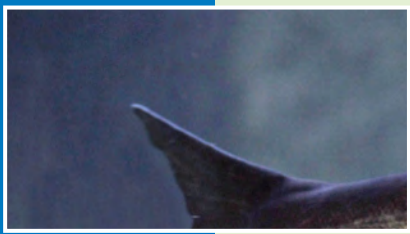
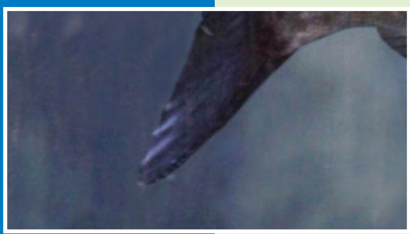
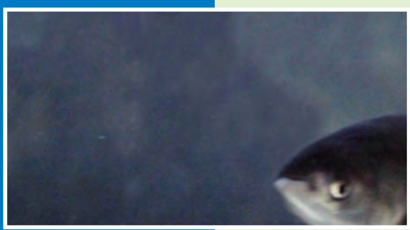
A risk analysis of bigheaded carp (Hypophthalmichthys sp.) in the Netherlands







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Preface

Two species of bigheaded carp (silver carp and bighead carp) are known to be invasive species of special concern. To gain insight into the occurrence of the alien bigheaded carp 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 Alien Species Team of the Food and Consumer Product Safety Authority have commissioned Bureau Waardenburg to carry out a risk analysis in co-operation with the Radboud University Nijmegen and the Central Veterinary Institute of the WUR.

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Summary

Two species of bigheaded carp are known to be invasive species in several countries: bighead carp *(Hypophthalmichthys nobilis)* and silver carp (*H. molitrix*). The largescale silver carp (*H. harmandi*), the third member of this genus, has never been recorded outside its natural range. This report is a risk analysis of these three species to assess the chances of entry, the probability of establishment and further spread, the potential impact and the possibilities of risk management.

The chances of entry

The chance of entry of released fish originating from garden ponds is high in bighead carp and the hybrid, but numbers involved are low. The resulting propagule pressure from garden ponds is low and less likely to result in the establishment of the bighead carp or the hybrid. The chance of entry from garden ponds is probably low in silver carp as this species has not been found during our survey. The chance of entry from stocking for bighead carp, silver carp and their hybrid is also considered high, but numbers can potentialy be much higher than in entry from garden ponds. This includes contaminated stocks of grass carp or common carp. Because of the resulting higher propagule pressure and the higher probability of etablishment, stocking gives the highest risk for establishment of bighead carp, silver carp or their hybrid in the Netherlands.

Other ways of entry are considered of minor importance. The chance of entry of the largescale silver carp is close to zero.

Most waters that are stocked with bigheaded carp or other cyprinid species are well isolated, preventing escapes to open water systems that allow reproduction. The most likely scenario's for stocked bigheaded carp to escape towards suitable waters systems is stocking in waters that are flooded by rivers or stocking in open water systems.

Probability of establishment

The analysis of hydrology-temperature match reveals that potential of spawning of the bighead and silver carp in the Dutch Rhine river distributaries cannot ruled out. However, if spawning were to occur, there are other environmental factors that will limit establishment and invasiveness of both species. Temperature regime, dissolved oxygen, food supply and salinity of most large water bodies are expected to limit the growth and condition and to cause morbidity and mortality for individuals of both species.

The overall effect of climate change on spawning ability are expected to be negligible. Future increases in water temperature, resultant food availability and changes in hydrological regime resulting from climate change may increase the growth and survival potential of Asian bigheaded carp.

Probability of further spread

When the bighead carp or silver carp becomes established in the Netherlands it is very likely that it will quickly disperse into all suitable habitats in the Netherlands.

Impacts

Both bighead carp and silver carp reduce zooplankton communities at higher population levels and change the species composition with smaller species becoming dominant. The densities of phytoplankton are normally not reduced, but the species composition might be altered with smaller species becoming dominant. These changes might have impact on populations of e.g. bivalve and fish species that use the same food source. Clear evidence for such impact is still absent.

Both species of bigheaded carp and their hybrid are known vectors of several alien parasites and diseases, this includes the Chinese pond mussel. Several of these organisms have the potential to establish in the Netherlands, but concerning the potential impact of these organisms little is known yet.

Because of the escape responses of silver carp (jumping out of the water), colitions with especially fast going watercrafts are of concern. So river stretches with abundant silver carp are becoming less attractive for water recreation. This has both local economic and social effects that might also be expected in the Netherlands when this species becomes established in high numbers.

Risk management

Established populations of bigheaded carp are only expected in large open water systems. Eradication or management of populations densities in such systems is complicated at the least. So management is more likely to be successful at the prevention level. Such prevention would in the Netherlands best focus on the prevention of deliberate stockings or accidental stockings by contaminated stocks of another species.

1 Introduction

The bigheaded carp originate from East Asia. Especialy since the 1960s two species of them, bighead carp and silver carp, have been introduced extensively and have proven to be invasive in many countries, including Eastern European countries and the USA. Several studies on the impact of these species reported on the potential to cause serious ecological, economic and social impacts. Therefore bigheaded carp can potentially interfere with the goals of various European Directives such as the Water Framework Directive (WFD) and the Habitat Directive (Nature 2000).

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

2 Taxonomy and distribution

This chapter provides information on the taxonomy, native range and introduction history of the three species of bigheaded carp and their hybrids. Furthermore a table is provided for the identification of the three species and some notes are given on the identification of hybrids. Subsequently, three other species of Asian carp are introduced: grass carp, black carp and Chinese sucker. These species will be discussed together with the bigheaded carp within this report.

2.1 Bigheaded carp

2.1.1 Taxonomy

The bigheaded carp (*Hypophthalmichthys* sp.) are a genus of the family Cyprinidae (carp or minnow family) belonging to the subfamily Leuciscinae. They are closely related to the genera *Ctenopharyngodon* (grass carps), *Mylopharyngodon* (black carps) and *Squaliobarbus* (barbell chubs). These genera are all exclusively East Asian genera. Typical carps, such as common carp (*Cyprinus carpio*) and Crucian carp (*Carassius carassius*) are included in the subfamily Cyprininae and are more distantly related (Cunha *et al.*, 2002). In total, three species are included in the genus *Hypophthalmichthys*, see table 2.1.

Table 2.1: List of known extant bigheaded carp species. Based on Fishbase.org

Scientific	English	Dutch
Hypophthalmichthys harmandi Sauvage 1884	largescale silver carp	-
Hypophthalmichthys molitrix (Valenciennes 1844)	silver carp	zilverkarper
Hypophthalmichthys nobilis (Richardson 1845)	bighead carp	grootkopkarper, marmerkarper

In the past the bighead carp (*H. nobilis*) was assigned to its own genus *Aristichthys*. Both the similarity in mitochondrial DNA and the fertility of the hybrids with silver carp (*H. molitrix*) supports the use of a single genus for all three species (Li *et al.*, 2009), which has become widely accepted nowadays, see e.g. Fishbase.org.

2.1.2 Description and recognition

The bigheaded carp are characterised by a stout body, a massive, scaleless head and unusual large opercles (fig. 2.1). The eyes are small, located far forward below angle of the jaw, and projecting downward. Scales are small, cycloid, and cover the entire body. They are unlikely to be confused with any other fish found in Europe.

Figure 2.1: Bighead carp showing the typical stout body and massive, scaleless head of bigheaded carp. Photo by M. Spencer Green.

2.2 Bighead carp (*Hypophthalmichthys nobilis*)

2.2.1 Description

The bighead carp differs from the other bigheaded carp species by its e.g. relatively big head, the relatively dark body with dark grey to black blotches and a keel that extends only slightly beyond the pelvic fins, see also §2.6. Furthermore, it can be diagnosed by the gill rakers that are not fused and have a comb-like appearance.

2.2.2 Native range

Bighead carp are native to large rivers and associated floodplain lakes in Eastern Asia (fig. 2.2). The natural range, which is a bit uncertain due to already ancient stockings in e.g. the Amur River Basin, includes the most southeastern part of Russia, the extreme north of North Korea and eastern China, where it is found in large rivers such as the Yellow River, Yangtze River and the Pearl River (Kolar *et al.*, 2007).

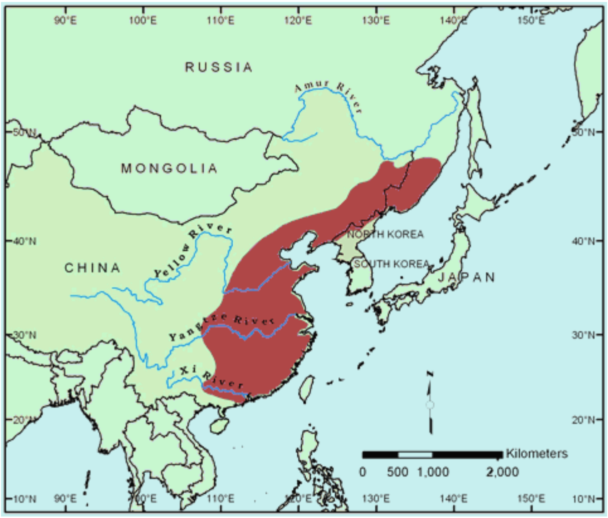


Figure 2.2: Natural range of the bighead carp (Hypophthalmichthys nobilis).Taken from Kolar et al. (2007).

2.2.3 Introductions

The bighead carp has been introduced in more than 72 countries in Asia, Africa, Europe, North America and South America. Within China the species has been successfully translocated into several provinces and is reported to be invasive in six of them. There are also reports of natural spawning from Vietnam, Japan, and Taiwan, and the species is considered invasive in Thailand (Tang, 1960; Kolar *et al*., 2007; Kuronuma, 1954; Welcomme & Vidthayanom, 2003). Further reports of established populations come from Central Asia, e.g. Armenia and Kazakhstan (Kolar *et al.*, 2007; Kottelat & Freyhof, 2007).

The bighead carp is established in the USA. The first importations date from the early 1970s. They were imported for biofiltration of sewage ponds and the use as a food fish. The first records in natural waters occur in the 1980s and by 2004 the species was recorded in 23 states. In 1989 the first evidence of natural reproduction was reported. It is now considered as being well established in the Mississippi, Missouri, Ohio, and Tennessee River Basins. A further expansion is anticipated (Kolar *et al*., 2007).

Several sources report that the bighead carp is established in the Danube River, e.g. Kolar *et al*. (2007). Others clearly state that bighead carp are solely present in Europe due to stocking practices and escapes, e.g. Kottelat & Freyhof (2007). As no reference could be found that actual provides evidence for the presence of self-sustaining populations or even spawning, we consider that the reports that bighead carp are established in the Danube to be unproven.

<u>The Netherlands</u>
The bighead carp has not been cultured or stocked on a largescale in the Netherlands. In the 1980s, several specimens were caught in the IJssel Lake area. It

was suspected that these originated from German fish farms in the Rhine River Basin (Nijssen & De Groot, 1987).

Recent records of this species are rare and mainly originate from anglers catching this species accidentally and fish stock assessments in fishing ponds (www.limnodata.nl), but also from e.g. the Worm in Limburg (www.limnodata.nl) and Wolderwijd (Wiegerinck *et al*., 2007). In most of these records the actual identity of the fish is uncertain as hybrids or even silver carp where insufficiently excluded. Two certain records, with the first site being kept secret, are:

30-4-2006	Netherlands; 27.5 kilos (www.karperwereld.nl).
17-03-2009	Tilburg Quirijnstokpark; 135.4-399.2; 74 centimeters; 5680 grams; (www.waarneming.nl).

Figure 2.3: A 55-pound bighead carp from the Netherlands. Taken from www.karperwereld.nl.

Figure 2.4: A bighead carp from Quirijnstokpark in Tilburg, the Netherlands. Picture by G. de Kinderen.

2.3 Silver carp (*Hypophthalmichthys molitrix*)

2.3.1 Description

The general appearance of the silver carp is much like a bighead carp (fig. 2.5). Major differences are the silver body, which lacks the blotting of the bighead carp, the ventral keel that extends towards the throat and the smaller head. Besides other more subtle differences, see also §2.6, the silver carp differs clearly in its gill rakers, which are fused and form a sponge-like structure instead of the comb-like structure of the bighead carp (Kolar *et al*., 2007).

Figure 2.5: An American silver carp showing the relatively small head and the silver body. Picture by the Department of Fisheries and Allied Aquacultures, Auburn University

2.3.2 Native range

According to Kamilov and Komrakova (1999) the silver carp is endemic to the large rivers of eastern China and far eastern Russia that flow into the Pacific Ocean (fig. 2.6). Others have stated that the silver carp is native to large lakes and rivers of China, northern Vietnam, and Siberia ranging from 21º N to 54º N latitude. Reports of this species from northern Vietnam are probably based on introduced populations (Kolar *et al*., 2007).

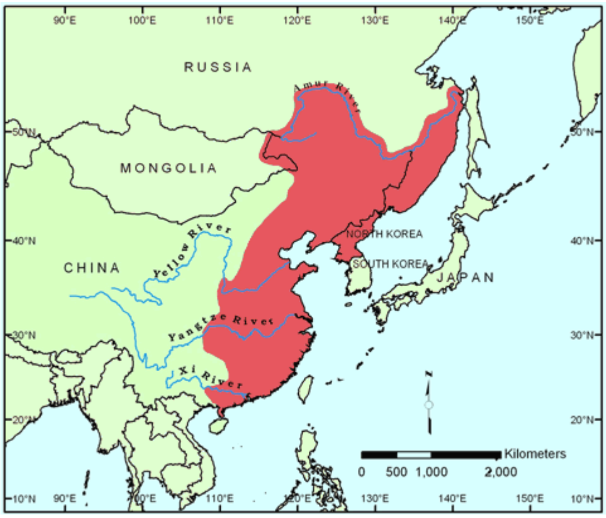


Figure 2.6: Natural range of the silver carp (Hypophthalmichthys molitrix).Taken from Kolar et al., 2007).

2.3.3 Introductions

The silver carp has been introduced widely throughout the world and is reported from at least 88 countries and territories.

<u>Danube</u>

Between 1959-1960 the silver carp was imported in several Eastern European countries. These fish originated from China. From 1963 onwards it was also present in the aquaculture of the Danube Delta. About ten years later silver carp were recorded in the natural systems of the Danube and subsequently have been thought to reproduce naturally. In particular, the growing number being caught, which could not be attributed to escapes from fish ponds alone, indicated reproduction. A study of the population structure of the silver carp in 1992 strengthened these thoughts and in 1997 actual larvae and juveniles were found in the Romanian part of the Danube (Schiemer *et al*., 2003; Staras & Otel, 1999; Ciolac, 2004).

A clear spawning migration of Asian carp (silver carp, bighead carp & grass carp) in the Romanian stretch of the Danube was recorded in the June 1998, at which time water temperature had increased from 19°C to 24°C. These fish weighed 6 to 12 kilograms, the size characteristic of sexual mature fishes (Ciolac, 2004).

