike-perch on native sea trout smolts (*Salmo trutta*) and Atlantic salmon smolts (*Salmo salar*) occurred (Jepsen *et al.*, 2000; Koed *et al.*, 2002). Pike-perch forage actively near physical bottle necks of fish migration and are responsible for a high mortality among sea trout and salmon smolts as they migrate seaward. Both these species became extinct in the Netherlands in the middle of the 20th century and in recent decades, great investments and efforts have been made to re-establish both species in the Rhine river basin. The presence of pike-perch could also reduce the survival of salmonid smolts during their seaward migration in the Netherlands.

The pike-perch is a known vector for the trematode *Bucephalus polymorphus*, that can cause very high mortality in native cyprinid fish species (Wallet & Lambert 1986 Cfm. Poulet *et al.*, 2009). As a result, a decrease in native cyprinid populations was observed in some French basins in the 1960s and 1970s (Lambert, 1997 Cfm. CABI, 2012). Moreover, decreases in native cyprinid populations have more recently been observed in water systems newly colonized by zebra mussel (*Dreissena polymorpha*), the primary host of this parasite (CABI, 2012). The pike-perch and zebra mussel are already infected by *Bucephalus polymorphus* in the Netherlands, therefore local populations of these exotic species can already be affected by this trematode. In Belgium, a large outbreak and associated impacts relating to this parasite have never been reported (Anseeuw *et al.*, 2011).
Gollasch *et al.* (2008) stated that pike-perch may introduce exotic parasites or diseases. For example, a new nematode, *Lucionema balatonense*, has been described existing in the swimbladder of pike-perch in Lake Balaton. Furthermore, the pike-perch rhabdovirus (Nougayrede *et al.*, 1992) may be a threat to Dutch pike-perch stocks. As no screening has been done in the Netherlands for this virus, it is not known if it is already present here. The transmission of (sub-)lethal diseases by pike-perch could have negative impacts on the growth or distribution of one or more native species.

The overall impact of the exotic pike-perch on native fish populations in similar countries to the Netherlands is high. Unfortunately responses of the Dutch fish fauna to the introduction of pike-perch have not been monitored. Currently, over 100 years after its initial introduction, it is unlikely that the presence of pike-perch will lead to further major changes in the native fish population or to the extinction of native species in the Dutch water system. On the other hand, the reintroduction of some (migratory) salmonid species following ecological restoration could be hampered due to predation pressure applied by the abundant pike-perch. Furthermore, the abundance of cyprinids, perch, smelt and other prey species as well as native predator fish species may be suppressed in the current situation as a result of pike-perch predation, competition and disease transmission.

Economic impact
Negative economic impacts of pike-perch have not been reported in international literature as pike-perch is, in most cases, of higher economic value than native fish species.

In the Dutch policy goals of the European Water Framework Directive (WFD), pike-perch is included in the fish stock assemblage scores for natural and artificial waters. The abundance of adult pike-perch is a measure of (commercial) fishing pressure. If more than 50 pike-perch are caught in the course of water body monitoring, a low occurrence of adult pike-perch (>42cm) in the sample will result in a lower score for large water bodies. Pike-perch presence will have a negative effect on WFD scores in both natural and artificial waters, as a higher biomass fraction of eurytopic fish is seen as undesirable. Overall, in the Dutch situation, pike-perch may have a negative influence on scores relating to the WFD ecological targets. If these targets are not met, penalties of the European Union will be applied.

Social impact
Contaminants, such as heavy metals, may accumulate in pike-perch as a result of it being a top-predator. Consumption of contaminated pike-perch could impact human health. However, screening of pike-perch from Dutch and foreign origins for contaminants did not indicate any threats to human health (Roessink, 2004; Pieters *et al.*, 2005).

10.2.6 Positive impact of introduction

Ecological impact
By feeding on planktivorous fish, pike-perch can positively influence water quality and reduce turbidity after biomanipulation (active reduction of planktivorous species) in turbid, nutrient rich lakes (Horppila *et al.*, 1998). Following a return to a state with low turbidity, recovery of pike and perch populations are an important factor in maintaining its stability (Olin *et al.*, 2006).

Economical impact
In many countries, introduced pike-perch have become an important species with a high market value for commercial fisheries (e.g. Crivelli 1995; Jacobsen *et al.* 2004; Anseeuw *et al.* 2011). Moreover in the Netherlands, pike-perch is one of the most important species for commercial fresh water fisheries, a business sector with a direct total turnover of approximately 10 million €/year for all species (Combinatie van Beroepsvissers, 2011). Yearly in the Netherlands, around 300,000kg pike-perch is landed by commercial fisheries, which is much lower than the amount demanded (Roessink, 2004). To meet the demand, 4 millionkg of pike-perch fillet is imported from Eastern Europe (Roessing, 2004).

Pike-perch is also an important target species for anglers in the Netherlands (Steyn, 2010; Smit *et al.*, 2004). The total (including indirect) turnover of the freshwater angling industry is estimated to be 360-600 million €/year generated by 1.6 million people fishing in the Netherlands (Smit *et al.*, 2004). Anglers targeting pike-perch make up about 5% of the angling community, but spend a relatively high amount of money on their hobby compared to other anglers (Steyn, 2010; Smit *et al.*, 2004).

Social impact

Pike-perch have a high recreational value because many anglers target the species either as a table fish, recreational species or for catch and release fishing tournaments (Steyn, 2010).

10.3 Risk classification

10.3.1 Available risk classifications

Table 10.3: Overview of risk classifications previously performed for pike-perch (Sander lucioperca).

	Belgium	Ireland	Macedonia	United States	United Kingdom
Scope	Risk assessment	Species prioritised for more detailed risk assessment	Risk assessment	Risk assessment	Risk assessmen t
Method	ISEIA	Invasive Species Ireland Risk Assessment	FISK	Ecological Risk Screening Summary	FISK
Risk classification	9/12 (Medium)	22/24 (High)	Moderately high	High	High
Source	http://ias.biodiversity.be/species/show/6	Kelly *et al.* (2013)	Simonovic *et al.* (2013)	http://www.fws.gov/injuriouswildlife/pdf_files/Sander_lucioperca_WEB_9-18-2012.pdf	Copp *et al.* (2009)
Additional information	Classified as a B3 species (widespread in Belgium featuring a moderate environmental hazard)	Scores ≥ 18 are classified as high risk	Classified as invasive		≥19 = High risk

Rationale for risk classification

Pike-perch are widespread and able to reproduce in Belgium. It features a high dispersion potential and its ability to colonise valuable habitats is judged as medium. Anseeuw *et al.* (2007) rated impacts in Belgium relating to predation and herbivory, competition with native species and disease transmission as medium for this species. Risks related to genetic effects were judged as low. Impacts on ecosystems relating to nutrient cycling, physical alteration and natural succession were all judged as low. However, likely alterations to food webs are expected. Populations of native piscivorous fish species (pike and perch) were locally depleted due to interspecific competition. The pike-perch is also a vector of the *Bucephalus polymorphus* parasite, that can affect native cyprinid fish species; however, a large outbreak of this parasite has never been reported in Belgium.

Kelly *et al.* (2013) gives an overview of prioritization risk assessment scores for multiple fish species but gives no rationale for the allocation of risk classifications.

Simonovic *et al.* (2013) gives an overview of FISK scores for multiple fish species but gives no rationale for the allocation of risk classifications.

The high risk result obtained from the assessment of risk in the United States was based on evidence of invasiveness in Europe and a favourable climate match. Pike-perch has been introduced to the United States many times, but has only one established population in Spirit Lake, North Dakota. In Europe, pike-perch has established itself in many introduced areas. Impacts from these introductions include reduced populations of prey fish and competitor fish, as well as trophic changes, and in the case of some Turkish lakes, extirpation of endemic species.

Copp *et al.* (2009) give an overview of FISK scores for multiple fish species but gives no rationale for the allocation of risk classifications.

10.3.2 current situation

Expert consensus scores
The total risk score attributed to the pike-perch was 11 out of a maximum risk score of 12 (table 10.4). This results in an overall classification of high risk for this species.

Table 10.4: Consensus scores and risk classifications for pike-perch (Sander lucioperca) in the current situation in the Netherlands.

ISEIA sections	Risk classification	Consensus score
Dispersion potential or invasiveness	high	3
Colonization of high value conservation habitats	high	3
Adverse impacts on native species	high	3
Alteration of ecosystem functions	likely	2
Global environmental risk	A - list category	11

Dispersion potential or invasiveness
The pike-perch is characterised by a high fecundity and is able to spread rapidly in the Netherlands. The absolute fecundity of pike-perch is approximately 1,000,000 eggs, but can be as high as 2,000,000 eggs per female (Lappalainen *et al.,* 2003). Historical records further support the rapidity with which the pike-perch can disperse, the fish is currently widely distributed throughout the Netherlands. It was concluded that pike-perch have a high dispersion potential and invasiveness in the Netherlands.

Colonisation of high conservation value habitats
63% of Pike-perch distribution occurs in areas designated under Natura 2000 in the Netherlands (appendix 1). Currently, pike-perch recorded distribution covers the Netherlands almost completely, including the Wadden Island, Texel. It has become established in all the larger rivers and connected waterways. Many fluvial habitats are protected under the European Habitats Directive and it was concluded that the pike-perch may pose a high risk to high conservation value habitats in the Netherlands.

Adverse impacts on native species
Despite the pike-perch being present in the Netherlands for over a century, no research addresses the impacts of this fish on native species. However, there is strong evidence from countries with a

similar climate that pike-perch have a high impact on native species. In the United Kingdom, pike-perch caused a crash in planktivorous cyprinid populations due to its predatory behaviour (Cowx, 1997 Cfm. Larsen & Berg, 2011). In a north east German lake, the introduction of pike-perch forced the population of perch away from their preferred habitat and populations of rudd decreased by 80% due to predation (Schulze *et al.,* 2006). Since both perch and rudd are also native to the Netherlands, such effects are also likely to occur here. Efforts to reintroduce sea trout and Atlantic salmon to the Netherlands in the Rhine and Meuse river system may be hindered by pike-perch as high predation of these species occurred in Denmark (Jepsen *et al.,* 2000; Koed *et al.,* 2002). It is unlikely that the pike-perch will negatively impact native species through hybridisation as no similar species exist in the Netherlands. It was concluded on the basis of evidence from foreign countries that pike-perch have a high impact on native species as a result of predation and interference and exploitation competition in the Netherlands.

Pike-perch are known to carry the trematode *Bucephalus polymorphus*. A decrease in native cyprinid populations has been observed in some French basins in the 1960s and 1970s as a result of transfer of this parasite from pike-perch, and recently in water systems newly colonized by the zebra mussel, the primary host of this parasite (CABI, 2012). Pike-perch and the zebra mussel are already infected by *B. polymorphus* in the Netherlands and it is likely that similar impacts occur here. Furthermore, the pike-perch rhabovirus, present in France, may cause disease in pike-perch (Nougayrede *et al.,* 1992). It was concluded, based on expert knowledge, that pike-perch will likely negatively impact native species in the Netherlands through the transmission of parasites and diseases.

Alteration of ecosystem functions

There is no evidence available in the Netherlands or from countries with similar climates that demonstrates that pike-perch will alter ecosystem functions in the Netherlands. Expert judgements were focussed, therefore, on the potential effect that pike-perch have on food webs. Other subcategories relating to ecosystem effects (modification of nutrient cycling or resource pools, physical modifications of the habitat and modifications of natural succession) were classified as data-deficient. The pike-perch can be categorized as a top-predator and occupies a higher trophic position in comparison with other predatory fish species (Kopp *et al.,* 2009). It can, for example, take large prey in a greater range of habitats and is a more flexible predator than the asp (*Leuciscus aspius*). Moreover, the pike-perch is used in lake management for the top-down biomanipulation of phytoplankton by selective removal of planktivorous fish (Jeppesen *et al.,* in press). It was concluded, based on expert judgement, that pike-perch will likely negatively impact ecosystem functions in the Netherlands due to its predatory behaviour.

Species classification

The species classification corresponds to the global environmental risk score of the ISEIA (table 10.4) combined with the current distribution of the non-native species within the country in question. The species classification for the pike-perch is A3 (Figure 10.4). This indicates a non-native species which is widespread and displays a high environmental hazard (i.e. ecological risk) that should be placed on the black list of the BFIS list system (i.e. ecological risk: ISEIA score 11: A category).

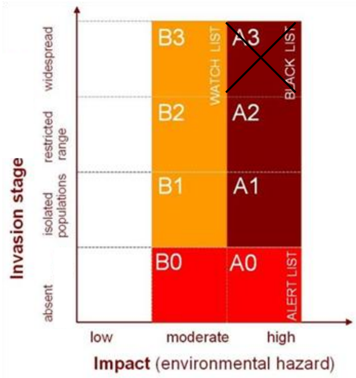

Figure 10.4: Pike-perch (Sander lucioperca) classification according to the BFIS list system.

10.3.3 Future situation

The optimal incubation temperature for pike-perch eggs is 11.5 to 20°C, while optimum growth occurs in the range of 28 to 30°C (Muntyan, 1977 Cfm. Lappalainen, 2003; Hokanson, 1977 cfm. Buijse & Houthuijzen, 1992). A two degrees Celsius increase in temperature in the Netherlands is predicted to have no effect on pike-perch reproduction, however growth may become more optimal. Pike-perch are already widely distributed in the Netherlands and the population is relatively stable. Moreover, risk scores are already assessed as high or likely in the current situation. Therefore, the risk assessment scores and distribution of this species are predicted to remain the same if only temperature is considered (table 10.5). The A3 classification under the BFIS list system would remain the same in this scenario.

Table 10.5: Pike-perch (Sander lucioperca) theoretical classification according to a potential future habitat scenario.

ISEIA sections	Risk classification	Consensus score
Dispersion potential or invasiveness	high	3
Colonization of high value conservation habitats	high	3
Adverse impacts on native species	high	3
Alteration of ecosystem functions	likely	2
Global environmental risk	A - list category	11

10.4 Risk management

10.4.1 Prevention of introduction

The pike-perch is distributed widely in the Netherlands. Natural dispersion through fish migration corridors and hydrological connections of water ways is virtually impossible to prevent. Nevertheless, spread to new water bodies and river systems, isolated from the current pike-perch distribution range, can be prevented. It is currently lawful for fishing right owners to stock pike-perch in water bodies where no pike-perch are initially present. Therefore, restrictions could be put in place that prevent the further spread of pike-perch to isolated water systems.

10.4.2 Elimination of populations

The current population of pike-perch in the Netherlands is widespread and the species occurs predominantly in large water systems. Only populations in relatively small isolated waters may be eliminated cost efficiently. Internationally, there is no available information that describe methods for the complete elimination of pike-perch populations. General options for the elimination of exotic fish species can be found in Appendix 4.

10.4.3 Management of populations

The pike-perch is a favoured species in commercial fisheries. The demand for pike-perch in the Netherlands is much higher than what can be provided by commercial Dutch fisheries. It is, however, impossible to completely deplete the pike-perch population. Furthermore, overfishing leads to suppressed fish stocks dominated by small fish (e.g. Kangur & Kangur, 1996).

Large scale eradication of the pike-perch has been applied in the United Kingdom (Roberts & Tilzey, 1996). This management strategy is only feasible when the rate of removal exceeds the rate of recruitment, there is a low probability of reinvasion, it is possible to target all individuals in a population and the strategy is supported by society and politics (Chadderton, 2003). When not all individuals can be removed, the management efforts can have an adverse impact. The intensive removal of pike-perch in the United Kingdom lead to a lower biomass and a decrease of mean length, but increased fish numbers (Smith *et al.*, 1995). Therefore, it was suggested that fish removal led to an increased predation intensity on prey fish populations, in fact the opposite of what was intended (Smith *et al.*, 1995). Therefore, eradication cannot be considered a feasible measure for the management of the pike-perch population in the Netherlands, particularly as it is widespread in a large water system.

In some cases, the invasion success of exotic species might be reversed by the alteration or rehabilitation of the water system (Van Kessel *et al.*, 2013). Ideally, completion of exotic species' life cycle is interrupted and completion of the native species' lifecycle facilitated. Pike-perch rely on deep, nutrient rich and turbid waters. In recent decades, water quality has improved with declining nutrient availability and lower turbidity. Conditions, therefore, have become more favourable for the pike (*Esox lucius*) and less favourable for pike-perch. Therefore, system rehabilitation and water quality improvement are suitable measures for the reduction of the pike-perch population and its potential impact.

11. PRUSSIAN CARP (*Carassius gibelio*)

11.1 General species description

11.1.1 Nomenclature and taxonomy

Order	Cypriniformes
Family	Cyprinidae
Genus	*Carassius*
Species	*Carassius gibelio* Bloch, 1782
Common name	Prussian carp (Dutch: Giebel)
Synonyms	*Carassius auratus gibelio* (Bloch, 1782) (Kottelat & Freyhof, 2007)

11.1.2 Species characteristics and identification

Figure 11.1: Prussian carp (Carassius gibelio) (length 20cm) (digitalnature.org).

Prussian carp (*Carassius gibelio*) have a relatively high and laterally compressed body. The scales are large, numbering 29 to 33 on the lateral line. The body is silvery to brown grey in colour. The mouth is terminal and has no barbels. The dorsal fin is relatively long with a straight or concave edge (Kottelat & Freyhof, 2007). Prussian carp can grow to a length of 35cm and live for about 10 years (Kottelat & Freyhof, 2007). In the Netherlands, the reported maximum length of Prussian carp is over 50cm (Emmerik & De Nie, 2006).

Prussian carp are often confused with crucian carp (*Carassius carassius*), wild goldfish (*Carassius auratus*) and common carp (*Cyprinus carpio*). These species are distinguished by a number of features (table 11.1).

Table 11.1: Distinguishing features to identify Carassius spp. and Cyprinus carpio (based on: Kottelat & Freyhof, 2007; Maes et al., 2007; Spikmans & Kranenbarg, 2010). Important note: the displayed species can hybridize and backcross, resulting in intermediate features and uncertain morphological identification.

