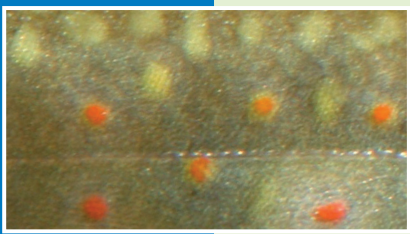
A risk analysis of exotic trout in the Netherlands



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Preface

In the last few years, rainbow trout and brook charr have been found in streams known for their rare indigenous fish species, like brook lamprey and common minnow. To get more insight into the occurrence of exotic trout species in the Netherlands, the possibility of them becoming invasive, the possible ecological, economical and social impacts, and the possibilities of risk management the Invasive Allien Species Team of the Plantenziektekundige Dienst have commissioned Bureau Waardenburg to carry out a risk analysis.

This risk analysis was carried out by Bureau Waardenburg:
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From the Team of Invasieve Exoten of the Food and Consumer Product Safety Authority the analysis was supervised by Mrs. dr. ir. José H. Vos and ir. J.W. Lammers.

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Samenvatting

Potentieel invasieve soorten
De salmoniden zijn, zowel voor de consumptie als voor de hengelsport, erg gewild. Nadat de inheemse soorten sterk achteruitgingen is men in Europa gaan experimenteren met Noord-Amerikaanse soorten. Verschillende van deze soorten hebben habitateisen die niet in Nederland vóórkomen, met als grootste knelpunt de watertemperatuur van de Nederlandse wateren die in de zomer te hoog ligt. Alleen voor de bronforel en de regenboogforel kon op basis van hun habitateisen een kans op vestiging niet op voorhand worden uitgesloten.

Van de bultrugzalm, de Chinookzalm, de Cohozalm, de beekridder en de Amerikaanse meerforel wordt niet verwacht dat ze zich kunnen vestigen in Nederland.

Regenboogforel
De regenboogforel is al in de 19e eeuw naar Europa gehaald en vanaf 1897 was ze ook aanwezig in de Nederlandse kwekerijen. In Nederland worden regenboogforellen vooral nog aangetroffen in de grotere rivieren, het IJsselmeer en enkele grotere, afgesloten wateren in het zuidwesten van Nederland. In het verleden is ze ook in kleine rivieren en beken waargenomen, zoals in Limburg en Brabant. Tegenwoordig wordt ze in deze systemen nog weinig gevonden. Recentelijk is ze nog wel in kleine aantallen gevangen in enkele Veluwse beken.

De in Nederland aangetroffen dieren zijn voornamelijk afkomstig van uitzettingen in het buitenland en uitzettingen in afgesloten wateren (bijvoorbeeld Oostvoornse Meer). Legale uitzettingen in open watersystemen lijken in Nederland niet plaats te vinden. Andere kleinschalige bronnen blijken te zijn: viskwekerijen, visvijvers, tuinvijvers, dierentuinen en illegale uitzettingen.

De regenboogforel die in Europa aanwezig is en ook in Nederland wordt gebruikt is een sterk gedomesticeerde vis die onder andere in zijn groeisnelheid en gedrag duidelijk verschilt van de moederpopulaties in het oorspronkelijke verspreidingsgebied in het westen van Noord-Amerika. Ondanks haar grote populariteit in de aquacultuur en de ontelbare uitzettingen heeft ze in Europa weinig stabiele populaties weten te vormen en tot op heden zijn er voor Europa dan ook geen aanleidingen om de regenboogforel invasief te noemen. Dit is met name opmerkelijk omdat wanneer wordt gekeken naar de habitateisen van deze soort er geen duidelijke knelpunten zijn aan te geven. Ook in Nederland is potentieel geschikt habitat aanwezig, maar dit beperkt zich wel tot de provincie Limburg.

Het niet slagen van de soms zeer grootschalige uitzettingen is vermoedelijk een combinatie van:

- de biologische weerstand van systemen, bijvoorbeeld in de vorm van parasieten of predatoren;
- de veranderde eigenschappen van de gedomesticeerde regenboogforel die haar minder geschikt maakt om wilde populaties te vormen, bijvoorbeeld groeisnelheid of antipredator gedrag;
- het voornamelijk uitzetten van vrouwelijke dieren.

Wanneer dit daadwerkelijk het geval is dan zou het gebruiken van niet-gedomesticeerde kweeklijnen in combinatie met een normale geslachtsverhouding mogelijk succesvoller kunnen zijn. Met de huidige kweeklijnen lijkt de kans op vestiging ook in Nederland klein te zijn.

Bronforel

De eerste meldingen uit Europa van de bronforel dateren al uit 1868. In Nederland zou ze rond 1895-1900 zijn geïntroduceerd. Succesvolle vestiging in Europa is voornamelijk bekend uit Noord-Europa en de berggebieden in Centraal-Europa. In Noord-Europa wordt de soort beschouwd als een invasieve soort die een bedreiging zou kunnen vormen voor de inheemse fauna. In Nederland is de bronforel sporadisch in het wild gemeld en voor een deel van de waarnemingen is het onzeker of het daadwerkelijk om deze soort ging. In Nederland blijkt namelijk ook de 'Elsässer saibling' voor te komen. Dit is de hybride van bronforel en beekridder, die in de aquacultuur populairder is dan de beide oudersoorten. Deze hybride heeft een sterk gereduceerd vruchtbaarheid, waardoor vestiging erg onwaarschijnlijk is.

Uit Nederland is één populatie van de bronforel bekend waarvan aannemelijk is dat ze zich zelfstandig in stand heeft weten te houden. Deze populatie is aanwezig geweest in de Geelmolense Beek (Veluwe) en heeft haar oorsprong vermoedelijk in uitzettingen rond 1900. Deze populatie was rond 1970 nog aanwezig. In 2008 is ook minimaal één bronforel gevangen in de Geelmolense Beek, deze zou echter ook afkomstig kunnen zijn geweest uit de aanliggende viskwekerij. De status van de bronforel in de Geelmolense Beek is dan nu ook onzeker.

Het beperkte aantal bronforellen dat in Nederland is aangetroffen is voornamelijk afkomstig van uitzettingen in het buitenland. Legale uitzettingen in open watersystemen, zoals die in het verleden wel hebben plaatsgevonden, lijken in Nederland niet meer plaats te vinden. De bronforel is recentelijk nog wel uitgezet in het Oostvoornse Meer. Andere mogelijke bronnen blijken te zijn: viskwekerijen, visvijvers, tuinvijvers en illegale uitzettingen.

De bronforel is relatief flexibel qua habitateisen, maar is slecht bestand tegen hogere watertemperaturen. Wateren die de voor deze soort geldende 16ºC-grens niet systematisch overschrijden zijn beperkt tot bronbeken in met name Limburg en op de Veluwe. Verder blijkt de bronforel zich in aanwezigheid van de Atlantische forel vrijwel alleen te kunnen handhaven in kleine bovenlopen. Het voorkomen van de Atlantische forel is in Nederland echter zeer beperkt. Locale vestiging van bronforel zoals die heeft plaatsgehad in de Geelmolense Beek lijkt dan ook op meer plaatsen mogelijk. Het is onwaarschijnlijk dat deze soort vanuit zo'n vestiging zich sterk zal uitbreiden en invasief wordt.

Impact

Ecologische impact

Zowel de regenboogforel als de bronforel kunnen potentieel een grote impact hebben op Nederlandse aquatische systemen door:

- predatie op inheemse vissoorten zoals de beekprik;
- predatie op inheemse amfibieën;
- predatie op inheemse ongewervelden;
- het overbrengen van visziekten.

De impact zal met name groot zijn in wateren die voor de binnenkomst van forellen geen grote roofvissen kennen, zoals veel bovenlopen van Nederlandse beken.

De competitie tussen bronforel en Atlantische forel, wat op Europese schaal als een probleem wordt gezien, zal in Nederland niet snel optreden doordat de Atlantische forel (nog) zeer beperkt voorkomt. De Atlantische zalm lijkt niet gevoelig voor competitie van beide soorten.

Economische en sociale impact

Populaties van regenboogforel of bronforel zullen zeker worden gewaardeerd en een positieve economische en sociale impact hebben die beperkt zal zijn tot de hengelsport en gelieerde bedrijfstakken.

Preventieve maatregelen en bestrijding

Gedurende het onderzoek bleek dat er in Nederland, door de afwezigheid van een centrale registratie, weinig informatie beschikbaar is over het uitzetten van vis. Een dergelijke registratie is niet alleen van belang voor de uitvoering van het exotenbeleid, maar zou ook een belangrijk hulpmiddel kunnen zijn bij de preventie van visziekten. De visstandbeheerscommissies en de visstandbeheerplannen die door deze commissies zullen worden opgesteld vormen een goede mogelijkheid meer inzicht te krijgen in de uitzettingen van forellen en vis in zijn algemeenheid.

Op het moment is het legaal om met toestemming van de visrechthebbende regenboogforel of bronforel uit te zetten, ook in open systemen. Dergelijke uitzettingen in open systemen vinden momenteel niet plaats, maar garanties dat ze in de toekomst niet zullen plaatsvinden zijn er niet. Een duidelijke verankeringen van het preventieve exotenbeleid, in bijvoorbeeld de beoordeling van de visstandbeheerplannen die nog moet plaatsvinden, zou de kans op dergelijke uitzettingen ook voor de toekomst kunnen beperken.

Het is onder de huidige wetgeving niet toegestaan, zonder toestemming van de visrechthebbende, forellen te laten ontsnappen uit bijvoorbeeld viskwekerijen of tuinvijvers. Duidelijke communicatie van dit gegeven naar bijvoorbeeld waterschappen, waardoor deze handelend kunnen optreden, kan helpen dergelijke ontsnappingen te beperken.

Op het moment dat zich een populatie regenboogforellen of bronforellen heeft weten te vestigen, dan is de enige reële maatregel om een dergelijke populatie te verwijderen het afvissen met elektrovisserij. De overige beschikbare middelen kunnen te weinig selectief worden toegepast of beschikken over te weinig draagvlak om toegepast te kunnen worden.

Conclusie

Het wordt niet waarschijnlijk geacht dat de regenboogforel of de bronforel zich in Nederland als invasief gaan gedragen. Kleine, lokale vestigingen van vooral de bronforel zijn, zolang deze soorten in bijvoorbeeld Veluwse beken terechtkomen, echter niet uit te sluiten. Gezien de potentiële impact van genoemde soorten kunnen hierdoor lokaal negatieve effecten optreden. De basis voor de uitvoering van een preventief beleid lijkt echter aanwezig te zijn en biedt goede kansen dergelijke locale vestigingen te voorkomen.

Gezien de beschreven ecologische impact mag worden aangenomen dat ook uitzettingen die niet leiden tot de vorming van populaties negatieve gevolgen kunnen hebben. Dit behoorde echter nadrukkelijk niet tot de vraagstellingen van onderhavig rapport.

Summary

Potential invasive species
The salmonids are very popular both for consumption and angling. After the decline of the indigenous species several North American species have been imported to Europe. Several of these species have habitat requirements which are clearly not present in the Netherlands, e.g. their need for low water temperatures. Only the rainbow trout and the brook charr could not be excluded beforehand.

The pink salmon, Chinook salmon, Coho salmon, Arctic charr, Alpine charr and the American lake charr are not expected to have the possibilities to establish in the Netherlands.

Rainbow trout
The rainbow trout was first imported in Europe in the 19th century and from 1897 it was also present in Dutch fish farms. Currently rainbow trout are mainly found in the larger rivers, the IJssel lake and several isolated lakes in the southwest of the Netherlands. In the past it was also regularly found in smaller rivers and streams, like in the provinces of Limburg and Brabant. Nowadays it has become rare in such waters. But recently the rainbow trout has been caught in small numbers in some streams on the Veluwe.

The in the Netherlands recorded rainbow trout mainly originate from stockings in neighboring countries and from stockings in isolated waters (e.g. Lake Oostvoorne). Legal stockings in open water systems seem to occur in the Netherlands. Other noted sources are: fish farms, fishing ponds, garden ponds, zoos and illegal stocking.

The rainbow trout which are used in the both Europe and the Netherlands are highly domesticated fish with e.g. faster growth and less effective ant predatory behavior. Although the rainbow trout is extremely popular in aquaculture and innumerous stockings have taken place it has seldom settled in Europe. So far there are no reasons to declare the rainbow trout invasive within Europe. This is especially remarkable as its habitat requirements seem to be met in many rivers within Europe. Also in the Netherlands some potential habitat seems to be present, although restricted to the province of Limburg. The lack of result of the often large scaled stockings is probably a result of:

- biological resistance of aquatic systems, e.g. parasites or predators;
- the highly domesticated character of the rainbow trout which makes it less suitable for forming populations in comparison, e.g. because of a higher growth rate or less effective ant predatory behavior;
- the stocking of mainly females.

If this is actually the case the use of wild strains, which are in culture in North America itself, in combination with a normal sex ratio might have better results.

Brook charr

The first reports of the brook charr from Europe date from 1868. The first imports in the Netherlands are from around 1895-1900. Established population in Europe are mainly known from northern Europe and alpine region in Central-Europe. In northern Europe this species is considered invasive and a potential threat for indigenous fauna. From the Netherlands the brook charr is reported sporadically from the wild and at least a part of these records are uncertain. This because as recently turned out that the 'Elsässer saibling' occurs also in the Netherlands. This hybrid between brook charr and Alpine charr, is more popular in aquaculture then its parent species. This hybrid has a strongly reduced fertility, because of which it is not likely to establish in the Netherlands.

Only one established population of the brook charr is known from the Netherlands. This population has been present in the Geelmolense Beek (Veluwe) and originates probably from stockings from around 1900. This population was still present in the 1970s. In 2008 at least one brook charr was caught in the Geelmolense Beek. This specimen might also have escaped from the neighboring fish farm.

The few brook charrs from the Netherlands mainly originate from stockings in neighboring countries. Legal stockings in open water systems, like occurred in the past, are not taking place currently. The brook charr has recently been socked in Lake Oostvoorne. Other potential sources are: fish farms, fishing ponds, garden ponds, and illegal stockings.

The brook charr is a relatively versatile species, but is sensitive for high water temperatures. Waters with temperatures not exceeding 16°C regularly are restricted to headwater streams which are mainly found in the province of Limburg and on the Veluwe. In coexistence with the Atlantic trout the brook charr is restricted mainly to headwater streams also. With the Atlantic trout still being very rare in the Netherlands competition will rarely be limiting. Local establishment of the brook charr like already has been recorded from the Geelmolense Beek might be possible on more locations. It is not likely to become invasive even after such local establishment.

Impact

<u>Ecological impacts</u>

Both rainbow trout and brook charr can potentially seriously effect Dutch ecosystems due:

- Predation on native fish species such as the brook lamprey;
- Predation on native amphibians;
- Predation on native invertebrate species;
- Transmitting disease.

Impact is likely to be especially high in systems lacking large predatory fish before entry of salmonid species, such as headwater streams.

Competition between brook charr and Atlantic trout, which is considered a problem in some European countries, is unlikely with the rarity of the Atlantic trout. The Atlantic salmon seems not to be sensitive for competition of either species.

<u>Economic impacts and social impacts</u>
Exploitable populations will certainly be appreciated and have a small positive economic and social impact restricted to the angling society and business.

Prevention of spread, eradication and control methods
For creating an effective policy on stocking of fish in general and salmonids in particularly, information about the species and the numbers stocked in public waters are an important prerequisite. Such information is currently lacking. Making it obligatory to report any stockings to a central, independent organization (e.g. 'Visstandbeheerscommisies') could create better insight in stocking practices. This may not only serve policies on exotic species, but may have an even greater use in fish disease prevention.

The stocking of both rainbow trout and brook charr is legal in even the open water systems. Such stockings are not taking place currently, but guaranties for them not taking place in the future can not be given. Clear incorporation of invasive species policies in fisheries policies or legislation could decrease the chance of such stockings taking place in the future.

Under current legislation escapes from e.g. fish farms or garden ponds are not aloud without the permission of the owner of the local fishing rights. Clear communication of this might help e.g. water boards in minimizing such escapes.

The use of chemicals and intensive netting is only applicable to systems only containing the unwanted fish species. In the Netherlands only systematic electro fishing seems to be a probable option for eradication or control.

Conclusion
It is not likely that the rainbow trout or the brook charr will become invasive in the Netherlands. Small, localized establishments of especially the brook charr van not be excluded. Because of the potential impact of these species negative impact can occur on this local scale. Both legislations and policies in fisheries do give a good starting point for the preventing these local establishments and their subsequent impact.

1 Introduction

In the Netherlands, two species of salmonids are indigenous: Atlantic salmon and Atlantic trout. Both species have long been of interest both to recreational and commercial fisheries. After a strong decline in the 19^{th} century, of especially the Atlantic salmon, a growing interest in aquaculture resulted in the first introductions of exotic salmonids. It was believed that these introductions might compensate for the decline of the indigenous species. Since then several species have been introduced all over Europe, with two species standing out; rainbow trout and brook charr.

Exotic salmonids have the potential to cause serious ecological, economic and social impacts and can interfere with the goals of various European Directives such as the Water Framework Directive (WFD), Bird Directive and Habitat Directive.

In this study, commissioned by the Food and Consumer Product Safety Authority, a risk analysis was undertaken to provide more insight into the present distribution of exotic salmonids in the Netherlands, their (potential) impacts, the probability of entry (introduction pathways), the probability of establishment, the probability of further spread and endangered areas. Subsequently, measures are identified to prevent further spread of these species and eradication and physical control methods are described that could be used to reduce the number of exotic salmonids in the Netherlands.

2 Overview salmonids in the Netherlands and Europe

Exotic trout species are likely to interact with native salmonids and, therefore, lessons can be taken from experiences with these native species in regard to the likelihood of the establishment of exotic trout populations. In this chapter the indigenous species of the Netherlands are briefly introduced.

Furthermore, insight is given in the exotic species that have been introduced in the Netherlands nowadays or in the past. Also other exotic species with known established populations in other European countries are discussed as these species could also be introduced in the Netherlands.

2.1 Indigenous species

In the Netherlands both the Atlantic salmon and the Atlantic trout are indigenous. The **Atlantic salmon** is an anadromous migratory fish found in the temperate and arctic regions of the Northern Hemisphere. They are limited to the waters of countries bordering on the North Atlantic Ocean and Baltic Sea (Kottelat & Freyhof, 2007). This species was once common in the Netherlands, although spawning Atlantic salmon have never been recorded in the Netherlands itself (Redeke, 1941). Its spawning grounds were previously found in the Alps and lower mountainous regions like the Vosges Mountains, the Eifel and the Ardennes (De Nie, 1996).

Figure 2.1: Atlantic salmon adult and smolts. Photos: Hans-Petter Fjeld & U.S. Fish and Wildlife Service.

Atlantic salmon has a strong homing behavior, normally returning to its native rivers. Some may wander to other rivers, but the majority will return to the river they were born. Because of this there is differentiation between different river systems. An Atlantic salmon from the Loire river differs in e.g. its migratory behavior from those from the former population of the Rhine.

In the 19th century the river Rhine and the river Meuse and their tributaries have been radically changed by dredging and straightening. This has altered the flow, clarity and temperature of these waters. Overfishing has diminished Atlantic salmon populations; the growing industry polluted the rivers with toxic substances and communities added raw sewage. Eventually, the Atlantic salmon disappeared from both the river Rhine and the river Meuse (fig. 2.2). Between 1957 and 1989 only six Atlantic salmons were caught in river Rhine; three of them had Scandinavian tags (De Nie, 1996).

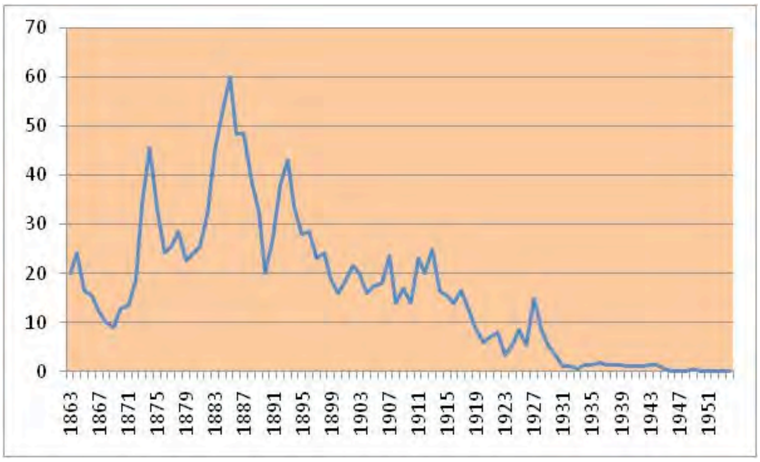


Figure 2.2: Numbers of Atlantic salmons per year presented at the fish auctions in the Netherlands (x 1000) between 1863 – 1954. Based on data from www.compendiumvoordeleefomgeving.nl.

The international Rhine Action Programme, which started in 1987, included measures for the reintroduction of the Atlantic salmon. This programme includes the restoration of spawning grounds and nursing areas. To recreate the original migration routes, fish ladders and passages are being built to overcome dams and power stations. The first Atlantic salmon migrated from the sea and the Lower Rhine into the Sieg River in 1990 (Steinberg *et al.* 1991). Also the first natural reproduction of Atlantic salmon was proved for the Sieg River system in the winter 1993/94. Successful natural reproduction was also observed in the following years in the Sieg and in other tributaries of the Rhine. The present condition of the spawning grounds and the migration barriers downstream, allows a small partial return of self-reproducing populations in the Rhine. The return of the Atlantic salmon to the Rhine is a result of the improved water quality, better dissolved oxygen concentrations and of intensive repeated stocking in the upstream regions of the Rhine and its main tributaries. Past destruction of the habitat, however, has been that dramatic that the current programme has only laid the groundwork for a possible, and very gradual, return to the Rhine. A full recovery of the past populations is unlikely (Brenner *et al*., 2004).

The native range of the **Atlantic trout** includes most European river drainages that flow in the Atlantic Ocean, North Sea, Baltic Sea and White Sea (Kottelat & Freyhof, 2007). Although nowadays the Atlantic trout is more common in the Dutch Rhine compared to the Atlantic salmon (fig. 2.4), this species has been a relatively rare species throughout

(De Nie, 1996). According to Redeke (1941) the Atlantic trout has been common in the southern parts of the province of Limburg. Although also Marquette (in lit) mentions the presence of populations in 1920-1930 in several streams in southern Limburg (Geul, Voer & Noor), this is probably an exaggeration. Aalderink (1911), who was in general well informed, actually only mentions the Geul as being a stream that harbored high enough numbers for trout fishing, but already in his time numbers had strongly declined due to poaching. Nowadays the Atlantic trout has no natural populations in the province of Limburg. It is still present in many streams, but this is the result of stocking (Crombaghs *et al*., 2000), although unconfirmed records of natural reproduction might suggest that it has recently established (R. Gubbels, pers. com.).

Figure 2.3: Adult and a juvenile Atlantic trout. The juvenile is a specimen from the Heelsumse Beek, Gelderland. Photo's: Sportvisserij Nederland & Matthijs de Vos.

The status of the Atlantic trout outside Limburg is even more debated. Redeke (1941), Aalderink (1911) and Bennet & Van Olivier (1825) all mention this species' presence in the province of Gelderland but without mentioning the actual sites. As stocking started around 1850, the reference to this species by Bennet & Van Olivier in 1825 at least suggests a natural occurrence in this province. Nowadays the only known naturally reproducing population in the Netherlands is in this province.

In 2004 a natural reproducing population was found in the Heelsumse Beek. With single historical records in 1975 and 1991/1992, it was assumed that this population existed for at least several decades. It might actually originate from stockings in the Heelsumse Beek or the Renkumse Beken in the late 19th century. These stockings were ordered by Willem III, who lived nearby and was a fanatic recreational fisherman (Soes & Spaans, 2005). Natural reproduction could be confirmed at least until 2009 (D.M. Soes, pers. obser.)

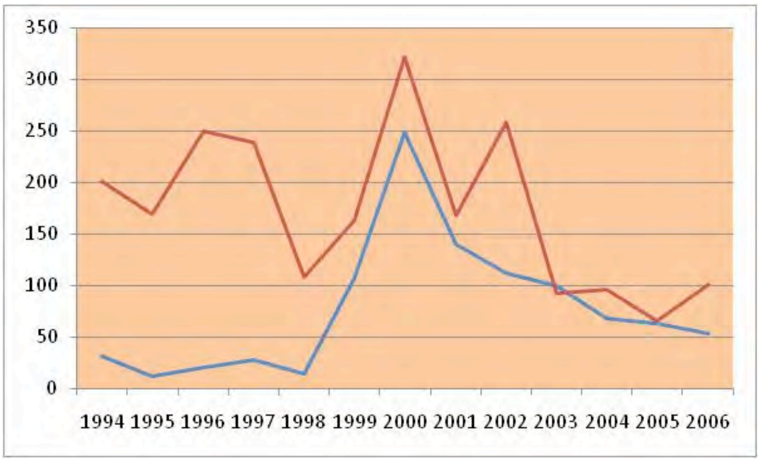


Figure 2.4: Numbers of Atlantic salmons (blue) and Atlantic trout (red) per year caught in the IMARES monitoring program between 1994 – 2006. Based on data from www.compendiumvoordeleefomgeving.nl.

De Groot (2002) mentioned a specimen of **Arctic charr** caught in the IJssel lake. He suggests that this might actually be a vagrant instead of an escape. With European populations of this species being anadromous above 65°N this should indeed be considered as a possibility. Both Naturalis, ZMA and IMARES have been asked for specimens of Arctic charrs, hoping to find the specimen mentioned by De Groot. No specimens were present in these collections. As the Arctic charr is regularly confused with brook charrs, Alpine charrs or hybrids the identity of the specimen mentioned by De Groot (2002) should be considered uncertain.