In Hungary natural reproduction has been reported from the Tisza River. These fish originate from both China and the former Soviet Union and were imported in the period between 1963 to 1969. After artificial propagation became routine production in Hungarian aquaculture increased rapidly. Practically all fish farms in Hungary stocked this species and considerable numbers have been stocked in natural waters, especially in river backwaters. In around 1980, the species was present in almost all natural water bodies in lowland areas. Successful spawning in natural waters was recorded in 1973 (K. Pinter, pers. com.). The population in the Tisza River was considered to be self sustaining in the 1970s (Pinter, 1980). In 2008 fry of the silver carp was still found in the banks of the artificial Tisza Lake, showing that natural spawning is still taking place and suggesting a self-sustaining population (Á. Harka, pers. com.).

Also in the Yugoslavian sections of the Danube the Asian carp are thought to be established, however, evidence is less convincing as is mainly based on catch by commercial fishermen and of sexually mature animals (Jankovic, 1998). The influence of escapes from aquacultural facilities is still large and should be considered a likely origin in cases where spawning, fry or young juveniles have not been detected (Sindilariu *et al*., 2006).

<u>The Netherlands</u>
In 1966 the silver carp was imported to the Netherlands by the OVB (Organisatie voor de Binnenvisserij). They have been cultured for experiments to study the possibility of the use of silver carp for the reduction of phytoplankton densities. Actual stockings in open water systems have not occurred and the experiments have been stopped at an early stage (Nijssen & De Groot, 1987). Confirmed (recent) records of this species are absent.

2.4 Largescale silver carp (*Hypophthalmichthys harmandi*)

2.4.1 Description

The largescale silver carp resembles the silver carp in general appearance. The largerscale silver carp has a deeper body, giving it an even more robust look (fig. 2.7). For a reliable identification scale counts are the most useful. The number of scales along the lateral line of the largescale silver carp range from 77 to 88 compared to the silver carp with 85 to 108. Scale rows above the lateral line in largescale silver carp range from 21 to 23 compared to 29 to 30 in the silver carp.

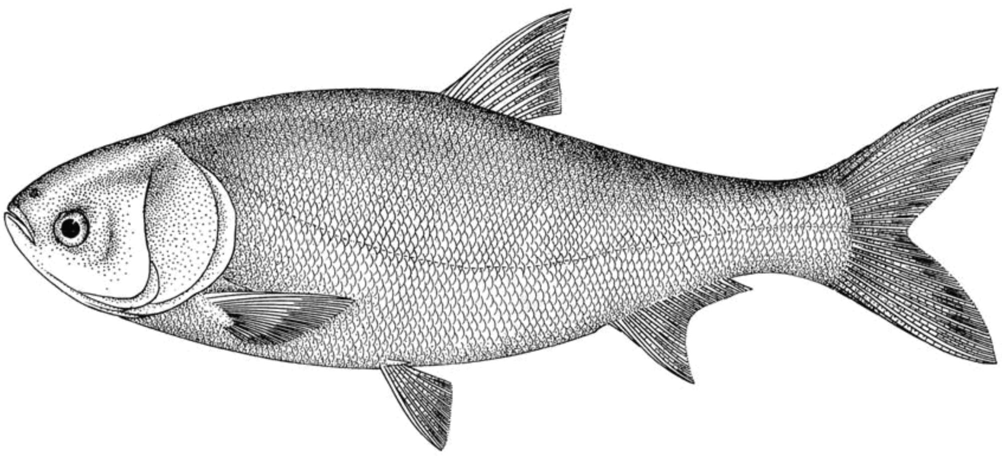


Figure 2.7: Largescale silver carp (Hypophthalmichthys harmandi). Taken from Chen et al. (1998).

2.4.2 Native range

Compared to the previous two species, the largescale silver carp has a much more limited, subtropical distribution (fig. 2.8). It is native to the Nandu Jiang River on Hainan Island (China) and the Hong Ha River Basin in northern Vietnam (Kolar *et al.*, 2007).

Figure 2.8: Natural range of the largescale silver carp (Hypophthalmichthys harmandi). Taken from Kolar et al. (2007).

2.4.3 Introductions

There are no reports on introductions of largescale silver carp outside its natural range and no established exotic populations are known. The introduction of hybrids of largescale silver carp and silver carp in the Syr-Darýa Basin in Kazakstan are known. These were obtained from northern Vietnam where largescale silver carp is present in aquaculture (Payusova & Shubnikova, 1986; Salikhov & Kamilov, 1995). These fish are assumed to be established, but further information on this population is lacking (Kolar *et al.*, 2007).

2.5 Hybrids

2.5.1 Description

Silver carp is known to hybridize with both largescale silver carp and bighead carp. These hybrids are fertile. Hybrids between largescale silver carp and bighead carp have not yet been reported but are likely to be possible.

Hybrids between silver carp and bighead carp, the only relevant hybrid in this study, are relatively difficult to recognise as they are variable in appearance and might resemble one of the parent species closely. With experience the hybrids can often already be distinguished on external characters, e.g. by the combination of a relatively small head, long pectoral fins and only few darker blotches on the body (P. Veenvliet, pers. com.). The more reliable character, except for molecular work, are the gill rakers. Hybrid fish have irregular gill rakers showing twisting or clubbing, which is absent or limited to only few gill rakers in the parent species, see figure 4.1. Post F-1 hybrids cannot be identified with morphological characters and can only be detected with molecular work (Lamer *et al*., 2011).

2.5.2 Occurrence

The hybrid between silver carp and bighead carp is both known from the natural ranges of the parent species and from introduced ranges, e.g. the Mississippi Basin. Furthermore, they are common in aquaculture because bighead carp tends to produce insufficient milt late in the season (Kolar *et al.*, 2007). This hybrid is also popular because of the combination of the feeding habits of the silver carp and the docility and fast grow of the bighead carp (Green & Smitherman, 1984).

<u>The Netherlands</u>
There are at least two records of the hybrid between silver carp and bighead carp in the Netherlands (P. Veenvliet, pers. com.) (fig. 2.9). The first record is of several introduced specimens caught in a water basin near Middelburg on 16 May 2009. These fish were translocated to the 'Middelburgse Vesten' in Middelburg (hsvmiddelburg.homeip.net). The second record is from 2010 and detailed information about the location is absent. The specimen had a total length of 110 centimeters and weighed about 22 kg (www.svbdelfland.nl).

Figure 2.9: A silver carp x bighead carp hybrid before being released into the Middelburgse Vesten (left) and silver carp x bighead carp hybrid caught in the western parts of the Netherlands. Photos taken from hsvmiddelburg.homeip.net and www.svbdelfland.nl.

2.6 Identification table for bigheaded carp

	bighead carp	silver carp	largescale silver carp
scales above lateral line	26-28	29-30	21-23
scales lateral line	98-100	85-108	78-88
gill filaments	not fused ('comb')	fused ('sponge')	fused ('sponge')
ventral keel	from vent to the base of the pelvic fins	from vent to close to the junction of the gill membranes	from vent to close to the junction of the gill membranes
pectoral fin	extends always well beyond the base of the pelvic fin	extends normally not beyond the base of the pelvic fin, sometime overlaps 10% of the length of the pelvic fin	extends not beyond the base of the pelvic fin.
color	mottled	silver without mottling	silver without mottling

F1-hybrids can only be distinguished from the parent species by the shape of the gill filaments. In typical specimens the rakers are partly twisted. In specimens with relatively more bighead carp like filaments they are clubbed or wavy, in specimens with more silver carp like filaments they can easily be separated with a light touch and have a ragged appearance.

2.7 Other Asian carp

Often the bigheaded carp are treated together with other species of large cyprinids addressed as a group with the name "Asian carp". Species normally included are grass carp (*Ctenopharyngodon idella*) and black carp (*Mylopharyngodon piceus*). A large Asian cyprinid species that is appearing in trade for both aquaria and garden ponds recently is the Chinese sucker (*Myxocyprinus asiaticus*). Some authors also include species of the genera *Cyprinus* and *Carassius*, which is maybe less appropriate as species included in these genera are partly indigenous in Europe and are only distantly related.

Here, the above mentioned three Asian carp species are discussed briefly, including some notes on their ecology. An risk analysis is not included.

2.7.1 Grass carp (*Ctenopharyngodon idella*)

The grass carp has a native range from Northern Vietnam to the Amur River on the border of Siberia and China. Established exotic populations are known from the Mississippi basin in the USA, Taiwan and the Philippines (Kottelat & Freyhof, 2007; Shireman & Smith, 1983). In Europe and the Netherlands it is a commonly stocked species without any self sustaining populations.

The grass carp is a large species with specimens of up to almost 120 centimeters and 50 pounds reported in the Netherlands. Larger juveniles and adults feed on macrophytes, including terrestrial ones during floods. Maturity is reached after 7-10 years at a length of about 60-80 centimeters. In its natural range spawning occurs during the monsoon season, when river water levels rise quickly. Temperatures at spawning range between 20 and 30°C and it is thought that the minimum temperature for spawning is around 18°C. The eggs are pelagic and hatch in 2-3 days whilst drifting downstream. The hatched larvae settle downstream in floodplains lakes and parts of rivers with little or no current (Kottelat & Freyhof, 2007; Shireman & Smith, 1983).

Figure 2.10: A grass carp showing the fleshy lips suitable for grazing macrophytes. Photo U.S. Fish and Wildlife Service.

In its native range the grass carp experiences annual air temperatures between -6°C and 25°C (Mandrak & Cudmore, 2004) and it has proven to survive well under Dutch climate conditions.

2.7.2 Black carp (*Mylopharyngodon piceus*)

The natural range of black carp includes China, parts of far eastern Russia, and northern Vietnam. Established exotic populations are known only from Turkmenistan and possibly Japan (Kottelat & Freyhof, 2007). In the USA there is some concern after the finding of several specimens in the Mississippi, as it has been realised that this species is hard to record because of its benthic behavior. It is present in aquaculture in at least Northern America, Russia and Eastern Asia (Nico *et al.,* 2005). In the Netherlands, it is probably only present sporadically in the pet trade and records from the wild are still lacking.

The black carp is a large species and specimens of over 1.8 meters and up to 60 kilograms in weight have been recorded within its natural range. It is a bottom dwelling molluscivore inhabiting large lowland rivers and lakes. Maturity is reached after 6-11 years and at a length of about one meter. For spawning it migrates upstream, where it spawns in open water at water temperatures of 19-30°C. The eggs are pelagic and hatch while drifting downstream. The hatched larvae settle downstream in floodplains lakes and parts of rivers with little or no current (Kottelat & Freyhof, 2007).

In its native range the black carp experiences annual air temperatures between -4°C and 23°C (Mandrak & Cudmore, 2004), suggesting that Dutch winter conditions are acceptable for this species.

Figure 2.11: A black carp from a North American fish farm. Photo U.S. Fish and Wildlife Service.

2.7.3 Chinese sucker (*Myxocyprinus asiaticus*)

The Chinese sucker originates from the Yangtze River basin in China and is endangered in the wild. So far no exotic populations are known and it has not yet been found in the wild in the Netherlands. Currently, all specimens present in trade have been caught in the wild in China.

The Chinese sucker is a novelty in the Dutch pet trade and is still rare. Most are sold as small juvenile fish of up to 10-20 cm in length. At this size they are unusual looking fish with their high build and black banding. Mature fish grow up to one meter in length and outgrow any aquarium and most garden ponds. In Germany it has become relatively popular as it has proved to be hardy and can overwinter in garden ponds (koicompetence.de). Being able to overwinter in such ponds, it is likely that this species will survive Dutch winters if escapes or dumped fish enter the wild. Information on the natural reproduction of this species is scarce and does not allow predictions into the possibility of reproduction in the Netherlands. No reproduction in garden ponds is known.

Figure 2.12: Juvenile (left) and adult Chinese suckers (Myxocyprinus asiaticus). Photo's: practicalfishkeeping.co.uk and Xinhua Photo.

3 General ecology

This chapter provides general information on the ecology of the three species of bigheaded carp. More detailed information on e.g. temperature tolerance or habitat requirements are given in chapter 5 (Probability of establishment). The information given is mainly based on the extensive literature review of Kollar *et al*. (2007).

3.1 Bighead carp

3.1.1 Habitat

In its natural range the bighead carp is a typical riverine species that is only found in large rivers and associated waters, like floodplain lakes. In other water bodies, such as lakes, ponds, reservoirs, without an open connection to a large river, bighead carp is only present when stocked.

Outside its natural range established populations are known mainly from large rivers. Exceptions are reports of successful spawning in a reservoir in Taiwan and in a canal in Turkmenistan, which suggest that spawning and establishment of populations in additional habitat types might be possible.

Adult habitat
Habitat use of adult fish has been studied in the Missouri River by telemetry. These data show a clear preference for slow flowing waters. Preferred locations were e.g. behind wing dikes (kribben) and tributaries in the floodplain areas. These segments were deep and slow flowing for the most part of the year.

Juvenile habitat
In North America juvenile bighead carp are typically found in floodplain wetlands, backwaters and low velocity areas, e.g. behind wing dikes. Yearling and juvenile bighead carp on the Yangtze River are thought to migrate to floodplain lakes.

3.1.2 Life cycle and reproduction

Bighead carp reach maturity at an age of 2 to 8 years, depending on climate, environmental conditions and sex. In temperate climates the average age at first breeding is 5 to 6 years, with the males in general maturing one year earlier then the females. At that time bighead carp weigh 5 to 10 kilograms and are 70 to 80 centimeters long.

Spawning of bighead carp is initiated by rising water levels following the heavy rains that occur in the spring or summer, or in Asia, during the monsoon season. When the water starts rising bighead carp migrate upstream to their spawning grounds. These spawning grounds are characterised by rapidly flowing and turbid water, e.g. at a confluence of rivers, among the rocks of rapids, or behind sandbars.

Mating generally takes place at the surface with males actively chasing females and sometimes leaping out of the water. Males often prod their heads against the bellies of females to stimulate egg release. Eggs and sperm are released simultaneously in the water column (pelagic spawning) and no further attention to the eggs is given by the parental fish.

Bighead carp have a high fecundity rate. In Russian waters, females spawning for the first time had an average stripped fecundity of 280,000 eggs whereas older spawners gave 478,000 to 549,000 eggs. In the Terek Region of the Caspian Basin, absolute individual fecundity of introduced bighead carp ranged from 316,300 to 1,860,800 eggs.

The released eggs are semi-buoyant and are generally thought to have to remain suspended in the water column by the turbulence of the moving water in order to hatch. Currents may carry larvae to quieter waters such as creeks, lakes, reservoirs, or flooded areas that become their nursery areas. Otherwise the larvae actively migrate away from river channels to vegetated calm waters.

Bighead carp are known to have amazingly fast growth rates. In fertile waters with temperatures above 14ºC, they can grow to 2.7 kg in less than one year and are capable of reaching 18 to 23 kg in 4 to 5 years. They can grow up to 1.5 m or more in length and more than 40 kg in weight.

There is little specific information on longevity of the bighead carp. The maximum age of bighead carp reported so far is 16 years (China). The oldest American specimens were two bighead carp that were caught from Lake Erie, Ontario. Both fish were 8-10 years old and displayed recent growth at the time of capture.