	Prussian carp (*Carassius gibelio*)	Goldfish (*Carassius auratus*)	Common carp (*Cyprinus carpio*)	Crucian carp (*Carassius carassius*)
Dorsal fin	Concave or straight edge	Concave or straight edge	Concave edge	Convex edge
Barbels	No barbels	No barbels	Two pairs of barbels	No barbels
Caudal peduncle	No spot	No spot	Weak dark spot in juveniles	Dark spot in juveniles
Base colour	Silver to grey brown	Bronze, golden brown to various other colours	Bronze to brown	Golden green to golden brown
Scales on lateral line	29-33	26-31	Various	31-36
Number of gill rakers on anterior gill arch	29-52	29-52	18	18-32
Peritoneum (internal feature)	Black	Black	-	Whitish

11.1.3 Life cycle

Habitat

Prussian carp inhabit a wide variety of still water bodies and lowland rivers and are usually associated with submerged vegetation (Kottelat & Freyhof, 2007). The species spawns in shallow waters on submerged vegetation or roots.

Larvae and juveniles live in sheltered littoral zones with a high coverage of vegetation or other structures (Kottelat & Freyhof, 2007).

The Prussian carp is described as a very tolerant fish species. The specific literature on tolerance of Prussian carp is scarce because the species was confused with the Goldfish until recently. However, both species are closely related and probably display similar tolerances toward different environmental factors, the most important values are summarized in table 11.2.

Table 11.2: Tolerance of Prussian carp (Carassius gibelio) to different environmental factors.

Environmental factor	Value	Life stage	Remarks	Reference
Temperature	0°C	-	Lower critical value	Van Beek (2000)
	41°C	-	Upper critical value	Van Beek (2000)
pH	4.5-10.5	-	Tolerated range goldfish	Szczerbowski (2001)
Oxygen	0.5mg/l	-	Threshold oxygen concentration for Prussian carp and Goldfish (10°C)	Gor'unova (1960 Cfm. Szczerbowski, 2001)
	0.6mg/l	-	Threshold oxygen concentration for Prussian carp and Goldfish (20°C)	Gor'unova (1960 Cfm. Szczerbowski, 2001)
	0.7mg/l	-	Threshold oxygen concentration for Prussian carp and Goldfish (30°C)	Gor'unova (1960 Cfm. Szczerbowski, 2001)
Salinity	7.3 g/l chloride	-	LC50 96 hours for Goldfish	Szczerbowski (2001)
	5 ppt	adult	Prussian carp population observed	Vetemaa *et al.* (2005)

Reproduction

Prussian carp reach maturity at a length of 20cm and an age of 2 to 3 years in optimal habitats that stimulate rapid growth. In suboptimal habitats, the length and age of maturity can range from 8 to 23cm and from 1 to 5 years (Szczerbowski, 2001). In warmer waters, fish mature at a relatively early age and at a smaller size. The fecundity of Prussian carp is high, a female can produce 100,000-860,000 eggs (Szczerbowski, 2001). Absolute fecundity has a positive correlation with fish length and body weight. Relative fecundity lies within the range of 300-900 eggs/gram of female body weight (Szczerbowski, 2001).

The reproduction biology of Prussian carp is rather complex. Some populations feature diploid individuals of both sexes, other populations consist only of triploid females, while there are also intermediate populations with both triploid and diploid fish (Kottelat & Freyhof, 2007; Maes *et al.*, 2007; Kalous & Knytl, 2011). Triploid only-female populations are sustained through gynogenetic reproduction (Zhou & Gui, 2002; Maes *et al.*, 2007). Triploid Prussian carp females are considered to be sperm parasites, as their eggs are activated by the sperm of other cyprinid species. In this case the nuclei of the reproductive cell do not fuse. Spermatozoa only adhere to the egg membrane and no genetic features of the sperm donor are transferred (Szczerbowski, 2001). Triploid Prussian carp females also produce eggs which can be fertilized by Prussian carp males, resulting in male and female offspring (Fan & Shen, 1990; Zhou & Gui, 2010). Another phenomenon observed in female Prussian carp is the occurrence of hermaphrodites (Szczerbowski, 2001). Hermaphrodites make sexual reproduction and the emergence of males possible in a female only population. Self fertilization of hermaphrodites has not been described in literature.

Prussian carp spawning occurs from the end of May until the end of July at water temperatures of 14 to 25°C (Szczerbowski, 2001; Kottelat & Freyhof, 2007). The species is a batch spawner and two or three egg batches are released during the season, the first batch being the largest (Szczerbowski, 2001). Eggs are adhesive and are laid on aquatic vegetation.

Diet

Prussian carp are flexible and omnivorous feeders (Szczerbowski, 2001). They feed on zooplankton, a variety of invertebrate, detritus and plants. Prussian carp can feed on very small planktonic organisms due to their dense gill rakers. Also, fish eggs and fry, including the eggs and fry of Prussian carp, are sometimes consumed.

Predators

Large predatory fish are able to predate on Prussian carp, for example the native pike (*Esox lucius*) and non-native pike-perch (*Sander lucioperca*) (Vetemaa *et al.*, 2005). Fish eating birds probably also predate on Prussian carp, for example cormorants and herons.

Parasites and diseases

Parasites of the Prussian carp overlap with those of the common carp (*Cyprinus carpio*). Apart from endemic nonspecific fish parasites and pathogenic bacteria, some publications give additional parasites and diseases more specific to the Prussian carp (table 11.3).

Table 11.3: Parasites and diseases described in Prussian carp (Carassius gibelio) (E = exotic in the Netherlands, N = Native in the Netherlands; Effect = disease/mortality in this species, if effect on other fish species is known (OS), this is also mentioned).

Parasite/disease	Location	Reference	Effect
Parasites			
Trichodina, Chilodonella, Ichthyobodo, Glossatella, Ichthyophthirius multifiliis (white spot), Dactylogyrus/Gyrodactylus spp., *Argulus* spp., (N)	Netherlands	Haenen, expert knowledge	Low to medium OS: idem
Hoferellus carassii	Hungary	Molnár *et al.*, 1989	Low to medium OS?
(*Posthodiplostomum cuticola* and *Diplostomum rutili*) and two nematode species (*Contracaecum microcephalum* and *Raphidascaris acus*)	Srebarna Lake, Bulgaria	Shukerova, 2005	Low to medium OS: idem
Dactylogyrus anchoratus (dujardin, 1845)	Czech Republic	Moravec, 2012.	Low to medium OS?
Bacteria			
Flavobacteriujm columnare (columnaris disease)(N) *Aeromonas salmonicida* atypical (carp erythrodermatitis) (N) *Aeromonas hydrophila/sobria/*spp. (N) Many opportunistic secondary bacteria, like *Pseudomonas fluorescens* (N)	Europe	Austin & Austin, 1999	Low to severe OS: idem (cyprinids, pike, eel, etc.)
Viruses			
Cyprinid herpesvirus 2 (CyHV-2) (E?)	in China since 2009 (High loss of individuals)	Xu *et al.*, 2013:	Severe OS: idem (goldfish)
CyHV-2 (E?)	Czech Republic since June 2011 (and upper Elbe River basin	Daněk *et al.*, 2012:	Severe OS: idem (goldfish)
SVCV: Spring viraemia of carp Virus (probably) (N)	Central and Western Europe, not in UK/Scandinavia	OIE, 2012	Severe OS: idem (cyprinid species)

11.1.4 Distribution

The natural distribution of Prussian carp is difficult to define because it has been transported throughout Europe and Asia for many centuries and confused with the gold fish (*Carassius auratus*) until recent years (Szczerbowski, 2001; Kottelat & Freyhof, 2007; Kalous & Knytl, 2011; FAO, 2013). The current recorded distribution of Prussian carp covers Europe extending toward Siberia and Eastern Asia, but it is still absent from the northern Baltic basin, Iceland, Ireland, Scotland and the Mediterranean islands (Kottelat & Freyhof, 2007; Maes *et al.*, 2007).

The Prussian carp is an exotic species in Western Europe which has become established in France, the UK, Germany, Denmark, Belgium and the Netherlands (FAO, 2013). In the Netherlands, Prussian carp was probably introduced centuries ago and it was not recognized as a distinct species, hence it has been treated as a single species with the crucian carp and wild goldfish (Redeke, 1941). Nijssen & de Groot (1987) suggest that the Prussian carp was introduced in the 19th century after the previously introduced goldfish.

In 2013, the distribution of the Prussian carp is widespread and completely covers the Netherlands including two Wadden islands (figure 11.2). There are surprisingly many recent observations in new, previously uncolonised areas (2000 to 2013). It is unknown if this increase is due to better knowledge and correct identification of the species or actual expansion of the species distribution.

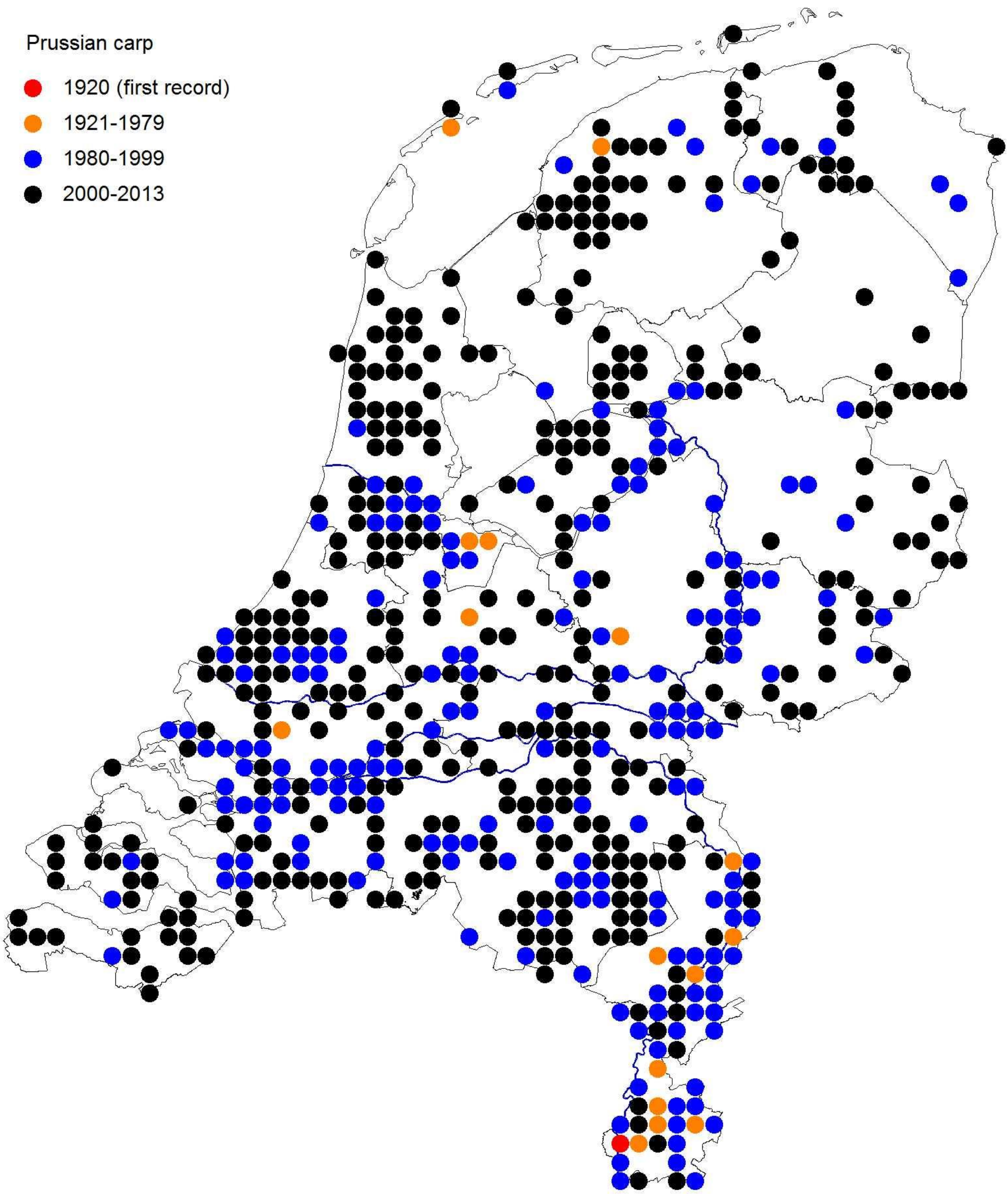

Figure 11.2: Prussian carp (Carassius gibelio) distribution history in the Netherlands from 1920 to 2013 (older records are plotted on top of more recent records) (RAVON/NDFF data).

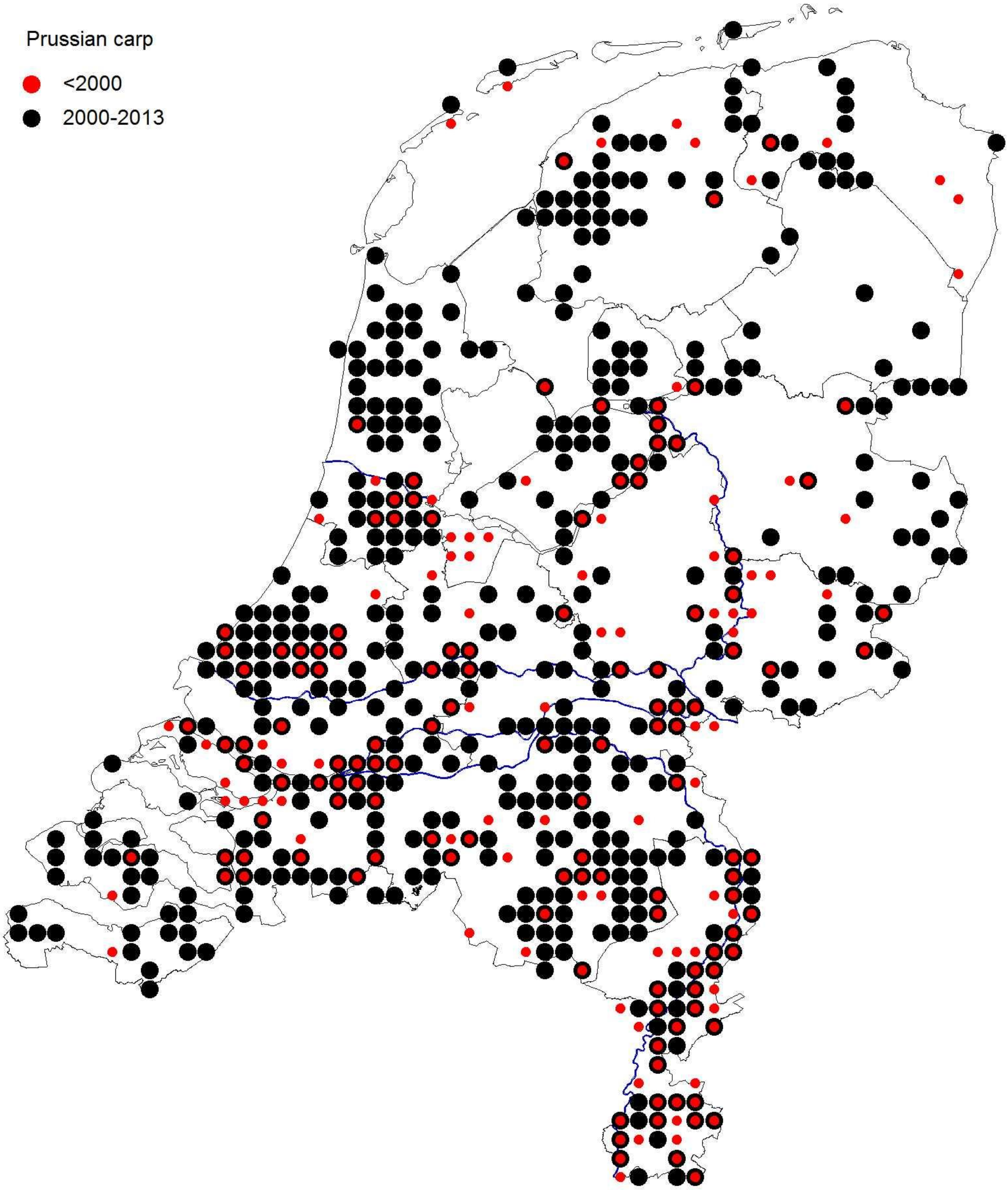

Figure 11.3: Prussian carp (Carassius gibelio) distribution in the Netherlands before and after 2000 (combined black and red dots indicate presence in both periods) (RAVON/NDFF data).

11.2 Risk assessment

11.2.1 Probability of entry

Pathways of introduction

The pathway leading to the first introduction of the Prussian carp to the Netherlands is unclear. It was probably shipped and stocked together with common carp. The initial introduction of

Prussian carp to Belgium was described as 'Unintentional' (Verreycken, 2007), probably occurring in the 17th century.

Prussian carp are sometimes used as baitfish (Kalous & Knytl, 2011). Therefore, the species could have been transported and released by anglers.

Like many other species (e.g. Gobiidae) Prussian carp can reach the Rhine river through the Main-Danube Canal that connects the Danube drainage basin to the Rhine drainage basin (Leuven *et al.*, 2009). However, it is cannot be concluded with certainty that the Prussian carp uses this pathway, because the species was present before the canals opening in 1992.

Pathways of future introduction
The Prussian carp is listed in the Dutch Fisheries Act. Therefore, the transport and introduction of this species to the Netherlands can occur legally. Stocking materials can be obtained from different areas (also other countries) and can be transported to many different water bodies where fishing rights apply.

It is very likely that Prussian carp will be transported and stocked as an unwanted species in the future for two reasons; 1) the species is often misidentified with the juveniles of the common carp, a commonly stocked species, 2) it can easily blend in with a batch of other cyprinid species when present in rearing ponds.

Live bait fishing can be a vector for the transport of exotic fish species. Live bait fishing is forbidden in the Netherlands, but it still occurs. Surplus live baitfish are likely to be disposed of in waters outside the actual distribution range of the fish.

11.2.2 Probability of establishment

Habitat suitability
Prussian carp are most abundant in well vegetated stagnant waters and the floodplains of rivers (Szczerbowski, 2001; Kottelat & Freyhof, 2007). Across the Netherlands many natural and artificial habitats will allow the completion of the Prussian carp life cycle.