2.2 Salmonid aquaculture and first introductions of exotic salmonids in the Netherlands

In the 19th century fisheries intensified with improved techniques. This also increased the interest in artificial reproduction to ensure future catches. To speed up this process King Willem III installed in 1852 a commission with the task to develop the culture of fish, 'Commissie voor de Vischfokkerij'. In the 1860s this gave rise to experimenting with Atlantic salmon, Atlantic trout and probably charrs (*Salvelinus alpines/umbla*). With the first successes Atlantic salmon were stocked in the larger rivers and Atlantic trout in streams and ponds of larger, mainly royal estates (Van Drimmelen, 1987).

After a display of American aquaculture at the America Exhibition in 1876 several European countries, including the Netherlands, showed interest in trying American species. In 1877, 100,000 eggs of the Chinook salmon were ordered and shipped from California, USA to the Royal Zoological Garden Artis, Amsterdam. Mather (1879) describes the journey of these eggs. They left California on the 7th of October 1877 by refrigerator car to New York. From here they were shipped with a 13-day journey to Bremerhaven before again being transported by car to Artis. By that time a large number of the eggs had already hatched, in what might have been the reason for the failing of

Artis to raise juvenile Chinook salmon from this first shipment. A second shipment was more successful and in 1879 50,000 juvenile Chinook salmon were released in the Meuse River near Tegelen. These experiments have been repeated in 1880 and 1881 (Nijssen & De Groot, 1987). Including the more extensive programs in Germany and France these stockings have failed in creating established populations (Kottelat & Freyhof, 2007).

Figure 2.5: Chinook salmon and rainbow trout Photos: U.S. Fish and Wildlife Service.

In the 19th century two other American salmonids were imported in Europe: rainbow trout and brook charr. These two species have been much more successfully incorporated into the European aquaculture and are still of great importance today. Also both of these species have established populations in several European countries (Kottelat & Freyhof, 2007). The fish farm Zwaanspreng (Beekbergen) was, in 1897, the first Dutch farm to import the rainbow trout. It succeeded in creating a successful program and the first 1,500 rainbow trout were stocked in 1898 in the waters surrounding 'Fort benoorden Spaarndam' (Nijssen & De Groot, 1987). Ever since the rainbow trout has been regularly cultured, stocked and caught in the Netherlands. Spontaneous reproduction is only known under artificial circumstances and has not yet been observed in the wild (Soes, 2005).

The brook charr has been introduced to Europe even earlier, in 1868. It quickly settled into German and French aquaculture. The first introduction in the Netherlands is hardly recorded (Nijssen & De Groot, 1987). Mulier (1900) mentioned it to be introduced between 1895 and 1900. It has not become as popular as the rainbow trout and its introductions have been relatively scarce. One of these introductions has been successful in creating an self-sustaining, but very local population (Soes *et al.*, 2009).

2.3 Other exotic salmonid species in Europe

Within Europe, besides the rainbow trout and brook charr only the American lake charr and the pink salmon have been successfully introduced (Kottelat & Freyhof, 2007). The American lake charr is native to North America from the Great lakes to Alaska. In the Great Lakes it has greatly suffered from the introduction of the European sea lamprey

(*Petromyzon marinus*) (Schneider *et al*., 1996). The species has been widely introduced outside its native range in many parts of the western United States and in other areas, including New Zealand and South America (Page, 1991). In Europe, established populations have been reported from lakes in France (Pyrénées), Germany (very local), Switzerland, northern Italy, Sweden and Finland (Lapland) (Keith & Allardi, 2001; Kottelat & Freyhof, 2007; Welcomme, 1988).

Lakes containing populations of American lake charr can be been described as large, deep, cold and well oxygenated. Temperature is a critical factor influencing lake trout. During field studies, lake trout are rarely found at water temperatures above 10 to 12°C (Marcus *et al*., 1984). As such lakes are absent in the Netherlands the American lake trout is not likely to establish here.

Figure 2.6: American lake charr. Photo: U.S. Fish and Wildlife Service.

The pink salmon is native to the northern Pacific basin in Russia, Japan, North China and North America. It has been introduced successfully in northern Finland and Russia with adults that migrate into the White Sea (Kottelat & Freyhof, 2007). Specimens from these introductions have turned up in Scottish and Irish waters (Maitland, 2004). For reproduction this salmon needs relatively cold and clean coarse gravel beds, which are not available in the Netherlands (Raleigh & Nelson, 1985). Also this species does not find is habitat requirements in the Netherlands and is not expected to establish.

Figure 2.7: Pink salmon. Photo: U.S. Fish and Wildlife Service.

Several salmonid species have been more or less incidentally introduced in Europe. None of these species has established, but one of them is worth mentioning as it has been recorded in the Netherlands. The Coho salmon, a species indigenous to the Pacific coast of Northern America, has been introduced in France (Bretagne and Normandie) in 1974 and 1975. A total of 60,000 one-year-old specimens were released. In 1982 two of them were caught in the Calandkanaal (Rotterdam) and in 1984 one specimen in the boat lifts of IJmuiden (Nijssen & De Groot, 1987). More recent records in Europe seem to be absent.

Figure 2.8: Coho salmon Photo: Twin Peaks Adventures.

Table 2.1: Overview of discussed salmonid species giving the English, Dutch and scientific names. Both the English and scientific names follow Kottelat & Freyhof (2007). For Dutch names Nijssen en De Groot (1987) are followed. Per species the reported status in the Netherlands and Europe is given, including the historical records.

			established	
English name	Dutch name	*Scientific name*	the Netherlands	Europe
pink salmon	bultrugzalm	*Oncorhynchus gorbuscha*	no	yes
rainbow trout	regenboogforel	*Oncorhynchus mykiss*	no	yes
Chinook salmon	Chinookzalm	*Oncorhynchus tshawytscha*	no	no
Coho salmon	Cohozalm	*Oncorhynchus kisatch*	no	no
Atlantic salmon	Atlantische zalm	*Salmo salar*	native	native
Atlantic trout	forel	*Salmo trutta*	native	native
Arctic charr	beekridder	*Salvelinus alpinus*	no	native
Alpine charr	beekridder	*Salvelinus umbla*	no	native
brook charr	bronforel	*Salvelinus fontinalis*	yes	yes
American lake charr	Amerikaanse meerforel	*Salvelinus namaycush*	no	yes

2.4 Salmonid species considered

Although many more species have been introduced in Europe, only rainbow trout and brook charr cannot be directly excluded to be able to establish populations in the Netherlands. In this report on invasive salmonids only these two species will be considered further.

3 Biology and ecology of the rainbow trout

3.1 Taxonomy

The taxonomy of the rainbow trout has caused long-term confusion. It has been known by over thirty scientific names, e.g. *Salmo gairdneri*, *S. irideus*, *Parasalmo gairdneri* and *Oncorhynchus mykiss*. The latter being the currently accepted name (Fishbase.org).

There are up to 15 native subspecies of rainbow trout in the western United States and Pacific Ocean. The actual number of recognized subspecies depends on the source. Some authors prefer to treat several of the subspecies, such as the Asian populations, as true species. If the Asian subspecies would be treated as a true species this will consequently mean that the rainbow trout present in Europe, which is from American origin, might be named *Oncorhynchus gairdneri* (Kottelat & Freyhof, 2007).

A steelhead trout is a sea run rainbow trout usually returning after two to three years at sea. It is not a subspecies or another taxon with taxonomic value, although it is important to recognize that there is a genetic or hereditary basis for its migratory behavior.

A 'golden trout' (goudforel) is not one of the subspecies of the rainbow trout but an aquaculture strain much appreciated for stocking in, for example, fish ponds.

Figure 3.1: Golden trout in a English farm pond (Photo: Morrisons).

In the Netherlands the name 'zalmforel' is much used for large rainbow trout with relatively pink meat. This color is achieved with adding (natural) carotenes in its food. These carotenes are not a problem for human health.

<u>Domesticated rainbow trout</u>
Many of the cultured strains of trout derive from the initial stock of the McCloud river hatchery in the 1880s. These trout belong to the subspecies *Oncorhynchus mykiss stonei*. This subspecies is residential and lacking migratory behavior (Vandeputte *et al.*,

2008). Further domestication included probably other subspecies, including steelheads. The level of genetic diversity in northern European rainbow trout strains is comparable with that of the North American domesticated strains and wild populations, indicating that the northern European rainbow trout strains have not significantly lost their variability due to breeding practices (Gross *et al*., 2007).

In the domestication process the rainbow trout obtained significant differences compared to wild strains. In a study where a wild strain was compared with a number of hatchery strains, growth performance of the wild strain was only half that of an average hatchery strain. Such differences illustrate the high divergence between wild and domesticated strains. Also large behavioral differences exist between wild and domesticated strains. Domesticated strains show much lower anti-predator and higher agonistic behavior (Vandeputte *et al*., 2008).

3.2 Description and identification

Rainbow trout have a typical salmonid shape, although body shape and coloration vary widely with habitat, age, sex, and degree of maturity. The back of the fish varies from blue-green to olive. Along the side of the body there is a reddish-pink band. The belly is usually silver. Small black spots are present on the back above the lateral line, and on the dorsal fins and tail. Rainbow trout from rivers and streams have normally the most intense pink stripe coloration and heaviest spotting followed by fish from lakes and lake-stream systems. Spawning trout are characterized by generally darker, more intense coloration (Johnsson, 2006; Kottelat & Freyhof, 2007).

Figure 3.2: Rainbow trout (Photo: J. Hunder)

3.3 Distribution

3.3.1 Native range

The rainbow trout is native to the drainages of the United States Pacific Coast from Alaska to Mexico, the waters of the Pacific Ocean and the eastern coast of Asia. The American natural range goes from the Kuskokwim River region of Alaska to the Baja

California Peninsula and the coastal rivers of Mexico. In Asia it is native from Kamchatka and south to the Amur drainage, Siberia (Kottelat & Freyhof, 2007).

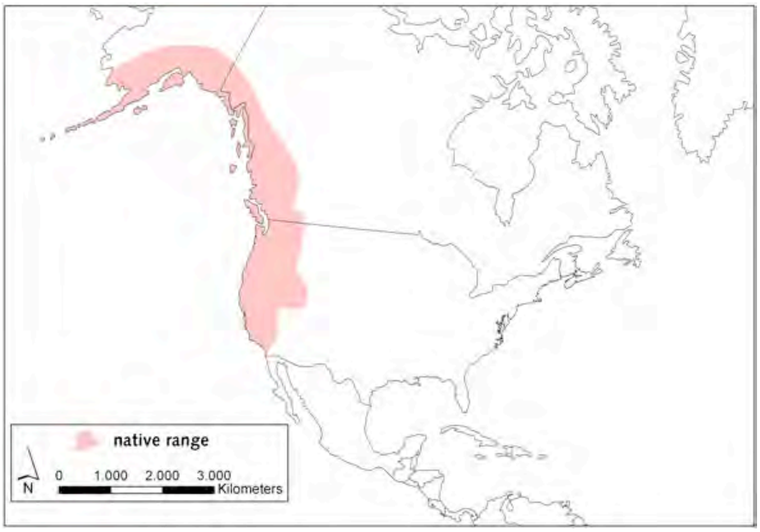


Figure 3.3: The native range of the rainbow trout within North America.

3.3.2 Established exotic populations

The rainbow trout is one of the most widely introduced fish species (Fausch, 2007). It has been introduced in over a hundred different countries in Europe, Asia, Africa, Oceania, North, Central and South America (table 2.1). Although the majority of introductions might have failed, it has established several populations on every continent on which it has been introduced to (Welcomme, 1988). In tropical regions it is restricted to areas above 1200 meters (Johnson, 2006).

Table 3.1: Overview of the introductions of the rainbow trout. Known dates of the first introduction and information on establishment are given. Data: Fishbase.org, Nobanis.org & Welcomme (1988).

Africa		
Azores Is.	unknown	established
Cameroon	unknown	unknown
Congo	1940	probably not established
Eritrea	unknown	established
Ethiopia	1967	established
Kenya	1905	established
Lesotho	unknown	probably established
Madagascar	1922	established
Madeira	unknown	established
Malawi	1906	established
Mauritius	1934	not established
Morocco	1925	probably established
Mozambique	unknown	unknown
Reunion	1940	established
South Africa	1897	established
Sudan	1947	probably established
Swaziland	1908	probably established
Tanzania	1927	probably established
Tunisia	1967	not established
Zambia	1942	not established
Zimbabwe	1910	established

Asia		
Afghanistan	unknown	established
China	1959	probably not established
India	1906	probably established
Indonesia	1929	not established
Iran	1966	established
Iraq	1968	not established
Israel	unknown	established
Japan	1877	established
Jordan	1966	established
Kazakhstan	1964-1966	established
Korea	1965	established
Kyrgyzstan	unknown	established
Lebanon	1960	not established
Malaysia	1935	probably not established
Nepal	1971	probably established
Pakistan	1918-1928	established
Sri Lanka	1889	established
Syria	1950-1974	not established
Taiwan	1957	probably established
Thailand	1973	not established
Turkey	1969	established
Ukraine	unknown	unknown
Uzbekistan	1976-1979	established

Oceania		
Australia	1894	established
French Polynesia	unknown	not established
Hawaii	1920	established
Kerguelen Is.	1959	established
New Zealand	1877	established
Papua New Guinea	1952	established
Tahiti	unknown	not established

Europe		
Austria	1885	established
Albania	1950-1974	probably established
Belgium	1882	not established
Bulgaria	1897	probably established
Cyprus	1969	probably not established
Czech Republic	1891	established
Denmark	1894	established
Estonia	1896	established
Finland	1897	probably not established
France	1879	established
Germany	1882	established
Greece	1950	probably established
Hungary	1885	established
Iceland	1951	established
Ireland	1900-1910	probably established
Italy	1895	established
Latvia	unknown	established
Liechtenstein	1900	probably not established
Lithuania	unknown	established
Luxembourg	1946	probably established
Netherlands	1898	not established
Norway	1900-1910	established
Poland	1882	established
Portugal	1909	established
Rumania	1885	established
Russia	1974	established
Slovakia	1891	established
Spain	1890-1899	probably established
Sweden	1891	established
Switzerland	1882	established
U.K.	1884	established
Yugoslavia	1891	established

South, Central & North America		
Argentina	1904	established
Bolivia	1942	established
Brazil	1913	probably established
Canada	1887	established
Chile	1905	established
Columbia	1926	probably not established
Costa Rica	1954	established
Dominican Republic	1985	established
Ecuador	1928	probably established
Guatemala	1982	unknown
Guyana	unknown	probably not established
Honduras	unknown	established
Mexico	unknown	probably not established
Panama	1925	established
Peru	1927	established
Puerto Rico	1934	probably not established
Uruguay	1957	not established
Venezuela	1934	probably established

Populations in Europe

The rainbow trout is common and widespread in European streams and lakes, but in most waters maintained only by regular stocking of hatchery-reared fishes. Several self-sustaining populations have established in alpine/hill streams in northern, central and southern Europe. Larger populations are known from Austria, Slovenia, Switzerland and the Serchio drainage (Italy). Probably several instances of natural reproduction have been overlooked because it masked by stocking (Kottelat & Freyhof, 2007).

Peter *et al*. (1998) found that non-native rainbow trout invaded the Alpine Rhine River and artificial channels tributary to it in Switzerland and Liechtenstein that were once occupied solely by native brown trout. They reported that the stable flow and temperature regimes produced by flow regulation allowed rainbow trout to begin spawning earlier than before, in late autumn. Moreover, their eggs incubated faster than brown trout, so rainbow trout fry began emerging at about the same time as brown trout and were of similar size, instead of smaller as is usual.

Populations in North America

The rainbow trout has been introduced to all U.S. states outside their native range (Fuller *et al*., 1999). Rainbow trout have been highly successful at establishing reproducing populations in the Southern Appalachian Mountains and have had moderate success in other regions, such as in the central Rocky Mountains, establishing reproducing populations in certain locations but not others (Fausch *et al*., 2001).

3.3.3 Colonization of the Netherlands

In 1898 the first rainbow trout have been stocked in the Netherlands. These fish originated from the Dutch fish farm Zwaanspreng. Ever since, the rainbow trout has been regularly cultured, stocked and caught in the Netherlands.

3.3.5 Current distribution in the Netherlands

In figure 2.4 and in appendix 2.2 an overview of the known records of the rainbow trout in the period 1983-2009 are given. Most records are from large rivers and the IJssel lake. It is especially regularly recorded in the river Meuse, with almost yearly records in the period 1993-2004 and in the IJssel lake. Numbers are small, mostly single specimens.

In the first half of the 1990s it was encountered relatively regularly in a number of streams in the province of Limburg, e.g. Geul, Voer and Swalm. Currently, it is much less frequent recorded, except in the Roer (R. Gubbels, pers. com.). In 2009, a monitoring program in a fish ladder in the river Roer near Roermond registered in total 4,558 fish. Of these fish 1,121 were salmonids (mainly Atlantic salmon and Atlantic trout). Rainbow trout were caught with a total of 11 specimens (W. Vergoossen, pers. com.). Also other records outside the larger rivers are largely from before 2000, e.g. the records in the province of Brabant and Drenthe.

Rainbow trout have also regularly been recorded from the Geelmolense Beek. Numbers are relatively high with 24 specimens in 2000, 11 in 2002 and 21 specimens in 2008. In 2008 different sizes were caught: 5, 10, 12, 35 and 40 centimeters. This indicates multiple escapes/releases or reproduction. According to the owner of the fish farm alongside the Geelmolense Beek, escapes are much more likely.

Figure 3.4: Records of the rainbow trout in the Netherlands. Made by Bureau Waardenburg.

Spontaneous reproduction is only known under artificial circumstances and has not yet been observed in the wild (Soes, 2005). Spontaneous reproduction is artificial circumstances is reported three times from the Veluwe. Rainbow trout stocked in a garden pond fed with ground water did produce some offspring, no further details are known (R. Neuteboom-Spijker, pers. com.). In Zoo Parc Wissel rainbow trout reproduced and some of the offspring did escape in the stream, which was connected with the different ponds within the zoo. For more details see §5.

In the 1970s a large number of rainbow trout were kept in a large groundwater fed pond (bronvijver). This pond is part of the estate 'Landgoed Bronbeek' in Arnhem. The stocked rainbow trout did create nests in the sand, which were well provided with oxygen due to the groundwater pressure present. The juveniles could escape predation because the edges of the pond were reinforced with metal boards with holes, which provided suitable hiding places (F. Moquette, pers. com.). When Landgoed Bronbeek was visited in 2010 no more rainbow trout were present and the pond looked unsuitable with its shallow water and weak current. It differed with the period rainbow trout were present due to less intensive maintenance and lower ground water levels compared with the 1970s.

3.4 Life history

3.4.1 Life cycle

Female rainbow trout normally become sexually mature in their third year. Males become sexually mature in their second or third year. Life expectancy in its original range averages three to five years in most southern lake populations, but life expectancy of steel head and northern lake populations might be four to eight years. Maximum size is also variable with population, area, and habitat. Steelhead may grow to 1.2 meter long and a weight of 16 kg, but in many streams it does not grow much larger then 40-50 centimeters (Raleigh *et al*., 1984).

Rainbow trout are well known for having anadromous populations. Also exotic populations can be anadromous such as one population from Norway (Saegrov *et al*., 2005). Juveniles live in freshwater for one to four years before migrating to the sea as smolts. They mature after spending one to four years in ocean waters and return to freshwater rivers to spawn. High numbers of the steelhead adults die after the first spawning, but some (3 to 53%) return to the ocean and spawn again the next year. There are both winter and summer-run steel head. Summer-run adults return in the spring and early summer. Winter-run steel head return rivers in the autumn and winter (Raleigh *et al*., 1984).

3.4.2 Reproduction

Rainbow trout usually spawn between February – May when temperatures raise above 10-15 °C. Hatchery selection has resulted in autumn spawning strains and, depending on the strain, the spawning of hatchery fish may occur in almost any month of the year (Behnke 1979). The rainbow trout is not capable of breeding when the peak emergence of fry corresponds to flood season and if temperatures do not fall below 13 °C.

The female generally selects a redd site ('nest' site) in gravel substrate at the head of a riffle or downstream edge of a pool in fast flowing water. Here the female excavates a hollow in the streambed gravel for the eggs. Between 700 and 4,000 orange-red eggs are laid per spawning event. The male then fertilizes the eggs and they are covered with a layer of gravel. The fecundity is approximately 2,000 eggs per kg somatic mass of females (Johnson, 2006; Kottelat & Freyhof, 2007).

Females only
In many cultured fish species, one of the sexes may have better production characteristics than the other or is more valuable in the market. In rainbow trout males mature earlier than females and during maturation undergo significant changes in appearance, growth and flesh quality which negatively influence the market value. Thus all-female stocks are preferred for large or salmon-trout (zalmforel) production. There are three ways of monosex rainbow trout production (Piferrer, 2001; Okumus, 2002; Vandeputte *et al*., 2008):

Direct feminization
In this process fish are treated during early development in the embryo or early feeding stages with estrogens to feminize them. This treated stock is not suitable as a brood stock.

Indirect feminization
This method includes a genetic modification and requires initially two generations to accomplish. The first step is to produce brood stock males that are genetically female and called a neomales or masculinised female. For this purpose, mixed sex first feeding fry are masculinised with methyl testosterone and grown to sexual maturity and aloud to develop testes and male secondary sexual characteristics. In the second step the males are used to fertilize normal eggs. The phenotypic males producing only female sperm (XX) will produce all female offspring. To identify the masculinised females a progeny test is performed.

Once an all-female stock has been achieved, it is relatively easy to maintain by masculinising every year a small portion of the offspring, thus closing the production cycle. The untreated part of the stock is grown out and marketed as females or retained as brood stock.

Triploids
Triploid trout can be obtained by heat shock or pressure shock following fertilization. Triploids are sterile; females develop no gonads while only male develop small testes. Unlike diploids, triploid fish do not mature sexually, and there is no decrease in flesh quality. However, the growth and survival of triploids is slightly lower than diploid fish. The growth rate of triploid families is strongly correlated with that of diploids from the same families, enabling genetic gain obtained in diploid fish to also be realized in triploid fish. The production of triploids is almost exclusively performed with all-female strains for a better production.

Also in the Netherlands stocking in fish farms, trout fishing ponds and isolated waters regularly involves all-female stockings. These all-female stocks result from indirect feminization as hormonal treatment of fish for human consumption and triploids are not (yet) accepted by consumers (G. Hertgers, pers. com.). The extent of all-female stockings compared to mixed stockings in the Netherlands is unclear.

3.4.3 Habitat

Optimal rainbow trout stream habitat is characterized by (Raleigh and Duff, 1980):
- oxygen rich, cold waters with relatively stable flow and temperatures;
- silt-free rocky substrates in riffle-run areas;
- an approximately 1:1 pool-to-riffle ratio, with areas of slow, deep water;
- well-vegetated stream banks;
- abundant cover in the stream itself;

The vegetation cover of banks is both important for maintaining low water temperatures and providing sufficient food (terrestrial insects) (Modde *et al*., 1986).

Lakes with large rainbow trout populations are in general cold, deep, oligotrophic lakes, but when the oxygen requirements are met they may also populate lakes with less favorable chemical qualities, particularly in reservoir habitats. Rainbow trout are primarily stream spawners and need tributary streams with gravel substrate in riffle areas for reproduction to be present (Raleigh *et al*., 1984).

3.4.4 Diet

Rainbow trout are opportunistic feeders (Goldstein and Simon, 1999). Their diet includes a wide variety of animal foods, depending upon size and habitat. Caddis flies, stoneflies, mayflies, and crane flies are important foods for fish inhabiting small streams, as well as larger prey such as crayfishes, salamanders, and frogs. Terrestrial preys known to be eaten are: earthworms, beetles, butterflies, moths, bees, and wasps, and almost half of diet may consist of these terrestrial preys (Needham 1969; Johnson, 1981; Cada *et al*., 1987). Daphnids are an important food in lakes (Galbraith, 1967).

Species will feed in a stream while maintaining position in current velocities of 13-21 cm/s. Dominant hierarchy among resident fish will determine the division of feeding stations being defended in a stream (Jenkins, 1969). Larger fish weighing in excess of 1-

2 kg usually feed especially at night and take larger prey such as fishes (Needham, 1969). Smaller rainbow trout tend to be inactive at night (Hill and Grossman, 1993). A study of rainbow trout in a Texan river, found this species to actively pursue drift prey. Drift declined during summer months and foraging efforts changed towards the benthos, with mayflies and snails becoming abundant in the diet (Halloran, 2000). At sea they feed mainly on fish and cephalopods (Kottelat & Freyhof, 2007).

In 2005 the stomach contents of 15 rainbow trout specimens collected from the Lake Oostvoorne in the Netherlands were analyzed, see table 3.2. Even in this relatively small sample a high diversity of prey items was found. Larger specimens had fish in their stomach but also small food items such as mud snails and isopods. Smaller specimens (<40 cm) mainly predated on invertebrates. As rainbow trout are thought to be mainly visual predators reacting on movement, it is remarkable that one of the trout had taken two lagoon cockles (*Cerastoderma glaucum*). This diet seems to favor the rainbow trout of this lake as they were in excellent condition (fig. 3.5) (Bonhof *et al*., 2007) and have a good growth rate of two centimeters per month (Gerlag, 2002).