3.1.3 Diet

Bighead carp are omnivore planktonic feeders, feeding mainly on sizes between 50 and 100 µm. It is not constrained to this range and particles of up to 3000 µm have been reported. Because it is feeding on larger particles the bighead carp is in comparison with the other two species of bighead carp, more efficient in feeding on zooplankton than phytoplankton. Only when large species are present is phytoplankton normally included in the diet in larger amounts, but when food is scarce also smaller phytoplankton can be ingested. In such circumstances food supply is limiting for the bighead carp.

The intake of food items other than plankton is much less studied. Bighead carp is known at larger sizes to feed on floating pellets in aquaculture, but is relatively inefficient at this. By pump-feeding it may also feed on benthic organisms, but this is probably in most situation only fed upon when plankton densities are temporarily too low.

3.1.4 Predators

Little is known about the predation on bighead carp, but is likely to be comparable to that of other freshwater fish. Eggs, larvae and small juveniles will be predated by a large number of vertebrate and invertebrate predators, including e.g. dragonfly larvae and sticklebacks. Larger juveniles will be predated only by specialised piscivores such as pike, zander, European wels, cormorants and otters.

Adult fish are so large that, except for humans, predators are absent in European waters.

3.2 Silver carp

3.2.1 Habitat

The silver carp is a riverine species that naturally only occupies large rivers and associated water bodies. The habitat preferences of both adult and juvenile fish are comparable with the bighead carp, see 3.1.1.

3.2.2 Life cycle and reproduction

Silver carp reach maturity at an age of 3 to 8 years, depending on climate, environmental conditions and sex. At that time silver carp weigh 2 to 5 kilograms.

Spawning, mating behavior and early development is much like the bighead carp.

Silver carp have a high fecundity rate, with upto five million eggs reported for large females. In North America the fecundity of six silver carp was relatively low, ranging from 57,283 to 328,538 eggs.

Silver carp are known to have amazingly fast growth rates. In fertile waters with high temperatures, they can grow to 5.4 kg in less than one year and are capable of reaching 18 to 23 kg in 4 to 5 years. They can grow up to 1.05 m or more in length and more than 40 kg in weight. There is little specific information on longevity of the silver carp. The maximum age of silver carp reported so far is 20 years.

3.2.3 Diet

The silver carp also consumes plankton by filtration, but it can ingest much smaller particles that the bighead carp. Because of this the silver carp is more efficient in feeding on phytoplankton and is generally known as a phytoplanktivore. This is incorrect as it also consumes large quantities of zooplankton. In experiments the smallest particles retained are algae of the genus *Chlorella* (3.2 μm). In field studies larger minimum sizes are reported (>10 μm), but it should be noted that both bighead carp and silver carp can to a certain extent feed size-selective. Thus in field studies selectivity may result in an underestimation of the actual sizes that can be retained.

Not all species of phytoplanton that are ingested are well digestible for the silver carp. Species of greenalgae belonging to the order Chlolorococcales, such as *Scenedesmus* and *Tetraedron*, are largely non-digestible and are secreted undamaged by the silver carp. Also mucilagenous cyanobacteria are not digested well. Non-mucilagenous cyanobacteria, diatoms and Cryptomonas species are digested well.

In aquaculture the silver carp does not feed well on (floating) pellets and is considered a more difficult species to feed. Contradictory to this there are reports of large amounts of detritus in the intestine of wild caught silver carp, suggesting that silver carp is not an obligatory plankton feeder and can supplement their diet with benthic organisms present in detritus (e.g. bacteria, ostracods and copepods).

3.2.4 Predators

Comparable with bighead carp, see 3.1.4.

3.3 Largescale silver carp

3.3.1 Habitat

The largescale silver carp is also a riverine species that naturally only occupies large rivers and associated water bodies. Outside of the spawning season adult fish prefer slow flowing, plankton rich waters.

3.3.2 Life cycle and reproduction

In its native range the largescale silver carp is reported to typically spawn in May and June, although spawning may be delayed until mid-August. Rains or floods stimulate the spawning migrations into rivers. Further specific information on the largescale silver carp is scarce. But because this species is closely related to the silver carp, the life cycle and reproduction is expected to be comparable.

3.3.3 Diet

The diet is comparable with the silver carp.

3.3.4 Predators

Comparable with bighead carp, see 3.1.4.

4 Chances of entry

This chapter provides information on the chance of entry for bigheaded carp into surface waters in the Netherlands. Firstly the availability and actual presence of bigheaded carp in the Dutch pet trade is discussed. This presence is studied by contacting relevant selling points. Subsequently six pathways that are considered to be relevant to the Dutch situation are discussed.

4.1 Presence in the Dutch pet trade

To get an insight into the availability of bigheaded carp in Dutch pet trade 52 selling points were contacted by e-mail and telephone during May 2011. Every selling point was asked for both silver carp (zilverkarper) and bighead carp (grootkopkarper/marmerkarper). The 52 selling points consisted of 20 garden pond specialist shops, 21 garden centres and 11 aquarium shops that also sell fish for garden ponds. Of the 52 selling points contacted 45 provided a response. At a total of five selling points bigheaded carp were directly available and an additional 12 selling points offered to order bigheaded carp. This represents that around 38% of selling points offer bigheaded carp for sale.

All bigheaded carp were offered with the name silver carp, except for one shop that offered both silver carp and bighead carp. This is in contrast with the information of Paul Veenvliet (pers. comm.) who only found bighead carp and hybrids in the Dutch pet trade.

To check the identity of the bigheaded carp sold in the Netherlands, six samples of bigheaded carp consisting of two specimens each were bought from five different selling points in June 2011. The identification of these specimens was mainly based on the structure of the gill rakers (fig. 4.1). One sample sold as bighead carp was indeed bighead carp. The other five samples, which were sold as ‘silver carp’, were actualy two samples of hybrids (bighead carp x silver carp) and three samples of bighead carp.

Because only six samples from spring 2011 were studied it cannot excluded that silver carp are sold in other shops or during other times of the year. These samples, however, confirm that bighead carp and its hybrids are at least more common in the Dutch pet trade than silver carp. A reason for this might be that both bighead carp and hybrids are less stressed during transport and therefore more easy to handle than silver carp (P. Veenvliet, pers. comm.).

To check the health status of the bigheaded carp sold, six samples of ten specimens have been provided for examination to the Central Veterinary Institute of Wageningen UR. These samples haven been examined for visible parasites and diseases, koi herpes and total health status. None of the examined fish did carry koi herpes virus or a disease not indigenous to the Netherlands. Two of the samples consisted of fish that were in good health and didn't carry any parasites. In the other samples the fish were skinny and were diagnosed to carry low numbers of *Ichthyophthirius multifiliis* (parasite causing freshwater white spot disease), *Chilodonella* sp. and/or *Dactylogyrus* sp. Both *Ichthyophthirius multifiliis* and *Chilodonella* sp. are indigenous and common diseaes of freshwater fish in the Netherlands. Because the *Dactylogyrus* sp. have not been identified to the species level it is not possible to know it is indigenous or not. In two samples the *Ichthyophthirius multifiliis* infections were heavy. Overall the fish in these four samples were not in good health and did have lowered survival expectancy when bought and released in garden ponds.

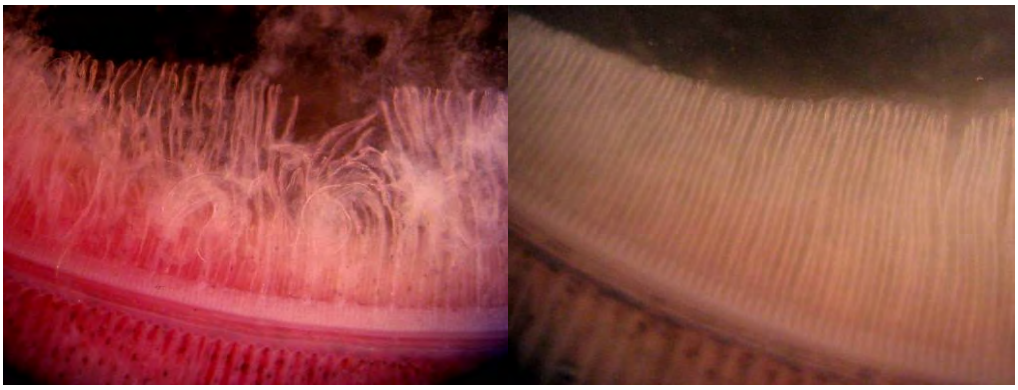


Figure 4.1: Gill rakers of a bighead carp x silver carp hybrid (left) and a bighead carp (right) obtained from Dutch pet trade. Note the deformation (twisting) of the hybrids rakers. Photos by D.M. Soes (Bureau Waardenburg).

4.2 Availability for Dutch pet trade

Silver carp, bighead carp and their hybrid are produced by Eastern European aquaculture in reasonable quantities, see also §4.6. With Eastern Europe being an important provider of ornamental fish for garden ponds, silver carp, bighead carp and their hybrid can be considered being readily available for the Dutch pet trade.

Largescale silver carp is probably not readily available for the Dutch pet trade because the import of this species from East Asia would be rather expensive in comparisson with the other two species and their hybrid.

4.3 Aquaria

All bigheaded carp species and their hybrids are unsuitable for aquaria. They get much too big and have feeding requirements that are extremely difficult to accomplish in aquaria. In most instances they are sold at an already reasonable size (12-20 centimeters) making it less likely that impulsive purchases are made.

No reports on keeping these species in aquaria could be found both in literature or on the internet (forums).

The chance of entry from aquaria (introductions from aquarium trade) is close to zero.

4.4 Garden ponds

Bigheaded carp are regularly sold for garden ponds, see §4.1. Based on discussions on internet forums and on information of pond related websites it is clear that they are often sold with the recommendation of using them as biofilters. In some cases this might give a good result, but a major problem is that in most ponds insufficient food for bigheaded carp is available. When they are not accustomed to eat dry food they become stunned or die of starvation. When they do eat artificial food, such as dried pellets, they might get too big for the normal sized garden ponds. Removal is often difficult because they jump and swim erratically when threatened.

When they become too big or turn out to be difficult to maintain in a healthy condition they are likely to become released into the wild. This is comparable to other fish species often kept in garden ponds, such as sturgeons (Acipenseridae) or koi (*Cyprinus sp.*).

None of the bigheaded carp have been reported to have produced offspring in garden ponds.

The chance of entry of bighead carp and the hybrid from garden ponds is high because they are regularly sold and are difficult to keep in good condition in garden ponds, however, numbers are low because of the absence of reproduction in garden ponds. The chance of entry of silver carp is presumed to be low, because it is unclear if it is actually present in the Dutch pet trade. The chance of entry of the largescale silver carp is close to zero.

4.5 Aquaculture

Both silver carp and bighead carp are not currently present in Dutch aquaculture. The silver carp was cultured by the OVB for a few years for experimental reasons, but this was terminated in the 1970s (Nijssen & De Groot, 1987). The major reason for the absence in aquaculture is that cyprinid species are hardly eaten by Dutch people.

On a worldwide scale the situation is very different. Based on the FAO data on the top 20 fish species present in freshwater aquaculture (fig. 4.2) cyprinid species dominate with 77 percent of the total freshwater fish production. The top five lists four cyprinids (grass carp, silver carp, common carp and bighead carp) and one non-cyprinid (Nile tilapia). Silver carp ranks second with an annual production of more than 4.0 million tonnes in 2009 and bighead carp fifth with almost 2.5 million tonnes. Until 2007, silver carp was actually the number one but as the growth in its production ceased, production of the grass carp, one of the other large Asian carp, surpassed it to became number one (fig. 4.3).

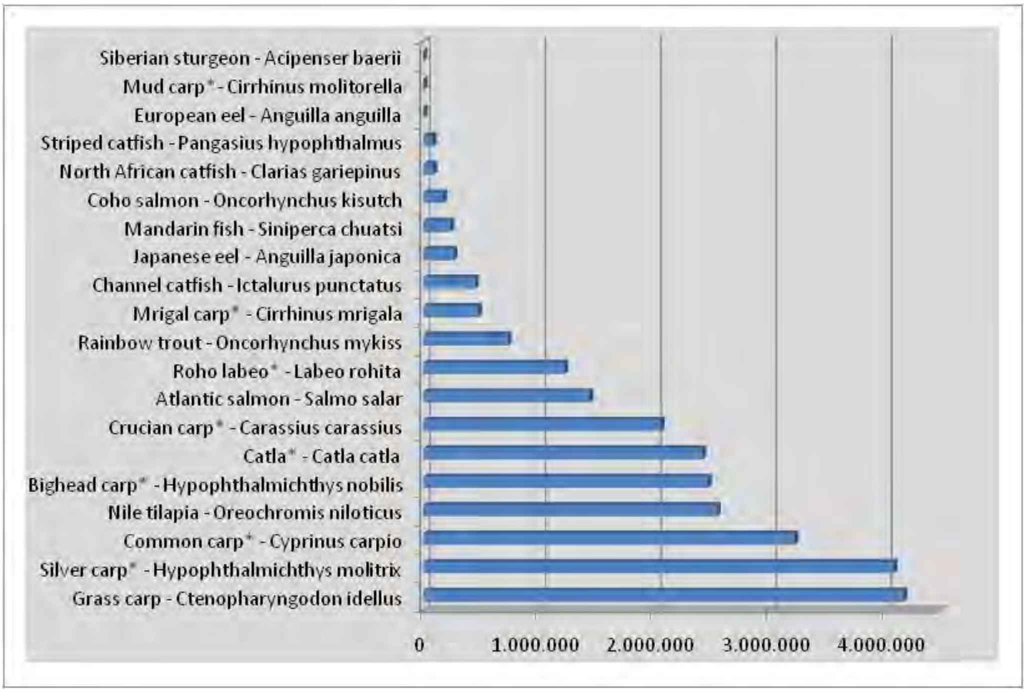


*Figure 4.2: The top 20 of freshwater fish species in aquaculture in 2009 based on FAO.org. Per species the number of produced tonnes is given. * = cyprinid species.*

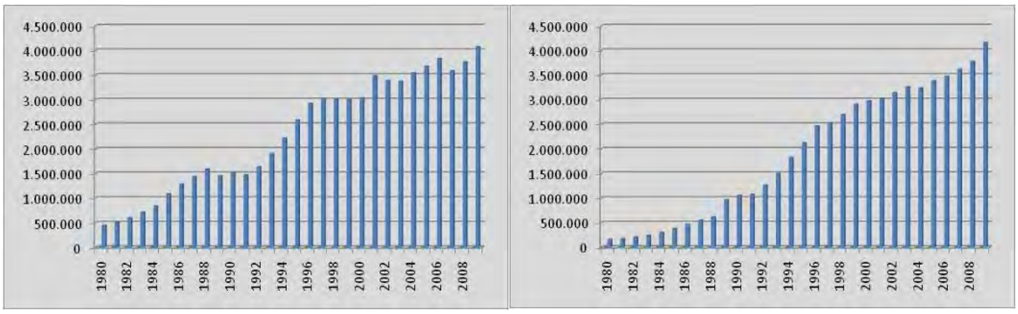


Figure 4.3: The annual production of silver carp and grass carp between 1980 – 2009 based on FAO.org. Per species the number of produced tonnes is given.