Propagule pressure
Initially, only one triploid female is needed in the presence of other cyprinids to establish a sustainable population of Prussian carp. Using multiple reproduction modes, including gynogenetic reproduction, Prussian carp can produce either clonal or mixed gene offspring (Maes *et al.*, 2007).

Population development
As shown in figure 11.1, the Prussian carp population is still developing. The species may be abundant in ponds, ditches and slow flowing waters.

Potential distribution range
The potential distribution of Prussian carp stretches to virtually all stagnant and slow flowing fresh to light brackish waters in the Netherlands. The potential of (further) establishment is therefore high.

11.2.3 Probability of spread

Species features that encourage spread

The Prussian carp is a very tolerant species with a high fecundity. The species is considered non-migratory (Szczerbowski, 2001), but occurs incidentally in fish migration surveys (e.g. Buysse *et al.*, 2003; Hladik & Kubecka, 2003). Therefore, Prussian carp dispersal capacity can be regarded as relatively high.

Spread in climatically similar countries

Prussian carp dispersal has been observed in both Germany and Belgium. In both countries the species dispersed initially by introduction and then naturally (Anonymous b). In Belgium, Prussian carp is currently one of the most abundant fish species in both stagnant and slow flowing waters (Buysse *et al.*, 2003; Verreycken, 2007). Here, the species is still spreading, but the population density seems to be declining (Maes *et al.*, 2007).

Potential spread in Netherlands

The potential for further spreading in the Netherlands is high. Aided by stocking, natural dispersal and migration corridors, Prussian carp could easily spread to numerous water bodies throughout the entire country.

11.2.4 Vulnerable areas

Prussian carp have often been recorded in areas protected under Natura 2000 (appendix 1). The preferred habitat for Prussian carp overlaps with that of a number of threatened and protected species, e.g. wheather loach (*Misgurnus fossilis*), spined loach (*Cobitis taenia*), crucian carp (*Carassius carassius*) and bitterling (*Rhodeus amarus*). These species live in well vegetated littoral zones and vegetated isolated waters in the Dutch river system. These habitats are of high ecological value and sometimes protected under the European Habitats Directive. Therefore, vulnerable areas not yet occupied by Prussian carp may still be colonised by this species through active stocking or natural dispersal.

11.2.5 Negative impact of introduction

Ecological impact

In Eastern and South-eastern Europe, the occurrence of the Prussian carp has been linked to a decline in native species and habitat degradation (e.g. Lusková *et al.*, 2010; Aydin *et al.*, 2011; Tarkan *et al.*, 2012). Habitat degradation results from the significant positive effect of Prussian carp density on the total phosphorus concentration that occurred for example in Turkey (Tarkan *et al.*, 2012). Prussian carp negatively affect native species through the following mechanisms: interference in reproduction, hybridization, competition for food and habitat (Paschos *et al.*, 2004; Lusková *et al.*, 2010; Lenhardt *et al.*, 2011; Perdikaris *et al.*, 2012).

In Turkey, several endemic fish populations have shown a serious decline (Tarkan *et al.*, 2012). Lusková *et al.* (2010) describe numerous populations of Prussian carp in the Czech Republic that have totally eliminated the previously dominant indigenous tench (*Tinca tinca*) and crucian carp from alluvial habitats such as pools, oxbows, and woodland lakes. Hybridization and introgression (fertile hybrids and back-crossing) of Prussian carp with crucian carp is a serious threat throughout Europe (Hänfling *et al.*, 2005; Lusková *et al.*, 2010; Wouters *et al.*, 2012; Knytl *et al.*, 2013). The crucian carp is a threatened (Red List) native species in the Netherlands.

The parasites and bacteria of the Prussian carp do not form a specific threat to Dutch native species. However, the virus CyHV-2 (Jung & Miyazaki, 1995) that is carried by this species causes considerable mortalities in Prussian carp in the Czech Republic and in China (Daněk *et al.*, 2012; Xu *et al.*, 2013) and in goldfish (*Carassius auratus*) (Hedrick *et al.*, 2006). Other cyprinids, such as the common carp, appear to be resistant to the virus so far (Hedrick *et al.*, 2006). It is, however, unknown if the virus will affect the crucian carp, a Red listed species closely related to the Prussian carp.

Economic impact

Economic losses in fisheries and aquaculture resulting from Prussian carp invasion have been reported in Greece, Turkey, Hungary and the Czech republic (Bársony & Szûcs, 2006; Lusková *et al.*, 2010; Aydin *et al.*, 2011; Perdikaris *et al.*, 2012; CAB International, 2012). In other countries, the economic impact of the Prussian carp has not been estimated (e.g. Vetemaa *et al.*, 2005).

The European Water Framework Directive (WFD) sets ecological goals for surface water bodies. In the Dutch WFD policy goals, one criterion is related to fish stock assemblages in natural and manmade waters. If the goals of the WFD are not met before 2027, penalties from the European Union will apply. The Prussian carp is one of a number of species used to calculate fish stock assemblage scores for both natural and artificial waters. The Prussian carp is classified as a phytofile species in the calculation for freshwater lakes and artificial waters and as a eurytopic species for the calculation relating to other natural waters. For freshwater lakes and artificial waters, Prussian carp occurrence will have a positive effect on the score, as a higher number of phytofile species results in a higher score. For other natural waters the species will have a negative effect, as a higher biomass fraction of eurytopic fish negatively influences the score. Furthermore, Prussian carp may positively influence the total phosphorus concentration of the water (Tarkan *et al.*, 2012) and a higher phosphorus concentration results in a lower score for this water quality parameter. Overall, Prussian carp will most likely reach their highest level of abundance in artificial habitats and could even have a slightly positive effect on WFD scores in the Netherlands. Therefore, the effects of negative economic impacts can be regarded as negligible.

Social impact

There is no available literature describing the negative social impact of Prussian carp in the Netherlands or elsewhere and a negative impact is not expected.

11.2.6 Positive impact of introduction

Ecological impact

There is no available literature describing the positive ecological impact of Prussian carp in the Netherlands or elsewhere and a positive impact is not expected.

Economic impact

Carassius spp. are of economic importance to aquaculture in Asia and a few Eastern European countries (e.g. Szczerbowski, 2001; Lenhardt *et al.*, 2011). Prussian carp have very limited market value in Central and Western Europe (Lusková *et al.*, 2010), but could be used as animal food (Perdikaris *et al.*, 2012). In the Netherlands, positive economic impacts are probably negligible.

Social impact

The Prussian carp is a target species for some recreational anglers (Stoop, 2010), but is not considered one of the most important fished species (Smit *et al.*, 2004).

11.3 Risk classification

11.3.1 Available risk classifications

Table 11.3: Overview of risk classifications previously performed for Prussian carp (Carassius gibelio).

	Belgium	Belgium	Montenegro, Serbia, Macedonia	United States	United Kingdom
Scope	Risk assessment	Risk assessment	Risk assessment	Risk assessment	Risk assessment
Method	FISK	ISEIA	FISK	Ecological Risk Screening Summary	FISK
Risk classification	High	12/12 (High)	Very high	High	High
Source	Verreycken *et al.* (2009)	http://ias.biodiversity.be/species/show/2	Simonovic *et al.* (2013)	http://www.fws.gov/injuriouswildlife/pdf_files/Carassius_gibelio_WEB_8-14-2012.pdf	Copp *et al.* (2009)
Additional information		Classified as an A3 species (widespread in Belgium featuring a high environmental hazard)	Classified as invasive		≥19 = High risk

Rationale for risk classification

Verreycken *et al.* (2009) do not give a specific rationale for the high risk FISK score awarded to the Prussian carp in Belgium. However, they do state that Prussian carp is one of the most widespread of the non-indigenous species in Flemish waters, and continues to expand its range.

The Prussian carp is widespread in Belgium, reproducing in the wild, featuring a high dispersal potential and its ability in colonizing natural habitats is high. Anseeuw *et al.* (2007) judge Prussian carp as a prolific species which is believed to be responsible for the decline of native fish, invertebrate and plant populations in different areas of Belgium. Furthermore, it is notorious for increasing water turbidity because of its habit of stirring up bottom sediments during feeding. Prussian carp has the potential to hybridise with other *Carassius* species and *Cyprinus carpio*. Impacts on food webs were judged to be high. The Prussian carp was judged to impact highly on habitats leading to a high score for physical alteration. Impacts on nutrient cycling were judged to be medium and impacts on natural succession were judged to be low. Impacts on native species due to predation and herbivory and the potential of disease transmission from Prussian carp were judged to be low. However, the risks associated with competition with native species and genetic effects were assessed as high.

Simonovic *et al.* (2013) gives an overview of FISK scores for multiple fish species but gives no rationale for the allocation of risk classifications.

The high risk result obtained from the assessment of risk in the United States was based on historical invasiveness and a favourable climate match. Prussian carp are responsible for the decline of some native cyprinid species, alteration of local habitats, and the species quickly establishes itself in new habitats as the result of a high reproductive rate. Its ability to reproduce via gynogenesis increases the risk of rapid population development and rapid spread. Individual high risk scores were allocated to the habitat degradation category due to increased turbidity, food web disruption and damage to native fish stocks due to competition with native fish species.

Copp *et al.* (2009) gives an overview of FISK scores for multiple fish species but gives no rationale for the allocation of risk classifications.

11.3.2 Current situation

Expert consensus scores
The total risk score attributed to the Prussian carp was 11 out of a maximum risk score of 12 (table 11.4). This results in an overall classification of high risk for this species.

Table 11.4: Consensus scores and risk classifications for Prussian carp (Carassius gibelio) in the current situation in the Netherlands.

ISEIA sections	Risk classification	Consensus score
Dispersion potential or invasiveness	high	3
Colonization of high value conservation habitats	high	3
Adverse impacts on native species	high	3
Alteration of ecosystem functions	likely	2
Global environmental risk	A - list category	11

Dispersion potential or invasiveness
The Prussian carp is characterised by a high dispersal potential and high fecundity in the Netherlands. A female can produce 100,000 to 860,000 eggs (Szczerbowski, 2001). It is also evident from historical records that Prussian carp are able to disperse rapidly in the Dutch freshwater system and there are surprisingly many new records in the 2000 to 2013 period. Nijssen & de Groot (1987) suggest that the Prussian carp was introduced in the 19th century; today it is widely distributed in the Netherlands including two Wadden islands. It was concluded that Prussian carp have a high dispersal and invasiveness potential in the Netherlands.

Colonisation of high conservation value habitats
The Prussian carp has been able to colonise high conservation habitats in the Netherlands such as the major rivers, floodplains and many stream systems, a number of which are protected under the European Habitats Directive. 44% of prussian carp distribution occurs in areas designated under Natura 2000 in the Netherlands (appendix 1). However, the species is likely to appear in low densities and does not usually dominate in these habitats. It was concluded that Prussian carp pose a high risk to high conservation value habitats in the Netherlands.

Adverse impacts on native species
There is no literature based evidence that suggests that Prussian carp exert adverse impacts on native species in the Netherlands. The preferred habitat for Prussian carp overlaps with that of a number of threatened and protected species in the Netherlands (European weatherfish, spined

loach, crucian carp and bitterling). Evidence from abroad indicates that Prussian carp negatively affect native species as a result of interference in reproduction, hybridisation and competition for food and habitat (Paschos *et al.,* 2004; Lusková *et al.,* 2010; Lenhardt *et al.,* 2011; Perdikaris *et al.,* 2012). Lusková *et al.* (2010) describe numerous examples where Prussian carp have totally eliminated the previously dominant indigenous species tench and crucian carp from alluvial habitats such as pools, oxbows, and woodland lakes in the Czech Republic. Both these species are indigenous to the Netherlands and the Netherlands and Czech Republic share a similar climate. It was concluded that the Prussian carp poses a high risk to native species in the Netherlands in relation to the negative impacts relating to herbivory, predation and interference and exploitation competition.

Hybridisation and introgression (fertile hybrids and back-crossing) of Prussian carp with crucian carp is thought to pose a serious threat in countries with similar climatic conditions to the Netherlands such as the United Kingdom (Hänfling *et al.,* 2005; Lusková *et al.,* 2010; Wouters *et al.,* 2012; Knytl *et al.,* 2013). The crucian carp is a native and threatened species in the Netherlands (Dutch Red List). However, in Belgium and on the European continent, the occurrence of hybrids of Prussian carp with crucian carp is rare. This is because of the low co-occurrence of diploid sexually reproducing Prussian carp and crucian carp in the same population. Genetic evidence suggests that the Prussian carp differs in origin from the wild goldfish (*Carassius auratus*) which hybridises with crucian carp in the United Kingdom (Hänfling *et al.,* 2005; Maes *et al.,* 2007). It was concluded that Prussian carp pose a medium risk to Dutch native species because of hybridisation and introgression with native species.

The Prussian carp carries many diseases and parasites, but these overlap strongly with those of common carp. No direct link has been established between these parasites and diseases and an increased risk to Dutch native species in literature. It was concluded using expert judgement, that the parasites and diseases of Prussian carp are likely to negatively impact native species in the Netherlands.

Overall it was concluded that Prussian carp pose a high risk to native species in the Netherlands based on the subcategories predation and herbivory, interference and exploitation competition.

Alteration of ecosystem functions

There is no literature based evidence that suggests that Prussian carp alter ecosystem functioning in the Netherlands. Evidence from observations in the Netherlands is circumstantial. In East and South-eastern Europe, occurrence of the Prussian carp has been linked to declines in native species and habitat degradation (e.g. Lusková *et al.,* 2010; Aydin *et al.,* 2011; Tarkan *et al.,* 2012). Tarkan *et al.* (2012) and Paulovits *et al.* (1998) stated that an increase in Prussian carp density contributed significantly to total phosphorus increase in Turkey, a country with a different climate to the Netherlands. Information is contradictory, but based on the Turkish evidence it was concluded by expert judgement that it is likely that the Prussian carp modifies nutrient cycling and resource pools in a similar way in our climatic region. However, the lack of evidence for the potential of the Prussian carp to cause physical modifications of habitats, modifications of natural succession and disruptions of food webs resulted in expert judgement being applied. It was concluded that it is unlikely that the Prussian carp would negatively affect these subcategories.

Overall, it was concluded that Prussian carp likely alter ecosystem functions in the Netherlands based on the species effect on nutrient cycling in Turkey.

Species classification

The species classification corresponds to the global environmental risk score of the ISEIA (table 11.4) combined with the current distribution of the non-native species within the country in question. The species classification for the Prussian carp is A3 (Figure 11.4). This indicates a non-native species that is widespread, is characterised by a high environmental hazard (i.e. ecological risk) that should be placed on the black list of the BFIS list system (i.e. ecological risk: ISEIA score 11: A category).

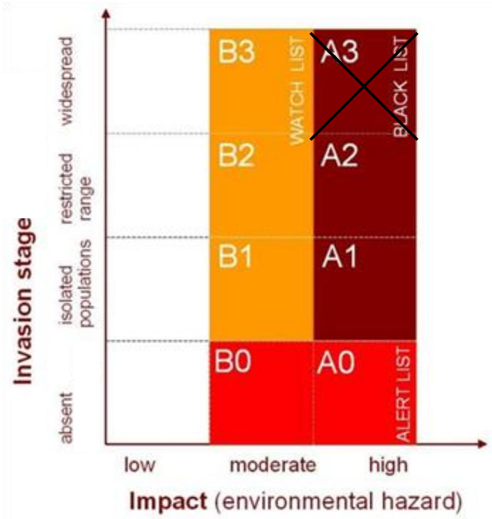

Figure 11.4: Prussian carp (Carassius gibelio) classification according to the BFIS list system.

11.3.3 future situation

The temperature tolerance of Prussian carp is 0 to 41°C (Van Beek, 2000). Spawning of Prussian carp occurs from the end of May until the end of July at water temperatures of 14 to 25°C (Szczerbowski, 2001; Kottelat & Freyhof, 2007). The temperature of many water-bodies in the Netherlands lies within these ranges at these times and predicted increases in temperature related to climate change are expected to have no effect on this species. Prussian carp are currently widespread in the Netherlands. Risk assessment scores and the distribution of the Prussian carp are expected to remain the same if only temperature is considered (table 11.5). Therefore, in this scenario the A3 classification under the BFIS list system will remain the same. Future improvements in water quality may have a positive influence on this species.

Table 11.5: Prussian carp (Carassius gibelio) theoretical classification according to a potential future habitat scenario.

ISEIA sections	Risk classification	Consensus score
Dispersion potential or invasiveness	high	3
Colonization of high value conservation habitats	high	3
Adverse impacts on native species	high	3
Alteration of ecosystem functions	likely	2
Global environmental risk	A - list category	11

11.4 Risk management

11.4.1 Prevention of introduction

The Prussian carp is distributed widely in the Netherlands. Natural dispersion through fish migration corridors and hydrological connections of water ways is virtually impossible to prevent. Nevertheless, spread to new water bodies and river systems, isolated from the current Prussian carp distribution range, can be prevented. It is currently lawful for fishing right owners to stock Prussian carp in water bodies where no Prussian carp are initially present. Therefore, restrictions could be put in place that prevent the further spread of Prussian carp to isolated water systems.

11.4.2 Elimination of populations

The current population of Prussian carp in the Netherlands is widespread. Only populations in relatively small isolated waters may be eliminated cost efficiently. Internationally, there is no available information that describe methods for the complete elimination of Prussian carp populations. General options for the elimination of exotic fish species can be found in Appendix 4.

11.4.3 Management of populations

Complete eradication is a management strategy that is only feasible when the rate of fish removal exceeds the rate of recruitment, there is a low probability of reinvasion, all individuals can be targeted in a population and the strategy is supported by society and politics (Chadderton, 2003). If not all individuals are removed, management efforts can have an adverse impact. Therefore, eradication is not a feasible measure for the management of the Prussian carp population as it features a high reproduction capacity and is widespread in the Netherlands.