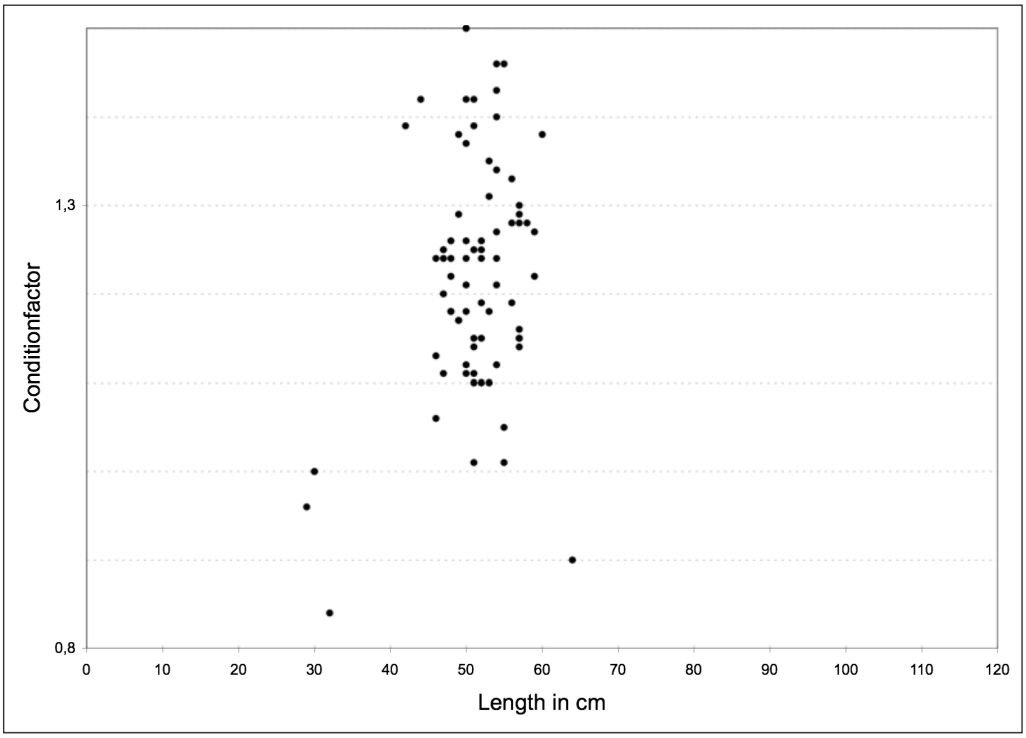


Figure 3.5: Condition of 71 specimens rainbow trout caught in Lake Oostvoorne in 2005. The condition factor and total length (cm) per specimen are given.

Table 3.2: Stomach contents of rainbow trout caught in 2005 (Bonhof et al., 2007). The total length (length) and the numbers per prey item are given.

		length														
Scientific name	English name	29	30	32	38	38	41	49	50	50	50	50	52	54	56	59
Polychaeta	polychaetes			1	1					1	1		1			
Hydrobiidae	mud snails	1			5	1	3		1			6	2			
Cerastoderma glaucum	lagoon cockle												2			
Branchiopoda	water fleas		1													
Amphipoda	amphipods	8	7	1	7	20	15			9	7	6	8	2	6	
Isopoda	isopods	94	56	4	92	2	14		2	23	12	59	26	14	5	16
Palaemonetes varians	common ditch shrimp												1			
Corixidae	water boatmen									1						
Chironomidae (adult)	chironomids (adult)												1			
Gasterosteus aculeatus	three-spined stickleback									5	3	4		3	1	2
Pomatoschistus microps	comon goby					1		1		1		2				1
Zoarces viviparus	viviparous eelpout							1						1		

3.4.5 Predators

The main predators of the rainbow trout are piscivorous fish species including their own kind, birds like herons and cormorants, aquatic mammals like otters, and humans.

3.4.6 Parasites and diseases

There are a variety of diseases and parasites that can affect rainbow trout; several of the more important ones are summarized in the table below.

Table 3.3: Recorded diseases of the rainbow trout. Source Fao.org

DISEASE	AGENT	TYPE	SYNDROME
Furunculosis	Aeromonas salmonicida	Bacterium	Inflammation of intestine; reddening of fins; boils on body; pectoral fins infected; tissues die back
Similar to furunculosis	Aeromonas liquefaciens	Bacterium	Smaller lesions on body that become open sores; fins become reddened and tissues break down
Vibriosis	Vibrio anguillarum	Bacterium	Loss of appetite; fins and areas around vent and mouth become reddened; sometimes bleeding around mouth and gills; potential high mortality
Bacterial kidney disease (BKD)	Corynebacterium	Bacterium	Whitish lesions in the kidney; bleeding from kidneys and liver; some fish may lose appetite and swim close to surface;
Bacterial gill disease	Myxobacterium	Bacterium	Loss of appetite; swelling and reddening of gills; eventually gill filaments mass together and become paler with a secretion blocking gill function in later stage
Infective Pancreatic Necrosis	IPN	Virus	Erratic swimming, eventually to bottom of tank where death
Infective Haematopoietic Necrosis	IHN	Virus	Erratic swimming eventually floating upside down whilst breathing rapidly after which death occurs; eyes bulge; bleeding from base of pectoral fins, dorsal fin and vent
Viral Haemorrhagic Septicaemia	VHS	Virus	Bulging eyes and, in some cases, bleeding eyes; pale gills; swollen abdomen; lethargy
White spot	Ichthyophthirius multifilis	Protozoan	White patches on body; becoming lethargic; attempt to remove parasites by rubbing on side of tank
Whirling disease (Myxosomiasis)	Myxosoma cerebralis	Protozoan	Darkening of skin; swimming in spinning fashion; deformities around gills and tail fin; death eventually occurs
Hexamitaisis Octomitis	Hexamita truttae	Protozoan	Lethargic, sinking to bottom of tank where death occurs; some fish make sudden random movements
Costiasis	Costia necatrix	Protozoan	Blue-grey slime on skin which contains parasite
Fluke	Gyrodactylus sp.	Trematode	Parasites attached to caudal and anal fins; body and fins erode, leaving lesions that are attacked by Saprolegnia
Trematodal parasite	Diplostomum	Trematode	Eye lens cloudy; loss of condition

4 Biology and ecology of the brook charr

4.1 Taxonomy

The brook charr is in contrast to the rainbow trout a rather monotypic species with no recognized subspecies (Fishbase.org). In the past the Aurora trout has been considered as a subspecies of the brook charr, but Aurora trout are known to have existed with sympatric populations of brook charr in their native lakes with little genetic mixing. This supports the recognition of Aurora trout as a distinct evolutionary unit and its present status as a species (Aurora trout Recovery Team. 2006).

Both popular names brook trout and brook charr are used for the same species. As it is included within the charrs (*Salvelinus sp*.) in this report the name brook charr is preferred.

4.2 Description and identification

A relatively easily recognizable species of charr by its dark green marbling on the back marked with paler vermiculations or marbling that extend onto the dorsal fin and sometimes the caudal, in combination with lighter sides marked with numerous pale spots and some red spots, each of the latter surrounded by a blue halo. The caudal fin is nearly straight or shallowly concave. Anal, pelvic and pectoral fins have a white edge followed by a black stripe, the rest of the fins being reddish. Sea-run fish are dark green above with silvery sides, white bellies and very pale pink spots (Fishbase.org; Kottelat & Freyhof, 2007).

Specimens from aquaculture and also stocked brook charr might be less distinctive due to genetic introgression with Alpine/Arctic charr (*S. alpines* s.l.) (Gross *et al*., 2004).

Figure 4.1: Brook charr from the Geelmolense Beek, the Netherlands. Photo: G. Hoefsloot.

The 'Elsässer saibling' problem

During the research for this report it was noted that several *Salvelinus*-specimens caught in Dutch trout farms and presented on the internet were hard to identify as brook, Arctic or Alpine charr. Most specimens had clear intermediate characters suggesting hybrids. When these pictures were presented to Dietmar Firzlaff, a German trout farmer, they actually turned out to be 'Elsässer saibling'. This hybrid had not been recorded before from the Netherlands. On 12 March 2010 another 'Elsässer saibling' was identified from Limburg. This specimen was caught during a monitoring program of a fish ladder in the river Roer near Roermond. The Roer is a tributary of the river Meuse. This showed that this hybrid is also found in the wild. The specimen from the Roer probably originated from a German trout farm in more upstream parts of the Roer (F. Moquette, pers. com.).

Figure 4.2: An 'Elsässer saibling' from the river Roer Photo's: Thijs Belgers.

The true 'Elsässer saibling' is a cross between Alpine charr (*S. umbla*) and brook charr (*S. fontinalis*). It is called so as it has been produced for the first time in the "Kaiserlichen Fischzuchtanstalt Hüningen" in the Elsass, nowadays France but formerly Germany (Petz-Glechner, 2005). Currently, it is most likely that also Arctic charr (S. *alpinus*) is involved as both species are often not recognized being distinct species and Swedish Arctic charrs are known to be stocked in Alpine lakes (Gross *et al*., 2004).

Maybe the name 'sparctic charr', used in America for the cross between brook charr and Arctic trout is applicable for the 'Elsässer saibling' present in European aquaculture.

First generation hybrids (F1) are usually morphologically intermediate between the parental species for most characters and recognizable as such, but F2 or parental backcrosses are much more difficult to identify and the use of genetic methods is the only reliable method to detect such specimens (Gross *et al*., 2004). This has implications for e.g. the brook charr reported from the Geelmolense Beek, the Netherlands (Soes *et al*., 2009). Although at least the well-photographed specimen shows clearly the characters of a brook charr it might actually be a F2 'Elsässer saibling' or a backcross.

In aquaculture, stocks of both parent species are kept for the production of the 'Elsässer saibling'. Although its fertility is much reduced it has been proven to be able to produce post-F1 generations. Normally the 'Elsässer saibling' is not used further in breeding practices of fish farms, due to much reduced fecundity and the less favorable performance of these post F1 generations (F. Moquette, pers. com.).

Theoretically it might have a minute potential to establish populations. Further information on how it compares to, e.g. the brook charr, is only present from aquaculture practices. It is known to be more hardy, to grow faster and having a postponed maturation. In pond culture especially its ability to tolerate higher temperature and lower oxygen saturation are of importance. Furthermore, it should be less susceptible for e.g. viral diseases (Klupp, 2000). Because of its better qualities in aquaculture it has become much more popular in comparison with other charrs. According to Dietmar Firzlaff it might comprise about 90% of the charrs cultured in Denmark and Germany.

As ecological information applicable to a risk analysis is absent and as its reproduction success is much reduced this hybrid will not be treated separately for the majority of this report and only reappear in the concluding remarks (§5).

4.3 Distribution

4.3.1 Native range

The brook charr is native in the eastern parts of North America, including most of eastern Canada from Newfoundland to the western side of Hudson Bay; south in the Atlantic, Great Lakes, and Mississippi River basins to Minnesota and northern Georgia (Page & Burr, 1991).

Figure 4.3: The native range of the brook charr. Source: Soil & Water Conservation Society of Metro Halifax. Made by Bureau Waardenburg.

In the United States brook charr have been extirpated in more than twenty percent of the streams that belonged to its former range. This is mainly due to extensive land use alterations, the establishment of competing non-native species and heavy urbanization and pollution. In many places they have been replaced by non-native brown trout and rainbow trout, particularly throughout the southern Appalachians. Because of the reduction several states have initialized recovery programs (Eastern Brook charr Joint Venture, 2005; MacCallum, 2007).

4.3.2 Established exotic populations

The brook charr has been widely introduced in North and South America, Europe, Asia, Oceania and Africa. Although the majority of introductions have been unsuccessful it has established local populations on every continent in which it has been introduced (Welcomme, 1988). Most of these established populations are present at high altitudes in alpine regions or in higher latitudes. This distribution is probably mainly due to the low tolerance of this species for high temperatures. (Kottelat & Freyhof, 2007).

Table 4.1: Overview of the introductions of the brook charr. Known dates of the first introduction and information on establishment are given. Data: Fishbase.org, Nobanis.org & Welcomme (1988).

Africa		
Kenya	1969	established
Morocco	1941	not established
South Africa	1950	not established
Zimbabwe	1955	established
Asia		
China	unknown	unknown
India	1963	not established
Iran	unknown	probably established
Japan	1901	established
Lebanon	unknown	probably not established
Turkey	1990-1999	established
Oceania		
Australia	unknown	established
Hawaii	1876	not established
New Zealand	unknown	established
Papua New Guinea	1974	established
South & Central America		
Argentina	1904	established
Bolivia	1948	established
Chile	unknown	established
Columbia	1955	unknown
Ecuador	unknown	unknown
Mexico	unknown	not established
Peru	1955	established
Venezuela	1937	established

Europe		
Austria	1970	established
Belgium	1890s	not established
Bulgaria	1930	established
Cyprus	1971	not established
Czech Republic	1890	established
Denmark	1895	established
Estonia	1896	not established
Finland	1895	established
France	1932	established
Germany	1890	established
Greece	unknown	not established
Hungary	<1940	probably established
Italy	>1895	established
Latvia	1902	established
Lithuania	1885	established
Netherlands	1895	not established
Norway	1870	established
Poland	1881	established
Portugal	unknown	not established
Rumania	<1900	established
Russia	1900-1924	established
Slovakia	1890	established
Spain	1934	probably established
Sweden	1972	established
Switzerland	1883	established
U.K.	1869-1871	established
Yugoslavia	1892	established

<u>Populations in Europe</u>

In Europe, the relatively rare confirmed established populations are mainly, but not exclusively, found in two regions: Northern Europe (e.g. Finland and Sweden) and Central Europe (e.g. Germany and Switzerland) (Kottelat & Freyhof, 2007). In the neighboring countries of the Netherlands this species is rare, see also §5. In Belgium established populations are absent. In Germany it is reported being rare in the southern parts, e.g. Kuhalmbach in Bavaria (Freyhof, 2003).

A well described population of brook charr is present in the **River Oriège** in the Pyrenees Mountains (France) that flows into the Ariège River (fig. 4.4). The brook charr has been introduced in the 1950s and coexists together with Atlantic trout. Other fish species are absent. The general distribution pattern within this river system equals other rivers with both brook charr and Atlantic trout with the brook charr dominating in the upstream sections and the Atlantic trout in more downstream sections.

Discharge of the River Oriège varies from 1 m3/s (winter and summer) to 15 m3 s/1 (spring flood), and water temperatures range from 0 to 13,5° C (Cucherousset *et al.*, 2008; 2007).

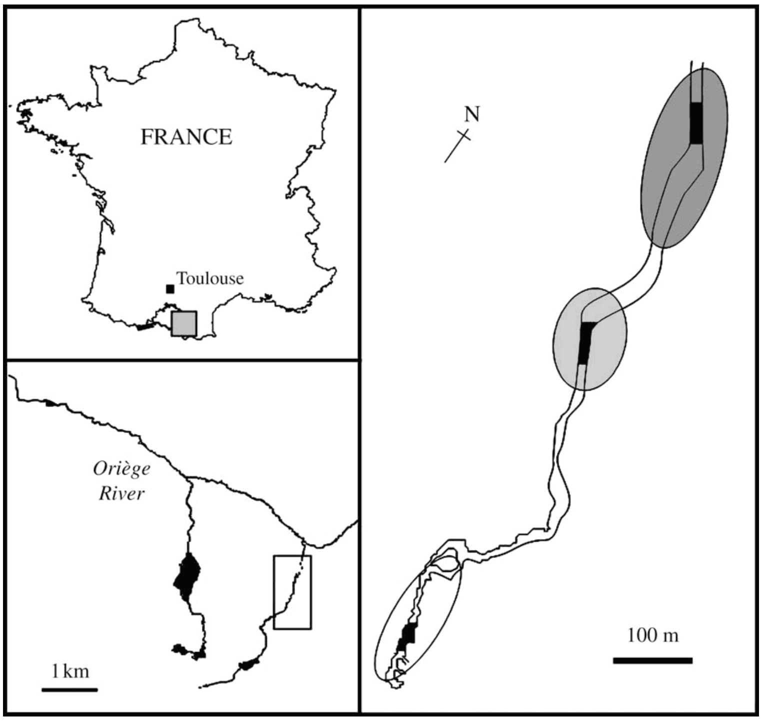


Figure 4.4: Map of the River Oriège (France) with location of the study area and the stretches sampled in the project of Cucherousset et al. (2007). Allopatry Salmo trutta : dark grey, sympatry: light grey and allopatry Salvelinus fontinalis: uncoloured.

Another well-studied system with an established population of brook charr is the **Upper Kemijoki River system** in northeastern Finland. Also in this river system the Atlantic trout coexists with the brook charr, which was introduced with multiple stockings in the 1970s and the 1980s. Based measurements in 2004, water temperature varied between five and 15°C in late summer. PCA analysis showed that allopatric brook charr sites were in narrower and more acid streams with lower current velocities, smaller substrates and deeper water, whereas allopatric brown trout sites were in wider, shallower, circumneutral streams with larger substrates. Sympatric sites tended to be intermediate in most characteristics.

In the river system few other fish species are present: European minnow (*Phoxinus phoxinus*), Alpine bullhead (*Cottus poecilopus*), brook lamprey (*Lampetra planeri*), burbot (*Lota lota*) nine-spined stickleback (*Pungitius pungitius*) and European grayling (*Thymallus thymallus*). The Alpine bullhead, a species comparable with the Dutch species of bullhead (*C. rhenanus* and *C. perifretum*), has been studied in this system for possible impacts of the brook charr; none of which could be found (Korsu *et al*., 2007; Korsu & Huusko, 2009).

Populations in North America
Beginning in the late 1800s, brook charr were introduced to 35 states in the USA and throughout much of western Canada (Fuller *et al*., 1999). The result of intensive transport has been widespread establishment of brook charr populations. Brook charr are now the most widely distributed and abundant non-native fish in the western USA, and have e.g. replaced native cutthroat trout (*Oncorhynchus clarkii*) throughout much of their native range (Dunham *et al*. 2002). This remarkably contrasts the situation in its native range with many extirpated and poor populations (Eastern Brook charr Joint Venture, 2005), showing that impressions from its native range can be misleading for its actual invasive capabilities.

Other exotic populations
The brook charr has also established in Asia, Africa, South America (table 4.1). In general there is little information available on the extent of its success. Only from New Zealand, Australia and Japan more will detailed information be reported.

Although the brook charr has established stable populations both in Australia and New Zealand, it receives much less attention as it is considered to be less harmful then rainbow trout and especially Atlantic trout. This is mainly due to its more local establishment and the fact it turns out to be less invasive in most regions (New Zealand Department of Conservation, 2003).

In Japan it has been widely introduced but has established only four populations. Two populations are known from lakes and two from streams (Kitano, 2004).

4.3.3 Colonization of the Netherlands

The first introduction of the brook charr in the Netherlands is hardly recorded (Nijssen & De Groot, 1987). Mulier (1900) mentioned it to be introduced between 1895 and 1900. No further information about early releases and their success is present.

4.3.5 Current distribution in the Netherlands

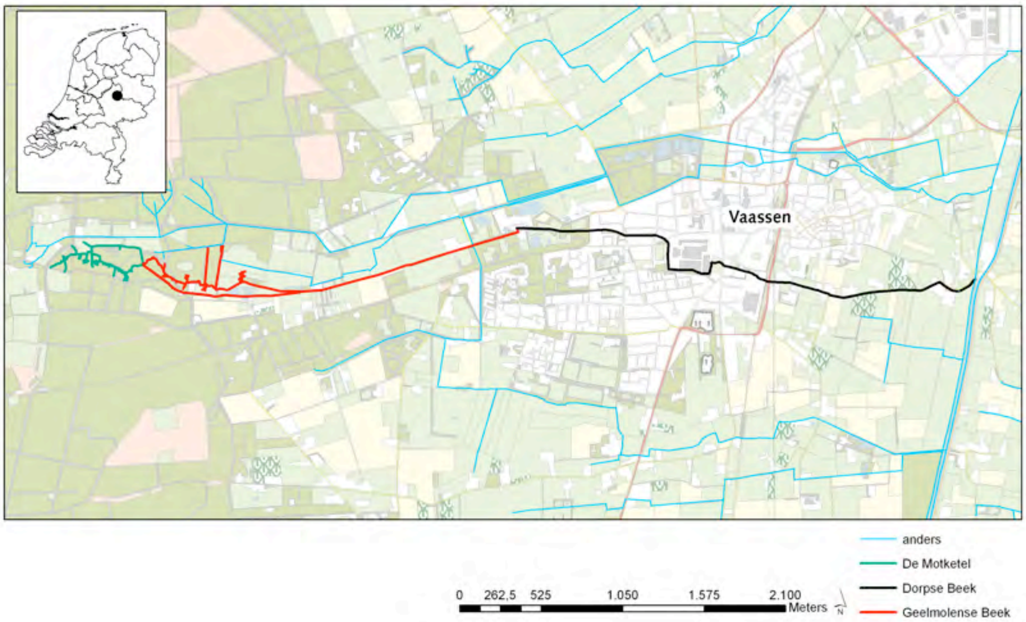
The brook charr is rarely reported from the Netherlands and when reported the identification is questionable as before this report the occurrence of the 'Elsässer saibling' has not been considered. In figure 4.5 and in appendix 1 an overview of the known records of the brook charr in the period 1983-2009 are given. Most records (83%) are from large rivers and the IJssel lake. It is especially regularly recorded in the river Meuse, with almost yearly records in the period 1993-2004, but numbers have stayed low throughout.

In the smaller systems it has been found in three streams belonging to the river Meuse tributary (Voer, Geul and Swalm), in all cases with only one (Voer, Swalm) or a few (Geul) specimens.

Figure 4.5: Records of the brook charr in the Netherlands. Made by Bureau Waardenburg.

Only one naturally reproducing population is known from the Netherlands. This population, which was present in the Geelmolense Beek, probably originated from the first introductions mentioned by Mulier (1900) and still existed in the 1970s (F.

Moquette, pers. com.). As no intermediate introductions had taken place and the brook charr had all this time been absent from the fish farms on the Veluwe, this population could be considered as a natural reproducing population. In 2008, four charrs were caught in the same brook, one specimen had clearly all characters of a brook charr. As they were of different lengths (5, 10, 12 and 25 cm) it could not be excluded that reproduction is still taking place, but as rumors about recent releases and/or escapes were also present the status of this populations is uncertain (Soes *et al*., 2009).



howing the location on the Geelmolense Beek. Made by Bureau Waardenburg.

The Geelmolense Beek (including De Motketel) is a small, artificial brook near Vaassen. In the upstream parts a fish farm, producing mainly rainbow trout, is present. Bottom sediment varies between sand and local gravel beds in the upstream parts to detritus rich fine sediments in more downstream parts. It is fed with both deep and shallow ground water. Water velocity is relatively constant; at around 0.30 meter/second. The water temperature is relatively cold all year round and normally varies between around five degrees Celsius in winter and 15 degrees Celsius in summer. The oxygen saturation is when measured at midday at least 70%. The Geelmolense Beek is considered to have an overall good water quality, both at present and also in the past (data Waterschap Veluwe; Kant, 1982).

In 2008, the brook charr was found together with rainbow trout (17 ex.), eel (1 ex.), three-spined stickleback (>300 ex.) and brook lamprey (18 larvae & 11 adults) (Soes *et al*., 2009).

4.4 Life history

4.4.1 Life cycle

Male brook charr can mature as early as age 0+ (Hunt 1966). In Wisconsin (USA), the smallest mature male recorded was approximately 8.9 cm long (McFadden 1961). For European waters Muus & Dahlström (in lit.) give the usual range as 2-3 years for males and 3-4 years for females (Jansson, 2008). May live up to 15 years old (Kottelat & Freyhof, 2007).

Coastal populations of brook charr from eastern Canada and north-eastern USA may move into salt water. Sea-run individuals normally differ in form (more robust) and colouration (more silvery) from brook charr that have never or have not recently been in salt water (Smith and Saunders 1958).

4.4.2 Reproduction

The brook charr is a typically autumn spawner, but sometimes may begin as early as late summer in the northern part of the original range or as early as late winter in the southern part (Sigler and Miller 1963). In Europe it is noted to spawn a bit earlier then the Atlantic trout and starting e.g. mid October in the Pyrenees Mountains (France) (Cucherousset *et al*., 2008). The brook charr highly preferres areas of ground water upwelling appear and may override substrate size as a site selection factor. Brook charr can be highly successful spawners in lentic environments in upwelling areas of springs. Spawning occurs at temperatures ranging from 4.5-10°C. The fertilized eggs are deposited in redds excavated by the female. Spawning success is reduced as the amount of silt increases and the inter-gravel oxygen concentration is lowered.

4.4.3 Habitat

Brook charr are the most generalized and adaptable of all *Salvelinus* species. They inhabit small headwater streams, large rivers, ponds, and large lakes in inland and coastal areas. In its native range it can be separated into two basic ecological forms: a short lived, small form, typical of small, cold stream and lake habitats and a long-lived, large, predaceous form associated with large lakes, rivers, and estuaries. The smaller, short-lived form is typically found south of the Great Lakes region and south of northern New England, while the larger form is located in the northern part of its native range. Although no subspecies have been recognized for these two forms, they respond as two different species to environmental interactions influencing life history. The lake form is not of importance to the Netherlands.

Typical brook charr habitat conditions are those associated with a cold temperate climate, cool spring-fed ground water, and moderate precipitation. Warm water temperatures appear to be the single most important factor limiting brook charr distribution and production.

Optimal brook charr riverine habitat is characterized by:

- clear, cold spring-fed water;
- a silt-free rocky substrate in riffle-run areas;
- an approximate 1:1 pool-riffle ratio with areas of slow, deep water;
- well vegetated stream banks;
- abundant in stream cover;
- relatively stable water flow, temperature regimes, and stream banks.

The vegetation cover of banks is both important for maintaining low water temperatures and providing sufficient food (terrestrial insects) (Modde *et al*., 1986). Brook charr south of Canada tend to occupy headwater stream areas, especially when rainbow and brown trout are present in the same river system (Raleigh, 1982).

4.4.4 Diet

Brook charr are opportunistic sight feeders, their diet varying with the time of year and food availability. But they do clearly show selective feeding, preferring larger prey items such as Trichoptera species with relatively large larvae (Forrester *et al*., 1994). The range of species predated is wide, including insects, molluscs, crustaceans, worms and fish (Raleigh & Nelson, 1985; www.fishbase.org). Also amphibians, especially in the larval phase, are sensitive to brook charr predation (Matthews *et al*., 2002). Even small mammals, like voles have been recorded as prey of adult brook charr (Scott & Crossman, 1973).