While China is by far the largest producer of silver carp, India and Bangladesh are also major producers of this species. Significant amounts of silver carp are also raised in Iran, the Russian Federation and Cuba. For bighead carp, China is also by far the major producer with a production that equals about 99 percent of the global total. The European production of silver carp is about 1.6 percent of the world production (65,000 tonnes), the production of bighead carp is about 0.25 percent (6,200 tonnes).

In China this production dates back to the Tan Dynasty (7th –10th Century) when there was a transition period from common carp culture to the rearing of grass carp, black carp, silver carp and bighead carp. Since the 1950s, after a breakthrough in artificial propagation, the aquaculture of silver carp and bighead carp, as well as other carp, spread tremendously into most regions of China. In particular silver carp has long been an important cultured species in China because:

- It is a herbivorous species and thus low in the food chain; feeding is therefore easily arranged at low cost;
- It can be kept in polyculture with other species, because of its specific niche;
- Artificial breeding is simple, so there is no reliance on natural resources;
- Production management is simpler and the rearing period is shorter than for other carp species.

Figure 4.4: Steamed silver carp head with chopped hot chili pepper, a Chinese delicacy from the Hunan Province. Photo by www.achinesefood.com.

Polyculture

Fish ponds that are enriched by chemical fertilisation, manuring or feeding practices contain a variation of natural fish food organisms living at different depths and locations in the water column. Most fish species feed predominantly on selected groups of these organisms. Polyculture is based on combining fish species with different feeding habits in proportions that effectively utilise these natural resources. As a result, higher yields can be obtained in comparison with monoculture and at lower costs.

Silver carp and bighead carp are often kept in polyculture together with grass carp, common carp and black carp. The combination of silver carp and/or bighead carp with tilapia species is also common practice (Bocek, 2004).

Since the 1960s silver carp and bighead carp have been widely introduced into European aquaculture for algal control and as a food source. They have become relatively popular in countries with a tradition in carp culture and consumption, mainly the Eastern European countries and the Balkans (www.fao.org). Also in Europe they are often used in polyculture.

The chance of entry from Dutch fish farms

Neither silver carp or bighead carp are currently present in Dutch fish farms. Furthermore, none of the bigheaded carp can be legally cultured for human consumption in the Netherlands as only species listed in the Animal Health and Welfare Act (Artikel 34 van de Gezondheids- en Welzijnswet voor dieren) are permitted. None of the bigheaded carp are included in this list (www.aquacultuur.wur.nl).

A review of possible new species for innovation in Dutch aquaculture did not list bigheaded carp as being promising (Kals *et al*., 2005). In particular, the low market prices for these species and the lack of interest for consumption in the Netherlands of these species justify the exclusion of these species. It therefore seems unlikely that silver carp or bighead carp will be cultured in the future in the Netherlands.

The chance of entry from Dutch fish farms is considered to be zero for all species of bigheaded carp and their hybrids.

4.6 Angling

Although their massive size would suggest otherwise, silver carp, bighead carp or their hybrid are not often targeted by anglers. This has to mostly do with the fact that both species are filter feeders. This means they are very difficult to catch with standard fishing tackle. In North America, Eastern Europe and Russia some techniques have been developed to catch these fish. The most effective and well-known technique is the “suspension” method. This involves a large dough ball, which slowly disintegrates. This ball is surrounded with little hooks. When a fish starts feeding on the falling particles, it will eventually reach the dough ball. When it bumps in to the ball it can become hooked on one of the hooks. Another lesser known technique is to fish by suspending bread flakes put in the path of a feeding fish.

In the Netherlands there is no dedicated angling on silver carp, bighead carp or their hybrid. This is mostly due to the facts that these species are rare and that they are hard to catch with standard angling techniques. Most reported catches are clearly accidentally hooked fish.

The chance of entry from angling related activities is low for silver carp, bighead carp and their hybrid. The chance of entry for largescale silver carp is close to zero.

4.7 Stocking

Silver carp or bighead carp have not been reported to have been stocked in Dutch waters, except for a few silver carp x bighead carp hybrids released in the Middelburgse Vesten in 2009. These fish originated from an abandoned carp farming pond and were amongst a large population of common carp, see also 2.5.

Fish stock assessments in three waters showed too high numbers of bigheaded carp to be easily explained by releases from garden ponds (www.limnodata.nl):

- Tegelen, urban water, RD 206.775-373.900, 1999-11-11, 48 specimens;
- Oldenzaal, fishing pond, RD 257.925-480.475, 1999-3-19, 10 specimens;
- Raamsdonksveer, urban water, RD 119.875-413.000, 2007-2-20, 8 specimens.

All three of these waters are isolated and have been stocked with fish by angling societies. It is most likely that the bigheaded carp in these waters were stocked by these societies. The reason for these stockings is probably at least partly explained by the reason given on an internet forum for the stocking of several silver carp in an urban water in Reuver (Limburg), namely that these silver carp were expected to decrease algae problems.

Besides deliberate stocking bigheaded carp can be stocked incidentally by contaminated common carp or grass carp stock. Such contamination can be expected especially when stock is imported from Eastern Europe where polyculture of bigheaded carp with common carp and grass carp commonly occurs.

The chance of entry from stocking
The chance of entry of silver carp, bighead carp or their hybrid from stocking is considered high based on the facts that both species are readily available for stocking in Eastern Europe and that actual stockings have taken place. With largescale silver carp probably not being available in trade the chance of entry is close to zero.

Biological control by using 'Asian carp' species
Four of the Asian carp species have regularly been applied for the biological control of phytoplankton, weeds and snails. These uses are briefly discussed below.

Silver carp and bighead carp
These plankton eating fishes have raised regular interest in the possibility of using them for controlling phytoplankton densities. It has indeed been found that these species can be effective in controlling mat-forming algae growth in small ponds. But they probably have limited use for biological control, because filter feeding by these species can actually result in increased nannoplankton concentrations, reduced zooplankton populations and, therefore, reduced water clarity (Kolar *et al.*, 2007), see also chapter 7.

Grass carp
The grass carp is a well known herbivore. It has a short alimentary tract making its digestion inefficient. About 50 percent of the food intake passes without being properly digested. Therfore, these fish need to consume large quantities of plant material to meet their energy requirements, making them relatively effective for the biological management of aquatic weeds. A negative aspect of the use of grass carp is the lack of selectivity when applied in higher densities. At low densities mainly soft aquatic weeds are consumed, like cabomba (*Cabomba caroliniana*) and Canadian water weed (*Elodea Canadensis*). At higher densities harder weed species are also eaten. Manipulating what is eaten by population density is complicated as it depends on a variety of factors including water temperature, plant species, age of the plants, size of the carp, etc. (Kempenaar *et al*., 2009).

Currently in the Netherlands grass carp are mainly applied in isolated waters for weed control. In most cases the effectiveness is low as the stocked densities are too low. Grass carp are also used in fishing ponds, e.g. in trout fishing farms (D.M. Soes, pers. observ.)

Black carp
Adult black carp are specialised molluscivores that have a true preference for snails and smaller bivalves. In North America they have become popular in aquaculture because of their effecteness in controlling snails that serve as an intermediate host for serious fish disease. They are, for example, used in hybrid striped bass (*Morone chrysops* x *M. saxatilis*) and fathead minnow (*Pimephales promelas*) culture (Wui & Engle, 2005). In the Netherlands they have a real potential to control, for example, swimmers itch by diminishing the snail species that are important intermediate hosts for the flatworm parasites (Schistosomatidae) that cause the swimmers itch.

4.8 Entry from neighbouring countries

4.8.1 Flanders

Both silver carp and bighead carp have been imported in Flanders in the 1960s. They have been stocked in ponds and channels but have not established. Nowadays bighead carp is believed to be absent and the silver carp is only known from a channel near Bocholt in northeastern Flanders (Verreycken *et al*., 2007; Vrielynck *et al*., 2003; www.vis.milieuinfo.be). In this channel seven specimens around seventy centimeters in length were caught during a fish stock assessment in 2003. The stocking of fish is a common practice in this channel and the probable origin of these specimens (Van Thuyne & Breine, 2004).

4.8.2 Wallonia

In Wallonia both silver carp and bighead carp have only been recorded incidentally and reproduction is considered to be absent (Philippart, 2004).

4.8.3 Germany

In former East Germany both silver carp and bighead carp have been imported in the 1960s and the 1970s from other Eastern European countries, including the former Soviet Union and Poland. These fish have subsequently successfully been incorporated in the carp culture that was already common in East Germany. The silver carp and bighead carp produced were used for consumption and for the stocking of, especially eutrophicated, lakes. Both species ended up in the wild, not only because of this stocking but also by escaping from fish farms (during flooding). The result is a widespread occurrence of both species in former East Germany (fig. 4.6). In recent years both silver carp and bighead carp have become much less popular in the aquaculture in the eastern parts of Germany and also field records show a clear decline. It is suspected that both species are likely to almost disappear in the coming decades (Füllner *et al.*, 2005).

Figure 4.5: A big silver carp from a German lake. Taken from www.fisch-hitparade.de.

The bigheaded carp are considered rare in the western parts of Germany, although it is under-recorded and more records exist than are present in the database of Fischartenatlas.de (J. Freyhof, pers. com.). One of the major reasons for the difference with former East Germany is that both silver carp and bighead carp have never become popular in aquaculture in the western parts of Germany (Krappmann, 2000).

Reproduction of either silver carp or bighead carp has never been recorded in Germany.

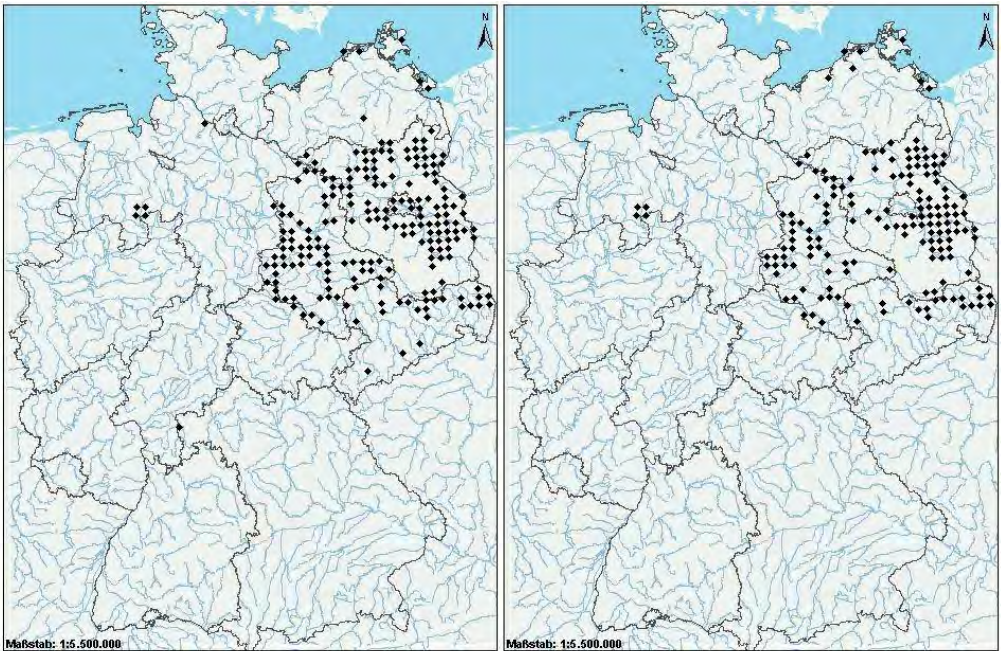


Figure 4.6: Distribution of silver carp and bighead carp according to fischartenatlas.de, accessed 22 April 2010. Black = recent recordings, Grey = data from literature, Red = data from literature with exact locality uncertain.

4.8.4 France

In France the silver carp is widely distributed but numbers are low (fig. 4.7). The bighead carp has only been recorded at two sites in western France. Both species have not been recorded to reproduce (Keith & Allardi, 2001). Probably most specimens recorded are associated with carp stockings in ponds and lakes for recreational fishing.

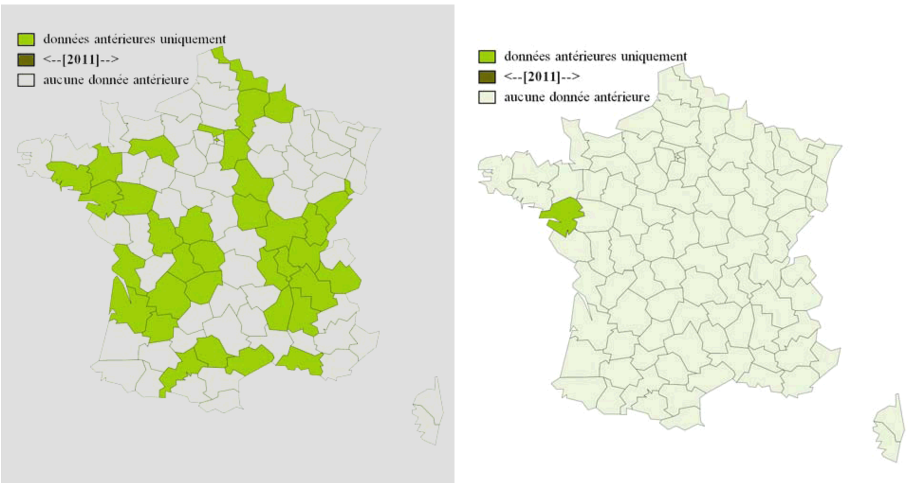


Figure 4.7: The distribution of silver carp (left) and bighead carp (right) in France with data upto 2010. Taken from (inpn.mnhn.fr).

4.8.5 Chances of entry from neighbouring countries

In all surrounding countries silver carp and bighead carp are rare in the wild. No reproduction has been recorded in any of them.

The chance of entry from neighbouring countries is considered low for silver carp, bighead carp or their hybrid and only single specimens can be expected. The chance of entry of the largescale silver carp is close to zero.

4.9 Conclusion chances of entry

The chances of entry from the possible pathways are summarised in table 4.1. From this table it is clear that the chance of entry of the largescale silver carp is close to zero. For bighead carp, silver carp and their hybrid stocking should be considered the most important pathway, especially as numbers involved are potentially high.

Table 4.1: The chance of entry in the Netherlands and the numbers involved per species and vector is given.

	bighead carp		silver carp		largescale silver carp		hybrid	
	entry	N	entry	N	entry	N	entry	N
aquaria	close to zero	-	close to zero	-	close to zero	-	close to zero	-
garden ponds	high	low	probably low	low	close to zero	-	high	low
angling	low	low	low	low	close to zero	-	low	low
fish farms	close to zero	-	close to zero	-	close to zero	-	close to zero	-
stocking	high	low-high	high	low-high	close to zero	-	high	low-high
neighbouring countries	low	low	low	low	close to zero	-	low	low

So far as information is available alien established popualtions outside the Netherlands of both silver carp and bighead carp have been the result of:

- stocking, including contaminated stocks of grass carp;
- escapes from (flooded) aquacultural facilities.

Although several other (potential) pathways are known, they have never been proven to be responsible for the establishment of bigheaded carp populations (Kolar *et al.*, 2007). The two mentioned pathways have in common that the number of specimens involved is relatively high, resulting in a relatively high propagule pressure.