In some cases the invasion success of exotic species might be reversed by altering or rehabilitating the water system (Van Kessel *et al.*, 2013). Ideally, completion of the exotic species life cycle is prevented and completion of the native species lifecycle is enhanced. However, in literature no measures to reverse Prussian carp invasion success were found.

Maes *et al.* (2007) suggested that the introduction of native predators, e.g. pike (*Esox lucius*), could help reduce the Prussian carp population. For example, in the Netherlands 800 pike were introduced in moorland pools in an effort to reduce the numbers of pumpkinseed (*Lepomis gibbosus*) present (Nijssen & Van Kleef, 2013).

12. RAINBOW TROUT (*Oncorhynchus mykiss*)

The information presented in this chapter is derived from the results of a literature and database quick scan and serves as input for impact scoring using the ISEIA risk protocol. More information about the rainbow trout is addressed by Soes & Broeckx (2010); "A risk analysis of exotic trout in the Netherlands".

Figure 12.1: Rainbow trout (Oncorhynchus mykiss) from Slovenia (length 35cm) (blikonderwater.nl)

12.1 Distribution in the Netherlands

The rainbow trout (*Oncorhynchus mykiss*) is widely distributed in the Netherlands (figure 12.2). However, numbers are low and individuals are normally observed alone (Soes & Broeckx, 2010). Most records originate from before the year 2000. It is probable that all records are the result of deliberate or accidental release or escapes from fish farms. The species is present in a variety of habitats, including high conservation value habitats (Natura2000). Examples of these are the river Geul and Roer in the Province of Limburg (the Netherlands).

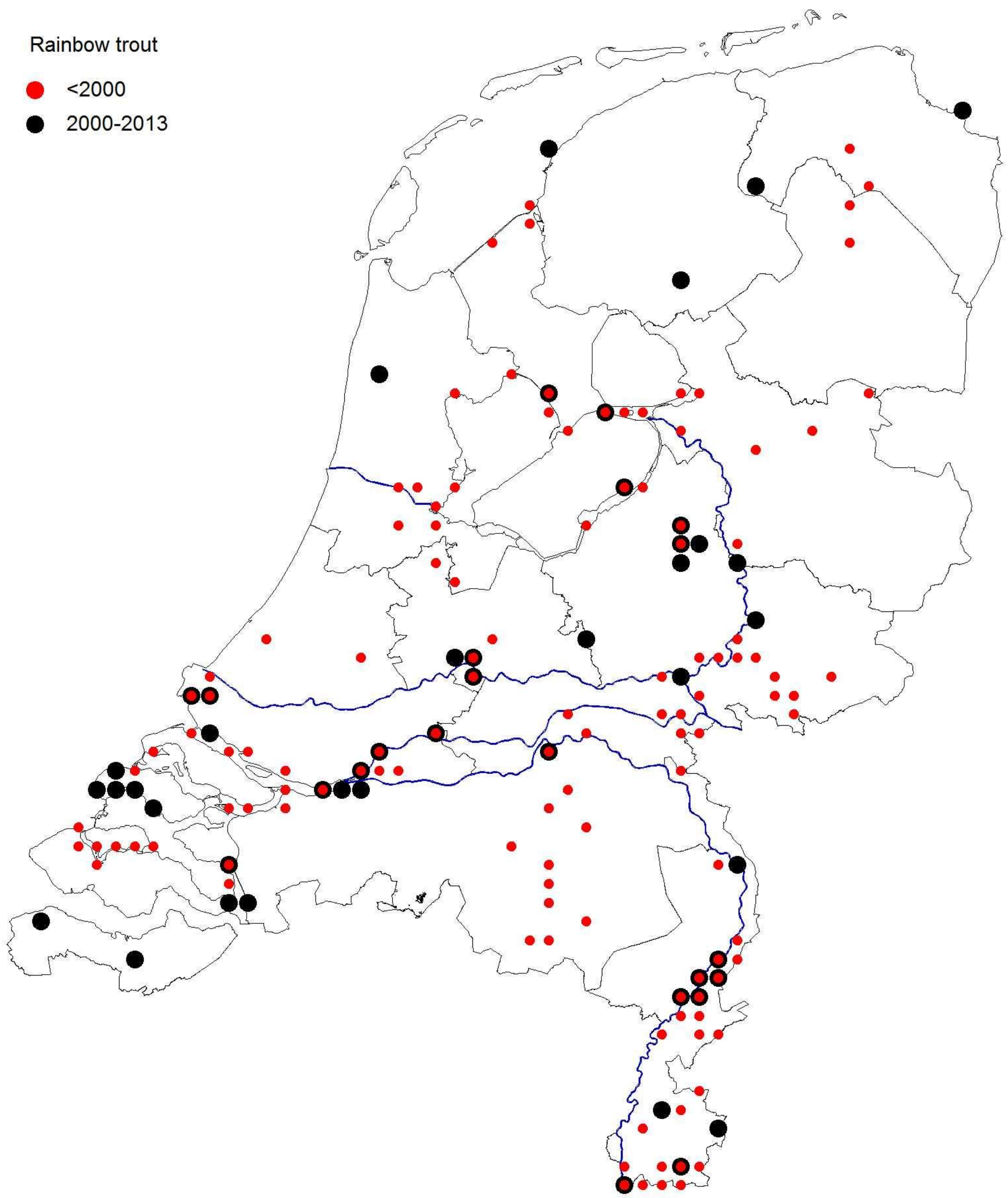

Figure 12.2: Geographical distribution of rainbow trout (Oncorhynchus mykiss) before and after 2000 (combined black and red dots indicate presence in both periods) in the Netherlands.

12.2 Potential spread in the Netherlands

The rainbow trout is a species with a high dispersal capacity (Raleigh, 1984). Populations of successfully spawning rainbow trout are not recorded in the Netherlands, possibly because large gravel beds that form suitable spawning sites are very rare (Schouten, 1995 cited in: Soes & Broeckx, 2010) and only available in a few streams in the Province of Limburg. However, rainbow trout strains are vulnerable to predation and these few streams are unlikely to be suitable for the establishment of populations (Soes & Broeckx, 2010). The species is recorded in various special areas of conservation listed under the Habitats Directive, in isolated as well as non-isolated areas, such as the Biesbosch, Haringvliet, Zwarte meer, Leenderbos, Groote Heide & De Plateaux and Kampina & Oisterwijkse Vennen. The removal of fish migratory barriers in the Netherlands will favour the spread of rainbow trout, as will the intentional release of rainbow trout. To date, successful reproduction has not been recorded in the wild in the Netherlands and therefore it is not likely that the species will become invasive here.

12.3 Ecological impact

As the species is not likely to reproduce in the Netherlands, the impact of rainbow trout on native species depends on the introduction frequency and density. A high introduction rate may cause irreversible negative impacts.

Predation
Non-native salmonids may impact negatively on native fish species (Korsu *et al.*, 2010; Morita *et al.*, 2004). Non-native rainbow trout effect the density of native fish species adversely through predation (Arismendi *et al.*, 2009). Moreover, when high densities of native fishes are present, the rainbow trout becomes more piscivorous (Arismendi *et al.*, 2012). Introduced trout can also impact severely on populations of montane amphibians, such as the mountain yellow-legged frog (*Rana muscosa*) in southern California, USA (Vredeburg, 2004).
Salmonids may cause a shift in the aquatic invertebrate community from larger active species to smaller inconspicuous species (Simon & Townsend, 2003; Dunham *et al.*, 2004; Molineri, 2008). However, the findings of Wissinger *et al.* (2008) contrast with the findings from North America and Europe. In their study, no declines in the abundance of benthic invertebrates were recorded.

Competition
The rainbow trout is a strong competitor for habitat. In the presence of this species, native fish species occupy less favoured habitats (Morita *et al.*, 2004) or narrow their range of mesohabitat use (Penaluna *et al.*, 2009). Baxter *et al.* (2007) showed that native Dolly Varden char biomass decreased by more than 75% as a result of the monopolization of terrestrial prey by rainbow trout.
Rainbow trout have a potential negative impact on native fish species through redd superimposition and disturbance (Taniguchi *et al.*, 2000; Nomoto *et al.*, 2010).

Disease transmission
Rainbow trout may be affected by a variety of sublethal and lethal diseases and parasites (Soes & Broeckx, 2010). These diseases and parasites may pose a serious threat to native fish species. For instance, bacterial kidney disease can be transmitted between wild brook trout and stocked brown trout and rainbow trout (Mitchum & Sherman, 2011). *Myxosoma cerebralis* can be transmitted from the rainbow trout by birds causing whirling disease in previously uncontaminated water bodies (Taylor & Lott, 2007). However, no data on the extent of these effects exist and no data are present specifically for the Netherlands.

Hybridization

Rainbow trout is not known to hybridize with any species native to Europe (Soes & Broeckx, 2010). Under controlled conditions, a hybrid between black sea trout (*Salmo labrax*) and rainbow trout was bred (Akhan *et al.*, 2011).

12.4 Risk classification

12.4.1 Available risk classifications

Table 12.1: Overview of risk classifications previously performed for the rainbow trout (Oncorhynchus mykiss).

	Germany, Austria	Norway	Montenegro, Bulgaria, Macedonia, Serbia	United Kingdom	South Africa
Scope	Risk assessment	Risk assessment	Risk assessment	Risk assessment	Informal risk assessment
Method	The German-Austrian Black List Information System (GABLIS)	2012 Norwegian Black List	FISK	FISK	None
Risk classification	Black list (management list)	Severe impact (Black list)	Moderately high	25 (high risk)	High invasive capacity and impacts related to predation on and competition with native fish species
Source	Nehring *et al.* (2010)	Gederaas *et al.* (2012)	Simonovic *et al.* (2013)	Copp *et al.* (2005)	http://www.nda.agric.za/doaDev/fisheries/03_areasofwork/Aquaculture/BIODIVERSITY/O%20%20mykiss%20final%20BRBA.pdf
Additional information	The Species requires management to reduce ecological impacts	Severe impact species are actually or potentially ecologically harmful and may become established across large areas. These species are included in the Black List.	Classified as invasive	Any positive score was considered high risk	

Rationale for risk classification

Nehring *et al.* (2010) state that the rainbow trout impacts the brown trout (*Salmo trutta*) through competition for habitat and food sources (Germany: Leuner *et al.*, 2000; Austria: Honsig-Erlenburg, 2005). It does not form a threat to native German or Austrian species due to parasites or diseases and there is an absence of knowledge on other ecosystem effects. The rainbow trout is a vector for the pathogen *Myxobolus cerebralis* which effects salmonid species, but this pathogen has so far only caused minor damage in Europe (Küppers, 2003). Potential occurrence of impacts due to hybridisation with native species are unknown. However, hybridisation between German and Austrian native and introduced salmonids cannot be ruled out (Utter, 2000; Fuller, 2006; Jonsson, 2006). It is not known if rainbow trout impact on German and Austrian species due to predation and herbivory, however, impacts due to the predation of amphibians, plankton and fish fry may occur at high fish densities (Fuller, 2006; Jonsson, 2006). The rainbow trout is a widespread species in Germany and Austria and is present in valuable trout habitat (Dußling & Berg, 2001). Reproduction potential is high as the species reaches sexual maturity after only one to five years (Kottelat & Freyhof, 2007). Potential spread is classified as high, however, the current population distribution appears to be stable. The widespread distribution of rainbow trout in German waters is largely dependent on restocking by anglers and water managers that occurred in the past and continues to occur today (Dußling & Berg, 2001; Füllner *et al.*, 2005; Musseleck, 1902). Rainbow trout does not monopolise natural resources in Germany and Austria. The species does not impact on human health in Austria or Germany. There are no known negative impacts of rainbow trout on the social-economy, however rainbow trout is beneficial to fisheries and recreational fishing (BMELV, 2006). It is unknown if climate change will have an effect on this species.

Gederaas *et al.* (2012) categorised rainbow trout as a severe impact species. The severe impact rating originated from risks associated with 'spread velocity' and 'impacts on other (native) species' which were rated as three out of a possible four and 'host of parasites or pathogens' which was rated four out of a possible four on the Norwegian risk scale. Rainbow trout can transmit the parasite *Gyrodactylus salaris* to the Atlantic salmon (*Salmo salar*), a Norwegian native species and an occasional visitor to Dutch waters (Gederaas *et al.*, 2012; Naturalis Biodiversity Center, 2013).

Simonovic *et al.* (2013) gives an overview of FISK scores for multiple fish species for Montenegro, Bulgaria, Macedonia and Serbia but gives no rationale for the allocation of risk classifications.

Copp *et al.* (2005) gives an overview of FISK scores for fish species of the United Kingdom, but gives no rationale for the allocation of risk classifications.
The conclusions from the South African risk analysis of rainbow trout were made using the following rationale. There will be escapees from any established South African culture facility unless best management practises are followed. Unless barriers are provided and the environment is unsuitable, rainbow trout will rapidly colonise and establish in any previously un-invaded river catchments where it is introduced. Introduced rainbow trout will compete with and/or predate on indigenous species in the area and will pose a risk to the continued survival of native fish species, especially those that are already range rare or range restricted. No hybridisation will occur with indigenous species. No diseases or parasites will be introduced.

12.4.2 Current situation

Expert consensus scores
The total risk score attributed to the rainbow trout was 10 out of a maximum risk score of 12 (table 12.1). This results in an overall classification of moderate risk for this species.

Table 12.1: Consensus scores and risk classifications for rainbow trout (Oncorhynchus mykiss) in the current situation in the Netherlands.

ISEIA sections	Risk classification	Consensus score
Dispersion potential or invasiveness	medium	2
Colonization of high value conservation habitats	high	3
Adverse impacts on native species	high	3
Alteration of ecosystem functions	likely	2
Global environmental risk	B - list category	10

Dispersion potential or invasiveness

The rainbow trout is widely spread in the Netherlands probably resulting from accidental and deliberate releases from fish farms. However, no records exist of the rainbow trout reproducing in the Netherlands. The cause of this has been attributed to the lack of potential breeding habitat. Spawning sites in the form of large gravel beds, are very rare in the Netherlands (Schouten, 1995 cited in: Soes & Broeckx, 2010) and only available in a few streams in the Province of Limburg. These few streams are unlikely to be suitable for the establishment of the fish as the rainbow trout is vulnerable to predation (Soes & Broeckx, 2010). The rainbow trout displays, however, a high dispersal capacity (Raleigh, 1984). It was concluded that rainbow trout have a medium dispersal and invasiveness potential in the Netherlands.

Colonisation of high conservation value habitats

The rainbow trout is present in high conservation value habitats in the Netherlands, such as the Natura 2000 river Geul and Roer stream systems in the Province of Limburg. 68% of rainbow trout distribution occurs in areas designated under Natura 2000 in the Netherlands (appendix 1). They often colonise high conservation value habitats and therefore pose a potential threat to red-listed species. It was concluded that the rainbow trout impacts highly on high conservation value habitats in the Netherlands.

Adverse impacts on native species

There is no information available describing the impact of rainbow trout on native species in the Netherlands. However, evidence from similar countries shows that the rainbow trout strongly competes with brown trout, a species native to the Netherlands. Nehring *et al.* (2010) state that the rainbow trout impacts the brown trout through competition for habitat and food sources (Germany: Leuner *et al.,* 2000; Austria: Honsig-Erlenburg, 2005). In the presence of this species, native fish species shift towards less preferred habitats (Morita *et al.,* 2004) or narrow their range of mesohabitat use (Penaluna *et al.,* 2009), both resulting in a reduction of local species richness. It was concluded that the rainbow trout has a high impact on native species in the Netherlands as a result of predation and herbivory and a medium impact on native species in the Netherlands as a result of interference and exploitation competition.

Endemic trout viruses (VHSV, IHNV, IPNV), present in Dutch fish farms where the rainbow trout is cultured, may pose a serious risk to various wild salmonid species. It is known from literature that these diseases occur in the rainbow trout of the Netherlands (O. Haenen, CVI personal observations) and in foreign countries. In the Netherlands, no cases of outbreaks of other important diseases, like Bacterial Kidney Disease, *Myxosoma cerebralis* or other viruses have been reported in wild salmonids. However no blanket monitoring for these types of fish diseases is carried out in the Netherlands and outbreaks may occur undetected (O. Haenen, CVI, personal observation). It was concluded that the rainbow trout poses a medium risk to native species in the Netherlands due to possible transmission of parasites and diseases.

The rainbow trout is not known to hybridise with any species native to Europe (Soes & Broeckx, 2010). The fish has been recorded in the Netherlands since 1941 and no hybrids with other fish species have been identified. It was concluded that rainbow trout have a low impact on native species in the Netherlands as a result of genetic effects.

Overall, it was concluded based on evidence derived from similar countries to the Netherlands that in locations where rainbow trout densities are high, a high impact on native species will occur due to impacts relating to predation.

Alteration of ecosystem functions
There is no information available describing the impact of the rainbow trout on ecosystem functioning in the Netherlands or in similar countries. Therefore a conservative judgement was made on the basis of expert judgement. The rainbow trout is a top predator and, in areas where stocking is high, negative impacts on the macroinvertebrate community are likely to occur. It was concluded that the rainbow trout would likely alter the food web in the Netherlands. It was considered unlikely that this species would negatively influence other subcategories (modification of nutrient cycling or resource pools, physical modifications of the habitat and modifications of natural succession).

Species classification
The species classification corresponds to the global environmental risk score of the ISEIA (table 12.1) combined with the current distribution of the non-native species within the country in question. The species classification for the rainbow trout is B3 (Figure 12.4). This indicates a non-native species that is widespread, displaying a moderate environmental hazard (i.e. ecological risk) that should be placed on the watch list of the BFIS list system (i.e. ecological risk: ISEIA score 10: B category).

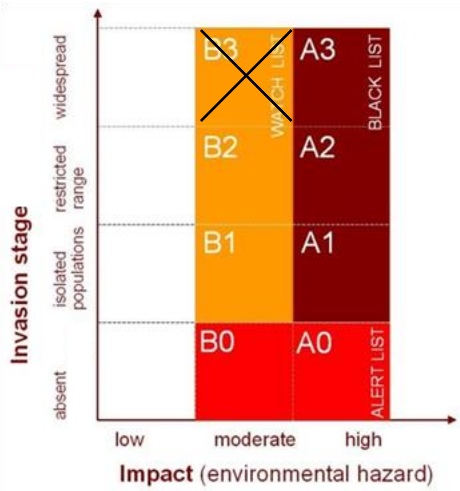

Figure 12.4: Rainbow trout (Oncorhynchus mykiss) classification according to the BFIS list system.