Juvenile trout mainly feed on small invertebrates such as insects and gammarids (Raleigh & Nelson, 1985). In lakes, juvenile brook charr are known to predate heavily on zooplankton species, like *Daphnia middendorffiana* (Cladocera) and *Hesperodiaptomus arcticus* (Copepoda) (Parker *et al*., 2001).

In most studies in its native range insects are the dominant prey item in brooks and streams. Larvae of Ephemeroptera, Plecoptera and Trichoptera and Diptera being the most common aquatic prey species. Of the terrestrial insects, the larvae of Lepidoptera and the adults of Diptera, Coleoptera, Hymenoptera and Homoptera are commonly found in the brook charr diet. Only in sizes above circa twenty centimetres fish are regularly included (Mookerij *et al*., 2004; Mistak *et al*., 2003; Strogen, 1979; Raleigh & Nelson, 1985).

4.4.5 Predators

The main predators of the brook charr are piscivorous fish species including their own kind, birds like herons and cormorants, aquatic mammals like otters, and humans.

4.4.6 Parasites and diseases

Brook charrs are susceptible to most parasitic, bacterial, fungal and viral diseases recorded in salmonids, but are resistant and healthy carriers of two major virus: Viral Hemorrhagic Syndrome (VHS) and Infectious Haematopoietic Necrosis (IHN) (Haffray, 2008; Roberts & Shepherd, 1997).

5 Risk analysis

In this chapter a risk analysis is provided for both rainbow trout and brook charr in the Netherlands using the information on biology and ecology provided in chapter 2 and 3.

5.1 The probability of entry

5.1.1 Fish farms

The rainbow trout is immensely popular in aquaculture. Worldwide production of rainbow trout was 537,000 tons in 2005, with Europe being the largest producer with 273,000. The main producing European countries are Norway (59,000+), Turkey (50,000+), Denmark, France and Italy (30-40,000+ each). Freshwater production is the most common in Europe, with the production of 172,000 tons portion-sized trout per year. Saltwater production is mainly carried out in Norway, Finland and Denmark (Vandeputte *et al*., 2008). Dutch trout farms produce about 100 tons of rainbow trout per year. A large proportion of this is for the trout fishing pond industry. The consumption of rainbow trout in the Netherlands was about 900 tons in 2007 and is mainly of imported fish (Van Diemen & Van Dongen, 2008).

The brook charr is less popular in aquaculture with a European production in 2004 of about 300 tons according to the Federation of European Aquaculture Producers (FEAP) (Haffray, 2008). These numbers might actually be an exaggeration as given numbers might actually include partly 'Elsässer saibling' as it does not report on the presence of this hybrid in aquacultural production at all. In the Netherlands both the brook charr and the 'Elsässer saibling' cannot be produced as, according to article 34 of the "Gezondheids- en welzijnswet voor dieren" (legislation on health and welfare for animals) it is not legal to produced for human consumption (www.aquacultuur.nl).

In the Netherlands there are six "forellenkwekerijen" (trout farms) registered at the "Kamer van Koophandel" (Chamber of Commerce):
- Forellenkwekerij de Tipbosch in Hellendoorn
- Forellenkwekerij 't Heutzputje in Vijlen
- Forellenkwekerij Reijmer in Pannerden
- Forellenkwekerij de Haere in Doornspijk
- Forellenkwekerij Keijzersberg in Blitterswijck
- Forellenkwekerij 't Smallert & 't Hol in Emst and Vaassen

When questioned, the **Forellenkwekerij de Reijmer** actually turned out not to breed fish, instead buying in rainbow trout from other farms to stock the trout fishing ponds. The **Forellenkwekerij 't Heutzputje** could not be contacted during this project and it was also not possible to establish whether or not it is currently active. The **Forellenkwekerij de Haere** breeds rainbow trout and 'zalmforel' and also sells to buyers within the Netherlands. This trout farm preferred to not to give further information.

Forellenkwekerij de Tipbosch produces only rainbow trout. They have recently started a breeding program for golden trout. In the past they have tried charrs but this has not been a success. They couldn't recall whether they had tried brook charr, Arctic charr or 'Elsässer saibling'. The rainbow trout are stripped for eggs and sperm within the farm itself. After the fertilization of the eggs they grow the larvae to adulthood themselves. When too few larvae are produced they buy fry from other farms, which are taken into production. As it is only one of the few trout farms in the Netherlands it delivers mainly to trout fishing ponds within the Netherlands. Furthermore, it sometimes delivers stocking fish to angling societies.

For the rearing of the eggs, larvae and the youngest fishes the Forellenkwekerij de Tipbosch uses tap water. Larger fish are reared in tanks with ground water. Excess water is led to several fish ponds they also own. This trout farm does not have any open connections with outside water systems.

Forellenkwekerij Keijzersberg mainly produces rainbow trout. In the past they have experimented with Atlantic trout and 'Elsässer saibling'. This practice has now ended as it was not economically viable. Both species needed about twice the amount of time to achieve a mark able size when compared to rainbow trout. These experiments ended about ten years ago.

They do not strip fish themselves but import fertilized eggs from Denmark. The fish are reared on ground water until they are about seven centimeters long. After this water from a nearby stream is used. From the rearing tanks the water flows into a sedimentation tank after which it is used in the fish ponds. From the fish ponds excess water flows back into the stream. Escapes are unlikely.
The rainbow trout produced amount to around 60-70 tons per year and is mainly sold to trout fishing ponds within the Netherlands. Also they regularly sell trout to consultancies and universities (e.g. Wageningen) for research projects.

Forellenkwekerij 't Smallert & 't Hol in Emst and Vaassen produces mainly for his own trout fishing ponds in 't Smallert. Some fish is sold to an local angling society, restaurants and garden pond owners. The majority of the stocked fish ('Elsässer saibling'), golden trout and rainbow trout) is bought from a German fish farm. In 2010 only some rainbow trout and golden trout were raised from self stripped and fertilized eggs. In the future they expect mainly to import fertilized eggs instead of producing these themselves. The raised fish is stocked in the fish ponds at a length of a few centimeters.

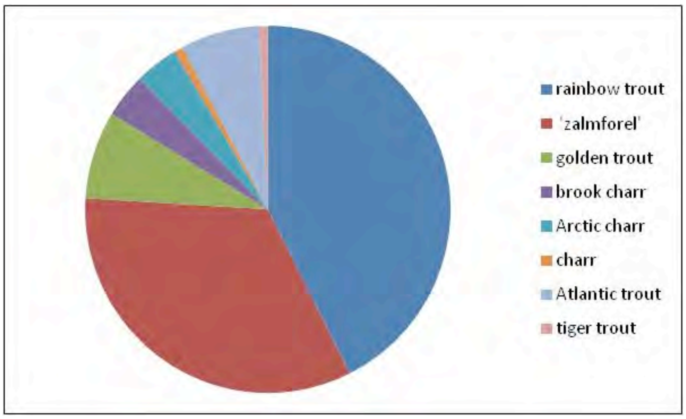
The fish farming is only done in 't Hol. This fish farm uses water from the Geelmolense Beek and also the excess water flows into this small stream. Some fish are known to escape with the excess water, especially the smaller specimens. Also from the regular catches during fish monitoring in the Geelmolense Beek suggest regular escapes (data Waterschap Veluwe), see also §3.
The chance of entry from fish farms is high but local ('t Hol).

5.1.2 Trout fishing ponds

Angling in trout fishing ponds is popular in the Netherlands. Distributed over the whole country there are about sixty farms offering this possibility (fig 5.1). In the eastern part of the Netherlands there are much more trout fishing ponds present than in the western parts. This is probably both due to the general better water quality in the eastern parts and the lower price of land.

Figure 5.1: Map showing the distribution of 60 trout fishing farms present in the Netherlands. Based on data from e.g. forelvissen.goedbegin.nl and troutfishingclub.nl. Map by Bureau Waardenburg

A total of 55 farms have responded to the enquiry about which species they stock in their ponds (fig. 5.2). The rainbow trout (including 'zalmforel') dominates the trout species stocked and is actually stocked in every farm. Charrs (brook charr, Arctic charr and 'Elsässer saibling') are said to be stocked in eleven farms (20%). The stocking of Arctic charrs is very unlikely as, because of its needs for low temperatures and high oxygen levels, it is not suited to conditions in the Netherlands. Probably the reported Arctic charrs are in reality 'Elsässer saibling', see also §4. Also golden trout (10 farms) and Atlantic trout (9 farms) can be regularly encountered in trout fishing ponds. Golden trout is said to be increasingly popular and will probably become even more common in the future. The tiger trout (hybrid between brook charr and Atlantic trout) is very rare and only mentioned by one farm.



rainbow trout	*Oncorhynchus mykiss*	55
zalmforel'	*Oncorhynchus mykiss*	43
golden trout	*Oncorhynchus mykiss*	10
brook charr	*Salvelinus fontinalis*	5
Arctic charr	*Salvelinus alpinus*	5
charr	*Salvelinus sp.*	1
Atlantic trout	*Salmo trutta*	9
tiger trout	*Salmo trutta x Salvelinus fontinalis*	1

Figure 5.2: Stocked trout species in Dutch trout fishing farms. The number of trout fishing farms stocked with each species is given.

Several farms also gave information about the origin of the stocked trout (fig. 5.3). Most farms bought their trout outside the Netherlands. Of the 18 farms that responded only two bought their trout from Dutch fish farms. Denmark (9) is the most common origin, followed by Germany (6) and France (4). Some farms buy fish from different farms from different countries (4).

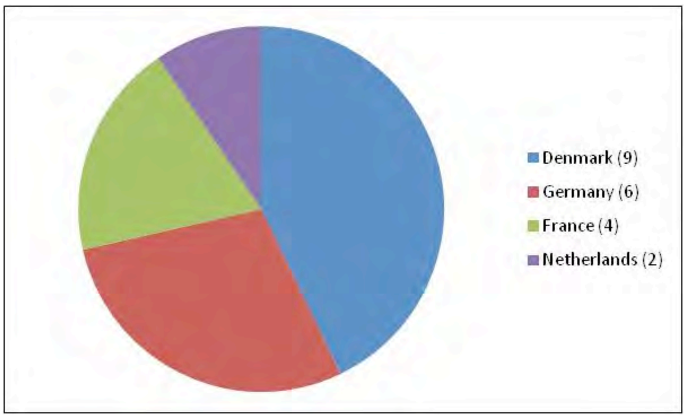


Figure 5.3: The origin of stocked trout at 18 trout fishing farms in the Netherlands.

Before the trout are released into the fishing ponds the fish are kept in tanks, making escapes very unlikely. As trout fishing ponds are only stocked with large trout escapes are uncommon, even when connections with nearby streams are present. Such large trout are easily prevented from escapes with simple fish screens. Flooding of fishing ponds, as reported from e.g. Belgium, have not been reported from the Netherlands. Some trout may 'escape' due to releases by visitors of the fishing ponds as they are expected to carry caught fishes home.

As escapes from trout fishing farms are only incidental, the chance of entry from trout fishing ponds is low, but present.

5.1.3 Consumption trade

Salmonids, although very popular consumption fishes, are not sold alive. Some shops are known to have show aquaria with trout, but even when these trout escape they are not likely to survive as their condition is often poor (P. Veenvliet, pers. com.).

The chance of entry from consumption trade is zero.

5.1.4 Private ornamental ponds

Outside the Netherlands salmonids are regularly kept in garden ponds. In the Netherlands, however, this is very rare (P. Veenvliet, pers. com.). The high oxygen demand is difficult to accomplish in the Netherlands. Garden ponds often become too hot in summer, making it necessary to create ponds of about two meters deep and use expensive equipment to oxidize the water. The best way to keep trout in the Netherlands is to use water from cold streams. In general, water boards do not permit the tapping of water from streams, decreasing the possibilities for creating such ponds. Furthermore, trout are not that popular because of their territorial behavior, making it almost impossible to keep them with other fish species.

Salmonids are not sold in pet shops or garden pond specialist shops as they are too hard to keep in good condition. In the Netherlands trout for stocking in ponds can only be bought directly from fish farms (P. Veenvliet, pers. com.). Fish farms known to sell salmonids incidentally for garden ponds are 't Hol/'t Smallert and Meuffels Winfried Fischzucht (Germany).

At least one garden pond with rainbow trout is present on the Veluwe. This pond is connected with the Hulshorster Beken and supplied with ground water. The owner has stated that his rainbow trout have even reproduced in his pond (R. Neuteboom-Spijker, pers. com.).

As rainbow trout and maybe brook charr are actually kept in garden ponds there is a slight chance they might escape. The chance of entry from garden ponds is low, but present.

5.1.5 Zoos

At present, two Dutch zoos keep rainbow trout: Dolfinarium Harderwijk and Zoo Parc Wissel (Dierenpark Wissel). Based on present enquiry (undertaken in 2010), brook charr are not present in Dutch zoos. The rainbow trout in Dolfinarium Harderwijk are kept in such a way that escapes are unlikely. In Zoo Parc Wissel this risk has clearly been present (Soes, 2005).

After the discovery of a small rainbow trout (≈15 cm) in a small stream south of Epe (Eperbeken), the small zoo called Zoo Parc Wissel, which borders this stream, was visited in 2002. This zoo turned out to keep a large number of rainbow trout (Soes *et al*., 2002).

Zoo Parc Wissel specializes in smaller animals like pygmy hippopotamus, white-nosed coati and Oriental small-clawed otter. It is most renowned for its collection of pygmy monkeys. Its ponds, which are largely interconnected, are fed with water from the 'Tongerense beek', part of the 'Eperbeken'. These ponds contained dozens of large rainbow trout. One of the keepers of the zoo stated that these rainbow trout were reproducing on a small scale. He guessed that the rainbow trout caught in the 'Eperbeken' originated from Zoo Parc Wissel. This reproduction is especially remarkable as the usual gravel beds used for egg depositing are totally absent.

In 2005 the reproduction in Zoo Parc Wissel was again confirmed and even was stated that successful reproduction had continued for several years (Otten, 2005).

In 2010, Zoo Parc Wissel was revisited to update the information. During this visit no rainbow trout were seen. One of the keepers told that the zoo has not been restocked with rainbow trout as they realized that the escapes that took place in the past were unwanted. At present, only a few old rainbow trout are left and no restocking is planned. With a normal life expectancy of four to six years (Root 1994), the zoo population will soon disappear completely. Clearly the reported reproduction has not resulted in a stable population.

The chance of entry from zoos in 2010 is low and very localized. Within two to three years the chance of entry from zoos is likely to be zero.

5.1.6 Entry from neighboring countries

Rainbow trout and brook charr from populations, stocking programs and escapes in neighboring countries might enter the Netherlands.

<u>Belgium</u>
For the presence of the rainbow trout in Flanders the collective fish stock assessment database of the Research Institute for Nature and Forest (vis.milieuinfo.be) is consulted. According to this database the rainbow trout is recorded 99 times in Flemish public waters since 1993. It is confined to four of the eleven Flemish River drainages: Demer-,

Dijle-, Meuse- en Upper Scheldt. Stocking programs with rainbow trout in public waters in Flanders ceased during the 1990s, except for an isolated lake and a drinking water reservoir (H. Verreycken, pers. comm.). Stocking with this species is still common practice in private ponds and in public waters in southern Belgium (i.e. Wallonia) (E. Branquart, in lit.). None of the stocking programs have resulted in a natural reproducing population of rainbow trout, so specimens observed in the present surveys are either escapees from neighboring ponds or stocked fish (Verreycken *et al*., 2007; Philippart, 2004).

In Flanders no recent stockings with brook charr are known (Hugo Verreycken, pers. med.). Since 1993, it has not been found during fish stock assessments (vis.milieuinfo.be). In Wallonia this species is still cultured and stocked in private waters. The species is known to escape from private ponds; especially during periods of high flooding. No established populations are present (Philippart, 2004).

Examples from specimens that are actually expected to have entered from Belgium are:

- Records of rainbow trout and brook charr in the Geul (Gubbels, 2000);
- Records of rainbow trout and brook charr in the Meuse probably are mainly fish from Belgium origin.

<u>Germany</u>

In Germany more or less established populations of the rainbow trout and the brook charr are only present in the south (Kottelat & Freyhof, 2007). In the 'Bundesländer', neighboring the Netherlands, Niedersachsen and Nordrhein-Westfalen, such populations have never been known to exist. In general, both exotic trout species are on the decline due to increasing discussions on the possibility that exotic trout species might interfere with reintroduction programs of the Atlantic salmon and might compete with the indigenous brown trout (e.g. Steffens, 2005). In Nordrhein-Westfalen it is not any longer permitted to stock public waters with rainbow trout and brook charr (MUNLV, 2003). Presence in this 'Bundesland' depends on illegal stockings, which still occur, and escapes from trout farms and private ponds. In Niedersachsen stocking is still permitted (Niedersächsischen Fischereigesetzes, 2005), but the low number of recent records of rainbow trout suggest that stocking here has also decreased (e.g. www.anglermap.de; www.fischartenatlas.de).

Examples from specimens that are actually expected to have entered from Germany are:

- Records of rainbow trout, brook charr and 'Elsässer saibling' in Swalm and Roer (Gubbels, 2000; W. Vergoossen, pers. com.);
- Records of single rainbow trout in fish ladders of polder Breebaart (Groningen) and Roptazijl (Friesland)(Brouwer *et al*.,2008).

<u>Other European countries</u>

Rainbow trout that had escaped from Danish trout farms are expected to be responsible for recent catches in Mecklenburg-Vorpommern, Germany (Winkler *et al*., 2007). Also specimens from the British Isles, where this species is widespread (Maitland, 2004), can venture into the North Sea. Such specimens might also reach the Netherlands.

For both species the chance of entry from neighboring countries is high, but numbers are expected to be relatively small as no established populations are present nearby. Both entry in streams and rivers crossing Dutch borders and entry from sea can be expected for the rainbow trout. Brook charr from European populations are much less likely to enter the sea and probably only enter from streams and rivers.

5.1.7 Trout stockings for angling

The stocking of fish for the improvement of angling possibilities is commonly carried out by angling societies. The majority of these angling societies in the Netherlands, at least 900, are related to Sportvisserij Nederland. The representation of smaller angler societies within the national society is done by eight regional societies (federaties):

- Hengelsportfederatie Groningen-Drenthe
- Hengelsportfederatie Fryslân
- Hengelsportfederatie Oost-Nederland
- Sportvisserij Noordwest Nederland
- Hengelsportfederatie Gooi en Eemland
- Hengelsportfederatie Midden-Nederland
- Sportvisserij Zuidwest-Nederland
- Sportvisserij Limburg

and an additional three specialist societies:

- KarperStudiegroep Nederland (carp)
- SnoekStudiegroep Nederland-Belgie (pike)
- Vereniging Nederlandse Vliegvissers (fly fishing)

In order to get more insight in rainbow trout and brook charr stocking, Sportvisserij Nederland, the eight 'federaties' and the Vereniging Nederlandse Vliegvissers were asked for information. From their responses it is clear that no overview of actual stockings is available. Furthermore, several of the organizations asked hesitated to provide data.

Hengelsportfederatie Groningen-Drenthe provided information on two isolated waters stocked with rainbow trout: Visplas Baggelhuizen (3,5 hectares) in Assen and Forellenplas De Slegge in Ter Apel. According to Sportvisserij Noordwest Nederland no stocking of exotic trout occurs in public waters within the area they represent.

Several other stockings were reported on various internet sites. The best known stocking is that of Lake Oostvoorne (province Zuid-Holland). Lake Oostvoorne is a brackish lake with a total area of circa 233 hectares. The lake is since 1995 yearly stocked with about 1,000 kilo of trout, mainly rainbow trout. Other stocked trout have been Atlantic trout and brook charr. Also in December 2009 the lake has been stocked with 900 kilo of rainbow trout and two specimens of golden rainbow trout (Bonhof *et al*., 2007; www.sportvisserijbelangen.nl).

In especially the southwestern parts of the Netherlands several other waters have been stocked with rainbow trout:

- Bufferbekken Keerkraksluizen: Since 1979 this 50 hectare water is stocked with rainbow trout and eel. The stocking of eel has recently been stopped. The stocking is arranged by the angling society 'Het Spanjooltje'.
- Kaaskenswater (Zierikzee): In 2009 was reported to be stocked with about 375 rainbow trout and 375 Atlantic trout. This stocking is done by HSV Oosterschelde.
- Grote Kreek (Ouwerkerk): In spring 2010 reported to be stocked with about 200 kilogram rainbow trout bought from a Belgium fish farm. Another 200 kilogram will be released in September. This stocking is done by HSV Oosterschelde.
- Kurenpolder (Hank): This 30 hectare water is stocked with rainbow trout.
- Veerse Meer: In the past stocked with large numbers of rainbow trout. Since 2004 the Veerse Meer again connected with the North Sea and subsequently the stockings have stopped.

In the Province Fryslân Heidemeer, a small lake near Heerenveen, is yearly stocked with about 1,000 kilogram rainbow trout. This stocking is done by Hengelsportvereniging Heerenveen and Hengelsportfederatie Fryslân.

Probably stockings of rainbow trout and maybe brook charr occur in more waters than listed above. But such stockings do not seem to occur in open water systems (streams or rivers). This is confirmed with information from water boards who uniformly commented that stockings of exotic salmonids are restricted to isolated waters. From some of these waters escapes probably happen, but with suitable habitats for reproduction being absent in their surroundings they are of no particular concern.

Legislation

According to the Flora- and fauna law (Flora- en faunawet) it is not legal to stock fish species in free nature except when they are included in the Fisheries law 1963 (Visserijwet 1963). Both rainbow trout and brook charr are listed in the Fisheries law making it legal to stock them in public waters, isolated or not. The only restriction is that permission is needed from the owner of the fishing rights of the water concerned.

Based on the information available the chance of entry in open water systems from stockings for angling is currently small. The awareness that rainbow trout and brook charr do not belong in Dutch rivers and streams probably stopped the stocking of these species, even though there are no legal constraints. Both Sportvisserij Nederland and the water boards have openly opposed the stocking of these exotic fish in open water systems creating an environment making such stockings less likely, but as stockings of both rainbow trout and brook charr are legal it can not be excluded to happen in the future.

The chance of entry of rainbow trout in isolated waters is high, those of the brook charr low. The chance of entry of both species due to stocking in open water systems seems to be currently zero, but there are no guarantees this will be a stable situation.

5.1.8 Trout stockings for commercial fishing

No stockings of exotic trout species for commercial fishing, including rainbow trout and brook charr, could be traced. Also no reports on commercial salmonid fishing could be found.

The chances of entry from stockings for commercial fishing is zero.

5.1.9 Illegal stockings

Illegal stockings (stockings without the knowledge of the owner of the fishing rights of a particular water) of rainbow trout have been reported on a very small scale in streams in two Dutch provinces. In these cases the number of stocked fish have been small.

The chance of entry from illegal stocking is small and the numbers of fish involved will probably be small.

5.1.10 Chance of entry

The chances of entry can be summarized as follows:

Rainbow trout
- The chance of entry from fish farms, neighboring countries and stocking in isolated waters is **high;**
- The chance of entry from trout fishing ponds, garden ponds, zoos, stocking in open water systems and illegal stocking is **low;**
- The chance of entry from consumption trade or commercial fishing is **zero.**

Brook charr
- The chance of entry from fish farms, neighboring countries, stocking in isolated waters, trout fishing ponds, garden ponds, stocking in open water systems and illegal stocking is **low;**
- The chance of entry from zoos and consumption trade is **zero.**

Except for the stocking in isolated waters the number of entering fish is small.

5.2 The probability of establishment

Both the rainbow trout and the brook charr have populations in streams and lakes. Large, deep lakes fulfilling the requirements of these species are not present in the Netherlands. So only the possibility of the establishment in streams is considered further.

The flood regimes of streams is an important factor determining the suitability for salmonid species. The brook charr, having a life cycle comparable with the Atlantic trout, is not likely to meet with problems in Western Europe. The rainbow trout has often been proven to be hampered by unsuitable flood regimes, so this factor will be discussed in relation to the rainbow trout.

Both the rainbow trout and the brook charr are versatile species with in general flexible habitat requirements. The most important limiting factors are the interrelated parameters water temperature and oxygen saturation. Especially the brook charr needs low temperatures and a high oxygen supply. The rainbow trout is more resistant to higher temperatures and lower oxygen supplies, but also this species has its limits. With reliable measurements of oxygen saturation being rarely present, only water temperature will be discussed in the following.

Another factor considered to be limiting for salmonids in general in the Netherlands is spawning substrate. Also this factor will be discussed. Finally the possibility of biotic resistance is discussed for both species. Biotic resistance can include factors such as diseases, parasites, competitive species and predators.

Water quality, including e.g. ammonia and phosphor pollution, are also of great importance, but this is not considered to be limiting in the current risk analysis as the Netherlands has committed to the Water Framework Directive. One of the goals of this directive is establishing a water quality fitting each water system. Such water qualities would not limit the establishment of salmonids such as the rainbow trout and the brook charr.

5.2.1 Habitat suitability rainbow trout and the probability of establishment

Flood regimes

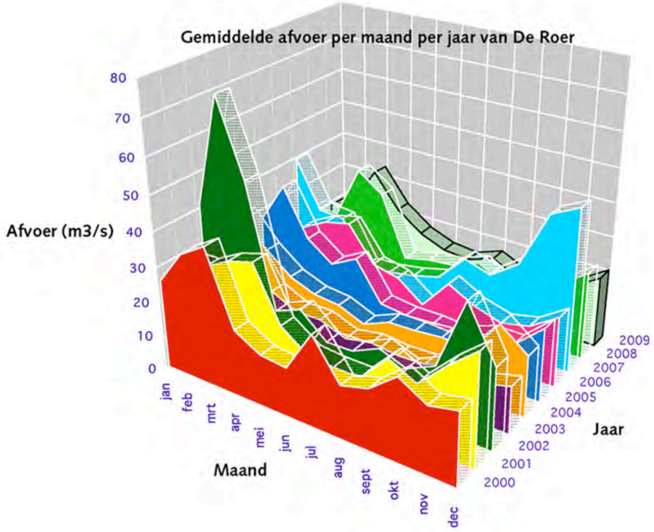
When comparing regions where rainbow trout invasions are successful, moderately successful or failed it turned out that rainbow trout was only successful in areas with a flood regime matching its native range. When floods coincide with the youngest larval stages the rainbow trout is unsuccessful in establishing populations. As these young stages lack sufficient swimming performance to counter act such floods they are simply flushed down stream (Fausch *et al*., 2001). Without sufficient cover this can occur from stream velocities as low as 10-25 cm/s (Heggenes & Traaen, 1988).