This might be comparable with e.g. the results of Korsu & Huusko (2009) that showed that the chance of establishment of brook trout (*Salvelinus fontinalis*) after artificial introductions is positively correlated with the numbers of introduced fish. But care should be taken in concluding that a high propagule pressure is needed for the establishment of bigheaded carp as several other studies have indicated that initial numbers can also be very low in succesfull colonization events in other fish species (Velez-Espino *et al.*, 2010; Drake, 2005).

The chance of entry from garden ponds is high in bighead carp and the hybrid, but numbers involved are low. The resulting propagule pressure is low and less likely to result in the establishment of the bighead carp or the hybrid. The chance of entry from stocking for bighead carp, silver carp and their hybrid is also considered high, but numbers can potentialy be much higher than in entry from garden ponds. This includes contaminated stocks of grass carp or common carp. Because of the resulting higher propagule pressure and the higher probability of etablishment, stocking gives the highest risk for establishment of bighead carp, silver carp or their hybrid in the Netherlands.

Most waters that are stocked with e.g. common carp are well isolated, preventing escapes to open water systems that allow reproduction. The most likely scenario's for stocked bigheaded carp to escape towards such waters systems is stocking in waters that are flooded by rivers or stocking in open water systems.

5 The probability of establishment

This chapter provides information on the potential for Asian bigheaded carp to colonise surface waters in the Netherlands. A description of the methodology applied is followed by a summary of the physiological tolerances of the Asian bigheaded carp. Subsequently, the results of an analysis comparing the physiological tolerances with the environmental conditions existing in potentially suitable water bodies in the Netherlands are described. The analyses into the probability of establishment were focused on relevant environmental factors such as temperature, food availability, salinity, water hardness and currents. Moreover, this includes a prediction of the effect of environmental change as a result of global warming using scenarios for the year 2050.

5.1 Materials and methods

5.1.1 Literature survey on physiological tolerances

The information on physiological tolerances of Asian bigheaded carp is mainly based on the extensive literature review of Kolar *et al.* (2007). A supplementary search was conducted to establish if further research has been published since the publication of this review. A systematic search was undertaken using the search engines Web of Science® and Google. Searches using Web of Science cover the world's leading scholarly literature in the sciences and examines proceedings of international conferences, symposia, seminars, colloquia, workshops, and conventions. Google was used to discover relevant grey material such as reports by nature or governmental organizations. Search terms were entered using the title and subject functions of the Web of Science. A similar approach was applied when using Google. Two approaches were used, initially to find information that would supplement that already found in Kolar *et al.* (2007) and subsequently to discover information on parameters not discussed within that survey. Firstly searches were made using the names of species in isolation to obtain information on all publications within the database and then limited to articles published after the most recent references cited in Kolar *et al.* (2007). Secondly, targeted searches were made in an attempt to find information on parameters not found in previous searches such as food and oxygen requirements. Information on physiological limits together with information regarding its source was then summarized into a table (Section 5.2, table 5.1).

5.1.2 Data collection – environmental parameters of Dutch water bodies

Data was collected for salinity, temperature, chlorophyll a, water hardness, dissolved oxygen and current velocity/discharges for the larger Dutch water bodies. Data was obtained from Waterbase.nl, a validated online database maintained by Rijkswaterstaat, the Dutch governmental body that is responsible for the management of the major waterways in the Netherlands. The range of parameters chosen was limited by the variety of information on physiological limits that could be obtained during the literature survey. Where possible, monitoring sites were selected where monitoring had been undertaken for at least 10 unbroken years previous to the year 2010.

5.1.3 Analyses of species – environment match

Analyses were undertaken by plotting environmental data retrospectively for each parameter and superimposing the available values on physiological tolerances of various life stages for each species. Where trends in spatial variation in the data were identified, maps were created to identify areas where the minimum effect concentrations for the Asian bigheaded carp were exceeded. Conclusions were then drawn from the interpretation of the graph in association with information gathered from scientific articles collected during the literature survey.

Detailed data on flow velocity in relation to discharge of water bodies were lacking. To assess the effect of flow velocity in the Rhine river distributaries on spawning ability data from Deinema & Van Mourns (2003) was used to create flow velocity-discharge relations for various locations in the river Waal. Ranges of suitable flow velocity for spawning was obtained for several locations where spawning had been triggered in the river Danube, the Kara Kum canal in Turkmenistan and water bodies of unknown location (Aliyev, 1976; Staras & Otel, 1999; Schiemer *et al.*, 2003; Chang, 1966; Holcik, 1976; Krykhtin & Gorbach, 1981; Kamilov & Salikhov, 1996). The flow–discharge relations, the temperature and flow ranges suitable for spawning and data on the periods of rising hydrographs were used to estimate potential of spawning behaviour in the bighead and silver carp for the Rhine tributaries. Each parameter was assessed to see if it fell within ranges observed during spawning of bighead and silver carps given in the literature. First durations when the temperatures of the water in the Rhine at Lobith were high enough to initiate spawning behaviour were calculated for the years 1989 to 2010. Water temperatures used were derived from the upper water level and it must be taken into account that temperatures can be up to three degrees lower near the channel bottom (Leuven *et al.*, 2011). These periods were then compared with discharge data to see if they coincided with a siginificant increase in discharge and if discharge remained above levels where spawning behaviour has been observed in the literature. It was assumed that a discharge increase of below 500m^3/s would not encourage spawning indicated by a minus (-). A discharge increase of 500 to 1000m^3/s was considered to be more likely to induce spawning and was indicated by a plus minus (+/-). Discharge increases of above 1000m^3/s were considered to be likely to induce spawning and were indicated by a plus (+). Similarly, flow rate was assessed and a plus was attributed to a year where flow rate reached any one of the different levels said to stimulate spawning in the literature. For example if it was observed in the literature that a flow rate of above 0.3m/s would stimulate spawning, it was used as a scenario for flow rate required to stimulate spawning in the Rhine at Lobith. If the flow rate at Lobith lay consistently above 0.3m/s at times when water temperature was sufficiently high, then a plus was entered under the 0.3m/s scenario. If the flow rate was inconsistent and fell below as-well as rising above the 0.3m/s limit then a plus minus was entered under the scenario. A final score (+,+/- or -) was given reflecting the overall balance of pluses and minuses given to each parameter for each year to assess the likelihood of spawning. The results of the assessment are given in a table in Appendix 1.

To estimate the effects of climate change, temperature data was collected for temperature from 38 different monitoring stations within the Netherlands. Only data originating from lakes and rivers was included in the analysis as these are the preferred habitats of the Asian carps. The maximum and minimum for each monitoring site was calculated for each year and an average for the all monitoring sites was determined. The average maximum and minimum were then plotted on a graph which was then extrapolated to the year 2050. This extrapolation was then used in a similar way to the other graphical analyses to establish the impact of climate change on the suitability of Dutch surface waters for Asian carp colonization. This extrapolation scenario was then compared to the four climate change scenarios put forward by Klein Tank & Lenderink (2009).

To create an overview of the overall potential for the Asian carps to survive and populate Dutch freshwaters, summary tables were created that identified where the environmental parameters under consideration (temperature, dissolved oxygen, chlorophyll a, water hardness and salinity) may hinder their establishment (table 5.1). The analysis was undertaken for a number of monitoring locations representative of different water types within the Netherlands. These were lake Markermeer, Lobith where the river Rhine enters the Netherlands, Bovensluis in the Limburgse Maas, Maassluis located towards the western part of the Netherlands and Puttershoek located in the Oude Maas near to Dordrecht. Data was analysed for the years 2005 to 2010 inclusively. The potentially limiting effects of the parameters were characterised in four ways represented by different colours in the tables (Red, yellow, orange and green). Red characterises a location where the environmental parameter is not limiting. Yellow describes an environmental parameter where an optimal range has been described in the literature and where the measurements at that location fall outside that optimal range. Orange defines a location where the measurements taken fall outside the physiological tolerances of the species but for a limited time only. In this case there remains a possibility that the limiting effects will be minimal. Green defines a location where the parameter measured exceeds the maximum or minimum tolerance of the species for an extended period resulting in a potentially significant limitation. A chequered pattern indicates a location where the effects of the environmental parameter considered will not be consistent due to the inter-annual variability of that parameter. However, the colour accompanying the chequered pattern represents the dominant condition at that particular monitoring station. A final total colour score is given that represents the most dominant colour category for all parameters per location.

5.2 Literature survey results

Table 5.1: Physiological limits for the bigheaded carp derived from literature.

	Bigheaded Carp	Silver Carp	Large Scale Silver Carp
Water hardness	• Possibly similar to that of silver carp (Kolar et al., 2007) • Hatching rate and egg size were not significantly effected by the different water qualities (Chapman & Deters, 2009)	• Successful reproduction reported between 40 and 490 mg/l $Ca^{2+}CO_3^{2-}$. Conflicting information on upper and lower limits from different authors (Kolar *et al.* 2007; Moody & Battaglin, 1995; H. Liu *cited in* Rach et al., 2010; USGS, 2008)	• requirements expected to be similar to silver carp (Kolar et al., 2007)
Temperature survival	• >5 °C for fingerlings (Negonovskaya, 1980) • <38.8 °C for young adults (Bettoli et al., 1985) • Generally cold tolerant as survive river and reservoirs that remain frozen for 4 to 6 months (Kolar et al., 2007)	• 16-40 °C for larva (Tripathi, 1989) • 43.5-46.5 °C lethal upper limit for 3-28 °C day old larva (Opuszynski et al., 1989) • Possibly more cold tolerant than bighead carp (Kolar et al., 2007)	• Possibly intolerant of temperate climates as native range is tropical / subtropical (Kolar et al., 2007).
Temperature spawning	• >14-15 °C to 30 °C (Opuszynski & Shireman, 1995; Chang, 1966; Verigin et al., 1978; Schrank et al., 2001) • temperature fluctuation does not influence natural reproduction (Opuszynski & Shireman, 1995)	• Outside 18-31 °C ovulation and hatching diminished + abnormal embryonic development (FAO, 1980). • 18-26 °C reported during spawning (Abdusamadov, 1987; Kaul and Rishi, 1993)	• Spawning requirements expected to be similar to silver carp (Kolar et al., 2007)
Temperature growth	• Fertile waters above 13.9°C bigheaded carp can attain 2.7kg in less than 1 year (Waterman, 1997).	• Max growth occurs between 24-34 °C (Mahboob & Sheri, 1997; Javed, 1988).	N.A.
Temperature feeding	• >10 °C for fingerlings (Negonovskaya, 1980) • >2.5 °C for adults (Chapman, unpublished data) • 20-30 °C optimum for adults (Ling, 1977) • Gut evacuation at low temperatures expected to be limited (Bialokov & Krzywosz, 1981).	• <15 °C reduced appetite , <8-10 °C feeding almost ceased (FAO, 1980; Tripathi, 1989) • <4 °C full gut contents. Less active above 30 °C (Chapman, unpublished data).	N.A.
Temperature activity	• Inactive below 2 °C, active above 4 °C (Chapman, unpublished data),.	• <4 °C reduced activity (Kolar et al., 2007) • <2 °C little movement (Kolar et al., 2007)	N.A.
Salinity	• 15-20 ppt (Adults) • 6-12 ppt (larvae and fingerlings) • 4 (11 day old fry). Above 2 ppt food intake, absorption, conversion efficiencies reduced affecting growth rate. • Generally saline tolerance increases with age and 6 ppt appears to be the critical maximum (Garcia et al., 1999)	• Highly conflicting. • Max. 1.5 ppt for fingerlings (Zang et al., 1989) • Max. 4 ppt for breeding (Waller, 1985) • 7.5-12 ppt for fry and fingerlings (Tripathi, 1989)	• No information. Possibly close to that of silver carp (Kolar et al., 2007)

	Bigheaded Carp	Silver Carp	Large Scaled Silver Carp
Dissolved oxygen	• Preferred range 7-10 mg/l (Stainbrook et al., 2007)	• Preferred range 7-10 mg/l (Stainbrook et al., 2007)	• Preferred range 7-10 mg/l (Stainbrook et al., 2007)
Flow velocity migration	• Rising hydrograph (Jennings, 1988; Pflieger, 1997)	• Rising hydrograph (Laird & Page, 1996)	• Spawning requirements expected to b similar to silver carp (Kolar et al. 2007)
Flow velocity spawning	• Spawning triggered by rising hydrograph, 0.6-2.3 m/s (Chang, 1966; Verigin et al. 1978). • Turbulent water e.g. confluence of rivers, rapids, behind sandbars etc. (Breeder & Rosen, 1966; Chang, 1966; Huet, 1970). • One example of spawning in a fast flowing (0.9-1.2 m/s) canal with no increase in discharge following introduction (Aliyev, 1976).	• Spawning triggered by rising hydrograph, 0.3-3.0 m/s (Chang, 1966; Holcik, 1976; Krykhtin & Gorbach, 1981; Kamoliv & Salikhov, 1996).	• Flowing waters, rains stimulate spawning into rivers (Pearl River Fisheries Research Institute, 1991; Chen, 1998). • Spawning requirements expected to b similar to silver carp (Kolar et al., 2007)
Flow velocity nursery area	• Calm waters (Huet, 1970)	• Low flow backwaters, creeks and reservoirs (Nikolsky, 1963).	• Requirements expected to be similar to silver carp (Kolar et al. 2007)
Turbidity spawning	• Visibility 10-15 cm, high level of suspended solids (Chang, 1966; Verigin et al. 1978).	• 1.2 kg/m^3 (Jankovic, 1992)	• Requirements expected to be similar to silver carp (Kolar et al., 2007)
Biomass (food)	• Primarily zooplanktiverous (Borutskiy, 1973; Lazareva et al. 1977) • Highly opportunistic (Kolar et al. 2007) (switch to phyto-plankton at low concentrations of zooplankton). • At 20^{o}C to maintain body mass carp weighing 2400 g require water with 255 µg/L macrozoolankton (dry) or 10.43 µg/L chlorophyll *a* (Cooke & Hill, 2010).	• Primarily a phytoplanktivore but highly opportunistic (Kolar et al., 2007). • May require some zooplankton in their diet to survive: 80% mortality after 5 weeks of feeding on *Scenedesmus* alone (Tarifeno-Silva et al., 1982). • At 20^{o}c to maintain body mass carp weighing 2400 g require water with 379 µg/L macrozoolankton (dry) or 15.5 µg/L chlorophyll *a* (Cooke & Hill, 2010).	• Nocturnal phytoplankton feeder(Pearl River Fisheries Research Institute, 1991; Chen, 1998) . • Feeding habits expected to be similar to that of silver carp (Kolar et al., 2007).
River length required for entrainment	• approximately 100 km (Krykhtin & Gorbach, 1981) • Probably dependent on water temperature and velocity (Kolar et al., 2007).	• >100 km (Krykhtin & Gorbach, 1981)	• Requirements expected to be similar to silver carp (Kolar et al., 2007).

5.3 Analysis and discussion

5.3.1 Temperature tolerance

Temperature data of large rivers, canals and lakes in the Netherlands was limited to the minimum and maximum values for all monitoring stations for each month for the period 2001-2010. These data were plotted together with the physiological limits of bighead and silver carps (Fig. 5.1 & 5.2).