12.4.3 Future situation

The temperature tolerance of the rainbow trout ranges from 2 to 30°C (Raleigh, 1984; Leuven *et al.,* 2011). A predicted two degrees Celsius increase in temperature in the Netherlands is unlikely to affect the rainbow trout as it is a relatively tolerant species. Currently, reproduction is limited due to a lack of suitable spawning habitat and predation (Soes & Broeckx, 2010). If only temperature is considered, the rainbow trout will remain widely distributed at low densities in the Netherlands and risk assessment scores are expected to remain the same (table 12.2). Therefore, the B3 classification under the BFIS list system would also remain the same.

Table 12.2: Rainbow trout (Oncorhynchus mykiss) theoretical classification according to a potential future habitat scenario.

ISEIA sections	Risk classification	Consensus score
Dispersion potential or invasiveness	medium	2
Colonization of high value conservation habitats	high	3
Adverse impacts on native species	high	3
Alteration of ecosystem functions	likely	2
Global environmental risk	B - list category	10

13. SEA TROUT (*Salmo trutta trutta*)

Based on a literature research and expert consensus it was decided not to define the sea trout (*Salmo trutta trutta*) as an exotic species, but as a native species. In this chapter a general species description is presented, but a risk assessment according to the methods used for exotic species has not been undertaken.

13.1 General species description

13.1.1 Nomenclature and taxonomical status

Order	Salmoniformes
Family	Salmonidae
Genus	*Salmo*
Subspecies	*Salmo trutta trutta* Linnaeus, 1758*
Common name	Sea trout (Dutch: zeeforel)
Synonyms	Atlantic trout

* Sea trout (*Salmo trutta trutta*) is a subspecies or morph of the brown trout (*Salmo trutta*) of the family of Salmonidae, subfamily Salmoninae. Besides the anadromous seatrout (*S. trutta trutta*), other subspecies within this group are the stream-resident brow trout (*S. trutta fario*) and lacustrine brown trout (*S. trutta lacustris*). However, whether these three species are indeed subspecies, or should be considered as morphs of the same species is still debatable. In the following sections, the classification of these three subspecies is followed and sea trout is used as the common name of the anadromous brown trout.

13.1.2 Species characteristics and identification

Figure 13.1: Sea trout (Salmo trutta trutta) from Norway (length 45cm) (blikonderwater.nl).

The sea trout (figure 13.1) is characterised by an adipose fin. 14 to 17 lines of scales are situated between the adipose fin and the lateral line. The sea trout displays a large number of black spots below the lateral line. The upper jaw does extend past the rear of the eye. The tail is convex shaped and the tail base is wide.

The longevity of the sea trout increases with latitude, and is only three to five years in Britain (Klemetsen *et al.*, 2013). The size of mature individuals ranges from 29 to 67cm (Jonsson, 1985) and maximally 90cm (Van Kessel & Didderen, 2012). Adults have brown coloured backs, and are silver coloured on the abdomen. The flanks of the fish are silver in colour with brownish to blackish spots (Van Kessel & Didderen, 2012).

13.1.3 Life cycle

Habitat

The brown trout uses a huge variety of habitats, varying from very small brooks to large rivers and from small lakes to fjords, habitat suitability depends on the presence of spawning substrate, appropriate temperature, and sufficiently good water quality. The anadromous sea trout subspecies occurs in rivers and lakes that are connected to the sea. During summer, they live near shores in fjords and coastal waters, mostly within 100km of the mouth of their home river (Klemetsen *et al.*, 2003).

Small parr generally prefer shallow waters of less than 20-30cm featuring relatively high velocity (10-50cm/s). Adult brown trout prefer deeper, slow-flowing sections, especially pools. stone substrates that can be used for cover are preferred, but the species also occurs on gravel, sand, silt, and mud (Heggenes *et al.* 1999). The juveniles of brown trout are able to feed at water temperatures as low as 0°C (Bremset, 2000).

Elliott & Elliott (2010) provide an overview of critical temperatures for the survival of brown trout; the upper limit for eggs is 13°C, for alevins, parr, and smolt 30°C; the lower limit for all these life stages is approximately 0°C. Stress in parr and smolt occurs at water temperatures of about 22 to 25°C. The optimum temperature for growth lies somewhere between 11.6°C and 19.1°C (Elliott & Elliott, 2010).

Reproduction

Klemetsen *et al.* (2003) summarize the most important aspects relating to reproduction of brown trout. Spawning takes place in autumn or winter. The species spawns on stone or gravel substrates, which is subsequently used by females to cover the eggs directly after fertilization. Spawning usually occurs in running water, however, spawning in lakes has also been observed. Each female generally spawns in several nests within the same location or at several locations in a river. The spawning sites are vacated directly after spawning; no guarding of nests takes place. Fecundity increases with the size of females: anadromous females of between 100 and 500 g produce 300 to 1500 eggs per spawning cycle (Jonsson & Jonsson, 1999; Klemetsen *et al.*, 2003).
Individuals in freshwater non-migratory populations become sexually reproductive at between one and ten years old. Anadromous individuals can often reproduce after only one summer at sea; in northern parts of its range generally two to three summers are required. About 40% (southern rivers) to 70% (northern rivers) of individuals die following reproduction (Klemetsen *et al.*, 2003).

Diet

The brown trout is an opportunistic carnivore, but specialisation on individual, specific prey items may take place, at least temporarily. Insect larvae are the main food item of juveniles. Adults feed mainly on zoobenthos, fish, surface insects, and littoral epibenthos (Klemetsen *et al.*, 2003; Gergersen *et al.*, 2006). Brown trout diet is less broad than for instance the Arctic char (*Salvelinus alpinus*) (Gergersen *et al.*, 2006).

Predators

Piscivorous fish e.g. cod (*Gadus morhua*), sea birds, seals, and otters (Lyse *et al.* 1998; Dieperink *et al.* 2001; Klemetsen *et al.*, 2003) are predators of the brown trout.

Parasites and diseases

Table 13.1 gives an overview of the parasites and diseases of the brown trout *s.l.*.

Table 13.1: Parasites and diseases described in brown trout (Salmo trutta s.l.) (E = exotic for the Netherlands, N = native for the Netherlands; Effect = disease/mortality in this species, if effect on other fish species is known (OS), this is also mentioned).

Parasite/disease	Location	Reference	Effect
Trichodina, Chilodonella, Ichthyobodo, Glossatella, Ichthyophthirius multifiliis (white spot), *Dactylogyrus/Gyrodactylus* spp., a.o. (N)	Europe	Haenen, expert knowledge freshwater stage of the fish)	Low to medium OS: idem (various fish species)
Diphyllobothrium dendriticum *D. ditremum* (E?)	Scotland	Turnbull (1992)	Low to medium OS: idem (various fish species)
Proteocephalus sp. (N)	Norway	Borgstrøm & Lien (1973)	Low to medium OS: idem (various fish species)
Haemohormidium sp (N?)	Not given	Bristow& Berland(1990)	Low to medium OS?
Eubothrium crassum (N?)	Irish Sea	Fahy (1980)	Low to medium OS?
Cyathocephalus truncatus (E?)	Norway	Halvorsen, & Macdfonald (1972)	Low to medium OS?
Eubothrium salvelini *E. crassum* (N?)	Northern Norway and the Islands of Spitsbergen and Jan Mayen	Kennedy (1982)	Low to medium OS?
Gyrodactylus truttae (E?)	Norway	Mo (1987)	Low to medium OS?
Bacteria			
Aeromonas salm.salm.(furunculosis) (N) *Aeromonas salm.* atypical(carp erythrodermatitis) (N) *Vibrio* spp. (N) *Yersinia ruckeri* (enteric redmouth disease) (N) *Renibacterium salmoninarum* (Bacterial Kidney Disease, BKD) (probably N)	Scotland	Turnbull (1992)	Medium to severe OS: idem (various fish species)
Viruses			
VHS Viral Haemorrhagic Septicaemia Virus (N) IHN Infectious Haematopoietic Necrosis Virus (N) IPN (Infectious Pancreatic Necrosis)(N) PD (Pancreas Disease)(Salmon Alpha Virus SAV) (probably E, present in UK)	Europe	Turnbull (1992)	Medium to severe OS: VHSV, IHNV, PD may be severe for salmonids, IPNV medium to severe to salmonids

13.1.4 Distribution

Distribution and habitat in natural range

The sea trout is an Atlantic species that occurs in large parts of Europe (from northern Scandinavia to the Mediterranean) and Western Asia and Northern Africa (Klemetsen *et al.*, 2003). The species inhabits cold streams, rivers and lakes (Kottelat & Freyhof, 2007).

Distribution outside natural range

The sea trout has been introduced in at least 24 countries outside of Europe (Elliott, 1994, cited in Klemetsen *et al.*, 2003). Introductions started as early as 1852 in eastern Russia, followed by New Zealand (1867-1885), the USA (1883), Canada (1887), Australia (1888), South Africa (1890), Japan (1892), and South America (between 1904-1938). As a result of this, the mainly European brown trout species became a global species (Klemetsen *et al.*, 2003). It is unclear which subspecies were used in introductions as most authors consider them morphs of the same species.

Distribution in the Netherlands

The migratory sea trout can be found in larger rivers, lakes and canals that are connected with the sea (figure 13.2). The species uses the coastal waters and estuaries for foraging. The Dutch rivers are used by the species as migration routes to reach spawning grounds in fast flowing medium sized rivers in upstream locations, outside the Netherlands. Sea trout spawning has not yet been recorded in the Netherlands (Van Kessel & Kranenbarg, 2012).

The stream-resident brown trout, is native to the Netherlands. Before 1940, it occurred in streams in the provinces of Limburg, Gelderland, and Overijssel, and in the river Meuse (Redeke, 1941). Currently, most of these streams have become unsuitable for spawning because of habitat degradation. The occurrence of brown trout in most locations in the Netherlands is the result of stocking by angling organisations (Crombaghs *et al.*, 2000; Soes & Broeckx, 2010). Population densities in the Netherlands are low compared to populations in neighbouring countries (Soes & Broeckx, 2010). There are only two naturally reproducing and self-sustaining populations of brown trout left in the Netherlands, in the Selzener brook and Heelsumse brook (Van Kessel & Kranenbarg, 2012). These populations probably originate from introductions (Van Kessel & Kranenbarg, 2012).

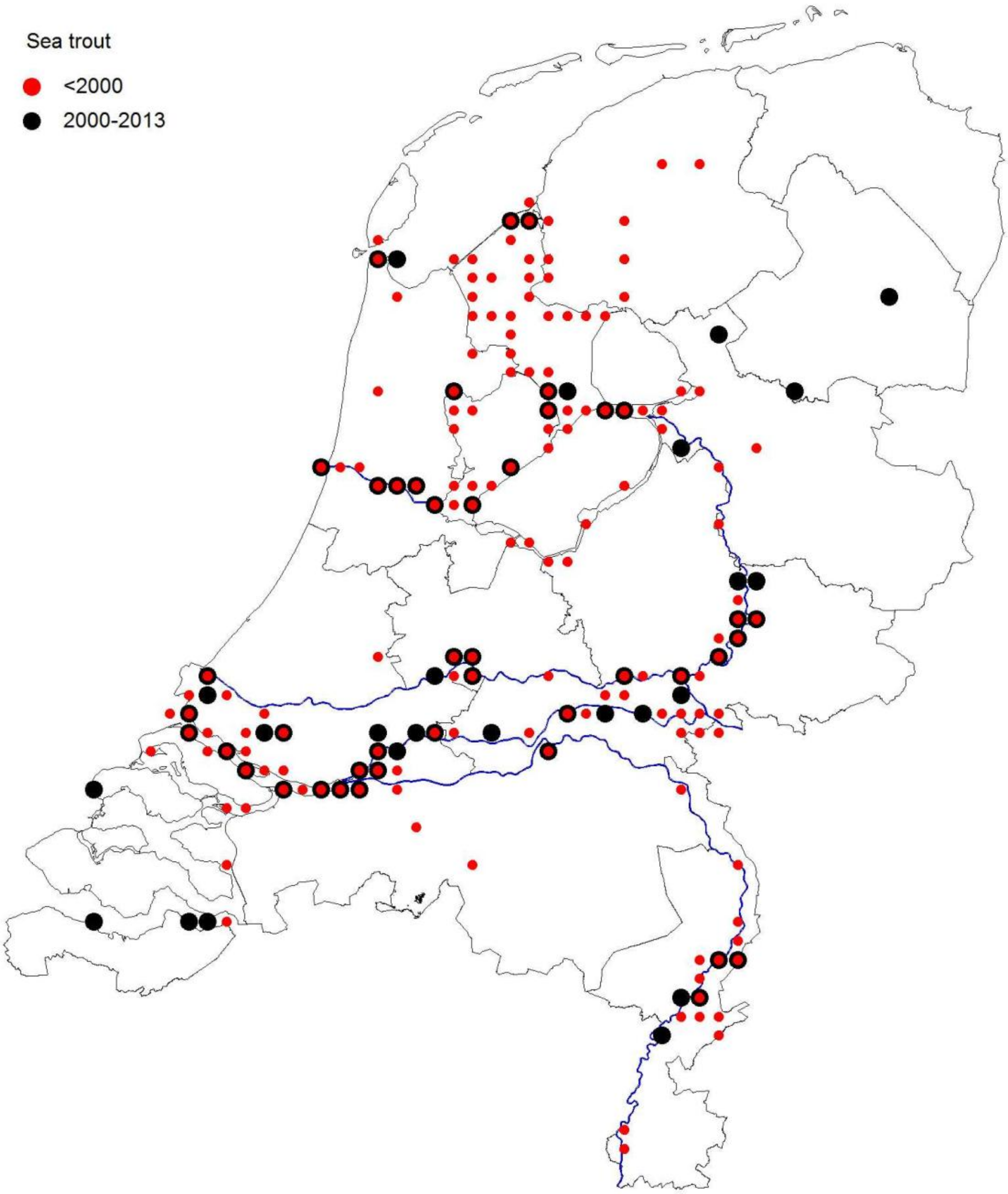

Figure 13.2: Sea trout (Salmo trutta trutta) distribution in the Netherlands before and after 2000 (combined black and red dots indicate presence in both periods) (RAVON/NDFF data).

13.2 Risk assessment

Being a migratory species native to the Netherlands, an assessment of risk that is applicable to a potentially invasive species is not suitable for the sea trout. However, stocking, re-stocking and reintroduction of sea trout could potentially pose a threat to other native species or indigenous strains of the species through, for example predation, competition, disease transmission or genetic mixing. It is therefore strongly advised that the guidelines set by the IUCN/SSC when stocking, re-stocking or reintroducing this, and other species to Dutch waters are respected (IUCN/SSC, 2013).

14. VENDACE (*Coregonus albula*)

14.1 General species description

14.1.1 Nomenclature and taxonomical status

Order	Salmoniformes
Family	Salmonidae
Genus	*Coregonus*
Species	*Coregonus albula* (Linnaeus, 1758)
Common name	Vendace (Dutch: kleine marene)
Synonyms	'Whitefish' and 'Baltic cisco'

14.1.2 Species characteristics and identification

Figure 14.1: Vendace (Coregonus albula) taken in the United Kingdom (Centre for Ecology & Hydrology, Lancaster)

The vendace is a small fish species that grows to a maximum length of 20 to 23cm. The species has a bluish green back, a white belly and silvery flanks (Kottelat & Freyhof, 2007). The vendace features grey fins which become darker towards their margins (Kottelat & Freyhof, 2007). Like all salmonidae the vendace has an adipose fin. Vendace eyes are large and their superior mouth is relatively small (Kottelat & Freyhof, 2007). The maximum lifespan of the vendace is approximately 10 years (Pauly & Froese, 2013).

14.1.3 Life cycle

Habitat

The vendace is a pelagic species that prefers clean, cold and oxygen-rich waters (Czerniejewski & Wawrzyniak, 2006). It is is most abundant in large deep lakes but also has anadromous populations and popутions living in the Baltic Sea (Czerniejewski & Wawrzyniak, 2006; Kottelat & Freyhof, 2007).

Reproduction

Spawning takes place along shores at a depth of around 3 to 10 m. In the Russian Kuybyshev Reservoir, spawning occurs in December on sandy-pebbly substrate at a depth of between 3 and 8 m (Semenov, 2011). During spawning, water temperature fluctuates between 0.5 and 2.9°C and it may take place under ice (Lesnikova, 1981; cfm Semenov, 2011). The absolute fecundity of females in the Kuybyshec Reservoir varies between 14,470 and 29,680 eggs and the diameter of eggs ranges from 1.2 to 1.3 mm. A decreased fecundity and a reduced fish size at first maturation was recorded in the invasive population of vendace in the sub-arctic Pasvik watercourse (Bøhn *et al.*, 2004).

Diet

The vendace is an obligate crustacean zooplankton feeder (Helminen *et al.*, 1990; Sandlund *et al.*, 1991; Bøhn & Amundsen, 2001; Northcote & Hammer, 2006; Scharf *et al.*, 2008). Prey selection may vary during the year (Kakareko *et al.*, 2008).

Predators

The ruffe (*Gymnocephalus cernuus*) predates on vendace eggs in the United Kingdom (Winfield *et al.*, 2004). 0+ vendace are an important dietary component of *Salmo salar* m. *sebago*, a landlocked form of Atlantic Salmon (*Salmo salar*) with a non-migratory life cycle present in Finland (Auvinen *et al.*, 2004). Smelt (*Osmerus epelanus*) have been recorded to prey on vendace larvae in Finland (Haakana *et al.*, 2009). Furthermore, in the Netherlands, pike (*Esox lucius*), perch (*Perca fluviatilis*), pike-perch (*Sander lucioperca*) and asp (*Leuciscus aspius*) are expected to be potential predators of the vendace.