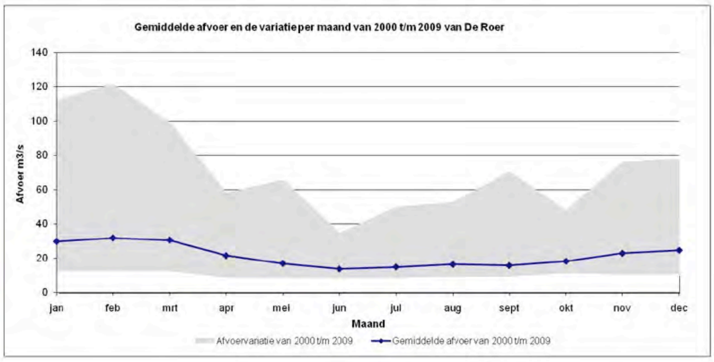
The Netherlands has a temperate marine climate with a yearly precipitate surplus. In the higher parts of the Netherlands precipitate surplus varies from 150 to 300 millimeter with an average of about 225 millimeters per year. Geographical differences are relatively small. The time period with a precipitate surplus runs from September to April. From April to September there is a precipitate shortage (Verdonschot, 1995).

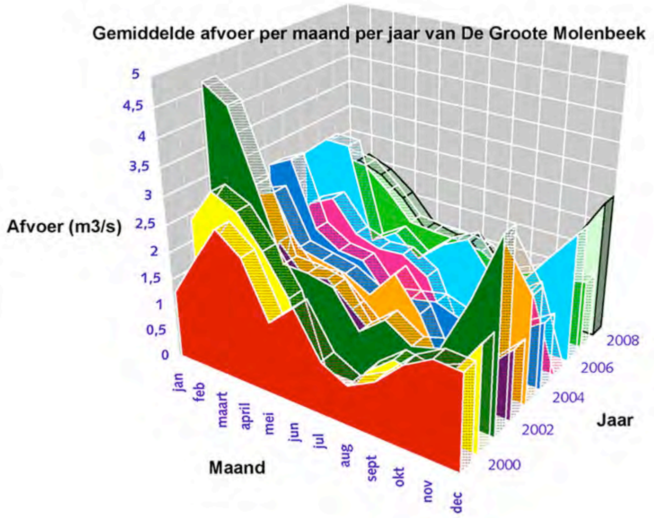
Overall, the timing of most floods in Dutch streams is similar to that in the native range of rainbow trout, resulting primarily from winter rains, which decline to lower flows in summer (fig. 5.4). Spring & summer floods do occur and are predicted to happen more often in the future due to climate change (www.knmi.nl). Such in their timing irregular floods might destroy the reproduction of one year when such a flood happens during the young stages of the rainbow trout and hinder the establishment temporarily , but are not considered a major obstruction for such an establishment (Fausch *et al*., 2001).

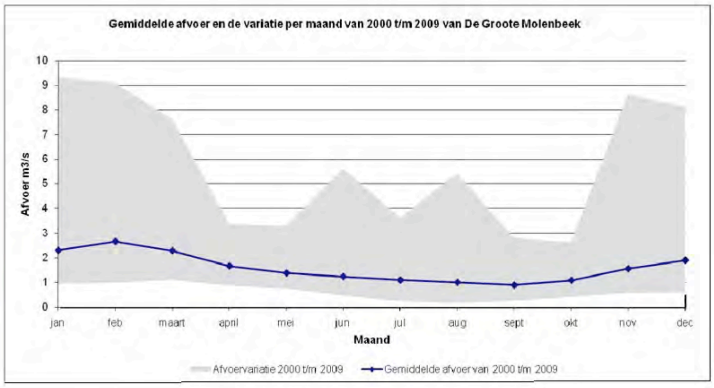
As has also been concluded for the United Kingdom (Fausch, 2007), a country with a comparable climate with the Netherlands, the flood regime should not be considered a problem for the establishment of the rainbow trout.

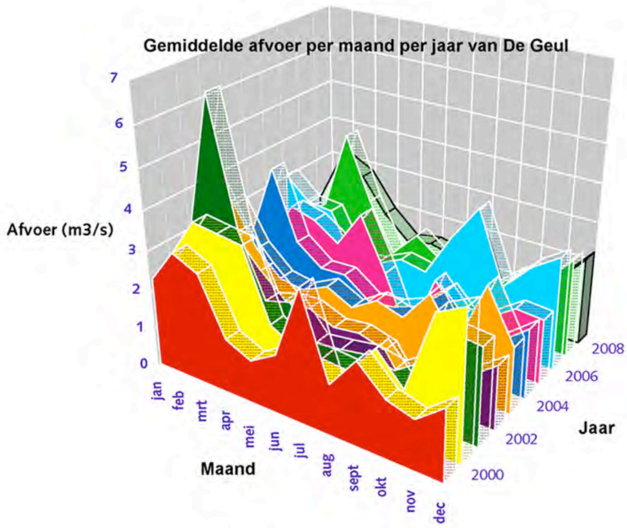
Figure 5.4: Flood regime of three Dutch streams. In the upper graph medium discharges per month per year are given. In the lower graph the medium discharge per month over the period 2000-2009 is given, together with the maximal and minimal discharges actual measured.

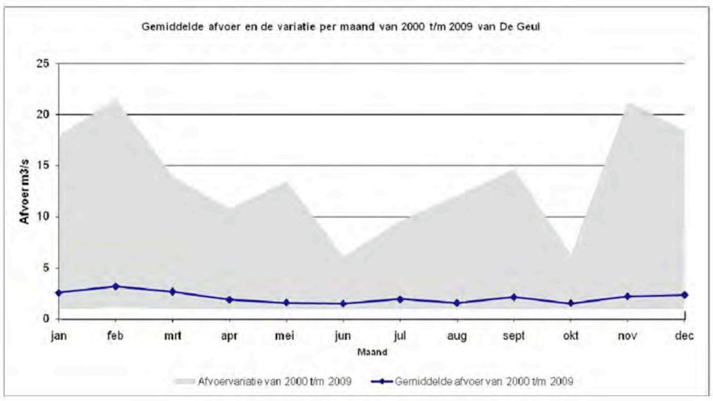

Gemiddelde afvoer per maand per jaar van De Roer
Afvoer (m3/s)
0
10
20
30
40
50
60
70
80
jan
feb
mrt
apr
mei
jun
jul
aug
sept
okt
nov
dec
Maand
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Jaar


Gemiddelde afvoer en de variatie per maand van 2000 t/m 2009 van De Roer
Afvoer m3/s
0
20
40
60
80
100
120
140
jan
feb
mrt
apr
mei
jun
jul
aug
sept
okt
nov
dec
Maand
Afvoervariatie van 2000 t/m 2009
Gemiddelde afvoer van 2000 t/m 2009


Gemiddelde afvoer per maand per jaar van De Groote Molenbeek
Afvoer (m3/s)
0
0,5
1
1,5
2
2,5
3
3,5
4
4,5
5
jan
feb
maart
april
mei
jun
jul
aug
sept
okt
nov
dec
Maand
2000
2002
2004
2006
2008
Jaar


Gemiddelde afvoer en de variatie per maand van 2000 t/m 2009 van De Groote Molenbeek
Afvoer m3/s
0
1
2
3
4
5
6
7
8
9
10
jan
feb
maart
april
mei
jun
jul
aug
sept
okt
nov
dec
Maand
Afvoervariatie 2000 t/m 2009
Gemiddelde afvoer van 2000 t/m 2009


Gemiddelde afvoer per maand per jaar van De Geul
Afvoer (m3/s)
0
1
2
3
4
5
6
7
jan
feb
mrt
apr
mei
jun
jul
aug
sept
okt
nov
dec
Maand
2000
2002
2004
2006
2008
Jaar


Gemiddelde afvoer en de variatie per maand van 2000 t/m 2009 van De Geul
Afvoer m3/s
0
5
10
15
20
25
jan
feb
mrt
apr
mei
jun
jul
aug
sept
okt
nov
dec
Maand
Afvoervariatie van 2000 t/m 2009
Gemiddelde afvoer van 2000 t/m 2009

Temperature

In comparison with other salmonids the rainbow trout is well adapted to higher temperatures and needs relatively warm water in summer for a good growth (Molony, 2001).

Raleigh *et al*. (1984) summarize temperatures ranges of the rainbow trout in its original range as follows:

- Embryo: Temperatures in the range of 7°C – 12°C have been reported as suitable;
- Fry: Temperatures between 13°C – 19°C are considered suitable with temperatures between 12,4°C – 15,4°C;
- Juvenile fish: Temperatures between 15°C – 20°C are optimal for fingerling growth;
- Adults: Temperatures toleration for adult fish range from 0 °C – 25°C , with an optimal range for growth and survival between 12°C – 18°C. Temperatures above 25°C are quickly detrimental.
- Spawning: Spawning is reported to occur at temperatures ranging from 2°C - 15.5°C.

Overall streams with a temperature range between 0°C – 20°C seem well suited for the rainbow trout. Summer temperatures should be above 15°C for optimal growth. Short periods with summer temperatures above 20°C are no problem.

In the Netherlands such a temperature regime is met with in most hill streams, only in small headwaters temperatures might be insufficient for a decent growth (Keizer-Vlek, *et al*., 2007; Verdonschot & Keizer-Vlek, 2008; Verdonschot, 2000a, b). Examples of drainages with suitable temperature regimes are the Roer drainage (Waterschap Roer en Overmaas, 2009) and the Grift drainage, Veluwe (data Waterschap Veluwe).

Spawning substrate

Rainbow trout needs relatively large spawning beds with coarse substrates with a high permeability to ensure a high oxygen supply for the embryos. Clothing with fine substrates (silt) hinders this circulations which is in most cases detrimental to the eggs. Suitable gravel varies from 0.3 to 10.0 centimeters in width, with a average of 1.5 to 6.0 centimeters being optimal(Raleigh *et al*., 1984). Under artificial circumstances they have proven to be able to reproduce in fine substrate with upwelling, oxygen rich groundwater (F. Moquette, pers. com.).

An extensive study of potential salmonid locations in the 1990s showed suitable gravel beds for spawning to be very rare (Schouten, 1995). By now many stream restoration projects have improved streams and generated some suitable locations, but clean, coarse gravel beds are still rare (H. Moller-Pillot, pers. com.).

Fast flowing streams with more extensive gravel beds are present only in the province Limburg, e.g. in the drainages of the Geul and the Roer. In Pleistocene areas gravel beds can also be present in a smaller scale. Examples of such streams are the Heelsumse Beek and the Verloren Beek. Such smaller beds with lower stream velocities are probably less likely to be able to support rainbow trout populations.

Biotic resistance

In many instances the known environmental requirements of the rainbow trout hardly can explain the lack of established populations in e.g. the United Kingdom (Fausch, 2007). It is suggested that biotic resistance might be an important, although not well understood factor explaining the unsuccessful establishments.

In Norway the whirling disease (*Myxobolus cerebralis*) and other parasites are suspected to account for the low rates of rainbow trout establishment (K. Hindar *in* Fausch, 2007). The rainbow trout is mostly highly susceptible for whirling disease, but resistant strains do occur. Remarkably one of the two known established populations in Germany is a whirling disease resistant strain (M. El-Matbouli *in* Fausch, 2007). With the whirling disease being indigenous in the Netherlands it might also be of importance in the Netherlands. When whirling disease is present it will occur mainly in streams occupied by Atlantic trout or Atlantic salmon, e.g. Roer, Geul and Slinge.

In most Dutch systems the rainbow trout will meet with predators such as piscivorous birds and other larger fish species. As especially the domesticated strains, which are normally stocked, have much lower anti-predator and higher agonistic behavior a relatively high predation risk is expected (Vandeputte *et al*., 2008). The high risk-taking of domesticated strains during feeding is probably triggered by higher levels of growth-hormone, which stimulates appetite (Biro *et al*., 2004). Also higher agonistic behavior is likely to increase exposure to predators, especially when fish densities are relatively high in comparison to suitable cover.

Biro *et al.* (2004) found that stocked domesticated rainbow trout had a significant higher risk ($p < 0.02$) to be predated by the great northern diver (*Gavia immer*) in comparison with wild stock. During a stocking program in the Keersop, the Netherlands in the 1970s it was observed that stocked rainbow trout had a poor survival, probably due to poor anti-predator behavior. Young rainbow trout (10-12 centimeters) were seen foraging in the open during daytime hours, making them vulnerable to e.g. pike (*Esox lucius*) and great cormorant (*Phalacrocorax carbo*) (F. Moquette, pers.com.). Also escaped, domesticated rainbow trout in the Geelmolense Beek, the Netherlands were remarkable sensitive to predation by great cormorants. A large (>40 centimeters), healthy rainbow trout was actually seen being killed due to damaging by a great cormorant (D.M. Soes, pers. obser.). Wild rainbow trout of such size would under normal circumstances not be that vulnerable.

Also the greater survival of rainbow trout stocked at larger size in Bad Medicine Lake, Minnesota was best explained by predation. The most important predators in this lake, northern pike, burbot, and walleye are expected to be size-selective in their predation and predate more heavily on smaller specimens (Cunningham & Anderson, 1992).

In fast flowing streams with a lot of cover and relatively few predatory fish domesticated rainbow trout are less likely to be sensitive for predation. The Geul with the chub (*Squalius cephalus*) being the most common predatory fish, is probably more suitable then e.g. the Roer with its calmer water and higher diversity in predatory fish (Crombaghs *et al*., 2000). A stream like the Keersop with a lot of pike is probably unsuitable, as been shown in the past.

Competition with Atlantic trout has also been mentioned as an explanation of the failure of the rainbow trout to establish in several places. But information is clearly inconclusive as the rainbow trout has also been able to establish in streams already occupied by Atlantic trout (Fausch, 2007).

Conclusion rainbow trout

Streams with suitable temperatures and suitable spawning habitat are only present in Limburg. Due to vulnerability of used rainbow trout strains for predation streams such as the Roer, with a high diversity in predatory fish, are less likely to be suitable for establishment of populations. Based on habitat suitability the probability of establishment is low.

The use of other aquacultural strains based purely on wild fish, which seem to be only present in Noth America, might increase the chances of establishment.

5.2.2 Habitat suitability brook charr and the probability of establishment

Temperature

The most limiting factor for the establishment of brook charr populations is water temperature, due to which they have almost exclusively established in Northern Europe or in alpine regions (Kottelat & Freyhof, 2007). With the Netherlands not belonging to these regions it is assumed that temperature will be one of the most limiting factors for the establishment of brook charr populations.

Raleigh (1982) summarizes temperatures ranges of the brook charr in its original range as follows:

- Embryo: Temperatures in the range of 4,5°C – 11,5°C have been reported as suitable;
- Fry: Temperatures between 9,8°C – 15,4°C are considered suitable with temperatures between 12,4°C – 15,4°C being optimal. Temperatures above 18 are lethal;
- Juvenile fish: Temperatures between 11°C – 14°C are optimal for fingerling growth;
- Adults: Temperatures toleration for adult fish range from 0 °C – 24°C , with an optimal range for growth and survival between 11°C – 16°C . Temperatures above 24°C are quickly detrimental.
- Spawning: Spawning occurs at temperatures ranging from 4.5-10°C.

Overall seem streams with a temperature range between 5°C – 16°C well suited for the brook charr. In Europe the brook charr spawns mid October, so suitable streams should have temperatures around this period below 10°C.

Both the River Oriège (France) with water temperatures ranging from 0 to 13,5°C , and the Upper Kemijoki River system (Finland) with water temperatures ranging from 5°C-15°C have upper temperatures within the optimal range of the brook charr. Also the Geelmolense Beek (the Netherlands) fits with circa 5°C in winter and 15°C in summer well into the optimal range. Temperatures in the Geelmolense Beek stay that low because it's fed with cold groundwater and has tree cover over most of its range.

In the Netherlands such a temperature regime is met with in springs and small streams which are at least partly ground water fed and have relatively large canopy cover (Keizer-Vlek, *et al*., 2007; Verdonschot & Keizer-Vlek, 2008; Verdonschot, 2000a, b). Larger streams become too warm in summer (Keizer-Vlek *et al*., 2007). Springs and cold streams are mainly found in Limburg, Veluwe and eastern Pleistocene areas (Achterhoek, Twente).

Spawning substrate

Brook charrs prefer coarse spawning substrates with upwelling, oxygen rich groundwater. The benefits of this are delivery of sufficient oxygen, removal of waste and temperature moderation during embryo development. In beds with strong upwelling of ground water the brook charr is also able to successfully reproduce in beds with coarse sand present (Power, 2002). The spawning substrates should allow a good circulation. Clothing with fine substrates (silt) hinders these circulations which is in most cases detrimental to the eggs. An extensive study of potential salmonid locations in the 1990s showed suitable gravel beds for spawning to be very rare (Schouten, 1995). By now many stream restoration projects have improved streams and generated some suitable locations, but clean, coarse gravel beds are still rare (H. Moller-Pillot, pers. com.).

Fast flowing streams with more extensive gravel beds are present only in the province Limburg, e.g. Terzieterbeek. In Pleistocene areas gravel beds can also be present in a smaller scale. Examples of such streams are the Heelsumse Beek and the Verloren Beek.

Biotic resistance

In general streams with native salmonid population are more likely to resist colonization in comparison to streams without (Fausch, 2007). Especially brook charr is reported to be outcompeted by European *Salmo* species (Kottelat & Freyhof, 2007). In streams with e.g. Atlantic trout the brook charr is mostly found in the smaller headwaters where it can still be successful. This distribution pattern is both found in Europe (brook charr introduced) and North-America (Atlantic trout introduced) (Korsu *et al*., 2007). The rainbow trout has been reported to be more successful in streams lacking other salmonid species, but is also known to be able to outcompete European *Salmo* species (Fausch, 2007; Kottelat & Freyhof, 2007).

In the Netherlands only one self-sustaining population of Atlantic trout is known in the Heelsumse Beek (Veluwe). Other larger populations of Atlantic trout, which are maintained by stocking, are present in the Geul and several streams in the Achterhoek (R. Gubbels, pers.com., M. de Vos, pers. com.). The densities in these streams are in comparison with populations in neighboring countries still low. So biotic resistance due to the presence of native salmonids is not expected to play a significant role because of the absence of native salmonids in most waters and when present the lower densities.

The domesticated rainbow trout is known to be relatively vulnerable to predation. Such seems not to be the case with the brook charr and it is believed to be comparable in this respect with the native Atlantic trout.

Conclusion brook charr

Springs and streams with suitable temperatures and suitable spawning habitat are locally present in Limburg and in Pleistocene areas. Such waters are small and will not be able to support larger populations. Small fish populations are less stable giving a higher risk for extinctions and a less likely establishment for a longer period. Based on habitat suitability the probability of establishment is low, with only incidental, local establishments expected.

5.3 The probability of spread

Like most salmonids the rainbow trout and the brook charr are capable of long movements, with both species having anadromous populations in their native range (Adams *et al*., 2000; Raleigh, 1984).

In 2007 Korsu & Huusko (2009) studied the movements of brook charrs released into several Finnish stream by tagging. A total, 221 (6%) fish were recaptured with information also provided on the recapture site. Of these fish, 75% were captured during the release year and 18% during the following year. Approximately half (51%) of the recaptured fish were 'Movers' which dispersed at least 5 km from the release site or had ascended small tributary streams close to the mainstream release sites. The rest of the recaptured fish (49%) were 'Stayers' that moved less than 5 km within the streams they had been released. The mean distance travelled by 'Movers' was 14 kilometers with the highest observed distance being about 80 kilometers.

Even though brook charr and rainbow trout are known to make long exploratory movements these may not result in spawning in a new location and are probably of minor importance for the invasion process (Adams *et al*., 2000).

Korsu *et al.* (2008) noted that brook charr within his 10 year study in the River Kemijoki had spread about 20 kilometers towards the headwaters. This is much faster then the results of Björkelid (2003) in Swedish streams with a invasion rate varying between 20 and 70 m/year, with a mean of 48 m/year. His results are consistent with those of Adams *et al*. (2000), with a rate of 39 m/year over a twenty-year period in an American stream. Rainbow trout probably does not differ too much from the brook charr with a recorded spread of 13-29 m/year in introduced populations in Tennessee (Strange & Habera, 1998).

Probability of spread in the Netherlands

When established, rainbow trout and brook charr can easily spread within the water system in which they have established. The chance of spreading from one water system to another decreases with the distance between water systems. They are only likely to establish in other water systems when they are able to build up relatively large founder populations.

Salmonids like rainbow trout and brook charr are relatively adapted taking natural obstacles, such as steep slopes and small waterfalls, but artificial obstacles such as dams will hinder spread. The policy of most water boards within the Netherlands to minimize the amount of obstacles for fish migration will probably favor the spread of both species.

5.4 Endangered areas

For predicting the potential of invasive species especially three predictors are thought to be reliable (Williamson, 1997; Weijden *et al*., 2007):

- The species has already been invasive in another region;
- The species is able to exert significant propagule pressure;
- The species fits into one of the present habitats.

Also for predicting the potential endangered areas these predictors seem to be highly applicable and will be discussed in the following.

5.4.1 Experiences in neighboring regions

In Belgium, neither species has been able to establish itself, although stocking of both species in at first hand appropriate looking habits has been much more common practice compared to the Netherlands (H. Verreycken, pers. comm.). In the German 'Bundesländer' neighboring the Netherlands (Niedersachsen & Nordrhein-Westfalen) no populations are present. Also in Mecklenburg-Vorpommern, a 'Bundesland' with a lot of water systems comparable with the Netherlands, no established populations of either rainbow trout or brook charr are present (Winkler *et al*., 2007).

Fausch (2007) studied the possibility of the rainbow trout becoming invasive in the United Kingdom. Rainbow trout have been stocked for over 120 years and are still routinely released in large numbers in the U.K. water to support angling. In England and Wales during 2000-2003, on average 2.1 million rainbow trout were stocked each year. All this stocking has resulted in two or three established populations of which only the Wye still has a significant self-sustaining population. When water temperature, flood regimes and general habitat were reviewed no particular reasons for the lack of success of the rainbow trout were detected. Biotic resistance might play a role, but no strong supportive data were found. In an internet forum discussion Steve Parton, a well known fly fisherman in the UK, suggested that the lack of established populations in the U.K. should be attributed to both the now common practice of only stocking female fish and the unsuitability of the domestic strains stocked currently.

During the survey of this report all European populations were found to be established have settled in areas with known indigenous salmonid populations. Not surprisingly as the especially the rainbow trout has similar habitat requirements as the Atlantic trout, except that the brown trout needs lower temperatures then the rainbow trout for reproduction (Molony, 2001). In the Netherlands spawning areas are only known from the Atlantic trout and thought to have been rare and local throughout the last two centuries.

The overall impression from neighboring countries is that the chances for the establishment of both rainbow trout and brook charr are small.

5.4.2 The importance of propagule pressure

Propagule pressure (number of individuals introduced, usually through multiple introductions) is one of the most important factors related to successful fish invasions. Although large propagule size is no guarantee for success as several large scale introductions in appropriate habitats have failed (Moyle & Marchetti, 2006).

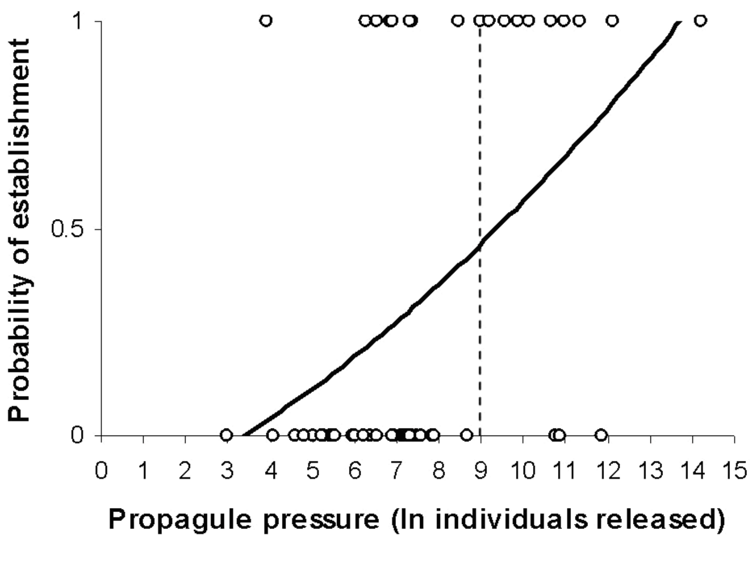


Figure 5.5: Site-specific probability of establishment (0 = failed, 1 = successful) as a function of propagule pressure (ln individuals released) for non-native brook charr in Finland. A logistic curve indicates the relationship between propagule pressure and establishment success. Vertical line indicates median propagule pressure in successfully established sites (c. 8000 released individuals). From Korsu & Huusko (2009).

Korsu & Huusko (2009) analyzed the importance of propagule pressure in the establishment of Finish brook charr populations (fig. 5.5). They found that the site-specific establishment success of brook charr was significantly related to the number of individuals released ($P = 0.003$). Median propagule pressure in successfully established sites was about 8000 individuals.