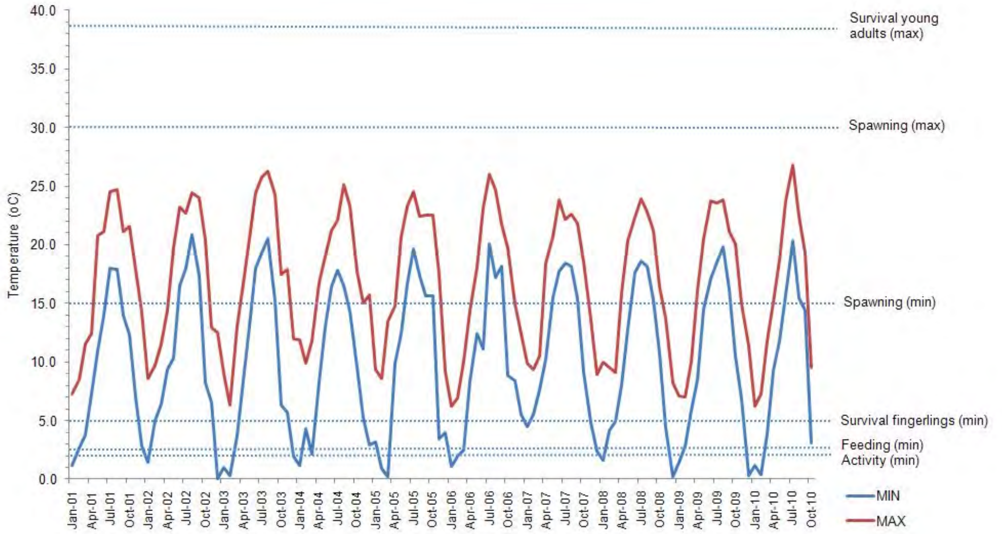


Figure 5.1: Temperature related physiological and behavioural limits for bighead carp in comparison with monthly maximum and minimum temperatures measured in the upper water layer of large Dutch rivers, lakes and canals in the period 2001-2010.

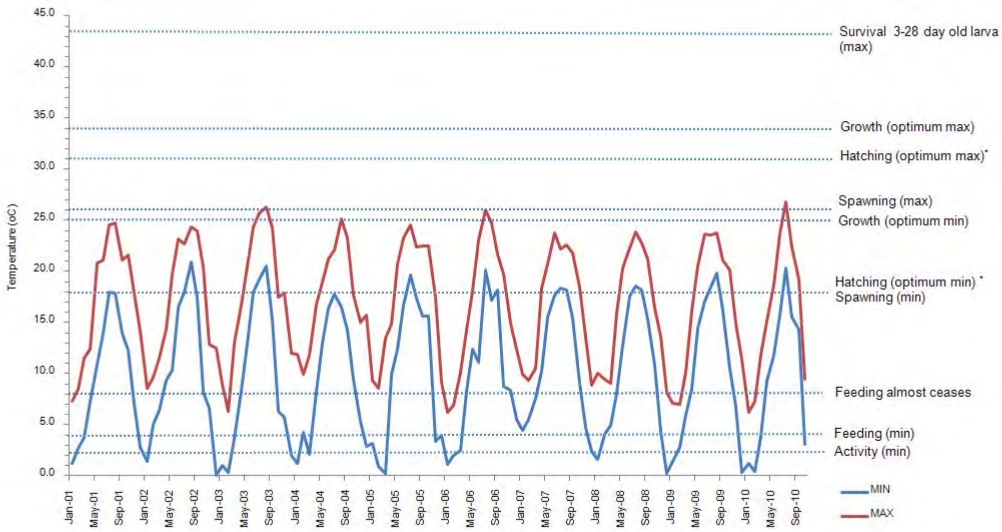


Figure 5.2: Temperature related physiological and behavioural limits for silver carp in comparison with monthly maximum and minimum temperatures measured in the upper water layer of Dutch rivers, lakes and canals in the period 2001-2010.

The environment-tolerance comparisons indicate that both bighead and silver carp are not limited in terms of the typical upper temperature limits that are found in Dutch freshwaters. Upper survival limits for the young of the bighead carp lie between 10 and 15°C above what is currently experienced in Dutch freshwaters. The maximum survival limit for the silver carp lies 16 degrees above the maximum summer temperature experienced in the Netherlands over the previous 10 years.

Surface water temperatures sit within the lower optimum range for silver carp hatching during the summer months and even the coldest areas will support hatching between the months of July and September for most years, in otherwise suitable conditions. Maximum water temperatures tend to lie below the ideal range for growth of silver carp. This may limit the time taken to reach maturity as growth has been found to be temperature dependent. Growth will still occur at a water temperature of 15°C but silver carp will require 1,000 degree days to reach maturity as opposed to 500 degree days at 30°C (Jhingran & Pullin, 1985, cited in Laws & Weisburd, 1990).

During the coldest months of the year feeding and activity of both species will be limited in some locations. However, there is anecdotal evidence to suggest that adults of both species can tolerate prolonged cold periods. In Alberta, Canada, silver carps successfully overwintered in ponds that were near 0^{o}C from around the beginning of November through to the end of April (B.Mackay, Alberta Department of Agriculture, Food and Rural Development, Lethbridge, Alberta, personal communication, 2004, cited in Kolar *et al.*, 2007). Bighead carp are present in rivers and reservoirs in the Manchurian Plain that remain frozen 4-6 months out of the year (Kolar *et al.*, 2007). Moreover, lowland rivers in the Netherlands show high vertical heterogeneity in water temperature. Minimum temperature near the river bottom can be up to 3°C higher in winter periods than in the surface layer, due to seepage of groundwater (Leuven *et al.*, 2011).

Temperature in isolation does not constitute a barrier to spawning for either species. In 2010 even in the coldest areas spawning was potentially possible for the bighead carp from the middle of June to the beginning of September and for the silver carp during July. In previous years (2008 and 2009) the period where minimum temperature for spawning and hatching for the silver carp was exceeded was from mid July to late August. In its native range, the bighead spawns between April and June, peaking in late May (Chang, 1966; Verigin *et al.*,1978).

Spawning by bighead carp is initiated by rising water levels following the heavy rains that occur in the spring or, in China, during the monsoon season (Jennings, 1988; Pflieger, 1997). Similar characteristics have been identified for the silver carp that often spawns after a sharp rise in water level (Verigin, 1979). Yi (1988) found that eggs of the bighead and silver carp were collected mostly on the rising hydrograph, as opposed to after the peak discharge. There appears to be a requirement for suitable temperature conditions to coincide with a rise in discharge to initiate spawning behaviour in these two species.

Information regarding the temperature tolerance of both the large scale silver carp and Asian carp hybrids is scarce. It has been suggested, however, that temperate climates may not satisfy the spawning requirement of the large scale silver carp due to the tropical / subtropical nature of its native range. Other physiological and behavioural temperature requirements of the large scale silver carp are suggested to be similar to the silver carp (Kolar *et al.*, 2007).

5.3.2 Hydrology-temperature match for reproduction

Spawning of the bigheaded carp and silver carp were recorded at flow velocities of 0.6-2.3 m/s and 0.3-3.0 m/s, respectively (Table 5.1). Successful reproduction of Asian bigheaded carp also require an increase of flow velocity because spawning is triggered by rising hydrographs (Chang, 1966; Holcik, 1976; Krykhtin & Gorbach, 1981; Kamoliv & Salikhov, 1996; Verigin *et al.*, 1978). However, Aliyev (1976) reported an example of spawning of both bighead and silver carp in the fast flowing (0.9-1.2 m/s) Kara Kum canal in Turkmenistan with no increase in discharge following species introduction. Increase in flow velocity may also occur in turbulent water such as confluences of rivers, rapids and behind sandbars (Breder & Rosen, 1966; Chang, 1966; Huet, 1970). In the river Danube reproduction of Asian carp appeared to be successful in years with water temperatures above 22°C and increased water velocity (high flood) after summer rainfalls from 0.6-1.4 m/s (Staras & Otel, 1999; Schiemer *et al.*, 2003).

The flow velocity in the summer bed of the rivers Rhine and Meuse in the Netherlands vary between <0.3 and >1.0 m/s (Duel *et al.*, 1996). However, the flow velocity in the Rhine river distributaries, such as the river Waal, may rise to 2.7 m/s during peak discharges in winter periods (Deinema & Van Meurs, 2003). In the rivers Rhine and Meuse turbulent water with high flow velocities may occur in groyne fields as a result of shipping activities. Ship passages may result in an increase of the flow rate of 0.80 m/s (personal observation; Ten Brinke, 2005). The flow velocities of large rivers are within the ranges required for spawning of Asian bigheaded carp.

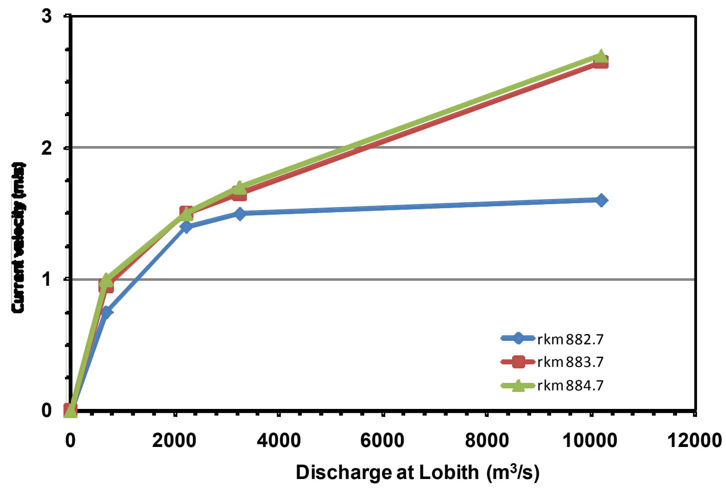


Figure 5.3: Relation between Rhine river discharge and flow velocity at various location in the river Waal as calculated with the Sobek model (data: Deinema & Van Meurs, 2003).

However, successful reproduction of bigheaded carp simultaneously requires high water temperatures and probably a rising hydrograph (see above). In the Netherlands suitable water temperature conditions for spawning only occur during late spring and summer periods. The duration of periods with suitable temperature conditions for reproduction may increase in future as a result of climate change. Increases of late spring and summer discharges of <500, 500-1000 or >1000 m^3/s that coincided with water temperatures that exceeded the minimum for bighead carp spawning at Lobith occurred during 0, 5 and 17 years over the period 1989-2010, respectively. For the silver carp, taking into account its different temperature requirement, these figures were 2, 11 and 9 years respectively (see Appendix). Therefore, the triggering of spawning of bigheaded and silver carp by rising flow velocities in the Rhine river distributaries is difficult to exclude.

The upper ranges of velocity required for spawning (2.7 - 3.0 m/s in the Dutch Rhine distributaries) will require an increase of river discharges to >12,000 m^3/s. The return period of such peaks discharges is less than once in 200 years in the river Rhine. Moreover, these peak discharges only occur in winter and early spring when water temperature is still a limiting factor for spawning. This scenario will therefore never occur during times of suitable water temperature. However other velocities that have been seen to induce spawning in both the bighead and silver carps (table 5.1) do occur within the summer period. For the bighead carp flow velocities of 0.6 and 0.9 m/s were consistently exceeded within periods when water temperature was high enough for spawning in all years over the period 1989-2010. In only three years did flow velocities drop below 1.2 m/s during the same suitable period. Individual observations within these years were inconsistent, however. Velocities climbed above 1.2 m/s at times, possibly allowing spawning to occur. The minimum flow velocity for spawning of the silver carp is 0.3 m/s. Flow velocity remained consistently above 0.3 m/s between 1989 and 2010 during periods of sufficient water temperature. It can be concluded that typical water velocities seen at Lobith in the river Rijn will only prevent spawning for the most extreme scenario of 2.7 - 3.0 m/s, the upper ranges of velocity reported to be required for spawning.

The results of the hydrology-temperature match analysis together with an overall score that expresses the possibility that bighead and silver carp could spawn in the Rijn at Lobith in the period 1989-2010 are presented in appendix 1. The final scores are a qualitative synthesis of the velocity, temperature and rising hydrograph analyses. Final scores cannot be compared across the different tables but are designed to give a yearly comparison for each individual species.

5.3.3 Impact of climate change on the probability of establishment.

The extrapolation analysis suggests that average minimum and maximum water temperatures in the Netherlands will increase by 0.7 and 0.5°C respectively when compared with 2010 figures (Fig 5.4 & 5.5). This represents the mildest increase for all scenarios examined. If the extrapolation is recalculated examining data series beginning in 1990 alone, then average increases are expected to be 1.1 and 0.7°C.
The Royal Netherlands Meteorological Institute (KNMI) developed four regional climate change scenarios (Van den Hurk *et al.*, 2006). Klein Tank & Lenderink (2009) suggest a maximum increase in air temperature of 2.8°C in summer from 1990 figures

for their most extreme scenario (table 5.2). Normally the groundwater near the land surface is 1-2°C warmer then the average air temp (Anibas *et al.*, 2007). Therefore, it was assumed that the most extreme air temperature rise scenario would result in a maximum increase in water temperature of 4.3°C in winter and 4.8°C in summer compared to 1990 figures. The effects of this temperature increase on the bighead and silver carp can be seen in figures 5.4 & 5.5.

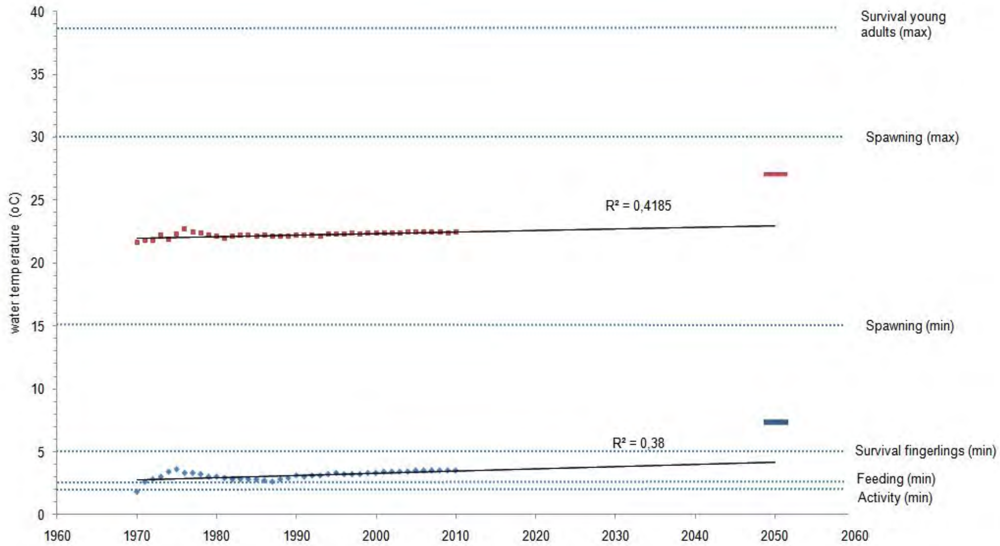
Table 5.2: Average air temperature change in the Netherlands in the period 1990-2050 according to four scenario's (Klein Tank & Lenderink, 2009).