Parasites and diseases

Limited literature can be found that describes the diseases of this species (table 14.1). The vendace is a salmonid, therefore some diseases occurring in other salmonids may possibly occur in this fish species.

Table 14.1: Parasites and diseases described for vendace (Coregonus albula) (E = exotic for the Netherlands, N = Native for the Netherlands; Effect = disease/mortality in this species, if effect on other fish species is known (OS), this is also mentioned)

Parasite/disease	Location	Reference	Effect
Trichodina, Chilodonella, Ichthyobodo, Glossatella, Ichthyophthirius multifiliis (white spot) Dactylogyrus/Gyrodactylus spp., a.o. (N)	Europe	Haenen, expert knowledge	Low to medium OS: idem (various fish species)
Diplostomum sp. (N) Tylodelphys clavata (E?) Proteocephalus exiguus (E?) Raphidascaris acus (E?) Ergasilus sieboldi (E?)	Poland	Kuształa *et al.* (2012)	Low to medium OS: idem (various fish species)
Bacteria			
Aeromonas salm.salm. (furunculosis (N) Aeromonas salm. atypical (carp erythrodermatitis) (N) Vibrio spp. (N) Yersinia ruckeri (enteric redmouth disease) (N) Renibacterium salmoninarum (Bacterial Kidney Disease, BKD (probably N)	Scotland	Turnbull (1992) based on probability and extrapolated from Arctic char	Medium to severe OS: idem (various fish species)
Virus			
VHSV (viral haemorrhagic septicaemia) potential carrier (N?)	Denmark	Skall *et al.* (2004)	Low for this species OS: may be severe to other salmonids

14.1.4 Distribution

Distribution and habitat in natural range

The natural distribution of the vendace includes the Baltic basin, lakes of the upper Volga drainage, some lakes of the White Sea basin and North Sea basin east of the Elbe drainage. The species is anadromous in the Gulf of Finland and marine in the northernmost freshened part of the Gulf of Bothnia (Kottelat & Freyhof, 2007). According to Elliot and Bell (2011), the species is also native to four lakes in the United Kingdom. In contrast to what is stated in Kottelat & Freyhof (2007), Soes (2009) refutes the vendace was a fish species native to the lower Rhine (Soes, 2009).

Distribution outside natural range

The vendace has frequently been introduced in lakes and reservoirs in northern and central Germany and Poland (Kottelat & Freyhof, 2007). Following introduction to Finnish headwaters in the 1950s to 1960s, the vendace invaded the Pasvik river system which borders Norway and Russia (Amundsen *et al.*, 1999). It was first recorded in the Pasvik river system in 1989 and by 1995 it had invaded the entire 120km water system.

Distribution in the Netherlands

Before 2009, vendace were thought to be native to, or at least recorded in the Netherlands. However, Soes (2009) extensively examined the Dutch vendace records and was unable to confirm them. Therefore, the vendace is unlikely to occur in the Netherlands.

14.2 Risk assessment

14.2.1 Probability of entry

Pathways of introduction
Not applicable to vendace, as it does not occur in the Netherlands. At present there are no breeding or introduction programs featuring this species and the current distribution of the fish is not situated in countries adjacent to the Netherlands.

Pathways of future introduction
The vendace is not present in the Netherlands or adjacent countries. The potential for introduction of the vendace to the Netherlands is low, but legally possible because the species is listed in the Fisheries Act.

14.2.2 Probability of establishment

Habitat suitability
The vendace prefers relatively high concentrations of oxygen and low water temperatures (Dembinsky, 1971; Hamrin, 1986, both cited in: Winfield *et al.*, 2004). The species spawns along shores and in clear lakes (Kottelat & Freyhof, 2007). Some deep lakes (sand or gravel pits) situated along the rivers Rhine and Meuse may provide suitable vendace habitat.

Propagule pressure
In the sub-arctic Pasvik watercourse, multiple vendace introductions must have contributed to the rapid genetic divergence of this species (Præbel *et al.*, 2013). In the Netherlands no introductions of vendace have been confirmed.

Population development
This section is not applicable to the vendace as the species does not occur in the Netherlands.

Potential distribution range
The potential distribution range of vendace would be confined to a very limited range which includes deep water lakes. Data on future climate change conditions suggest a mean increase of >2°C in water temperature (Elliot & Bell, 2011). Such a water temperature increase will result in a severe decrease in suitable vendace habitat suggesting that the long-term viability of present suitable lake habitats is extremely low.

14.2.3 Probability of spread

Species features that encourage spread
The vendace is an anadromous species with a high dispersal capacity (Amundsen *et al.*, 1999).

Spread in climatically similar countries
In the United Kingdom (UK) the species is native, but occurrence is limited to a low number of suitable lakes. Spread to other water bodies has not been observed in the UK. The species is relatively abundant in a large number of lake systems in north-west Poland (Czerniejewski & Wawrzyniak, 2006). Here the species' range has expanded over the last century due to active stocking (Czerniejewski & Wawrzyniak, 2006).

Potential spread in Netherlands
If introduced in the Netherlands, spreading of the species is unlikely because it is confined to a limited range of suitable habitat.

14.2.4 Vulnerable areas

Some deep lakes (sand or gravel pits) situated along the rivers Rhine and Meuse may provide suitable vendace habitat. These habitats have, however, low conservation value in the Netherlands.

14.2.5 Negative impact of introduction

Ecological impact

The vendace is considered a zooplanktivorous specialist (Helminen *et al.*, 1990; Sandlund *et al.*, 1991; Bøhn & Amundsen, 2001). The invasive population of vendace in the Pasvik watercourse has a severe impact on the zooplankton community and was also found to adapt to a broader diet niche and even turned piscivorous, most likely as a result of depletion of its preferred food source (Bøhn & Amundsen, 2001; Amundsen *et al.*, 2009; Liso *et al.*, 2011).

The use of the pelagic zone by roach is less frequent in lakes with vendace than in lakes without vendace, possibly due to competition for food resources (Beier, 2001). Moreover, the native whitefish (*C. lavaretus*) population from the Pasvik watercourse exhibited a shift from pelagic to littoral habitat and a decline in species density as a result of competition with vendace (Bøhn & Amundsen, 2004; Bøhn *et al.*, 2008). Conversely, in the UK, introduced ruffe probably contributed to the local extinction of vendace within its native range (Winfield *et al.*, 2010).

The vendace could be a carrier of the VHSV virus. VHSV (type 1) has been present in the Netherlands for decades. Literature on the impact of disease transmission by vendace is, however, scarce. The impact of the vendace by way of disease transmission is probably negligible.

Hybrids between the invasive vendace and native whitefish (*Coregonus lavaretus*) have been recorded. Theses hybrids attain sexual maturity, reproduce actively and their fecundity is high (Kahilainen *et al.*, 2011). in future, if the vendace were to occur in the Netherlands, hybridization with the native houting (*Coregonus oxyrinchus*) may also be possible.

Non-native vendace may cause severe declines in local populations of native species (> 80%), a decline of local native species richness and declines of rare species on a regional scale. The species is known to impact severely on existing food webs. Negative effects are difficult to reverse.

Economic impact
No negative economic impact caused by the introduction of the vendace has been recorded or is expected.

Social impact
No negative social impact caused by the introduction of the vendace has been recorded or is expected.

14.2.6 Positive impact of introduction

Ecological impact
No positive ecological impact caused by the introduction of vendace has been recorded or is expected.

Economic impact
The vendace is important to the commercial fisheries of Northern and Eastern Europe (Salonen, 1999; Degerman *et al.,* 2001; Salonen & Mutenia, 2004; Czerniejewski & Wawrzyniak, 2006).

Social impact
In some countries, the vendace is a commercially exploited fish species and may have a recreational value as a sport fish.

14.3 Risk classification

14.3.1 Available risk classifications

No risk assessments were found for the vendace.

14.3.2 Current situation

The status of the vendace is currently unclear. No evidence that would support a classification of the vendace as a native or non-native species in the Netherlands is available.

Expert consensus scores
The total risk score attributed to the vendace was 7 out of a maximum risk score of 12 (table 14.2). This results in an overall classification of low risk for this species.

Table 14.2: Consensus scores and risk classifications for vendace (Coregonus albula) in the current situation in the Netherlands.

ISEIA sections	Risk classification	Consensus score
Dispersion potential or invasiveness	medium	2
Colonization of high value conservation habitats	medium	2
Adverse impacts on native species	likely	2
Alteration of ecosystem functions	unlikely	1
Global environmental risk	C - list category	7

Dispersion potential or invasiveness
There is no available evidence that describes the dispersion potential or invasiveness of the vendace in the Netherlands. The records of the vendace have been extensively examined by Soes (2009) and could not be confirmed. Therefore, it is unlikely that the vendace occurs in the Netherlands. In Russia, the absolute fecundity of females varies between 14,470 and 29,680 eggs (Semenov, 2011). Moreover, the vendace was able to colonise the 120km long Pasvik river system in six years in Finland (Amundsen *et al.,* 1999). It was concluded that once introduced, despite the low habitat suitability in the Netherlands, there is a medium risk that the vendace would disperse and become invasive in the Netherlands.

Colonisation of high conservation value habitats
The vendace is not recorded in the Netherlands, however its preference for cold and oxygen-rich habitats and its distribution in other countries suggests that it could, if introduced, occasionally colonise high conservation value habitats in the Netherlands. It was concluded that the vendace poses a medium risk in this category.

Adverse impacts on native species
There is no evidence from literature that suggests that the vendace may have a negative impact on native species in the Netherlands. However, the vendace is considered a zooplanktivorous specialist (Helminen *et al.,* 1990; Sandlund *et al.,* 1991; Bøhn & Amundsen, 2001). In Finland, the invasive population of the vendace in the Pasvik watercourse has a severe impact on the zooplankton community and was also found to adapt to a broader diet niche, even eating other fish, most likely as a result of depletion of its preferred food source (Bøhn & Amundsen, 2001; Amundsen *et al.,* 2009; Liso *et al.,* 2011). In Sweden, competition for food resources may be why roach (*Rutilus rutilus*) uses the pelagic compartment in lakes populated with vendace less frequently than in lakes where it is absent (Beier, 2001). Because of the lack of evidence from countries similar to the Netherlands, expert judgement was applied. It was concluded that it is likely that the vendace would impact native species in the Netherlands as a result of predation. Moreover, it is likely that native species are impacted as a result of interference and exploitation competition as the vendace is a specialised zooplanktivore that will very likely interfere with more facultative zooplanktivores such as many cyprinids (roach, bream, white bream and others) and possibly with many juvenile fish (L. Nagelkerke, pers. comm.).

Hybridisation between the vendace and native whitefish (*Coregonus lavaretus*) has been recorded in Finland, the resulting hybrid was highly reproductive. In the Netherlands, hybridization with the maraena whitefish (*Coregonus maraena*) and native houting (*C. oxyrinchus*) could also be possible, however both species are rare (Van Kessel & Kranenbarg, 2012). Because of the lack of evidence from countries similar to the Netherlands, expert judgement was applied. It was concluded that it is unlikely that vendace would impact native species in the Netherlands as a result of genetic effects.

The disease and parasites of the vendace are poorly documented, no serious disease cases are known for the Netherlands or from abroad. It was concluded using expert judgement that it is unlikely that the diseases and parasites of the vendace will effect native species in the Netherlands.

Overall, the evidence presented originates from countries that are climatically different to the Netherlands. It is not certain if this evidence is relevant for the Dutch situation. Due to the deficiency of data, expert knowledge was applied. It was concluded that it is likely that the vendace would have a negative impact on native species if it were present in the Netherlands. This was based on the risk scores obtained for effects relating to predation and genetic effects.

Alteration of ecosystem functions
There is no literature based evidence that describes any impact of the vendace on ecosystem functioning in the Netherlands or climatically similar countries. In Finland, where it became invasive, the vendace has had an effect on the zooplankton community, but this evidence is not relevant for the Dutch situation due to climatic differences. However, in general, specialist zooplanktivores may have an impact on food webs. Due to lack of evidence, it is unclear whether this impact can be classified as a disruption in the Dutch context. It was concluded that it is unlikely that the vendace will disrupt food webs in the Netherlands.

Due to the lack of evidence, it was concluded that it is unlikely that the vendace will cause negative impacts relating to modification of nutrient cycling or resource pool, physical modifications of the habitat and modifications of natural succession. Overall, it was concluded that it is unlikely that the vendace will have an impact on ecosystem functions in the Netherlands.

Species classification

The species classification corresponds to the global environmental risk score of the ISEIA (table 14.2) combined with the current distribution of the non-native species within the country in question. The vendace received a score of C0 and is not categorised in the list of the BFIS list system (Figure 14.2). This indicates a non-native species that is absent from the Netherlands and features low environmental hazard (i.e. ecological risk: ISEIA score 7: C category).

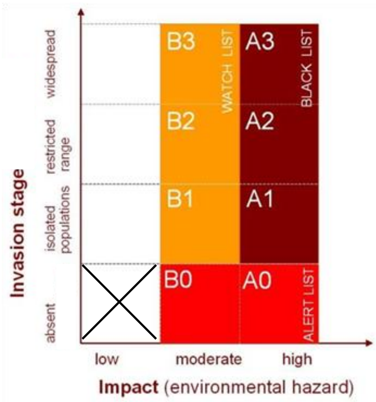

Figure 14.2: Vendace (Coregonus albula) classification according to the BFIS list system.

14.3.3 Future situation

The vendace prefers relatively high concentrations of oxygen and low water temperatures (Dembinsky, 1971; Hamrin, 1986, both cited in: Winfield *et al.,* 2004). The vendace spawns in waters where temperature fluctuates in the range of 0.5 to 2.9°C and spawning may take place under ice (Lesnikova, 1981 cfm Semenov, 2011). Therefore, a two degrees Celsius increase in temperature in the Netherlands will likely result in a reduction in potentially suitable habitat for the vendace. As a result, future risks associated with dispersion potential and invasiveness and colonization of high value conservation habitats are likely to reduce from medium to low risk and the species is unlikely to establish in the Netherlands (table 14.3). Therefore, the global risk score of the vendace is reduced from a seven to a five and the species will remain uncategorised in the list of the BFIS list system.

Table 14.3: Vendace (Coregonus albula) theoretical classification according to a potential future habitat scenario.

ISEIA sections	Risk classification	Consensus score
Dispersion potential or invasiveness	low	1
Colonization of high value conservation habitats	low	1
Adverse impacts on native species	likely	2
Alteration of ecosystem functions	unlikely	1
Global environmental risk	C - list category	5

14.4 Risk management

14.4.1 Prevention of introduction

The vendace is currently absent from the Netherlands. Restrictions with regard to the breeding and stocking of the species may prevent future introductions.

14.4.2 Elimination of populations

There is no information available concerning the elimination of vendace populations. See Appendix 4 for general elimination options for exotic fish species.

14.4.3 Management of populations

For the only non-native population of vendace, removal to reduce competitive pressure on native species has been suggested as a management option (Bøhn & Amundsen, 2001). This management option would, however, not reverse the invasion (Bøhn & Amundsen, 2001).

15. NORTHERN WHITEFIN GUDGEON (*Romanogobio belingi*)

The information presented in this chapter describes the results of a literature and database quick scan and serves as input for impact scoring using the ISEIA risk protocol. Supplementary information describing the northern whitefin gudgeon can be found in the report by Spikmans *et al.* (2010); “Plaag Risico Analyse van tien exotische vissoorten in Nederland”.

Figure 15.1: Northern whitefin gudgeon (Romanogobio belingi) (length 9cm) (digitalnature.org).

15.1 Distribution in the Netherlands

The northern whitefin gudgeon is present in most of the major rivers in the Netherlands, for example the Rhine, Waal, IJssel and Meuse (Figure 15.2). The distribution of the species is restricted to these rivers and their artificial floodplain habitats (Dorenbosch *et al.*, 2011; Spikmans *et al.*, 2010).

The occurrence of northern whitefin gudgeon in the Netherlands has gone unnoticed for a number of years because of its resemblance with the river gudgeon. The species probably colonised Dutch water bodies in the 1990s (Spikmans *et al.*, 2010). Since 2007, the gudgeon species were properly distinguished in the Netherlands during the MWTL (active large river monitoring program of Rijkswaterstaat). The densities of these species, recorded yearly, fluctuated between 2007 and 2012 (Figure 15.3). It is possible that the population of whitefin gudgeon is decreasing in the Netherlands, as the species is found in a decreasing number of river sections and transects within these river sections. Moreover, the number of river sections featuring a mean density of > 5/ha of fish is also decreasing.