The consequence for the need of high propagule pressure is that for a likely establishment of both exotic salmonids a large founder population needs to be nearby or an intensive stocking program is needed. As founder populations in neighboring countries are absent and stocking programs in appropriate habitat are failing at the moment it is based on the predictor propagule pressure not very likely that rainbow trout or brook charr will establish themselves in the Netherlands.

5.4.3 Habitat suitability

Suitable habitats for the rainbow trout and the brook charr are only expected to be present on a rather small scale, see also 5.2. Rainbow trout is most likely to establish in larger streams in the southern province of Limburg. Several streams like the Roer might be unsuitable due to the predation risk. Brook charr might find suitable habitats more widespread in the Netherlands but these are confined to small headwater streams.

5.4.4 Endangered areas

Combining the information from abroad, propagule pressure and habitat suitability it is concluded that in the current situation endangered areas are almost absent and that both species are not expected to become invasive in the Netherlands. The only exception, actually based on reported reproduction, seems to be the water system at the east flank of the Veluwe. Past reproduction of the brook charr indicates that the establishment of this species is possible in this area.

The current situation in the Geelmolense Beek is unknown. In 2008 four charrs have been caught, but only one specimen had been photographed in such a manner that it could be positively identified as brook charr. The other specimens might actually have been 'Elsässer saibling'. Also rainbow trout is present in this area. Reproduction of the rainbow trout has only been proven under artificial circumstances in a zoo and a garden pond, natural reproduction seems to be absent.

The presence of both species on the Veluwe is very localized and would normally be of little concern, but as this area also supports the largest brook lamprey (Habitat Directive species) population of the Netherlands more care than usual should be taken. Furthermore are plans developed to reconstruct the water systems in this area. This may result in better opportunities for especially the brook charr due to a better interconnectivity of potential suitable streams.

5.5 Impacts

Ecological impacts

Competition with native salmonids

Salmonids are highly competitive against each other, in especially smaller systems often leaving only room for one or two species per locality. Their comparable feeding habits and food sources play a big role in this competition, but outcomes are influenced by environmental characters such as fish density, water temperature or flow variability (Blanchet *et al*., 2007).

Interactions between exotic trout and native Japanese salmonids are relatively well known. Several native species have declined due to the release of brown trout, rainbow trout and brook charr (Morita *et al*., 2004; Kitano, 2004). Especially the impact of rainbow trout on Dolly Varden charr (*Salvelinus malma*) populations has been studied. By combining field experiments and field studies Baxter *et al*. (2007) showed that rainbow trout almost monopolized the terrestrial prey, the major food resource for also the white-spotted charr in many streams. In sites with even low densities of rainbow trout the biomass of Dolly Varden charr was more than 75% lower then in sites without rainbow trout. In these sites the rainbow trout usurped the terrestrial prey subsidy, causing a more then 75% decrease in the biomass of terrestrial invertebrates in Dolly Varden charr diets. In the experimental setup this competition resulted in a 31% decrease in growth of the charr.

Figure 5.6: Dolly Varden charr (Salvelinus malma)

Competition with Atlantic salmon
Reports of negative impact of rainbow trout or brook charr on Atlantic salmon appear to be at least rare. Rainbow trout populations have not yet been found in waters used also by Atlantic salmon, probably accounting for a lack of reports on their interaction.

The interaction between brook charr and Atlantic salmon has been studied in Quebec, Canada. In the studied stream both species occur natively. Although there were some similarities in the diet composition, the overlap was small irrespective of the time and the day of sampling. The brook charr behaved more like a generalist, with terrestrial prey being dominant. The Atlantic salmon selected aquatic prey over terrestrial, had a narrower diet breadth, and specialized on mayflies (Ephemeroptera) (Mookerij *et al*., 2004). Such differences in diet composition are mostly associated with a spatial segregation caused by inter-specific competition.

Behavioral observations and field experiments suggest that Atlantic salmon are more aggressive and dominant over brook charr forcing the latter out of its preferred riffles (Gibbson *et al*., 2003). Because of this dominance, brook charr are less likely to seriously effect Atlantic salmon population by competition. Its potential impact on reintroduction programs in the Netherlands is considered to be low, although Hendry & Cragg-Hine (2003) suggest that it still should be considered in the English situation.

Competition with Atlantic trout
The reciprocal invasions of the brook charr and the Atlantic trout have been reviewed by Korsu *et al*. (2007). In eastern North America the Atlantic trout, which has spread extensively within the native range of the brook charr, has excluded the brook charr from many larger streams. In invaded areas small headwater streams serve as refuges for the brook charr. The Atlantic trout excludes the brook charr especially by its more aggressive behavior. In Europe invasions of the brook charr in Atlantic trout areas result in the same distribution. Here brook charrs exclude Atlantic trout from small headwater streams, especially as they are acidic. In these headwater streams the brook charr has a much better reproductive output compared to the Atlantic trout. This results in the outcompeting of the Atlantic trout. For several local varieties of the Atlantic trout the headwater streams serve as refugees. Exclusion by the brook charr can lead to extinction of these unique European populations.

Competition between rainbow trout and brown trout has been little studied in Europe. Peter *et al*. (1998) reported successful invasions of rainbow trout in streams already occupied by Atlantic trout. Some impact on the population level might indeed be expected, but severe impact seems unlikely beforehand as the Atlantic trout is known to outcompete *Oncorhynchus*-species in their native range (Belica, 2007).

<u>Hybridization with native salmonids</u>
Rainbow trout, belonging to a genus (*Oncorhynchus*) not native to Europe and having a distinctly different spawning season, is not known to hybridize successfully with species native to Europe. Charrs (*Salvelinus*) are very well-known for hybridizing. Careless

releases and a lack of a clear concept of genetic diversity in freshwater fishes within Europe has let to genetic fowling of many unique *Salvelinus*-taxa (Freyhof & Huckstorf, 2006; Kottelat & Freyhof, 2007; P. Veenvliet, pers. comm.). This is not a problem in the Netherlands as charrs are not indigenous here.

Brook charr also hybridizes with brown trout resulting in so called tiger trout. This intergeneric hybrid is sterile and cannot cause any genetic fowling (Jansson, 2008). But these reproductive interactions, which are actually observed in the wild (France), could be detrimental to the reproduction success and add to competitive abilities of both species (Cucherousset *et al*., 2008).

Figure 5.7: A tiger trout (Salvelinus fontinalis x Salmo trutta) showing its typical marbled pattern and a tiger trout caught in 2010 in the Roer (the Netherlands). Foto's: O. Vohringer & Thijs Belgers.

<u>Impact on other native fish species</u>

Rainbow trout is reported to predate on Western brook lampreys (*Lampetra richardsoni*) and their eggs (Bernstein & Montgomery, 2008; Confederated Tribes of the Umatilla Indian Reservation Spring, 2004). Such can also be expected from the brook charr as it has a broad diet comparable with the rainbow trout. With the brook lamprey (*Lampetra planeri*) being comparable with the Western brook lamprey, predation on the brook lamprey is most likely. The brook lamprey is found locally in Pleistocene parts of the Netherlands (De Nie, 1996). It is a rare species and Red-listed in the Netherlands as threatened (www.minlnv.nl). Most populations of this species are located in small streams, often headwaters, in absence of larger predatory fish. Invasions of rainbow trout or brook charr in these small streams are likely to have an impact that should be considered (Maitland, 2003). In the Geelmolense Beek rainbow trout, brook charr and brook lamprey did co-exist. Densities of the brook lamprey were low, but the role of predation by salmonids was unclear (Soes & Hoefsloot, 2009).

Although predation and the alteration of food webs are most likely to impact native bony fish species other than salmonids, there is little evidence of such impact in European streams (Korsu *et al*., 2008). European research on the impact of both rainbow trout and brook charr focused almost exclusively on native salmonids (e.g. Jansson, 2008; Korsu *et al*., 2008). Most reports on impact on non-salmonids are from the southern hemisphere. Here freshwater galaxiids (Galaxiidae), a family confined to the southern hemisphere, are under a lot of pressure due to the releases of especially rainbow trout and brown trout. The often specialized galaxiids are both predated and outcompeted by the more plastic salmonids leading to major decline within this group (McDowall, 2006; Perry, 2007; Simon & Townsend, 2003; Crowl *et al*., 1992).

Not only galaxiids have been reported being negatively affected by exotic trout. In Japan negative effects of rainbow trout, brown trout and brook charr on a goby (*Rhinogobius sp*.) and a sculpin (*Cottus nozawae*) have been noted (Kitano, 2004). In the Colerado River (USA) the non-native rainbow trout predated heavily upon the already endangered humpback chub (*Gila cypha*), a cyprinid species (Marsch & Douglas, 1997).

Both predation and competition are likely to effect Dutch non-salmonid species also. In several instances exotic trout species have been mentioned as possible threats for species native in the Netherlands, e.g. sculpin (*Cottus perifretum*) (Seeuws, 1998), spirlin (*Alburnoides bipunctatus*) (Crombaghs *et al*., 2000) and grayling (*Thymallus thymallus*) (Uiblein *et al*., 2001). Especially species in smaller streams lacking native, larger predatory species are likely to be vulnerable and are regarded as potentially highly impacted.

Predation on other vertebrate groups

Exotic salmonids are known to be responsible for several declines in populations of amphibians and even reptiles (Jansson, 2008; Finlay & Vredenburg, 2007; Fausch, 2007; Bosch *et al*., 2006). Most declines are due to releases of rainbow trout or brook charr in formerly fish free habitats. Releases of *Salvelinus sp*. in Slovenian Alpine lakes with endemic forms of the Alpine newt (*Ichtyosaura alpestris lacusnigri*) led to declines in the number of populations of these rare forms (P. Veenvliet, pers. comm.; Veenvliet & Kus-Veenvliet, 2008). These lakes didn't have any fish populations and the Alpine newt was actually the top predator in these lakes (Schabetsberger & Jersabek, 1995). In Spain the introduction of brown trout and brook charr in fish free streams resulted in the eradication of the Iberian frog (*Rana iberica*) from several streams (Bosch *et al*., 2006).

Matthews *et al*. (2002) found a negative relationship between exotic trout populations and the mountain garter snake (*Thamnophis elegans elegans*). Amphibians are a prerequisite for mountain garter snake persistence in the Sierra Nevada (USA) and the introduction of trout into formerly fish free streams have serious effects, not just on their prey but also on their predators.

These declines of amphibian species by introduced salmonids occur largely by predation on larvae, but non-lethal effects can also be relevant. Many amphibian species avoid breeding in water bodies containing chemicals from fish predators such as salmonids (Bosch *et al*., 2006).

In the Netherlands several amphibian species can be found in streams, with the common frog (*Rana temporaria*) being the most common one. The population of this species in the Geelmolense Beek might be affected by the presence of both rainbow trout and brook charr. Red-listed species are less common in streams (Van Delft *et al*., 2009). Of the Red-listed species only the fire salamander (*Salamandra salamandra*) is known to be strongly associated with streams. The Palmate newt (*Lissotriton helveticus*), another Red-listed species, is infrequently found in small, slow flowing streams (Creemers & Van Delft, 2009). Both species could potentially be highly impacted when exotic trout species colonized streams inhabited with these species.

<u>Predation on resident invertebrate species</u>

Invertebrates are heavily predated by salmonids in general and are likely to be affected when exotic species are introduced. One of the most common noted effects in the aquatic invertebrate communities is a shift from the larger, more active species towards smaller, inconspicuous species (Simon & Townsend, 2003; Dunham *et al*., 2004; Molineri, 2008). Typical species negatively affected by exotic trout are freshwater crayfish, damselflies, larger mayflies and caddisflies (Simon & Townsend, 2003). In a streams already occupied by a native species Englund & Polhemus (2001) didn't find such effects after the introduction of rainbow trout, presumably as the community was already pre-adapted due to the presence of this native salmonid with a diet comparable with the rainbow trout.

In New Zealand streams, introduced brown trout and rainbow trout change the diurnal activity and microhabitat selection of invertebrate prey. Mayflies (*Nesameletus ornatus*) from streams containing trout are more active during the night than mayflies from streams with only native galaxiids. Mayflies (*Baetis* spp.) spend less time on the surface of the rocks when trout are present. Furthermore there is an increase in night drift of e.g. snails (*Potamopyrgus antipodarum*), caddisflies (*Olinga feredayi*, *Aoteapsyche colonica*) and mayflies (*Baetis caelestis*). Such adaptive behaviour can lessen the effects of predation and prevent extirpation (Simon & Townsend, 2003).

In lakes, exotic trout often induce a decrease in larger bodied zooplankton species and an increase of smaller bodied species. The selective predation on larger zooplankton of trout reduces both the competition and the predation by species such as phantom midges (*Chaoborus* sp.) favouring the smaller cladocerans, rotifers and other smaller zooplankton (Carpenter & Kitchell, 1993; Simon & Townsend, 2003).

Predation of trout on herbivorous invertebrates can also induce an increase in algal biomasses and changes in algal assemblages. In a comparison of streams Biggs *et al*., (2000) found that algal assemblages in streams with exotic trout were dominated by erect taxa that are more susceptible to grazing.

Although the described impact on invertebrate communities has only been demonstrated for water systems that are distinctly different from Dutch waters in species composition their impact is likely comparable in Dutch streams and lakes. Depending on whether waters are fishless or not the impact of rainbow trout and brook charr is likely to be potentially low to high.

Transfer of diseases

One of the major problems in the transfer of (exotic) fish, such as the rainbow trout, is the possibility these fishes act as vectors for exotic disease. Well known examples of introduced diseases in the Netherlands are *Anguillicola crassus*, a nematode infecting eel and causing damage to the swim bladder of the eel, and spring viremia of carp (SVC), a viral disease that can cause significant mortality of common carp. Both disease were introduced in Western-Europe with fish transports of respectively eel and carp (Lazard & Dabbadie, 2003).

Also exotic salmonids are well known to have acted as vectors of exotic diseases. *Myxosoma cerebralis* is a harmless, common parasite of Atlantic trout, but an aggressive kidney disease of salmonids such as rainbow trout (whirling disease). It has been introduced in North America via infected trout imported from Europe (Faisal, 2004). Another example, the bacterial disease furunculosis appeared both in Europe and South America following the introduction of rainbow trout from Western North America (Lazard & Dabbadie, 2003).

With salmonids being very important in aquaculture and fisheries the total number of known diseases and parasite is relatively numerous (Roberts & Shepherd, 1997). A complete description of all disease and parasites would be beyond the scope of this risk analysis. In the following two examples will be given. The first, *Gyrodactylus salaris*, is a parasite which in its alien range has caused serious damage to salmon stocks. Rainbow trout and possibly also brook charr can be vectors for this parasite.

Gyrodactylus salaris

Gyrodactylus salaris is a small monogenean ectoparasite (about 0.5 millimeter long), which mainly lives on the skin of freshwater Atlantic salmon. Other suitable, but little affected hosts are rainbow trout, grayling and several species of charr. It attaches to the fish by a large specialized posterior attachment organ. When feeding, the parasite attaches its anterior end to the fish with cephalic glands. It inverts its pharynx through the mouth and releases a digestive solution with enzymes which dissolves the salmon skin. Mucus and dissolved skin are then sucked into the gut. This feeding activity results in ulcers and lesions in the fish skin (Bakke *et al*., 2007). The disease involving G. salaris is named gyrodactyliosis.

G. salaris probably has an original distribution that includes the Karelian part of Russia and the Baltic parts of Finland and Sweden (Johnsen, 2006). The Baltic race or group of the Atlantic salmon, which has coevolved with *G. salaris*, shows a strong immune response to the parasite and is hardly affected. When *G. salaris* was transported with juvenile salmon into Norwegian populations (East Atlantic race or group) infections with the same parasite has caused epidemics that have devastated stocks of Atlantic salmon in many rivers. The density of salmon parr in infected rivers has been reduced on an average of 86% and the catch of salmon in infected rivers are reduced on an average of 87% (Johnsen, 2006).

Other Atlantic populations of the Atlantic salmon are also expected to be vulnerable for *G. salaris*, but patterns have not proven to be consistent. One of the complications is the presence of several strains of *G. salaris* also differing in pathogenicity (Hansen *et al*., 2003). A strain found in Danish rainbow trout farms was experimentally shown to cause hardly any problems in Atlantic salmon (Lindenstrøm *et al*. 2003). Currently, it has to be concluded that the diversity within the species *G. salaris* is highly complex and further research is needed for a clear understanding of the patchwork of strains found (Bakke *et al*., 2007). With strains differing in pathogenicity this consequently will surely affect the understanding of impact.

The current alien status of *G. salaris* is uncertain due to identification problems. Verified reports are known from Norway, Sweden, Finland, Russia, Denmark, Italy, Ukraine, Georgia and Bosnia Herzegovina (Bakke *et al*., 2007). Its status in the Netherlands in unknown (O. Haenen, pers. com.). In infected countries it is mainly found in trout farms, with fish transports being the dominant vector. In infested river systems, such as present in Norway and Sweden, it can spread naturally and it is also able to move from one river system to another using salmonids as a vector. It can't withstand sea water, but brackish water up to about 25ppt can be tolerated (Høgåsen *et al*., 2009; Peeler, 2006; Soleng *et al*., 1998).

The international Rhine Action Programme uses currently mainly Atlantic salmon originating from the Atran river system, southwest Sweden for stocking (F. Moquette, pers. com.). This river system ends in the Kattegat, the connection between the North Sea and the Baltic Sea. In the Atran river system high infections with *G. salaris* have been found, but is not considered to be a major problem, although some evidence for negative impact is reported (Malmberg in Bakke *et al*., 2007; Karrlson *et al*. in Johnsen, 2006). Also within the Rhine restocking program *G. salaris* is not considered to be a great threat (Dr. Schäfer (Fisch-Veterinärs), pers. com.). But as a thorough risk analysis considering the existence of several strains with different pathogenicity seems to be absent the basis for such an assumption is rather thin, especially as rainbow trout transports from e.g. Denmark give an actual risk of introducing *G. salaris* in the river Rhine system (B.O. Johnsen & L. Bachmann, pers. com.).

G. salaris doesn't reproduce very successfully on Atlantic trout and is consequently no problem in this species (Bakke *et al*., 2007).

Figure 5.8: Gyrodactylus salaris. Photo: T. Atle Mo.

Infectious salmon anaemia (ISA)

Infectious salmon anaemia (ISA) is an infectious viral disease of Atlantic salmon. The disease was first reported in Norway in 1984, but has since been reported in Canada, the USA, the Faroe Islands, Ireland and Scotland. The outbreak of ISA in Scotland in 1998-99 was successfully eradicated. Atlantic salmon is the only susceptible species known to develop clinical disease, but ISA virus can replicate in rainbow trout and Atlantic trout.

In Norway, cases of ISA have occasionally been reported in fresh water farms but generally in hatcheries which use partly sea water. The overwhelming majority of cases occur in farmed fish in sea water. The virus has been detected in wild fish but cases of clinical disease have only been reported in farmed fish.

The virus can be transmitted through water, but the highest risk factors for spread of disease are movement of live fish, discharge of untreated blood and contact with infected vehicles and equipment.

With little information on how this disease behaves in wild fish it is hardly possible to give a reliable statement of potential impact of this disease to e.g. the stocking programmes of the Atlantic salmon. Further studies seems to be warranted.

Interference with goals of the Water Framework Directive (WFD) and/or Natura 2000 Directive

In the Water Framework Directive, goals have been identified for both the water quality and the ecological values present in different water systems. In the Habitat and Bird Directives, goals have been identified for habitats and birds. Ecological effects of exotic salmonids could interfere with these goals especially when high densities occur in a particular water system.

Examples are the changing of fish or invertebrate communities that will negatively interfere with the goals of the Water Framework Directive and predation of species listed in the Natura 2000 Directive such as brook lamprey and bitterling.

Economic and social impacts
Angling is a popular leisure activity in the Netherlands of reasonable economical value (Smit *et al*., 2004). Species such as rainbow trout and brook charr are valued for their angling possibilities. Exploitable populations will certainly be appreciated and have a small positive economic and social impact restricted to the angling society and business.

5.6 Risk identification conform the Fisk method

The threats posed by introduced species have led to the need to develop policies to minimize the risk. For the development of such policies standardized and clear assessment tools are of great importance. One of the available tools is the Fish Invasiveness Screening Kit (FISK), which has already been applied in the U.K., Belgium and Balearus (Copp *et al*., 2005; Copp *et al*., 2009, Mastitsky *et al*., 2010; Verreycken *et al*., 2010). The results of this method are presented in appendix 3 and 4.

The brook charr (score 14) belongs within the Netherlands according to FISK not to the group of high-risk species (species with a score > 18) (Copp *et al*., 2009). Although it cannot be excluded that the brook charr might establish small, isolated populations, this species is not expected to become invasive, see also § 5.4. The results of FISK are consistent with this conclusion. Its low score are mainly due to the low climate matching as the brook charr is poorly adapted to lowlands in marine temperate regions.

The rainbow trout in the Netherlands (score 20) belongs according to FISK to the group of high-risk species with a relatively low score (Copp *et al*., 2009). Its higher score in comparison with the brook charr is mainly due the fact that it is much more adapted to the Dutch climate. The score is high when compared with the expert judgement conducted in this report. This can readily be explained by the fact that FISK does not include information on the amount of suitable habitat, which is probably minimal within the Netherlands. Furthermore is the mechanism behind the lack of invasiveness of the rainbow trout is in many instances not well understood. Especially more complicated mechanisms, such as biotic resistance, are likely to be less covered in FISK.

5.2.3 Conclusions

- The outcome of the FISK method for the rainbow trout is a score of 20. That means that the species fall into category high-risk species.
- The outcome of the FISK method for the brook charr is a score of 14. That means that the species does not fall into category high-risk species.
- The FISK method gives too little weight to the amount of suitable habitat within the assessed region.

6 Risk Management

6.1 Prevention of spread

Creating insight in stocking practices

For creating an effective policy on stocking of fish in general and salmonids in particularly, information about the species and the numbers stocked in public waters are an important prerequisite. Even an organization such as Sportvisserij Nederland seems to lack currently such information.

Making it obligatory to report any stockings to a central, independent organization (e.g. 'Visstandbeheerscommisies') could create better insight in stocking practices. This may not only serve policies on exotic species, but may have an even greater use in fish disease prevention.

Preventing the stocking in open water systems

To prevent the establishment of the rainbow trout or the brook charr the stocking of these species in suitable systems should be prevented. Furthermore is such stocking unwanted as stocked trout may be a vector for diseases harmful to indigenous salmonid species.

Currently 'Visstandbeheerscommissies' are preparing fish management plans (visstandbeheerplannen), which will need governmental approval. Also the stocking of fish needs to be described in these management plans. Incorporation of preventive policies on exotic species in the formal check of these management plans might regulate such stockings.

Another way to prevent the stocking of these species is creating legislation. The incorporation of the exotic crayfish might be considered a good example of how such legislation might be created.

Preventing escapes from fish farms, garden ponds, etc.

It is permitted to keep both rainbow trout and brook charr on private properties. But it is regulated in both the Flora- and fauna law and the Fisheries law that such waters should be isolated from public water systems in such a way that escapes of e.g. rainbow trout is prevented. This also applies to fish farms. Communication this information on legislation might help e.g. water boards in preventing such escapes.

So called fish screens are easy to install and relatively cheap. These fish screens will prevent larger fish from escaping. Fish screens are in general ineffective for the prevention of escapes of fry and small juveniles. Fish screens that might prevent even fry and small juveniles from escaping need a too fine mesh size, making them very laborious to maintain their functionality.

Preferably fry and small juveniles in fish farms are kept in so called recirculation systems and have no open connections with streams. Such systems can even be provided with UV-treatment killing all organisms such as fry.

Another possibility is a “sock” screen or the like fitted in the entrance of the outlet pipe to prevent escape of even the smallest fishes from the pond or tank.

Preventing the spread of disease

Prevention of the spread of serious fish diseases quickly effects international trade. Because of this, legislation has been developed at a the level of the European Union. Within the European Union policies have concentrated on the most serious diseases with control possibilities. The most relevant legislation is Council Directive 2006/88/EC which lays down (www.crl-fish.eu):

- minimum control measures in the event of a suspicion or outbreak of certain diseases in aquatic animals;
- minimum preventive measures aimed at increasing the awareness of the competent authorities, aquaculture production businesses operators and others related to this industry, concerning diseases of aquaculture animals;
- the animal health requirements to be applied for the placing on the market and the imports of aquaculture animals and products thereof.

The diseases and susceptible fish species covered by the Directive are categorized in two lists:

Exotic diseases: Epizootic haematopoietic necrosis (EHN) and epizootic ulcerative syndrome (EUS) are considered exotic in the Community and fish infected with such diseases are killed and destroyed as soon as possible to prevent the spread of the disease. Where fish are suspected of being infected or infected with an exotic disease, movement of fish, whether dead or alive, eggs and gametes are not allowed without the authorisation of the official service.

Non-exotic diseases: Viral haemorrhagic septicaemia (VHS), infectious haematopoietic necrosis (IHN), Koi herpes virus disease (KHVD) and infectious salmon anaemia (ISA) diseases are important endemic diseases that should be contained and eradicated in the long term.

When one of the above mentioned disease is detected on e.g. a fish farm it is obligatory to report this to the Food and Consumer Product Safety Authority (Voedsel en Waren Autoriteit (VWA)). The information on the website of the VWA differs remarkably from the Directive 2006/88/EC. Clear information which is readily available is important for a successful implementation and improving such is of importance to minimize the risk of the listed diseases.

6.2 Eradication and physical control methods

In countries where exotic trout species have established populations researchers have experimented with a variety of physical controls to eradicate or reduce such populations.

The following physical control methods have been applied to reduce or eradicate established populations of exotic salmonids.

Forbidding release of captured fish by recreational fishermen
Although physical control methods via commercial and recreational fishing are not considered the most successful ones, they are often the only possibility (Thresher, 1997). In Australia it is e.g. forbidden by law to release caught carp (*Cyprinus carpio*). The carp is an exotic fish species in Australia and considered harmful (Graham *et al*., 2005).