	1	2	3	4
Winter	0.9°C	1.1°C	1.8°C	2.3°C
Spring	0.9°C	1.2°C	1.8°C	2.6°C
Summer	0.9°C	1.4°C	1.7°C	2.8°C
Autumn	0.9°C	1.3°C	1.8°C	2.7°C

If the different scenarios for temperature increase are compared with the physiological tolerances of the Asian bigheaded carp, it can be seen that even in the most extreme scenarios, the maximum temperature for spawning of the silver carp is exceeded by one degree for scenario 4 in table 5.2 (Fig. 5.4 and 5.5). However this condition will only occur in a limited number of places and for a limited time period and therefore will not rule out the possibility of spawning. Increases in maximum temperature will bring the silver carp closer to its ideal temperature range for growth, improving its survival chances in Dutch inland waters. In the most extreme scenario in table 5.2, bighead carp fingerlings would suffer no mortality according to average minimum temperatures. Even in the mildest prediction for 2050, based on a minimum average temperature rise to 4.2°C taken from the extrapolated scenario, the silver carp would no longer be prevented from feeding due to low winter temperatures.

After examining all temperature scenarios available it can be concluded that, when examined in isolation, temperature increase due climate change alone will increase the likelihood that species of Asian carp will survive and colonise Dutch surface waters. This conclusion may also be valid for the large scale silver carp as their physiological and behavioural temperature requirements are suggested to be similar to that of the silver carp (Kolar *et al.*, 2007).

Van Deursen (2006) simulated changes in the Rhine river discharge as a consequence of the four KNMI'06 climate change scenarios that were developed by Van den Hurk *et al.* (2006). These simulations show that discharges may increase by 10-20% during the winter period but may decrease by 2-40% during summer. Based on these results it is expected that the frequency and extent of rises in flow velocities during peak discharges in late spring and summer may slightly decrease compared to the current situation. However, the frequency of a temperature-flow velocity match for spawning might slightly increase due to prolonged periods with suitable water temperature. Therefore, it is assumed that the overall effect of climate change on spawning ability of Asian bigheaded carp will be negligible and spawning ability in future will be more or less similar compared to the current situation.



Historical maximum — maximum scenario 4 for 2050

Historical minimum — minimum scenario 4 for 2050

Figure 5.4: Extrapolation of flow trends in minimum and maximum temperature conditions compared to physiological tolerances of bighead carp

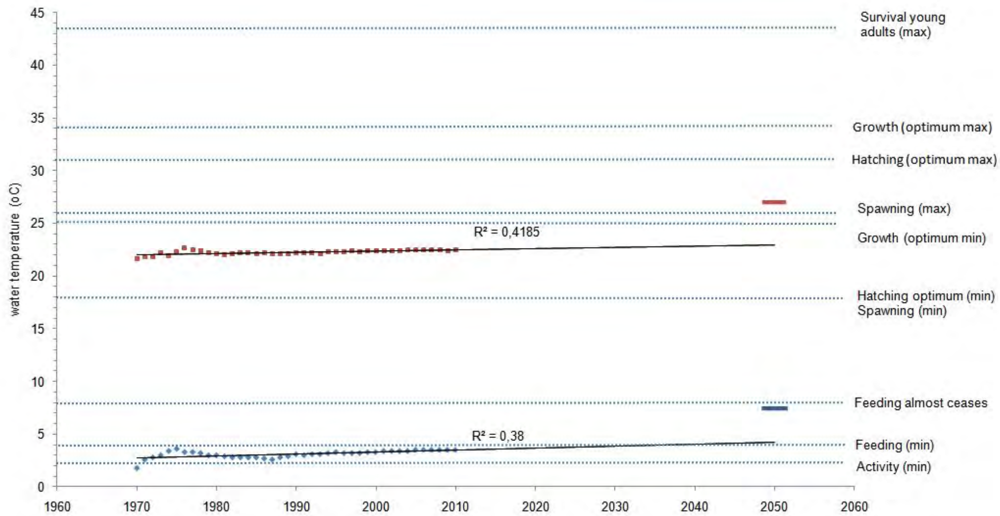


Figure 5.5: Extrapolation of flow trends in minimum and maximum temperature conditions compared to physiological tolerances of silver carp

Historical maximum — maximum scenario 4 for 2050

Historical minimum — minimum scenario 4 for 2050

5.3.4 Salinity tolerance

Dutch inland waters are subject to a coastal salinity gradient and salt discharges that may restrict the ability of bigheaded carp to colonise these areas. When comparing the salinity tolerance of the Asian bigheaded carp with salinity data it can be seen that a spatial differentiation exists between areas where Asian carp may and may not be affected by elevated salinity concentrations. Monitoring points where salinity concentrations lie above the minimum effect concentration for bighead and silver carp are identified in Fig. 5.6.

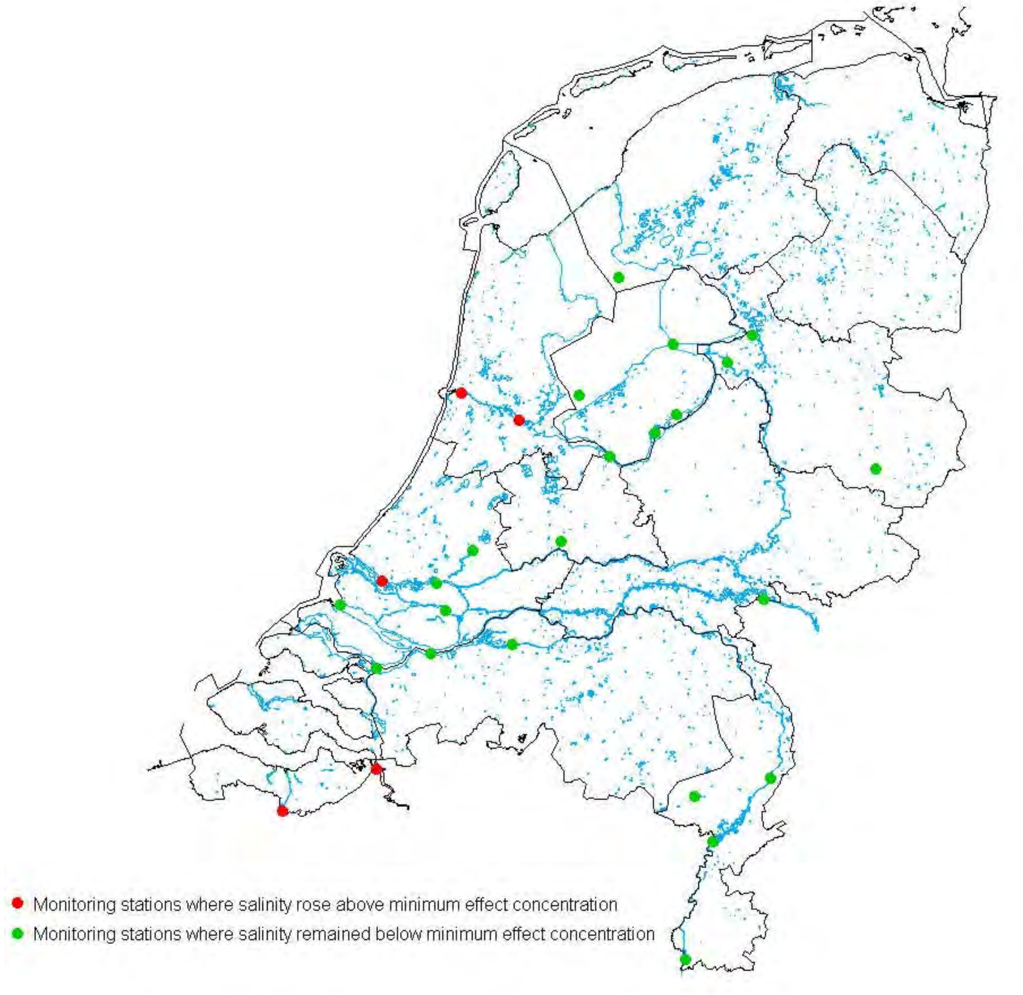


Figure 5.6: Locations in the Netherlands where salinity rose above the minimum effect concentration for silver and bighead carp (data period 2001-2010).

In the period 2001-2010, measurements from 81% of monitoring stations in large inland rivers and lakes indicated that maximum salinity levels lay below the minimum effect concentration for bighead and silver carp. Exceedence of minimum effect concentrations for salinity occurred only in water bodies that were located in coastal areas. The results of a more detailed analysis of conductivity data from monitoring stations where the minimum effect concentration were exceeded can be seen in Fig. 5.7.

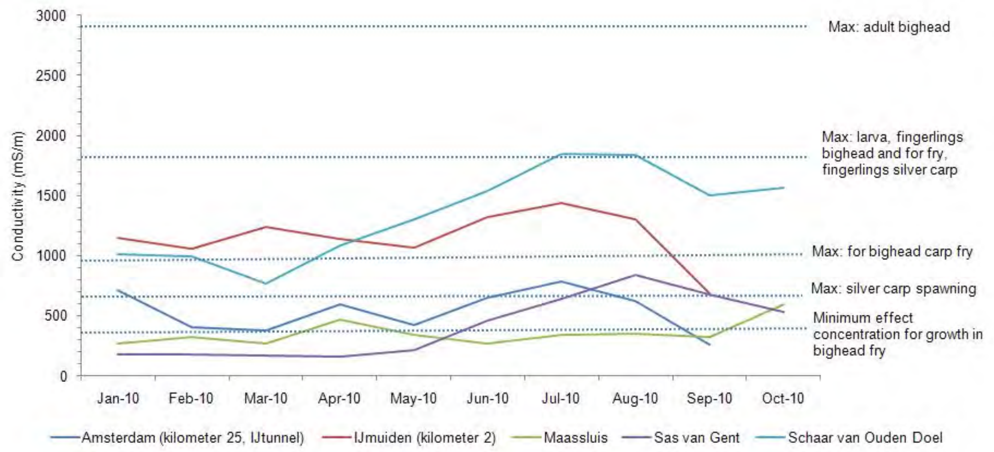


Figure 5.7: Physiological tolerance and behavioural limits for silver and bighead carp in comparison with conductivity of water bodies at monitoring stations where minimum effect concentrations were exceeded in 2010.

Even in the few locations where salinity may have an effect, it can be seen that there are only two locations, Schaar van Ouden Doel, Shelde Estuary east of Terneuzen , and IJmuiden, located very near the coast, where salinity will have an effect on the survival of bighead carp fry. Other maximum tolerances for the survival of the different life stages of these species lie above the maximum measured salinity level for 2010. The spawning of silver carp will be limited by salinity in four out of five estuarine locations at times when other environmental factors would allow this species to spawn. However, spawning ability is expected to be minimal at these extreme downstream locations, because of low flow velocity. The growth of bighead fry will also be effected by salinity at some points in the year in all estuarine water bodies. When examining the evidence for the Netherlands as a whole, it can be concluded that salinity of large inland waters will have very little effect on the ability of Asian carps to colonise Dutch freshwaters, except water bodies in river estuaries.

Information regarding the salinity tolerance of both the large scale silver carp and Asian carp hybrids is scarce. Physiological and behavioural salinity tolerances of the large scale silver carp are suggested to be similar to that of the silver carp (Kolar *et al.*, 2007).

5.3.5 Dissolved oxygen requirement

The optimum range for dissolved oxygen for bighead, silver and largescale silver carps lies within 7 to 10 mg/l (Stainbrook *et al.*, 2007). In 51% of the monitoring stations in large rivers and lakes in the Netherlands, dissolved oxygen levels have dropped below 7mg/l during the summer in the period 2001-2010 (Fig. 5.8). It can be seen that oxygen levels are constantly maintained within optimum limits within the major lakes (IJsselmeer, Markermeer and randmeren), downstream regions of the rivers Maas, Waal and Nederrijn and in several estuarine regions in the south-western part of the Netherlands. For these regions dissolved oxygen concentration will not reduce the probability of bighead and silver carp colonization.

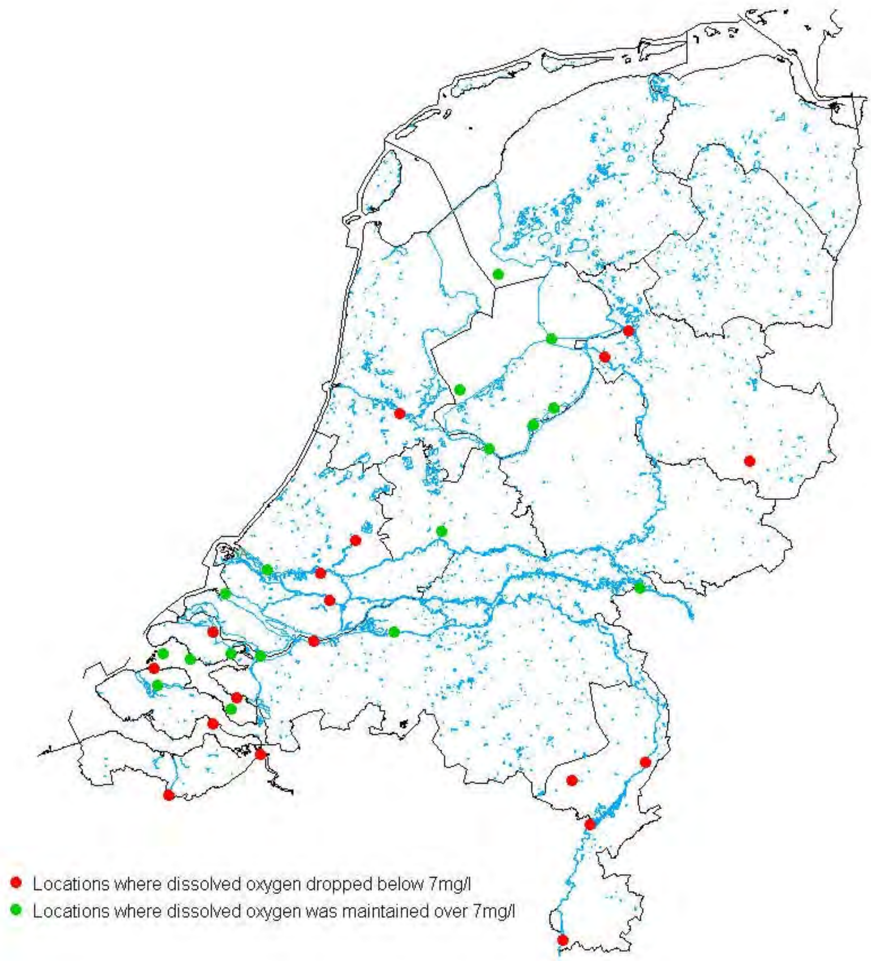


Figure 5.8: Locations in the Netherlands where dissolved oxygen was maintained above and dropped below the optimal range for silver and bighead carp (period 2001–2010).

It should be noted that the map indicates any measurement where a drop below 7 mg/l occurred within the specified time period. This indicates areas where suboptimal conditions occurred only. As a result the possibility of Asian carp colonization in these areas is reduced but not excluded. Figure 5.9 clarifies to what extent and for how long the lower optimal limit was exceeded for locations identified for 2010.