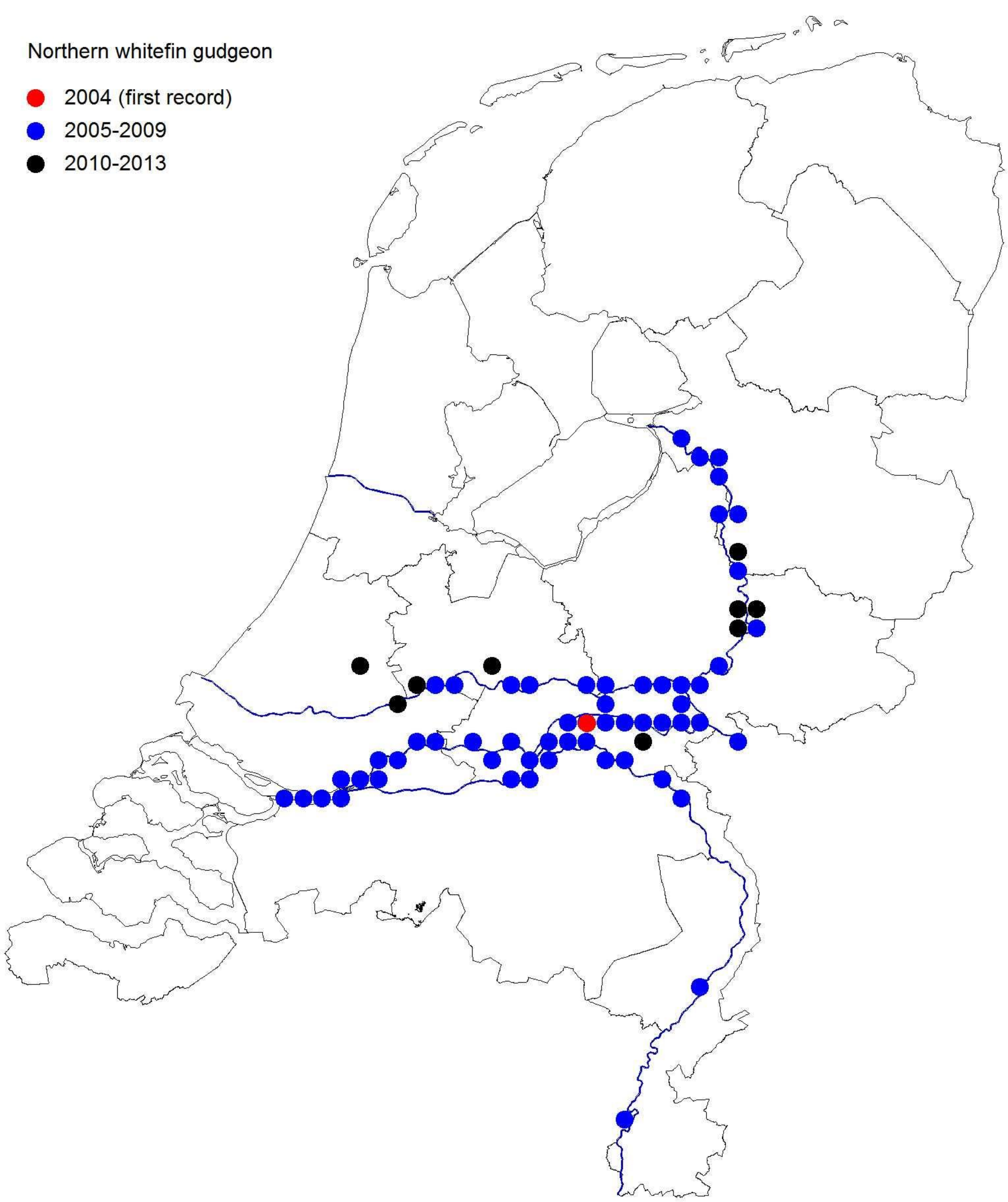

Figure 15.2: Geographical distribution history of the northern whitefin gudgeon (Romanogobio belingi) in the Netherlands (older records are plotted on top of more recent records) (RAVON/NDFF data).

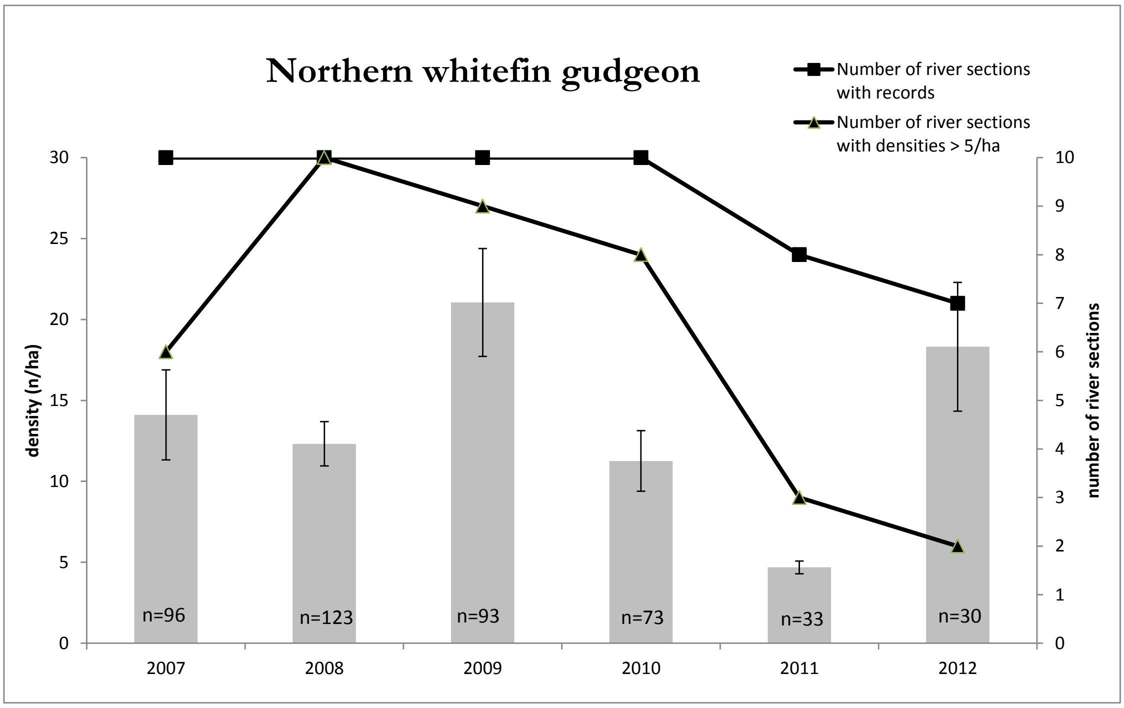

Figure 15.3: Mean density (±SE) of northern whitefin gudgeon (Romanogobio belingi) within monitoring transects of ten sections of the rivers Rhine and Meuse. Only data from transects where the species was present were analysed (n = number of transects). The number of river sections with species records and the number of river sections with densities > 5/ha are also presented (Data Rijkswaterstaat Waterdienst).

15.2 Potential spread in the Netherlands

The northern whitefin gudgeon is widely distributed throughout the major rivers of the Netherlands. The species was first recorded in the Netherlands in 2004 (Soes *et al.*, 2005), but had already been identified in 1998 to 1999 from locations in the river Rhine on the Dutch-German border (Freyhof *et al.*, 2000). Therefore, it is likely that the species was introduced to the Netherlands some years prior to the first year of record (Spikmans *et al.*, 2011). It is not known if the species is capable of spreading into the tributaries of the major Dutch rivers.

The northern whitefin gudgeon can easily disperse over distances of more than 1km/year by active or passive means (data Rijkswaterstaat Waterdienst). The species is recorded in most conservation areas along the major Dutch rivers registered under the Habitats Directive, such as the Biesbosch, Gelderse Poort, Uiterwaarden Waal, Uiterwaarden Ijssel and Grensmaas.
Information describing the reproductive capacity of this fish is limited. Females spawn four times per spawning season at intervals of approximately two weeks (Wanzenböck & Wanzenböck, 1993). The fecundity of the species is unknown (Naseka *et al.*, 1999).

15.3 Ecological impact

No direct impacts due to predation, competition, hybridization or disease transmission relating to the northern whitefin gudgeon on native species are described in literature.

However, an increase of northern whitefin gudgeon in the lowland rivers of the Hungarian Great Plain coincided with a decrease of the gudgeon *Gobio gobio* (Harka & Bíro, 2007). At present, northern whitefin gudgeon is widely spread in Dutch rivers. Gudgeon used to be abundant in

these systems, but nowadays the species is nearly absent. It has been argued that the disappearance of gudgeon from the larger Dutch rivers may be the result of competition with the northern whitefin gudgeon (Spikmans *et al.*, 2011). However, at some locations within its native range, northern whitefin gudgeon seems to live sympatrically with gudgeon (Balon *et al.*, 1988; Copp & Jurajda, 1993).
Whitefin gudgeon show a food partitioning overlap with gudgeon (*Gobio gobio*) with reference to their morphological capabilities (Van Onselen, 2013), therefore food competition could occur.
The existence of hybrids between northern whitefin gudgeon and other species of *Gobio* has never been confirmed. However, some specimens in the lower Morava River in Czechia are presumed to be hybrids of northern whitefin gudgeon and gudgeon (Naseka *et al.*, 1999).

In the Netherlands impact of northern whitefin gudgeon on native gudgeon has been hypothized. The disappearance of gudgeon from the large Dutch rivers was suggested to be a result of competition with the northern whitefin gudgeon (Spikmans *et al.,* 2011). In the lowland rivers of the Hungarian Great Plain, the increase of northern whitefin gudgeon coincided with a decrease in gudgeon (Harka & Bíro, 2007). A recent study on the feeding potential of both gudgeon species suggests that the northern whitefin gudgeon is more specialised in micro-food than the gudgeon, which would give it a selective advantage in the presence of such food (Van Onselen *et al.,* 2013). Furthermore the northern whitefin gudgeon could have an advantage over gudgeon in polluted waters, because it can exist under conditions of severe water pollution (Ruchin *et al.*, 2008).

15.4 Risk classification

15.4.1 Available risk classifications

No risk assessments were found for the northern whitefin gudgeon.

15.4.2 current situation

Expert consensus scores
The total risk score attributed to the northern whitefin gudgeon was 9 out of a maximum risk score of 12 (table 15.1). This results in an overall classification of moderate risk for this species.

Table 15.1: Consensus scores and risk classifications for the northern whitefin gudgeon (Romanogobio belingi) in the current situation in the Netherlands.

ISEIA sections	Risk classification	Consensus score
Dispersion potential or invasiveness	high	3
Colonization of high value conservation habitats	high	3
Adverse impacts on native species	medium	2
Alteration of ecosystem functions	unlikely	1
Global environmental risk	B - list category	9

Dispersion potential or invasiveness
The distribution of the northern whitefin gudgeon is restricted to the rivers Rhine, Waal, IJssel and Meuse and their artificial floodplain habitats (Dorenbosch *et al.,* 2011; Spikmans *et al.,* 2010). The fecundity of the northern whitefin gudgeon is unknown (Naseka *et al.,* 1999), however, being

a cyprinid a high fecundity is likely. The northern whitefin gudgeon has a strong dispersal potential and it has shown in the past that it can exist in high densities in the Netherlands. It was concluded that the northern whitefin gudgeon has a high dispersal potential and invasiveness in the Netherlands.

Colonisation of high conservation value habitats
81% of northern whitefin gudgeon distribution occurs in areas designated under Natura 2000 in the Netherlands (206 of 254km-squares). It has been recorded in relatively high densities in surveys of groynefields and different floodplain water-bodies in 2007 and 2009 in the Netherlands (Dorenbosch *et al.,* 2011; Van Kessel & Kranenbarg, 2012). These habitats border Natura 2000 areas. Therefore, it was concluded that the northern whitefin gudgeon often colonises and poses a high risk to high conservation value habitats in the Netherlands.

Adverse impacts on native species
Evidence relating northern whitefin gudgeon to adverse impacts on native species in the Netherlands or climatically similar countries is unavailable. However, it is possible that the gudgeon (*Gobio gobio*) is displaced by this species. Spikmans *et al.* (2011) suggested that the disappearance of gudgeon from the large Dutch rivers could be attributed to competition with the northern whitefin gudgeon. Moreover, in the lowland rivers of the Hungarian Great Plain, the increase of northern whitefin gudgeon coincided with a decrease in gudgeon (Harka & Bíro, 2007). A recent study on the feeding potential of both gudgeon species suggests that the northern whitefin gudgeon is more specialised in micro-food than the gudgeon, which would give it a selective advantage in the presence of such food (Van Onselen*.,* 2013). However, other authors suggest that, in some locations within its native range, the northern whitefin gudgeon can live sympatrically with the gudgeon (Balon *et al.,* 1988; Copp & Jurajda, 1993). Based on the interference and exploitation competition subcategory, it was concluded that the northern whitefin gudgeon likely impacts native species in the Netherlands. Not enough information was available to make an expert judgement of the risk posed by potential parasites and diseases carried by the northern whitefin gudgeon and impacts related to genetic effects and predation and herbivory on native species in the Netherlands. Therefore, these subcategories were classified as data deficient.

Alteration of ecosystem functions
There is no literature evidence to suggest that the northern whitefin gudgeon has a negative impact on any subcategory relating to alteration of ecosystem functioning in the Netherlands or other climatically similar countries (modification of nutrient cycling or resource pools, physical modifications of the habitat, modifications of natural succession, disruptions of food webs). Therefore, expert judgement was applied and it was concluded that it is unlikely that the northern whitefin gudgeon has a negative impact on ecosystem functioning in the Netherlands.

Species classification
The species classification corresponds to the global environmental risk score of the ISEIA (table 15.1) combined with the current distribution of the non-native species within the country in question. The species classification for the northern whitefin gudgeon is B2 (Figure 15.4). This indicates a non-native species exhibiting a restricted range and displaying a moderate environmental hazard (i.e. ecological risk) that should be placed on the watch list of the BFIS list system (i.e. ecological risk: ISEIA score 9: B category).

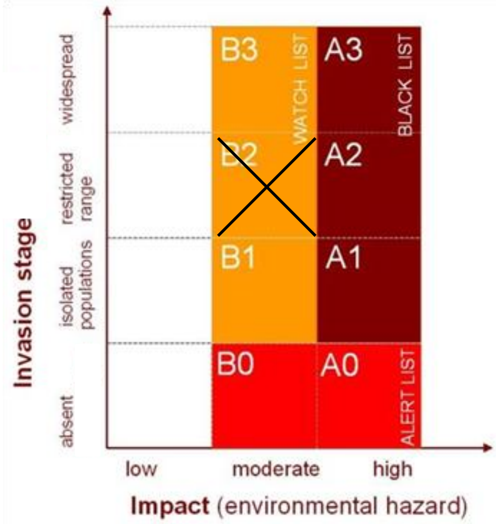

Figure 15.4: Northern whitefin gudgeon (Romanogobio belingi) classification according to the BFIS list system

15.4.3 Future situation

It is expected that a two degrees Celsius increase in temperature will have a limited effect on the northern whitefin gudgeon in the Netherlands. The recorded distribution of the northern whitefin gudgeon is not expected to exceed a restricted range in the Netherlands and there are some signs that it has reduced locally in the last two years (reduction in records). If only temperature is considered, it is expected that the restricted range of the northern whitefin gudgeon and risk assessment scores in the Netherlands will remain the same (table 15.2). Therefore, the B2 classification under the BFIS list system is also expected to remain the same.

Table 15.2: Northern whitefin gudgeon (Romanogobio belingi) theoretical classification according to a potential future habitat scenario.

ISEIA sections	Risk classification	Consensus score
Dispersion potential or invasiveness	high	3
Colonization of high value conservation habitats	high	3
Adverse impacts on native species	likely	2
Alteration of ecosystem functions	unlikely	1
Global environmental risk	B - list category	9

16. GENERAL DISCUSSION

16.1 Risk assessment

The risk assessment resulted in the allocations of risk classification scores. Table 16.1 gives an overview of the risk scores attributed to the fish species analysed for the current situation in the Netherlands. The species posing the highest ecological risk are the common carp, pike-perch and Prussian carp, these species have a widespread recorded distribution in the Netherlands. The asp, brook trout, grass carp, rainbow trout, cross carp and northern whitefin gudgeon received moderate ecological risk scores. The Arctic char, eastern mudminnow and vendace received low ecological risk scores. The cross carp received a moderate ecological risk score according to the ISEIA methodology. However, this score is largely based on expert judgment. Expert judgment is applied to nine out of 10 categories and the score does not reflect the experts opinion that this species carries a similar risk as the common carp and Prussian carp (high ecological risk). In general, if a species is likely to pose a high ecological risk to native species and ecosystem functions according to expert judgment, it will receive a lower overall score than if this assessment of risk is based on evidence obtained from scientific literature from the Netherlands or a comparable climatic region. Therefore, any species that is judged according to expert judgment may receive a lower ecological risk classification that does not reflect its true risk to native species and ecosystem functions. The risk assessments for Arctic char, asp, eastern mudminnow, cross carp, vendace and northern whitefin gudgeon contain over 50% of scored risk assessment categories where expert judgment was applied (Appendix 2 & 3).

Table 16.1: Summary of risk assessment group scores in the current situation in the Netherlands.

Species	ISEIA risk score	Invasion stage	BFIS list category
Arctic char	6	absent	C0
Asp	9	widespread	B3
Brook trout	9	isolated populations	B1
Common carp	11	widespread	A3
Eastern mudminnow	8	restricted range	C2
Grass carp	10	widespread	B3
Hybrid cross carp	9	isolated populations	B1
Pike-perch	11	widespread	A3
Prussian carp	11	widespread	A3
Rainbow trout	10	widespread	B3
Vendace	7	absent	C0
Northern whitefin gudgeon	9	restricted	B2

BFIS list category - A: high environmental hazard (black list); B: moderate environmental hazard (watch list); C: low environmental hazard (unclassified); 0: absent; 1: isolated populations; 2: restricted range; 3: widespread.

Table 16.2 gives an overview of the risk scores attributed to the fish species analysed for a future scenario in the Netherlands. The future scenario is defined as a two degree Celsius increase in temperature resulting from climate change. Common carp and grass carp may benefit in this scenario and received a higher ecological risk score than in the current situation. The vendace and the Arctic char are less likely to occur in the Netherlands in the future scenario and received a lower ecological risk score.

Table 16.2: Summary of risk assessment scores according to a future scenario in the Netherlands (two degree Celsius temperature increase).

Species	ISEIA Risk score	Invasion stage	BFIS list category
Arctic char	5	absent	C0
Asp	9	widespread	B3
Brook trout	9	isolated populations	B1
Common carp	12	widespread	A3
Eastern mudminnow	8	restricted range	C2
Grass carp	12[a]	widespread	A3
Hybrid cross carp	9	isolated populations	C1
Pike-perch	11	widespread	A3
Prussian carp	11	widespread	A3
Rainbow trout	10	widespread	B3
Vendace	5	absent	C0
Northern whitefin gudgeon	9	restricted	B2

[a]Worst case scenario; BFIS list category - A: high environmental hazard (black list); B: moderate environmental hazard (watch list); C: low environmental hazard (unclassified); 0: absent; 1: isolated populations; 2: restricted range; 3: widespread.

16.2 Risk management

The majority of species assessed in these risk analyses are already widespread in the Dutch water system. Prevention of introduction and further spread is, however, still an important measure to protect native species and unoccupied valuable habitats from the unwanted impacts of these exotic fish species. Based on the results of this risk analysis, legislation that allows the legal introduction of exotic fish should be reconsidered for at least some of the analysed species. Additionally, the approach that allows the stocking of hybrids, in this case Elsässer saibling (*Salvelinus fontinalis* x *Salvelinus alpinus*) and the 'cross carp' (*Cyprinus carpio* X *Carassius* spp.), should be urgently reconsidered as they are able to reproduce.