A survey in New South Wales found that even with the mentioned legislation about 11% of carp were released after capture by recreational fishermen (Graham *et al*., 2005). These recreational fishermen probably released their caught carp because of ethical reasons. Australian internet forums clearly showed a lot of debate on the necessity of killing captured carp. Especially inexperienced fishermen causing a great amount of animal suffering are considered a problem (D.M. Soes, pers. obser.).

In the Netherlands rainbow trout and brook charr are appreciated game fishes. Furthermore has the catch and release of coarse and game fishes been much promoted and is the killing of e.g. carp, even for consumption, becoming extremely rare. This gives little ground for installing legislation or policy, which involves the killing of game fish such as rainbow trout or brook charr. Also a discussion during a recent meeting of the Vissennetwerk (3-6-2010) clearly showed that such legislation or policy would receive little support.

Eradication by piscicides and fishing
Experience from the United States shows that attempts to eradicate trout have varying degrees of success. The use of piscicides such as rotenone can pose serious risks to other species, and methods not involving chemicals that have been successful include systematic electrofishing in streams and gill netting in small lakes (Jansson, 2008).

The use of chemicals and intensive netting is only applicable to systems only containing the unwanted fish species. In the Netherlands only systematic electrofishing seems to be a probable option.

7 Conclusions and recommendations

7.1 Conclusions

Conclusions probability of entry

The chances of entry can be summarized as follows:

Rainbow trout

- The chance of entry from fish farms, neighboring countries and stocking in isolated waters is high;
- The chance of entry from trout fishing ponds, garden ponds, zoos, stocking in open water systems and illegal stocking is low;
- The chance of entry from consumption trade is zero.

Brook charr

- The chance of entry from fish farms, neighboring countries, stocking in isolated waters, trout fishing ponds, garden ponds, stocking in open water systems and illegal stocking is low;
- The chance of entry from zoos and consumption trade is zero.

Conclusions probability of establishment

Rainbow trout

Suitable streams with suitable temperatures and suitable spawning habitat are only present in Limburg. Due to vulnerability of used rainbow trout strains for predation streams such as the Roer, with a high diversity in predatory fish, are less likely to be suitable for establishment of populations. Based on habitat suitability the probability of establishment is low.

The use of other aquacultural strains based purely on wild fish, which seem to be only present in Noth America, might increase the chances of establishment.

Brook charr

Springs and streams with suitable temperatures and suitable spawning habitat are locally present in Limburg and in Pleistocene areas. Such waters are small and will not be able to support larger populations. Small fish populations are less stable giving a higher risk for extinctions and a less likely establishment for a longer period. Based on habitat suitability the probability of establishment is low, with only incidental, local establishments expected.

Conclusions probability of further spread

When established, rainbow trout and brook charr can easily spread within the water system in which they have established. The chance of spreading from one water system to another decreases with the distance between water systems. They are only likely to establish in other water systems when they are able to build up relatively large founder populations.

Conclusions endangered areas
Combing the experiences from neighboring countries, propagule pressure and habitat suitability it is concluded that in the current situation endangered areas are almost absent and that both species are not expected to become invasive in the Netherlands. The only exception, actually based on reported reproduction, seems to be the water system at the east flank of the Veluwe. Here local establishment might be possible, especially of the brook charr.

Conclusions impacts
Ecological impacts
Both rainbow trout and brook charr can potentially seriously effect Dutch ecosystems due:
- Predation on native fish species such as the brook lamprey;
- Predation on native amphibians;
- Predation on native invertebrate species;
- Transmitting disease.

Impact is likely to be especially high in systems lacking large predatory fish before entry of salmonid species, such as headwater streams.

Competition between brook charr and Atlantic trout, which is considered a problem in some European countries, is unlikely with the rarity of the Atlantic trout. The Atlantic salmon seems not to be sensitive for competition of either species.

Economic impacts and social impacts
Exploitable populations will certainly be appreciated and have a small positive economic and social impact restricted to the angling society and business.

Conclusions prevention of spread
For creating an effective policy on stocking of fish in general and salmonids in particularly, information about the species and the numbers stocked in public waters are an important prerequisite. Such information is currently lacking. Making it obligatory to report any stockings to a central, independent organization (e.g. 'Visstandbeheerscommisies') could create better insight in stocking practices. This may not only serve policies on exotic species, but may have an even greater use in fish disease prevention.

The stocking of both rainbow trout and brook charr is legal in even the open water systems. Such stockings are not taking place currently, but garanties for them not taking place in the future can not be given. Clear incorperation of invasive species policies in fisheries policies could decrease the chance of such stockings taking place in the fututre.

Under current legislation escapes from e.g. fish farms or garden ponds are not aloud without the permission of the owner of the local fishing rights. Clear communication of this might help e.g. water boards in minimizing such escapes.

Conclusions eradication and control methods

The catch and release of coarse and game fishes have been much promoted. This gives little ground for installing legislation or policy, which involves the obligatory killing of game fish such as rainbow trout or brook charr. Also a discussion during a recent meeting of the Vissennetwerk (3-6-2010) clearly showed that such legislation or policy would receive little support.

The use of chemicals and intensive netting is only applicable to systems only containing the unwanted fish species. In the Netherlands only systematic electrofishing seems to be a probable option for eradication or control.

7.2 Recommendations

The current information on the presence of both rainbow trout and brook charr on the Veluwe is unsatisfying. A better understanding of the situation in the Geelmolense Beek and the Eperbeken/Verloren Beek is needed to establish the actual need for eradication measures in these streams.

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APPENDICES

Appendix 1: Distribution data of the rainbow trout (*Oncorhynchus mykiss*)

organisation	locality	year	numbers	x	y
Veluwe	Geelmolense beek	2008	1	190734	477565
Veluwe	Geelmolense beek	2008	1	190734	477565
Veluwe	Geelmolense beek	2008	1	191713	477506
Veluwe	Geelmolense beek	2008	1	191150	477550
Henrik de Nie	Geul	1983	1	192000	309000
Henrik de Nie	Haringvliet	1994	1	63000	428000
Rijkswaterstaat Imares	Het IJ	1995	1	125805	485800
Rijkswaterstaat Imares	Het IJ	1999	1	125805	485800
Rijkswaterstaat Imares	Hollandsch Diep	1996	1	104041	414071
Rijkswaterstaat Imares	Hollandsch Diep	1999	1	96824	411479
Rijkswaterstaat Imares	Hollandsch Diep	2006	1	103642	414539
Rijkswaterstaat Imares	Hollandsch Diep	2006	1	103642	414539
Rijkswaterstaat Imares	IJsselmeer	1997	1	158004	515012
Rijkswaterstaat Imares	IJsselmeer	2002	1	158004	515012
Rijkswaterstaat Imares	IJsselmeer	2002	1	158004	515012
Rijkswaterstaat Imares	IJsselmeer	2002	1	158004	515012
Henrik de Nie	Maas	1993	1	205000	369000
Henrik de Nie	Maas	1993	2	205000	370000
Rijkswaterstaat Imares	Maas	1994	1	198521	360456
Rijkswaterstaat Imares	Maas	1994	1	198896	364241
Rijkswaterstaat Imares	Maas	1995	1	201028	366355
Rijkswaterstaat Imares	Maas	1995	1	201028	366355
Rijkswaterstaat Imares	Maas	1995	1	201028	366355
Rijkswaterstaat Imares	Maas	1995	1	201028	366355
Rijkswaterstaat Imares	Maas	1995	1	201028	366355
Rijkswaterstaat Imares	Maas	1996	1	201028	366355
Rijkswaterstaat Imares	Maas	1997	1	204232	368072
Rijkswaterstaat Imares	Maas	1998	1	204232	368072
Rijkswaterstaat Imares	Maas	1998	1	204232	368072
Rijkswaterstaat Imares	Maas	1998	1	204232	368072
Rijkswaterstaat Imares	Maas	1998	1	204232	368072
Rijkswaterstaat Imares	Maas	1999	1	204232	368072
Rijkswaterstaat Imares	Maas	2001	1	204232	368072
Rijkswaterstaat Imares	Maas	2001	1	204232	368072
Rijkswaterstaat Imares	Maas	2002	1	204232	368072
Rijkswaterstaat Imares	Maas	2002	1	204232	368072
Rijkswaterstaat Imares	Maas	2003	1	204232	368072
Rijkswaterstaat Imares	Maas	2003	1	204232	368072
Rijkswaterstaat Imares	Maas	2004	1	205437	369659
Rijkswaterstaat Imares	Nederrijn	2001	1	138140	444080
NHG Limburg	Swalm	1990	1	202000	360000
Sportvisserij Nederland	Voer	2008	1	179977	308499

Appendix 2: Distribution data of the brook charr (*Salvelinus fontinalis*)

organisation	locality	year	numbers	x	y
NHG Limburg, extern gegeven visatlas	Voer	1990	1	178000	308000
NHG Limburg, extern gegeven visatlas	Voer	1990	1	179000	308000
NHG Limburg, extern gegeven visatlas	Voer	1990	1	183000	308000
NHG Limburg, extern gegeven visatlas	Maas	1990	1	185000	346000
NHG Limburg, extern gegeven visatlas	Gulp grens	1990	1	188000	309000
NHG Limburg, extern gegeven visatlas	Gulp Pesaken	1990	1	188000	312000
NHG Limburg, extern gegeven visatlas	Selzerbeek Geul	1990	1	191000	314000
NHG Limburg, extern gegeven visatlas	Geul	1990	1	192000	309000
NHG Limburg, extern gegeven visatlas	Geul	1990	1	192000	311000
NHG Limburg, extern gegeven visatlas	Sinselbeek	1990	1	192000	313000
NHG Limburg, extern gegeven visatlas	Maas onder Roermond	1990	1	192000	354000
NHG Limburg, extern gegeven visatlas	Maas bij Herten/Roermond	1990	1	195000	355000
NHG Limburg, extern gegeven visatlas	Selzerbeek	1990	1	196000	312000
NHG Limburg, extern gegeven visatlas	Roer	1990	1	196000	355000
NHG Limburg, extern gegeven visatlas	Swalm Maas	1990	1	199000	362000
NHG Limburg, extern gegeven visatlas	Maas	1990	1	201000	366000
NHG Limburg, extern gegeven visatlas	Swalm	1990	1	202000	360000
NHG Limburg, extern gegeven visatlas	Roer	1990	1	203000	349000
NHG Limburg, extern gegeven visatlas	Maas (5x5 hok)	1990	1	205000	369000
NHG Limburg, extern gegeven visatlas	Maasstuw bij Belfeld	1990	1	205000	370000
	Millingerwaard	1994	1	195000	429000
NHG Limburg, Henk Heijligers	Voer ,Withuis	1997	1	178700	308500
NHG Limburg, Henk Heijligers	Voer ,Mesch	1995	25	179000	308300
NHG Limburg, Henk Heijligers	Geul ,Meerssen	1997	4	180700	321300
NHG Limburg, Henk Heijligers	Gulp	1991	1	190800	314400
NHG Limburg, Henk Heijligers	Putbeek ,Echter Broek	1997	1	195400	346200
NHG Limburg, Henk Heijligers	Selzerbeek	1991	1	196300	312200
NHG Limburg, Henk Heijligers	Selzerbeek	1993	1	198200	310700
Henrik de Nie		1990	1	30000	395000
Henrik de Nie		1987	1	30000	400000
Henrik de Nie		1990	1	30000	400000
Henrik de Nie		1990	1	35000	390000
Henrik de Nie		1988	1	35000	395000
Henrik de Nie		1990	1	35000	395000
Henrik de Nie		1990	1	40000	395000
Henrik de Nie		1990	1	45000	395000
Henrik de Nie		1990	1	50000	395000
Henrik de Nie		1971	1	50000	422000
Henrik de Nie		1990	1	60000	435000
Henrik de Nie		1994	1	62000	427000
Henrik de Nie		1990	1	62000	428000
Henrik de Nie		1992	1	63000	427000
Henrik de Nie		1992	1	63000	428000
Henrik de Nie		1992	1	63000	428000
Henrik de Nie		1993	1	63000	429000
Henrik de Nie		1994	1	63000	429000
Henrik de Nie		1994	1	64000	438000
Henrik de Nie		1990	1	65000	435000
Henrik de Nie		1994	1	65000	438000
Henrik de Nie		1993	1	65000	444000
Henrik de Nie		1993	1	65000	444000

organisation	locality	year	numbers	x	y
Henrik de Nie		1991	1	66000	444000
Henrik de Nie		1992	1	66000	444000
Henrik de Nie		1993	1	68000	443000
Henrik de Nie		1993	1	68000	444000
Henrik de Nie		1993	1	68000	444000
Henrik de Nie		1987	1	70000	390000
Henrik de Nie		1988	1	70000	390000
Henrik de Nie		1992	1	70000	390000
Henrik de Nie		1987	1	70000	405000
Henrik de Nie		1990	1	70000	405000
Henrik de Nie		1991	1	70000	405000
Henrik de Nie		1991	1	72000	424000
Henrik de Nie		1993	1	73000	391000
Henrik de Nie		1993	1	73000	391000
Henrik de Nie		1991	1	75000	405000
Henrik de Nie		1992	1	75000	405000
Henrik de Nie		1993	1	75000	405000
Henrik de Nie		1992	1	75000	420000
Henrik de Nie		1993	1	75000	420000
Henrik de Nie		1978	1	81000	451000
Henrik de Nie		1987	1	85000	410000
Henrik de Nie		1989	1	85000	410000
Henrik de Nie		1992	1	85000	410000
Henrik de Nie		1993	1	86000	411000
Henrik de Nie		1993	1	86000	411000
Henrik de Nie		1993	1	86000	415000
Henrik de Nie		1992	1	87000	412000
Henrik de Nie		1994	1	106000	447000
Henrik de Nie		1968	1	115000	415000
Henrik de Nie		1992	1	117000	418000
Henrik de Nie		1985	1	118000	493000
Henrik de Nie		1985	1	119000	493000
Henrik de Nie		1994	1	120000	491000
Henrik de Nie		1994	1	125000	425000
Henrik de Nie		1975	1	125000	470000
Henrik de Nie		1993	1	125000	485000
Henrik de Nie		1993	1	125000	485000
Henrik de Nie		1985	1	125000	486000
Henrik de Nie		1993	1	126000	427000
Henrik de Nie		1985	1	127000	484000
Henrik de Nie		1985	1	128000	483000
Henrik de Nie		1993	1	129000	425000
Henrik de Nie		1993	1	129000	425000
Henrik de Nie		1993	1	130000	465000
Henrik de Nie		1985	1	132000	491000
Henrik de Nie		1992	1	137000	445000
Henrik de Nie		1994	1	140000	555000
Henrik de Nie		1990	1	144000	454000
Henrik de Nie		1990	1	144000	454000
Henrik de Nie		1993	1	147000	521000
Henrik de Nie		1993	1	147000	521000
Henrik de Nie		1993	1	148000	397000

organisation	locality	year	numbers	x	y
Henrik de Nie		1994	1	150000	560000
Henrik de Nie		1994	1	151000	565000
Henrik de Nie		1989	1	154000	370000
Henrik de Nie		1994	1	155000	390000
Henrik de Nie		1989	1	156000	371000
Henrik de Nie		1992	1	157000	405000
Henrik de Nie		1993	1	157000	405000
Henrik de Nie		1994	1	158000	380000
Henrik de Nie		1992	1	158000	389000
Henrik de Nie		1994	1	158000	389000
Henrik de Nie		1993	1	158000	514000
Henrik de Nie		1993	1	158000	515000
Henrik de Nie		1993	1	159000	424000
Henrik de Nie		1993	1	159000	424000
Henrik de Nie		1994	1	161000	414000
Henrik de Nie		1994	1	163000	433000
Henrik de Nie		1972	1	164000	509000
Henrik de Nie		1991	1	166000	379000
Henrik de Nie		1982	1	166000	404000
Henrik de Nie		1986	1	166000	404000
Henrik de Nie		1993	1	167000	426000
Henrik de Nie		1993	1	174000	513000
Henrik de Nie		1987	1	177000	308000
Henrik de Nie		1986	1	177000	312000
Henrik de Nie		1987	1	177000	312000
Henrik de Nie		1988	1	177000	312000
Henrik de Nie		1989	1	177000	312000
Henrik de Nie		1990	1	177000	312000
Henrik de Nie		1987	1	178000	308000
Henrik de Nie		1994	1	178000	308000
Henrik de Nie		1994	1	178000	492000
Henrik de Nie		1994	1	178000	512000
Henrik de Nie		1990	1	179000	308000
Henrik de Nie		1994	1	179000	308000
Henrik de Nie		1975	1	182000	323000
Henrik de Nie		1994	1	183000	308000
Henrik de Nie		1992	1	184000	512000
Henrik de Nie		1993	1	185000	346000
Henrik de Nie		1990	1	188000	309000
Henrik de Nie		1987	1	188000	311000
Henrik de Nie		1990	1	188000	312000
Henrik de Nie		1992	1	188000	443000
Henrik de Nie		1988	1	189000	430000
Henrik de Nie		1990	1	190000	310000
Henrik de Nie		1993	1	190000	327000
Henrik de Nie		1990	1	190000	355000
Henrik de Nie		1990	1	191000	314000
Henrik de Nie		1988	1	191000	430000
Henrik de Nie		1985	1	191000	508000
Henrik de Nie		1993	1	192000	309000
Henrik de Nie		1994	1	192000	313000
Henrik de Nie		1990	1	192000	354000

organisation	locality	year	numbers	x	y
Henrik de Nie		1988	1	192000	429000
Henrik de Nie		1992	1	193000	419000
Henrik de Nie		1993	1	193000	480000
Henrik de Nie		1993	1	194000	517000
Henrik de Nie		1990	1	195000	310000
Henrik de Nie		1991	1	195000	355000
Henrik de Nie		1991	1	195000	355000
Henrik de Nie		1990	1	195000	360000
Henrik de Nie		1994	1	195000	518000
Henrik de Nie		1990	1	196000	312000
Henrik de Nie		1994	1	196000	312000
Henrik de Nie		1983	1	196000	355000
Henrik de Nie		1983	1	196000	356000
Henrik de Nie		1985	1	196000	356000
Henrik de Nie		1988	1	196000	437000
Henrik de Nie		1980	1	196000	446000
Henrik de Nie		1973	1	198000	332000
Henrik de Nie		1983	1	198000	351000
Henrik de Nie		1990	1	199000	362000
Henrik de Nie		1984	1	200000	446000
Henrik de Nie		1992	1	201000	366000
Henrik de Nie		1989	1	203000	360000
Henrik de Nie		1994	1	204000	392000
Henrik de Nie		1993	1	205000	369000
Henrik de Nie		1993	1	205000	370000
Henrik de Nie		1990	1	205000	445000
Henrik de Nie		1990	1	205000	450000
Henrik de Nie		1990	1	210000	445000
Henrik de Nie		1990	1	215000	435000
Henrik de Nie		1990	1	215000	440000
Henrik de Nie		1990	1	220000	430000
Henrik de Nie		1990	1	220000	435000
Henrik de Nie		1975	1	229000	505000
Henrik de Nie		1983	1	235000	555000
Henrik de Nie		1995	1	235000	581000
Henrik de Nie		1983	1	236000	568000
Henrik de Nie		1983	1	237000	558000
Henrik de Nie		1994	1	242000	572000
Henrik de Nie		1990	1	244000	515000
Rijkswaterstaat Imares	Haringvliet	1998	1	70249	422482
Rijkswaterstaat Imares	Haringvliet	1998	1	70249	422482
Rijkswaterstaat Imares	Zoommeer	1997	1	71647	391565
Rijkswaterstaat Imares	Haringvliet	1996	1	71994	424419
Rijkswaterstaat Imares	Zoommeer	1996	2	73485	391406
Rijkswaterstaat Imares	Zoommeer	1996	2	73485	391406
Rijkswaterstaat Imares	Zoommeer	2000	1	73755	390974
Rijkswaterstaat Imares	Zoommeer	2000	1	73755	390974
Rijkswaterstaat Imares	Zoommeer	1999	1	74252	389464
Rijkswaterstaat Imares	Volkerak	1995	1	86207	411279
Rijkswaterstaat Imares	Volkerak	1995	1	86207	411279
Rijkswaterstaat Imares	Volkerak	1996	1	86207	411279
Rijkswaterstaat Imares	Haringvliet	2005	1	96218	410966

organisation	locality	year	numbers	x	y
Rijkswaterstaat Imares	Hollandsch Diep	1995	1	96419	411372
Rijkswaterstaat Imares	Hollandsch Diep	1995	1	96419	411372
Rijkswaterstaat Imares	Hollandsch Diep	1995	1	96719	411369
Rijkswaterstaat Imares	Hollandsch Diep	2001	1	96824	411479
Rijkswaterstaat Imares	Hollandsch Diep	1997	1	96824	411479
Rijkswaterstaat Imares	Hollandsch Diep	1997	1	96824	411479
Rijkswaterstaat Imares	Hollandsch Diep	2001	1	96824	411479
Rijkswaterstaat Imares	Hollandsch Diep	2005	1	103642	414539
Rijkswaterstaat Imares	Hollandsch Diep	2005	1	103642	414539
Rijkswaterstaat Imares	Hollandsch Diep	2006	1	103642	414539
Rijkswaterstaat Imares	Hollandsch Diep	2006	1	103642	414539
Rijkswaterstaat Imares	Hollandsch Diep	2005	1	103642	414539
Rijkswaterstaat Imares	Hollandsch Diep	2005	1	103642	414539
Rijkswaterstaat Imares	Hollandsch Diep	2003	1	103839	414648
Rijkswaterstaat Imares	Hollandsch Diep	2003	1	103839	414648
Rijkswaterstaat Imares	Hollandsch Diep	2003	1	103839	414648
Rijkswaterstaat Imares	Hollandsch Diep	2003	1	103839	414648
Rijkswaterstaat Imares	Hollandsch Diep	2002	1	104844	414971
Rijkswaterstaat Imares	Hollandsch Diep	2000	1	104844	414971
Rijkswaterstaat Imares	Hollandsch Diep	2001	1	104844	414971
Rijkswaterstaat Imares	Hollandsch Diep	2000	1	104844	414971
Rijkswaterstaat Imares	Hollandsch Diep	2001	1	104844	414971
Rijkswaterstaat Imares	Nwe Merwede	1999	2	106846	415971
Rijkswaterstaat Imares	Nwe Merwede	2001	1	106846	415971
Rijkswaterstaat Imares	Amer	2000	3	107850	414979
Rijkswaterstaat Imares	Amer	2001	1	107850	414979
Rijkswaterstaat Imares	Amer	2000	1	107850	414979
Rijkswaterstaat Imares	Nwe Merwede	2002	1	107850	414979
Rijkswaterstaat Imares	Nwe Merwede	2002	1	107850	414979
Rijkswaterstaat Imares	Amer	2003	1	107850	414979
Rijkswaterstaat Imares	Nwe Merwede	2001	1	110454	420370
Rijkswaterstaat Imares	Nwe Merwede	1996	1	110768	419477
Rijkswaterstaat Imares	Nwe Merwede	1997	1	110768	419477
Rijkswaterstaat Imares	Nwe Merwede	1995	1	110768	419477
Rijkswaterstaat Imares	Nwe Merwede	1997	1	110768	419477
Rijkswaterstaat Imares	Nwe Merwede	2005	1	111561	421973
Rijkswaterstaat Imares	Nwe Merwede	1998	1	111561	421973
Rijkswaterstaat Imares	Nwe Merwede	2004	1	111665	422065
Rijkswaterstaat Imares	Nwe Merwede	2003	1	111665	422065
Rijkswaterstaat Imares	Nwe Merwede	2002	1	113263	423386
Rijkswaterstaat Imares	Noordzeekanaal	1994	1	120189	491010
Rijkswaterstaat Imares		1997	1	125805	485800
Rijkswaterstaat Imares		1998	1	125805	485800
Rijkswaterstaat Imares	IJsselmeer	1995	1	125805	485800
Rijkswaterstaat Imares		1995	1	125805	485800
Rijkswaterstaat Imares		1999	1	125805	485800
Rijkswaterstaat Imares		1998	1	125805	485800
Rijkswaterstaat Imares		1998	1	125805	485800
Rijkswaterstaat Imares		1997	1	125805	485800
Rijkswaterstaat Imares		1998	1	125805	485800
Rijkswaterstaat Imares		1998	1	125805	485800
Rijkswaterstaat Imares		1999	1	125805	485800