Once introduced, it is difficult to eliminate unwanted populations of all exotic species. Only exotic fish populations in relatively small isolated water bodies can be eliminated with limited collateral damage to native species. Currently, the complete drainage of a water body and humane euthanization by physical means is the only available legal method for the elimination of exotic fish species. Piscicides (substances used to kill fish) are a convenient method for the humane euthanization of a group of collected individual fish and for the treatment of entire water bodies. However, when applied in the environment, the use of piscicides can have unwanted side effects as they also target native invertebrate and fish species. Currently, piscicides cannot be used in the Netherlands due to legal restrictions (Schiphouwer *et al.*, 2012).

Management of established populations has proven to be very difficult, or even impossible for species that have established large populations in large water bodies. Management of populations by increasing fishing pressure is not advised, as this can create undesirable, large populations of fish consisting of small individuals. Populations of some species, potentially Prussian carp and eastern mudminnow, can be managed by the introduction of a native predator, for example pike. Other control options are based on reproduction success. The introduction of genetically modified, daughterless individuals will lead to reduced species reproduction in the long term (e.g. the daughterless carp program, Gilligan *et al.*, 2005). The introduction of sterile (triploid) grass carp specimens will prevent reproduction in this species. The implantation of an erodible poison capsule in stocked specimens of grass carp has been suggested as a method of shortening life span

(Thomas *et al.*, 2006). Furthermore, habitat alterations could reduce the impact of invasive species (Van Kessel *et al.*, 2013). For example, the neutralisation of acidified habitats could reduce the success of the eastern mudminnow.

Finally, the risks of disease transmission during the transportation of fish should be considered as some species have been proven to carry diseases which can cause severe impacts on native species. Currently, fish transports are not screened for the occurrence of (exotic) diseases. Moreover, the accidental transport of other exotic species, for example exotic macroinvertebrates, along with exotic fish cargo may also occur. Therefore, the screening of national and international transports and the taking of measures to prevent the spread of diseases and the coincidental spread of other exotic species is strongly advised.

16.3. Recommendations

Based on the results of this risk analysis the following recommendations are made:

- The stocking exotic fish species, in particular Prussian carp, pike-perch, grass carp and fertile hybrids (cross carp), should be stopped or regulated.
- It is strongly advised to screen national and international transports and to take measures to prevent the spread of diseases and the coincidental spread of other exotic species.

We recommend additional research to enhance the knowledge of the risks posed by exotic species in the Netherlands:

- Determine if the genotype of the native crucian carp has already been compromised by hybridisation with Prussian carp, goldfish and common carp.
- Determine the impact of asp on native species and ecosystem functioning.
- Determine if the eastern mudminnow affects ecosystem functioning and impacts on native species, for example if the eastern mudminnow is able to expand its range to more habitats of the wheaterfish and exerts impacts on this species.
- Determine if the whitefin gudgeon exerts impacts on the native gudgeon.
- Determine the impacts of brook trout and rainbow trout on native species and ecosystem functioning.
- In addition to the information in this report, assess and classify the risks of the fertile hybrid of brook trout and Arctic char (Elsässer saibling).

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APPENDIX 1: Analysis of exotic fish species occurrence (number of records) in Natura 2000 areas (only areas with records of one or more target species are included)

Natura 2000 area	Eastern mudminnow	Brook trout	Prussian carp	Grass carp	Common carp	Rainbow trout	Asp	Pike-perch	Northern whitefin gudgeon
Abtskolk & De Putten			3	3	1			6	
Achter de Voort, Agelerbroek & Voltherbroek					8			9	
Alde Feanen			2		11		2	35	
Arkemheen			3	1	8		1	13	
Bekendelle					5				
Biesbosch	2	3	66	49	230	25	189	488	22
Binnenveld				1	6			4	
Boezems Kinderdijk			3		30		6	21	
Borkeld					1				
Boschhuizerbergen	7								
Botshol					5			6	
Brabantse Wal					9			1	
Broekvelden, Vettenbroek & Polder Stein			1		6			7	
Brunssummerheide			2	1	3		1	2	
Bunder- en Elslooërbos			2		3			1	
Buurserzand & Haaksbergerveen					3				
Canisvliet					7			5	
Coepelduynen				1	1			1	
De Wieden			3	1	15		9	45	
De Wilck					1				
Deelen								8	
Deurnsche Peel & Mariapeel	167		4		19			7	
Dinkelland			1		1				
Donkse Laagten					1				
Drentsche Aa-gebied				1	1	1		5	
Drents-Friese Wold & Leggelderveld			1		2			1	
Duinen Ameland					6				
Duinen Den Helder-Callantsoog					5			4	
Duinen en Lage Land Texel					12			8	
Duinen Goeree & Kwade Hoek					7	1		7	
Duinen Schiermonnikoog			1						
Duinen Terschelling			4						

Duinen Vlieland			13		10				
Eemmeer & Gooimeer Zuidoever				3	17		4	20	
Eilandspolder			2		21			13	
Elperstroomgebied			1						
Fochteloërveen			2					1	
Gelderse Poort	1		33	15	210	10	151	441	31
Geleenbeekdal			6		9				
Geuldal		1	18	4	31	13		1	
Grensmaas	1		11		28	2	20	71	1
Grevelingen						2		3	
Groote Gat					4				
Groote Peel	53		1		1				
Groote Wielen			1		6		1	8	
Haringvliet		1	69	17	169	11	96	862	
Hollandsch Diep		2	31	20	140	7	163	698	27
Holtingerveld			1		1			2	
IJsselmeer	1	2	18	10	94	16	15	1003	
Ilperveld, Varkensland, Oostzanerveld & Twiske					71			65	
Kampina & Oisterwijkse Vennen	49		4	2	27	1		2	
Kempenland-West	62		1	2	19			1	
Kennemerland-Zuid			4	31	82			4	
Ketelmeer & Vossemeer			9	19	31	8	10	46	
Kolland & Overlangbroek					1				
Kop van Schouwen			15		20	2			
Korenburgerveen					1				
Krammer-Volkerak			38		59	3	4	301	
Landgoederen Brummen			1		3				
Landgoederen Oldenzaal			1						
Langstraat					4			1	
Lauwersmeer			7	2	23			94	
Leekstermeergebied				4	8			13	
Leenderbos, Groote Heide & De Plateaux	176		17		57	1		7	
Lepelaarplassen								4	
Leudal	1				1			1	
Lingegebied & Diefdijk-Zuid			3	10	28		4	48	
Loevestein, Pompveld & Kornsche Boezem			5	5	20	5	9	18	1
Lonnekermeer					2				
Loonse en Drunense Duinen & Leemkuilen			1	1	14		5	3	
Maasduinen	6		9	5	8		2	16	
Manteling van Walcheren					4			2	
Markermeer & IJmeer			3	16	124	4	17	540	
Markiezaat			12		17	3	2	39	
Meijendel & Berkheide			2	2	45			13	
Meinweg			1	1	3				
Naardermeer			2	10	26			14	

Nieuwkoopse Plassen & De Haeck			1		14		3	25	
Noorbeemden & Hoogbos			1			2			
Noordhollands Duinreservaat			2	11	8				
Noordzeekustzone			4		7			1	
Oeffelter Meent			13		3		4	5	4
Olde Maten & Veerslootslanden					7				
Oostelijke Vechtplassen	2				140		7	173	
Oosterschelde			7		35	12		41	
Oostvaardersplassen			1	2	76			42	
Oude Maas			12		19		20	91	
Oudegaasterbrekken, Fluessen en omgeving			1		13			82	
Oudeland van Strijen				2	6			7	
Polder Westzaan					56			36	
Polder Zeevang					12			10	
Regte Heide & Riels Laag			4		3				
Roerdal		1	21	1	32	12	6	17	
Rottige Meenthe & Brandemeer				1	1			5	
Sarsven en De Banen	29				6				
Schoorlse Duinen			2		3				
Sint Jansberg					2			2	
Sint Pietersberg & Jekerdal			6		13			2	
Sneekermeergebied			2		5		2	51	
Solleveld & Kapittelduinen			13		15	3		5	
Springendal & Dal van de Mosbeek			3		2				
Strabrechtse Heide & Beuven	28			1	4		1		
Swalmdal	1	2	15	2	15	7	6	13	1
Uiterwaarden IJssel			56	23	347	12	560	845	53
Uiterwaarden Lek			11		11		12	20	2
Uiterwaarden Neder-Rijn	2		12	1	55		50	116	11
Uiterwaarden Waal			8	33	77	4	117	237	53
Uiterwaarden Zwarte Water en Vecht			2		11		9	20	
Ulvenhoutse Bos			1						
Van Oordt's Mersken					1			3	
Vecht- en Beneden-Reggegebied				6	12	4	5	11	
Veerse Meer			3		5			3	
Veluwe	1	3	9	3	66	17	33	52	
Veluwerandmeren			71	5	75	4	24	73	
Vlakte van de Raan					1				
Vlijmens Ven, Moerputten & Bossche Broek	6		5		12		11	11	
Vogelkreek			4		10			9	
Voordelta		1	2		15	13	2	32	
Voornes Duin				1	8	18	1	24	
Waddenzee			6	3	42	6	7	49	
Weerribben					8		1	14	
Weerter- en Budelerbergen & Ringselven	86		1	3	29			11	

Westduinpark & Wapendal			3		12			3	
Westerschelde & Saeftinghe			3		40			12	
Wierdense Veld					1				
Wijnjeterper Schar					1			1	
Willinks Weust					3				
Witte en Zwarte Brekken								10	
Witte Veen					2				
Wormer- en Jisperveld & Kalverpolder			2		42		3	49	
Zeldersche Driessen					6			8	
Zoommeer			13		17	5	1	41	
Zouweboezem					10		3	11	
Zuidlaardermeergebied			5	1	8	1		20	
Zwanenwater & Pettemerduinen				2	12			1	
Zwarte Meer			44	13	54	7	5	47	
Zwin & Kievittepolder					5				
Total records in N2000 area	681	16	807	351	3341	240	1604	7381	206
Total records outside N2000 area	502	18	1011	513	5700	117	770	4400	48

APPENDIX 2: Risk classification group scores: current situation

	Arctic char	Asp	Brook trout	Common carp	Eastern mudminnow	Grass carp	Cross carp	Pike-perch	Prussian carp	Rainbow trout	Vendace	Northern whitefin gudgeon
Dispersion potential or invasiveness	2	3	2	3	2	1	2*	3	3	2	2	3
Colonisation of high conservation value habitats	1	3	3	3	3	3	2*	3	3	3	2	3
Adverse impacts on native species												
1) Predation/Herbivory	2*	2*	2	2	2*	3	2*	3	3	3	2*	dd
2)Interference and exploitation competition	2*	dd	2	2	dd	3	2*	3	3	2	2*	2*
3) Transmission of diseases to native species	2	1*	2*	2*	dd	2	1*	2*	1	2	1*	dd
4) Genetic effects	1	1*	2	2	1*	1	3	1*	2	1	1*	dd
Alteration of ecosystem functions												
1) Modification of nutrient cycling or resource pools	1*	dd	dd	3	1*	3	2*	dd	2*[,b]	1*	1*	1*
2) Physical modifications of the habitat	1*	dd	dd	3	1*	3	2*	dd	1*	1*	1*	1*
3) Modifications of natural succession	1*	dd	dd	3	1*	3	2*	dd	1*	1*	1*	1*
4) Disruptions of food webs	1*	1*[,a]	2*	3	1*	3	2*	2*	1*	2*	1*	1*
ISEIA score:	6	9	9	11	8	10	9	11	11	10	7	9
Invasion stage:	absent	widespread	isolated populations	widespread	restricted range	widespread	isolated popluations	widespread	widespread	widespread	absent	restricted
BFIS list category:	C0	B3	B1	A3	C2	B3	B1	A3	A3	B3	C0	B2

*Expert judgement; dd= deficient data; [a]Has some effect but this is not large enough for the species to be categorised under medium risk; [b]Based on a single study containing correlation evidence linking nutrient enrichment with the species. BFIS list category - A: high environmental hazard (black list); B: moderate environmental hazard (watch list); C: low environmental hazard (unclassified); 0:absent; 1:isolated populations; 2:restricted range; 3:widespread.

APPENDIX 3: Risk classification group scores: future situation

	Arctic char	Asp	Brook trout	Common carp	Eastern mudminnow	Grass carp	Cross carp	Pike-perch	Prussian carp	Rainbow trout	Vendace	Northern whitefin gudgeon
Dispersion potential or invasiveness	1	3	2	3	2	3	2	3	3	2	1	3
Colonisation of high conservation value habitats	1	3	3	3	3	3	2	3	3	3	1	3
Adverse impacts on native species												
1) Predation/Herbivory	2	2	2	3	2	3	2	3	3	3	2	dd
2)Interference and exploitation competition	2	dd	2	3	dd	3	2	3	3	2	2	2
3) Transmission of diseases to native species	2	1	2	3	dd	2	1	2	1	2	1	dd
4) Genetic effects	1	2	2	3	1	1	3	1	2	1	1	dd
Alteration of ecosystem functions												
1) Modification of nutrient cycling or resource pools	1	dd	dd	3	1	3	2	dd	2	1	1	1
2) Physical modifications of the habitat	1	dd	dd	3	1	3	2	dd	1	1	1	1
3) Modifications of natural succession	1	dd	dd	3	1	3	2	dd	1	1	1	1
4) Disruptions of food webs	1	1	2	3	1	3	2	2	1	2	1	1
ISEIA score:	5	9	9	12	8	12[a]	9	11	11	10	5	9
Invasion stage:	absent	widespread	isolated populations	widespread	restricted range	widespread	isolated popluations	widespread	widespread	widespread	absent	restricted
BFIS list category:	C0	B3	B1	A3	C2	A3	B1	A3	A3	B3	C0	B2

N.B. All assessments of the future situation are based on expert judgement; dd= deficient data; [a]Worst case scenario; [b]Based on a single study containing correlation evidence linking nutrient enrichment with the species; BFIS list category - A: high environmental hazard (black list); B: moderate environmental hazard (watch list); C: low environmental hazard (unclassified); 0:absent; 1:isolated populations; 2:restricted range; 3:widespread.

APPENDIX 4: General options for exotic fish species elimination.

Elimination measures are generally limited to enclosed water bodies and there is a lack of effective methods for dealing with fish in large water systems (Meyer *et al.,* 2006; Britton *et al.*, 2010). In general, there are only a few methods available for complete population elimination in isolated or spatially constrained populations (Britton *et al.*, 2008; Britton *et al.*, 2010).

Draining of water bodies and euthanizing unwanted individuals

The first method is to eradicate all unwanted individuals and involves the complete drainage of a water body. Following this, fish are collected and euthanized. Humane euthanization can for example be carried out by physical means, for example by a blow to the head followed by phiting (puncturing of the brains) (Schiphouwer *et al.*, 2012). The downside of this method is that it is difficult to collect all fish from the deeper parts of the water body, which stays wet, and it is labour intensive to manually euthanize many fish (Schiphouwer *et al.*, 2012). Piscicides (agents administered in a lethal dose to fish) can be used to euthanize larger quantities of fish under controlled conditions, however, the use of piscicides is illegal in the Netherlands (Schiphouwer *et al.*, 2012).

The drainage and euthanasia method has been successfully applied to pumpkinseed sunfish (*Lepomis gibbosus*) and fathead minnow (*Pimephales promelas*) in the Netherlands (Bosman, 2004; Spikmans *et al.*, 2011), however, the method of euthanization was in both cases humanely and legally questionable.

Application of piscicides to treat an entire water body

Piscicides can be used to kill all fish quickly and humanely, however, the use of piscicides is illegal in the Netherlands (Schiphouwer *et al.*, 2012). Worldwide, the most commonly used substance is rotenone, which is relatively cheap to buy (Ling, 2003; Clearwater *et al.*, 2008; Wynne & Masser, 2010). Another example of a piscicide that humanely kills fish is benzocaine (Schiphouwer *et al.*, 2012). Before treating a whole water body using a piscicide, it is advised to firstly lower the water level, so less of the substance is needed. The use of piscicides is forbidden in the Netherlands (Schiphouwer *et al.*, 2012) as there are a number of drawbacks in the use of these substances. For example, all animals with gills, including native species, and many invertebrates will be killed (Ling, 2003). In the United Kingdom, the use of rotenone has been legalized. Britton & Brazier (2006) applied the method successfully to eradicate the topmouth gudgeon (*Pseudorasbora parva*) in a UK lake. During the procedure, the majority of native species was spared by prior removal using nets. In the 1970s, common carp were eradicated by rotenone from about 20 Tasmanian water bodies, which remained free of the species for over 20 years (Roberts & Tilzey, 1996). Rotenone has also been used in Norway to 'ecologically reset' entire rivers and eradicate salmon infected with an exotic disease (Hulland, 2012). The method was applied in rivers with a poor ecological status and a relatively small catchment area. The rivers quickly recovered ecologically after the measure was undertaken (Hulland, 2012). Moreover, in Yellowstone park, a tributary was successfully cleared of non-native brook trout (*Salvelinus alpinalis*) by applying the piscicide antimycin. However, the use of piscicides is controversial in large, species rich rivers (Hulland, 2012).

The material and labour costs involved in clearing all fish from a water body using the piscicide rotenone can vary from a few 1000 euros for a 2.5 hectare pond, to over 20 million euros for a small river (Jolley & Willis; Britton & Brazier, 2006; Hulland, 2012).

Active fishing to eliminate populations

Active fishing methods, such as angling, electrofishing and seine netting, can be used to remove fish from water bodies. The elimination of small populations of fish using active fishing methods may be successful (Copp *et al.*, 2007), but there is a high risk that a few individuals will be missed (Diggle *et al.*, 2004). Moreover, elimination by active fishing methods may require a lot of effort compared to the use of piscicides (Buktenica *et al.*, 2013) and may become expensive, exceeding available funds.