organisation	locality	year	numbers	x	y
Rijkswaterstaat Imares		1999	1	125805	485800
Rijkswaterstaat Imares	Waal	2001	1	128611	425877
Rijkswaterstaat Imares	Markermeer	1999	1	133026	516414
Rijkswaterstaat Imares	Nederrijn	2006	1	133028	445139
Rijkswaterstaat Imares	Nederrijn	2003	1	133028	445139
Rijkswaterstaat Imares	Nederrijn	2004	1	133028	445139
Rijkswaterstaat Imares	Nederrijn	2002	1	135229	446093
Rijkswaterstaat Imares	Nederrijn	2001	1	135938	445979
Rijkswaterstaat Imares	IJsselmeer	1997	1	150277	564377
Rijkswaterstaat Imares	IJsselmeer	1997	1	150277	564377
Rijkswaterstaat Imares	IJsselmeer	1999	6	150277	564377
Rijkswaterstaat Imares	IJsselmeer	1997	1	150277	564377
Rijkswaterstaat Imares	IJsselmeer	1996	2	151986	564840
Rijkswaterstaat Imares	IJsselmeer	1996	1	151986	564840
Rijkswaterstaat Imares	IJsselmeer	1996	2	151986	564840
Rijkswaterstaat Imares	IJsselmeer	1996	1	158004	515012
Rijkswaterstaat Imares	IJsselmeer	1996	1	158004	515012
Rijkswaterstaat Imares	IJsselmeer	2002	1	158004	515012
Rijkswaterstaat Imares	IJsselmeer	1995	3	158004	515012
Rijkswaterstaat Imares	IJsselmeer	2002	1	158004	515012
Rijkswaterstaat Imares	IJsselmeer	2000	1	158004	515012
Rijkswaterstaat Imares	IJsselmeer	2003	1	158004	515012
Rijkswaterstaat Imares	IJsselmeer	1995	1	158004	515012
Rijkswaterstaat Imares	IJsselmeer	1996	1	158004	515012
Rijkswaterstaat Imares	IJsselmeer	2000	1	158004	515012
Rijkswaterstaat Imares	IJsselmeer	1998	2	158004	515012
Rijkswaterstaat Imares	IJsselmeer	2000	2	158004	515012
Rijkswaterstaat Imares	IJsselmeer	2002	1	158004	515012
Rijkswaterstaat Imares	IJsselmeer	1997	1	158004	515012
Rijkswaterstaat Imares	IJsselmeer	2002	1	158004	515012
Rijkswaterstaat Imares	IJsselmeer	2002	1	158004	515012
Rijkswaterstaat Imares	IJsselmeer	2000	1	158004	515012
Rijkswaterstaat Imares	IJsselmeer	2000	1	158004	515012
Rijkswaterstaat Imares	IJsselmeer	2000	2	158004	515012
Rijkswaterstaat Imares	IJsselmeer	2000	1	158004	515012
Rijkswaterstaat Imares	IJsselmeer	1996	1	158004	515012
Rijkswaterstaat Imares	IJsselmeer	2003	1	158004	515012
Rijkswaterstaat Imares	IJsselmeer	2000	1	158004	515012
Rijkswaterstaat Imares	IJsselmeer	2002	1	158004	515012
Rijkswaterstaat Imares	IJsselmeer	1996	1	158004	515012
Rijkswaterstaat Imares	IJsselmeer	2002	2	158004	515012
Rijkswaterstaat Imares	IJsselmeer	2000	1	158004	515012
Rijkswaterstaat Imares	IJsselmeer	1996	1	158004	515012
Rijkswaterstaat Imares	IJsselmeer	1997	1	158004	515012
Rijkswaterstaat Imares	IJsselmeer	1998	1	158004	515012
Rijkswaterstaat Imares	IJsselmeer	1997	1	158004	515012
Rijkswaterstaat Imares	IJsselmeer	2000	2	158004	515012
Rijkswaterstaat Imares	IJsselmeer	2002	1	158004	515012
Rijkswaterstaat Imares	IJsselmeer	2003	2	158004	515012
Rijkswaterstaat Imares	IJsselmeer	1995	1	158004	515012
Rijkswaterstaat Imares	IJsselmeer	2000	2	158004	515012
Rijkswaterstaat Imares	IJsselmeer	1998	1	158004	515012

organisation	locality	year	numbers	x	y
Rijkswaterstaat Imares	IJsselmeer	1998	1	158004	515012
Rijkswaterstaat Imares	IJsselmeer	1996	1	158004	515012
Rijkswaterstaat Imares	IJsselmeer	1999	2	158037	515012
Rijkswaterstaat Imares	IJsselmeer	1999	3	158037	515012
Rijkswaterstaat Imares	IJsselmeer	1999	1	158037	515012
Rijkswaterstaat Imares	IJsselmeer	1999	1	158037	515012
Rijkswaterstaat Imares	Maas	2003	1	159403	424586
Rijkswaterstaat Imares	Maas	1998	1	159403	424586
Rijkswaterstaat Imares	Maas	1999	2	159403	424586
Rijkswaterstaat Imares	Maas	2000	1	159403	424586
Rijkswaterstaat Imares	Maas	2005	1	159403	424586
Rijkswaterstaat Imares	Maas	1998	1	159403	424586
Rijkswaterstaat Imares	Maas	2000	1	159403	424586
Rijkswaterstaat Imares	Maas	1999	2	159403	424586
Rijkswaterstaat Imares	Maas	1998	1	159403	424586
Rijkswaterstaat Imares	Maas	2002	1	159403	424586
Rijkswaterstaat Imares	Maas	2002	1	159403	424586
Rijkswaterstaat Imares	Waal	1994	1	164821	433976
Rijkswaterstaat Imares	Waal	1994	1	164821	433976
Rijkswaterstaat Imares	Wolderwijd	1998	1	166530	482909
Rijkswaterstaat Imares	Ketelmeer	2000	1	174045	513361
Rijkswaterstaat Imares	Ketelmeer	1999	1	174045	513361
Rijkswaterstaat Imares	Ketelmeer	1996	1	174046	513027
Rijkswaterstaat Imares	Ketelmeer	2001	1	174046	513027
Rijkswaterstaat Imares	Ketelmeer	2005	1	174046	513138
Rijkswaterstaat Imares	Veluwemeer	1994	1	177055	491511
Rijkswaterstaat Imares	Ketelmeer	1994	1	178418	512434
Rijkswaterstaat Imares	Ketelmeer	1994	1	178418	512434
Rijkswaterstaat Imares	Veluwemeer	1998	1	181874	493705
Rijkswaterstaat Imares	Maas	2005	1	194603	355362
Rijkswaterstaat Imares	Maas	2004	1	194603	355362
Rijkswaterstaat Imares	Zwartemeer	1994	1	195105	518013
Rijkswaterstaat Imares	Maas	1995	1	201028	366355
Rijkswaterstaat Imares	Maas	1996	1	201028	366355
Rijkswaterstaat Imares	Maas	1998	1	204232	368072
Rijkswaterstaat Imares	Maas	1998	1	204232	368072
Rijkswaterstaat Imares	Maas	1998	1	204232	368072
Rijkswaterstaat Imares	Maas	1998	1	204232	368072
Rijkswaterstaat Imares	Maas	1998	1	204232	368072
Rijkswaterstaat Imares	Maas	1997	1	204232	368072
Rijkswaterstaat Imares	Gelderse IJssel	1998	1	205346	475995
Rijkswaterstaat Imares	Gelderse IJssel	1999	1	205444	451798
Rijkswaterstaat Imares	Gelderse IJssel	2000	1	208047	473409
Rijkswaterstaat Imares	Gelderse IJssel	2001	1	210752	458586
Rijkswaterstaat Imares	Gelderse IJssel	2000	1	211791	456501
Rijkswaterstaat Imares	Waal	2001	1	127159	425236
Rijkswaterstaat Imares	Waal	2001	1	127159	425236
Rijkswaterstaat Imares	Waal	2001	1	127159	425236
Rijkswaterstaat Imares	Waal	2000	1	127159	425236
Rijkswaterstaat Imares	Waal	2000	1	127159	425236
Rijkswaterstaat Imares	Waal	2001	1	127654	425234
Rijkswaterstaat Imares	Waal	1994	1	128611	425877

organisation	locality	year	numbers	x	y
Rijkswaterstaat Imares	Waal	1994	1	128611	425877
Rijkswaterstaat Imares	Waal	1995	2	128611	425877
Rijkswaterstaat Imares	Waal	1994	1	128611	425877
Rijkswaterstaat Imares	Waal	1994	2	128611	425877
Rijkswaterstaat Imares	Waal	1995	1	128611	425877
Rijkswaterstaat Imares	Waal	1994	1	128611	425877
Rijkswaterstaat Imares	Waal	1995	1	128611	425877
Rijkswaterstaat Imares	Waal	1995	1	128611	425877
Rijkswaterstaat Imares	Waal	2001	1	129118	426079
Rijkswaterstaat Imares	Waal	2002	1	129118	426079
Rijkswaterstaat Imares	Waal	2001	1	129118	426079
Rijkswaterstaat Imares	Waal	2001	1	129118	426079
Rijkswaterstaat Imares	Waal	2004	1	129118	426079
Rijkswaterstaat Imares	Lek	2005	1	137043	444696
Rijkswaterstaat Imares	Lek	1994	1	137433	444991
Rijkswaterstaat Imares	Maas	2004	1	159105	423993
Rijkswaterstaat Imares	Maas	2003	1	159105	423993
Rijkswaterstaat Imares	Maas	2004	1	159105	423993
Rijkswaterstaat Imares	Maas	2003	1	159105	423993
Rijkswaterstaat Imares	Maas	2003	1	159105	423993
Rijkswaterstaat Imares	Maas	2006	1	159105	423993
Rijkswaterstaat Imares	Maas	2006	1	159105	423993
Rijkswaterstaat Imares	Maas	1999	1	159507	424586
Rijkswaterstaat Imares	Maas	2002	1	159507	424586
Rijkswaterstaat Imares	Maas	1995	1	159507	424586
Rijkswaterstaat Imares	Maas	1994	1	159507	424586
Rijkswaterstaat Imares	Maas	2002	1	159507	424586
Rijkswaterstaat Imares	Maas	1997	1	159507	424586
Rijkswaterstaat Imares	Maas	2000	1	159507	424586
Rijkswaterstaat Imares	Maas	2001	1	159507	424586
Rijkswaterstaat Imares	Maas	2000	1	159507	424586
Rijkswaterstaat Imares	Maas	1994	1	159507	424586
Rijkswaterstaat Imares	Maas	1999	1	159507	424586
Rijkswaterstaat Imares	Maas	1999	2	159507	424586
Rijkswaterstaat Imares	Maas	2000	1	159507	424586
Rijkswaterstaat Imares	Maas	2005	1	159530	423974
Rijkswaterstaat Imares	Maas	2005	1	159530	423974
Rijkswaterstaat Imares	Maas	2005	1	159530	423974
Rijkswaterstaat Imares	Maas	2006	1	159530	423974
Rijkswaterstaat Imares	Maas	2002	1	159598	424679
Rijkswaterstaat Imares	Maas	2000	1	159598	424679
Rijkswaterstaat Imares	IJssel/Rijn	2002	1	193711	440586
Rijkswaterstaat Imares	Waal	1999	1	128611	425877
Rijkswaterstaat Imares	Waal	1999	1	128611	425877
Rijkswaterstaat Imares	Waal	1999	1	128611	425877
Rijkswaterstaat Imares	Waal	1999	1	128611	425877
Rijkswaterstaat Imares	Waal	1999	1	128611	425877
Rijkswaterstaat Imares	Lek	2000	1	137433	444991
Rijkswaterstaat Imares	Lek	2000	1	137433	444991
Rijkswaterstaat Imares	Lek	2000	1	137433	444991
Rijkswaterstaat Imares	Maas	1997	1	159507	424586
Rijkswaterstaat Imares	Maas	1997	1	159507	424586

organisation	locality	year	numbers	x	y
Rijkswaterstaat Imares	Maas	1994	5	159507	424586
Rijkswaterstaat Imares	Lek	1994	1	137433	444991
Rijkswaterstaat Imares	Waal	1995	1	128611	425877
Rijkswaterstaat Imares	Maas	1995	1	159507	424586
Rijkswaterstaat Imares	Maas	1995	1	159507	424586
Rijkswaterstaat Imares	Waal	1994	1	128611	425877
Rijkswaterstaat Imares	Waal	1994	1	128611	425877
Rijkswaterstaat Imares	Waal	1994	1	128611	425877
Rijkswaterstaat Imares	Lek	1994	1	137433	444991
Rijkswaterstaat Imares	Waal	2005	1	129118	426079
Rijkswaterstaat Imares	Waal	2005	1	129118	426079
Rijkswaterstaat Imares	Lek	2001	1	137433	444991
Waterschap Veluwe	De Motketel	2008	1	190734	477565
Waterschap Veluwe	De Motketel	2008	1	190734	477565
Waterschap Veluwe	Geelmolense beek	2008	1	191713	477506
Waterschap Veluwe	Geelmolense beek	2008	1	191150	477550
Waterschap Veluwe	Geelmolense beek	2002	10	191771	477450
Waterschap Veluwe	Geelmolense beek	2000	onbekend	192305	477549
Waterschap Veluwe	Geelmolense beek	2000	12	192305	477549
Waterschap Veluwe	Geelmolense beek	2000	2	192136	477503
Waterschap Veluwe	Geelmolense beek	2000	4	192305	477549
Waterschap Veluwe	De Motketel	2008	5	190734	477565
Waterschap Veluwe	De Motketel	2008	2	190734	477565
Waterschap Veluwe	Geelmolense beek	2008	1	191713	477506
Waterschap Veluwe	Geelmolense beek	2008	4	191346	477514
Waterschap Veluwe	Geelmolense beek	2008	3	191150	477550
Waterschap Veluwe	Geelmolense beek	2008	2	192091	477482
Waterschap Veluwe	Verlorenbeek	2006	1	194400	483100
Waterschap Veluwe	Hartense Molenbeek	2004	1	196294	478264
Waterschap Veluwe	Hartense Molenbeek	2004	1	196166	478256
Waterschap Veluwe	Hartense Molenbeek	2004	1	196018	478203
Waterschap Veluwe	Rode Beek	2004	2	192970	477956
Waterschap Veluwe	Rode Beek	2004	1	192970	477956
Waterschap Veluwe	Geelmolense beek	2002	1	192431	477578
Waterschap Veluwe	Geelmolense beek	2000	4	192821	477696
Waterschap Veluwe	Geelmolense beek	2000	1	192305	477549
Waterschap Veluwe	Geelmolense beek	2000	1	192305	477549
Waterschap Veluwe	Geelmolense beek	2000	meerdere	192305	477549
Sportvisserij Nederland	De Swalm te Swalmen	2005	1	198475	362235
Sportvisserij Nederland		1994	1	176900	309200
Sportvisserij Nederland		1994	1	176900	309200
Sportvisserij Nederland		1994	2	176900	309200
Sportvisserij Nederland		1994	2	176900	309200
Sportvisserij Nederland		1994	0	176900	309200
Sportvisserij Nederland		1994	2	176900	309200
Sportvisserij Nederland		1994	1	176900	309200
Sportvisserij Nederland	Visstand Jeker en Voer	2008	1	179977	308499
Sportvisserij Nederland	Visstand Jeker en Voer	2008	1	179977	308499
Sportvisserij Nederland	Visstand Jeker en Voer	2008	1	179977	308499

Appendix 3: Fish Invasiveness Scoring Kit for the rainbow trout (*Oncorhynchus mykiss*)

	Fish Invasiveness Scoring Kit (G.H. Copp, R. Garthwaite & R.E. Gozlan)				
		Latin name:	*Oncorhynchus mykiss*		
		Common name:	rainbow trout		
		Assessor:	Menno Soes		
Question ID		**Risk query:**			
		Biogeography/historical	**Reply**	**Comments & References**	**Certainty**
1	1,01	Is the species highly domesticated or cultivated for commercial, angling or ornamental purposes?	Y	chapter 3	4
2	1,02	Has the species become naturalised where introduced?	Y	chapter 3	4
3	1,03	Does the species have invasive races/varieties/sub-species?	Y	chapter 3	4
4	2,01	Is species reproductive tolerance suited to climates in the risk assessment area (1-low, 2-intermediate, 3-high)?	2	chapter 3 and 5	2
5	2,02	What is the quality of the climate match data (1-low; 2-intermediate; 3-high)?	3	chapter 5	4
6	2,03	Does the species have broad climate suitability (environmental versatility)?	Y	chapter 3 and 5	4
7	2,04	Is the species native to, or naturalised in, regions with equable climates to the risk assessment area?	Y	chapter 3 and 5	4
8	2,05	Does the species have a history of introductions outside its natural range?	Y	chapter 3	4
9	3,01	Has the species naturalised (established viable populations) beyond its native range?	Y	chapter 3	4
10	3,02	In the species' naturalised range, are there impacts to wild stocks of angling or commercial species?	Y	chapter 5	4
11	3,03	In the species' naturalised range, are there impacts to aquacultural, aquarium or ornamental species?	Y	chapter 5	4
12	3,04	In the species' naturalised range, are there impacts to rivers, lakes or amenity values?	Y	chapter 5	4
13	3,05	Does the species have invasive congeners?	N	chapter 2	4
14	4,01	Is the species poisonous, or poses other risks to human health?	N	chapter 5	4
15	4,02	Does the species out-compete with native species?	Y	chapter 5	4
16	4,03	Is the species parasitic of other species?	N	chapter 3	4
17	4,04	Is the species unpalatable to, or lacking, natural predators?	N	chapter 3	4
18	4,05	Does species prey on a native species (e.g. previously subjected to low (or no) predation)?	Y	chapter 3 and 5	4
19	4,06	Does the species host, and/or is it a vector, for recognised pests and pathogens, especially non-native?	Y	chapter 5	4
20	4,07	Does the species achieve a large ultimate body size (i.e. > 10 cm FL) (more likely to be abandoned)?	Y	chapter 3	4
21	4,08	Does the species have a wide salinity tolerance or is euryhaline at some stage of its life cycle?	Y	chapter 3	4
22	4,09	Is the species desiccation tolerant at some stage of its life cycle?	N	chapter 3	4
23	4,10	Is the species tolerant of a range of water velocity conditions (e.g. versatile in habitat use)	Y	chapter 3	4
24	4,11	Does feeding or other behaviours of the species reduce habitat quality for native species?	Y	chapter 5	4
25	4,12	Does the species require minimum population size to maintain a viable population?	Y	chapter 5	4
26	5,01	Is the species a piscivorous or voracious predator (e.g. of native species not adapted to a top predator)?	Y	chapter 3	4
27	5,02	Is the species omnivorous?	Y	chapter 3	4
28	5,03	Is the species planktivorous?	Y	chapter 3	4
29	5,04	Is the species benthivorous?	Y	chapter 3	4
30	6,01	Does it exhibit parental care and/or is it known to reduce age-at-maturity in response to environment?	N	chapter 3	4
31	6,02	Does the species produce viable gametes?	Y	chapter 3	4
32	6,03	Does the species hybridize naturally with native species (or uses males of native species to activate eggs)?	N	chapter 5	4
33	6,04	Is the species hermaphroditic?	N	chapter 3	4
34	6,05	Is the species dependent on presence of another species (or specific habitat features) to complete its life cycle?	N	chapter 3	4
35	6,06	Is the species highly fecund (>10,000 eggs/kg), iteropatric or have an extended spawning season?	N	chapter 3	4
36	6,07	What is the species' known minimum generation time (in years)?	2	chapter 3	4
37	7,01	Are life stages likely to be dispersed unintentionally?	N	chapter 5	4
38	7,02	Are life stages likely to be dispersed intentionally by humans (and suitable habitats abundant nearby)?	Y	chapter 5	4
39	7,03	Are life stages likely to be dispersed as a contaminant of commodities?	N	chapter 5	4
40	7,04	Does natural dispersal occur as a function of egg dispersal?	N	chapter 3 and 5	4
41	7,05	Does natural dispersal occur as a function of dispersal of larvae (along linear and/or 'stepping stone' habitats)?	N	chapter 3 and 5	4
42	7,06	Are juveniles or adults of the species known to migrate (spawning, smolting, feeding)?	Y	chapter 3 and 5	4
43	7,07	Are eggs of the species known to be dispersed by other animals (externally)?	N	chapter 5	4
44	7,08	Is dispersal of the species density dependent?	Y	chapter 5	4
45	8,01	Any life stages likely to survive out of water transport?	N	chapter 5	4
46	8,02	Does the species tolerate a wide range of water quality conditions, especially oxygen depletion & high temperature?	N	chapter 3 and 5	4
47	8,03	Is the species susceptible to piscicides?	Y	chapter 6	4
48	8,04	Does the species tolerate or benefit from environmental disturbance?	N	chapter 3 and 5	4
49	8,05	Are there effective natural enemies of the species present in the risk assessment area?	Y	chapter 3 and 5	4
		Outcome:	Reject		
		Score:	20		
		Biogeography	12		
		Score partition: Undesirable attributes	7		
		Biology/ecology	1		
		Biogeography	10		
		Questions answered: Undesirable attributes	12		
		Biology/ecology	24		
		Total	46		
		Aquacultural	10		
		Sector affected: Environmental	22		
		Nuisance	2		

Appendix 4: Fish Invasiveness Scoring Kit for the brook charr (*Salvelinus fontinalis*)

	Fish Invasiveness Scoring Kit (G.H. Copp, R. Garthwaite & R.E. Gozlan)				
		Latin name:	*Salvelinus fontinalis*		
		Common name:	brook charr		
		Assessor:	Menno Soes		
Question ID		**Risk query:**			
		Biogeography/historical	**Reply**	**Comments & References**	**Certainty**
1	1,01	Is the species highly domesticated or cultivated for commercial, angling or ornamental purposes?	Y	Chapter 5	4
2	1,02	Has the species become naturalised where introduced?	Y	Chapter 4	4
3	1,03	Does the species have invasive races/varieties/sub-species?	N	Chapter 4	4
4	2,01	Is species reproductive tolerance suited to climates in the risk assessment area (1-low, 2-intermediate, 3-high)?	1	Chapter 5	4
5	2,02	What is the quality of the climate match data (1-low; 2-intermediate; 3-high)?	2	Chapter 5	4
6	2,03	Does the species have broad climate suitability (environmental versatility)?	N	Chapter 4	4
7	2,04	Is the species native to, or naturalised in, regions with equable climates to the risk assessment area?	N	Chapter 4	4
8	2,05	Does the species have a history of introductions outside its natural range?	Y	Chapter 4	4
9	3,01	Has the species naturalised (established viable populations) beyond its native range?	Y	Chapter 4	4
10	3,02	In the species' naturalised range, are there impacts to wild stocks of angling or commercial species?	Y	Chapter 5	4
11	3,03	In the species' naturalised range, are there impacts to aquacultural, aquarium or ornamental species?	?	Chapter 5	4
12	3,04	In the species' naturalised range, are there impacts to rivers, lakes or amenity values?	Y	Chapter 5	4
13	3,05	Does the species have invasive congeners?	Y	Chapter 2	4
14	4,01	Is the species poisonous, or poses other risks to human health?	N	Chapter 5	4
15	4,02	Does the species out-compete with native species?	Y	Chapter 5	4
16	4,03	Is the species parasitic of other species?	N	Chapter 4	4
17	4,04	Is the species unpalatable to, or lacking, natural predators?	N	Chapter 4	4
18	4,05	Does species prey on a native species (e.g. previously subjected to low (or no) predation)?	Y	Chapter 5	4
19	4,06	Does the species host, and/or is it a vector, for recognised pests and pathogens, especially non-native?	Y	Chapter 5	4
20	4,07	Does the species achieve a large ultimate body size (i.e. > 10 cm FL) (more likely to be abandoned)?	Y	Chapter 4	4
21	4,08	Does the species have a wide salinity tolerance or is euryhaline at some stage of its life cycle?	Y	Chapter 4	4
22	4,09	Is the species desiccation tolerant at some stage of its life cycle?	N	Chpater 4	4
23	4,10	Is the species tolerant of a range of water velocity conditions (e.g. versatile in habitat use)	Y	Chapter 4	4
24	4,11	Does feeding or other behaviours of the species reduce habitat quality for native species?	Y	Chapter 5	4
25	4,12	Does the species require minimum population size to maintain a viable population?	Y	Chapter 5	3
26	5,01	Is the species a piscivorous or voracious predator (e.g. of native species not adapted to a top predator)?	Y	Chapter 4	4
27	5,02	Is the species omnivorous?	N	Chapter 4	4
28	5,03	Is the species planktivorous?	Y	Chapter 4	4
29	5,04	Is the species benthivorous?	Y	Chapter 4	4
30	6,01	Does it exhibit parental care and/or is it known to reduce age-at-maturity in response to environment?	N	Chapter 4	3
31	6,02	Does the species produce viable gametes?	Y	Chapter 4	4
32	6,03	Does the species hybridize naturally with native species (or uses males of native species to activate eggs)?	Y	Chapter 5	4
33	6,04	Is the species hermaphroditic?	N	Chapter 4	4
34	6,05	Is the species dependent on presence of another species (or specific habitat features) to complete its life cycle?	N	Chapter 4	4
35	6,06	Is the species highly fecund (>10,000 eggs/kg), iteropatric or have an extended spawning season?	N	Chapter 4	4
36	6,07	What is the species' known minimum generation time (in years)?	3	Chapter 4	4
37	7,01	Are life stages likely to be dispersed unintentionally?	N	Chapter 5	4
38	7,02	Are life stages likely to be dispersed intentionally by humans (and suitable habitats abundant nearby)?	Y	Chapter 5	4
39	7,03	Are life stages likely to be dispersed as a contaminant of commodities?	N	Chapter 5	4
40	7,04	Does natural dispersal occur as a function of egg dispersal?	N	Chapter 5	4
41	7,05	Does natural dispersal occur as a function of dispersal of larvae (along linear and/or 'stepping stone' habitats)?	N	Chapter 5	4
42	7,06	Are juveniles or adults of the species known to migrate (spawning, smolting, feeding)?	Y	Chapter 4 and 5	4
43	7,07	Are eggs of the species known to be dispersed by other animals (externally)?	N	Chapter 5	4
44	7,08	Is dispersal of the species density dependent?	Y	Chapter 5	4
45	8,01	Any life stages likely to survive out of water transport?	N	Chapter 4	4
46	8,02	Does the species tolerate a wide range of water quality conditions, especially oxygen depletion & high temperature?	N	Chapter 4 and 5	4
47	8,03	Is the species susceptible to piscicides?	Y	Chapter 6	4
48	8,04	Does the species tolerate or benefit from environmental disturbance?	N	Chapter 4 and 5	4
49	8,05	Are there effective natural enemies of the species present in the risk assessment area?	Y	Chapter 4	4
		Outcome:	Evaluate		
		Score:	14		
		Biogeography	5,5		
		Score partition: Undesirable attributes	7		
		Biology/ecology	1		
		Biogeography	10		
		Questions answered: Undesirable attributes	12		
		Biology/ecology	24		
		Total	46		
		Aquacultural	5		
		Sector affected: Environmental	16		
		Nuisance	1,5		

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