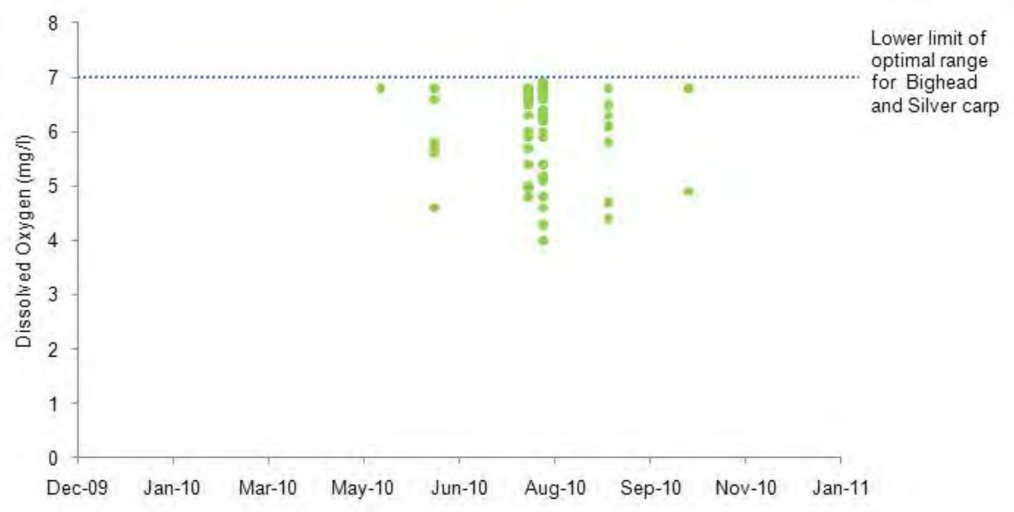


Figure 5.9: Duration and extent by which dissolved oxygen levels dropped below 7 mg/l at locations in large rivers and lakes identified in 2010.

For the locations where oxygen dropped below 7 mg/l, it can be seen that this will occur during the summer months, coinciding with potential spawning periods. There was no further data regarding absolute minimum oxygen tolerance of the Asian carps found during the literature study. However, sub-optimum dissolved oxygen levels associated with other unfavourable conditions may discourage Asian carp colonisation in the locations with oxygen depletion (Fig. 5.8). No data regarding the dissolved oxygen tolerance of hybrid species of Asian carp were found during the literature study.

5.3.6 Feeding requirement

Chlorophyll-a concentrations were analysed for data derived from monitoring stations over the period 2001-2010. These were compared with the minimum chlorophyll-a requirements of adult bighead and silver carp (2400 g) to maintain their body weight. These are 10.4 µg l^{-1} and 15.5 µg l^{-1}, respectively (Cooke & Hill, 2010). No data was available for the large scale silver carp or hybrids of the Asian carps. However, it is expected that the largescale silver carp has a similar feeding requirement to that of the silver carp (Kolar *et al.*, 2007). In general, when lakes were excluded from the analysis and only rivers were examined, the majority of chlorophyll-a concentrations fell below levels required to sustain adult silver and bighead carp body mass (Fig. 5.10).

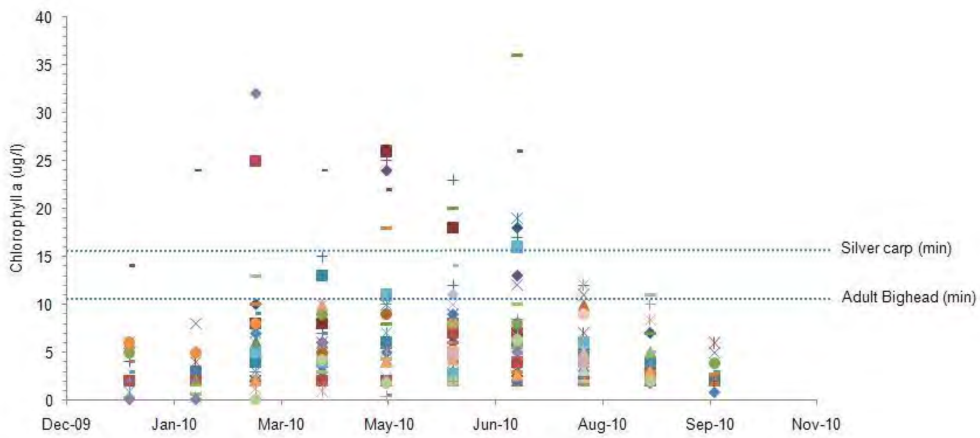


Figure 5.10: Chlorophyll-a concentrations measured in Dutch rivers in 2010 compared with minimum concentrations needed to sustain the body weight of adult silver and bighead carp.

The river Rhine at Lobith pontoon is typical of the chlorophyll-a levels identified in river systems in the Netherlands (Fig. 5.11). It was observed that certain lakes e.g. lake Markermeer (Fig. 5.12), exhibited a chlorophyll-a concentration above that of other water bodies in the Netherlands and therefore would not be limiting for either bighead or silver carp if they were directly introduced to these water bodies. This differentiation in observations between water body types suggests that adults of species introduced directly to certain lakes will be more able to maintain body mass than those entering Dutch surface waters via rivers.

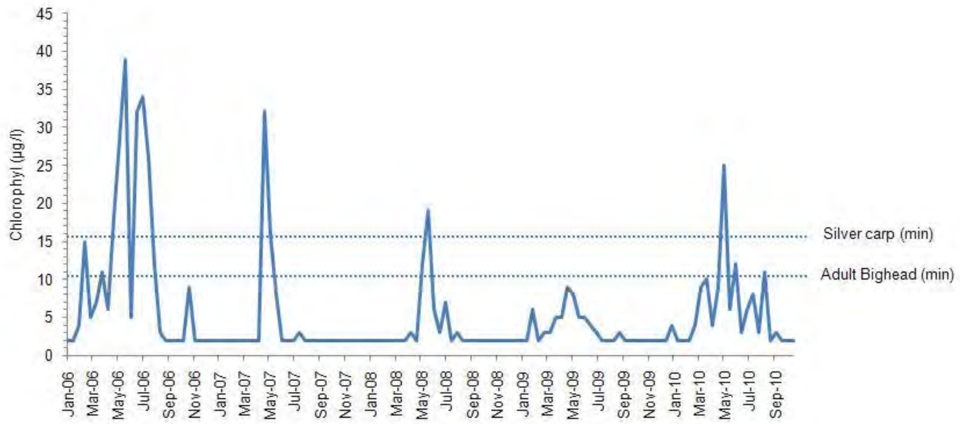


Figure 5.11: Chlorophyll-a concentration measured in the river Rhine at Lobith pontoon over the period 2006-2010 compared with minimum concentrations needed to sustain the bodyweight of adult silver and bighead carp.

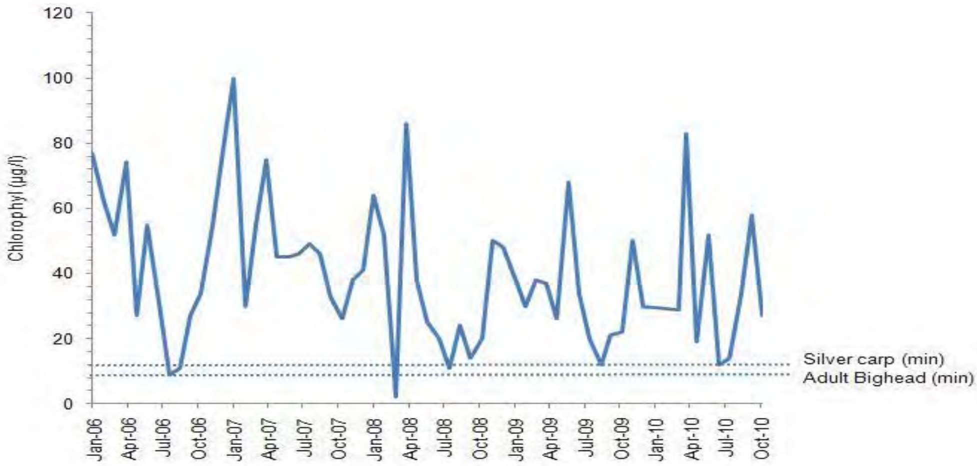


Figure 5.12: Chlorophyll-a concentrations measured at lake Markermeer in the period 2006-2010 and minimum chlorophyll a concentration required for growth in silver and bighead carp.

The limited concentrations of chlorophyll-a reflecting lower concentrations of phytoplankton in the river water at Lobith will affect the silver carp most as, while both species feed on phyto- and zooplankton, the silver carp is primarily phytoplanktivorous. The bighead carp is primarily zooplanktivorous and will, therefore, be less effected by the relatively low concentrations of chlorophyll-a. Both species are, however, highly opportunistic in their feeding strategies, switching from phytoplankton to zooplankton and vice-versa at times when the concentrations of either food source is limited (Kolar *et al.*, 2007). The adaptive capacity of both species to low concentrations of different types of food source suggest that low levels of phytoplankton alone would not rule out their colonisation of Dutch freshwaters.

5.3.7 Water hardness

There is a possibility that when incubated in soft water, eggs of the bighead and silver carp can burst prematurely and cause premature hatching Chaudhuri (1979). Eggs of the silver carp absorb water after release from the female, causing them to become turgid and increase substantially in size. The volume of water that diffuses within an egg is most likely determined by (1) the difference in ionic concentration between the egg and the water that surrounds it and (2) the elasticity of the egg membrane Rach *et al*. (2010). A number of studies have produced conflicting results concerning the effect of water hardness on hatching success. These studies are explored in the following sections initially examining implications for the silver carp and subsequently the bighead carp.

Table 5.3: Overview of experimental data relating water hardness to hatching success in the silver carp (Hypopthalmichthys molitrix).

water hardness ($Ca^{2+}CO_3^{2}$ mg/l)	hatching success (%)	reference
50*	29-41	Rach *et al*. (2010)
100*	18-30	Rach *et al*. (2010)
150*	13-30	Rach *et al*. (2010)
200*	14-29	Rach *et al*. (2010)
250*	11-16	Rach *et al*. (2010)
100-200	3-5	Gonzal *et al*. (1987)
300-500	23-29	Gonzal *et al*. (1987)

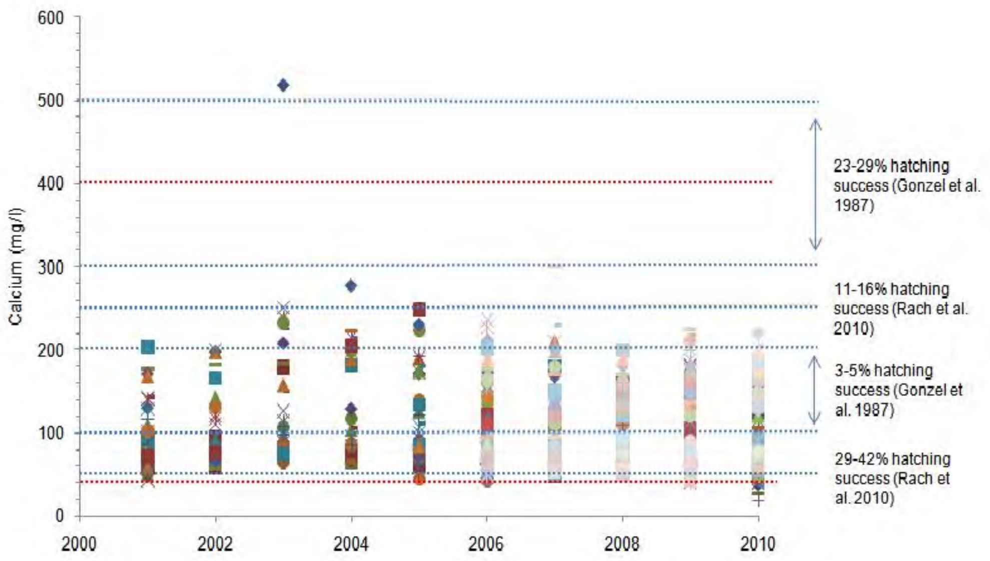
* Concentrations during initial egg hardening phase followed by incubation in water with 50 and 250 mg/L.

It can be seen that there are conflicting data regarding the tolerance of silver carp to water hardness (table 5.3). Data obtained by Gonzal *et al*. (1987) suggest that hatching success is highest in relatively hard waters (300-500 mg/l). Lowest hatching success was reported at a water hardness of 100 and 200 mg/l. However, Rach *et al*. (2010) observed that during the initial egg hardening phase, silver carp eggs placed in relatively soft water (50 mg/l) had a significantly greater chance of hatching success compared to those placed in harder water (250 mg/l). Changes in water hardness following the initial egg hardening phase appeared to have little effect.

Qualitative assessments and field observations regarding the effect of water hardness and hatching success of the silver carp are given in table 5.4. Field observations confirm that it is possible for the eggs of the silver carp to hatch in waters of very different hardness (40-400 mg/l). Assessments of North American rivers indicate that ranges of water hardness lying between 121 and 419 mg/l will pose no likely limitation to hatching success.

Table 5.4: Overview of field observations and qualitative assessments relating water hardness to hatching success in the silver carp (Hypopthalmichthys molitrix)

river	information type	water hardness ($Ca^{2+}CO_3^{2}$ mg/l)	reproduction	reference
Illinois River, USA	field observation	200-400	successful	USGS (2008)
Yangtze River, China	field observation	40-80	native range	H. Liu *cited in* Rach *et al.* (2010)
Mississipi River, USA	qualitative assessment	151-419 (median values)	no likely limitation	Kolar *et al.* (2007); Moody & Battaglin (1995)
Ohio River, USA	qualitative assessment	121-180 (median values)	no likely limitation	Kolar *et al.* (2007); Moody & Battaglin (1995)
Missouri River, USA	qualitative assessment	>180 (median values)	no likely limitation	Kolar *et al.* (2007); Moody & Battaglin (1995)



Maximum and minimum water hardness where field observations have revealed successful Silver carp breeding

Figure 5.13: Water hardness of large freshwater rivers and lakes in the Netherlands between 2001 and 2010 and physiological tolerances of silver carp (Hypopthalmichthys molitrix).

Fig. 5.13 shows the ranges of water hardness occurring in Dutch surface waters between 2001 and 2010 with the extremes of tolerance range for the silver carps found during experimentation and observed in the field superimposed. The graph illustrates the conflicting nature of evidence regarding the influence of water hardness on silver carp reproduction. If the results of Gonzel *et al*. (1987) are taken in isolation, then in nearly every location monitored water hardness falls below the minimum optimum range for silver carp hatching and survival. This suggests that hatching success of the silver carp in Dutch freshwaters will likely be within or below the 3-5% range. However the conclusions of Rach *et al*. (2010) suggest that hatching success will range between 11% and 42% for regions exhibiting the hardest and softest water, respectively. To understand the effect this would have on reproduction, hatching rates should be considered in association with the high fecundity of silver carp. Estimates of fecundity have differed per geographic region and fish size, varying between 315,000 to 1,340,500 eggs per female Kolar *et al*. (2007). Therefore even at a the minimum levels of 3% survivorship and a fecundity of 315,000 from a single female, 9450 individuals may be expected to survive to hatching.

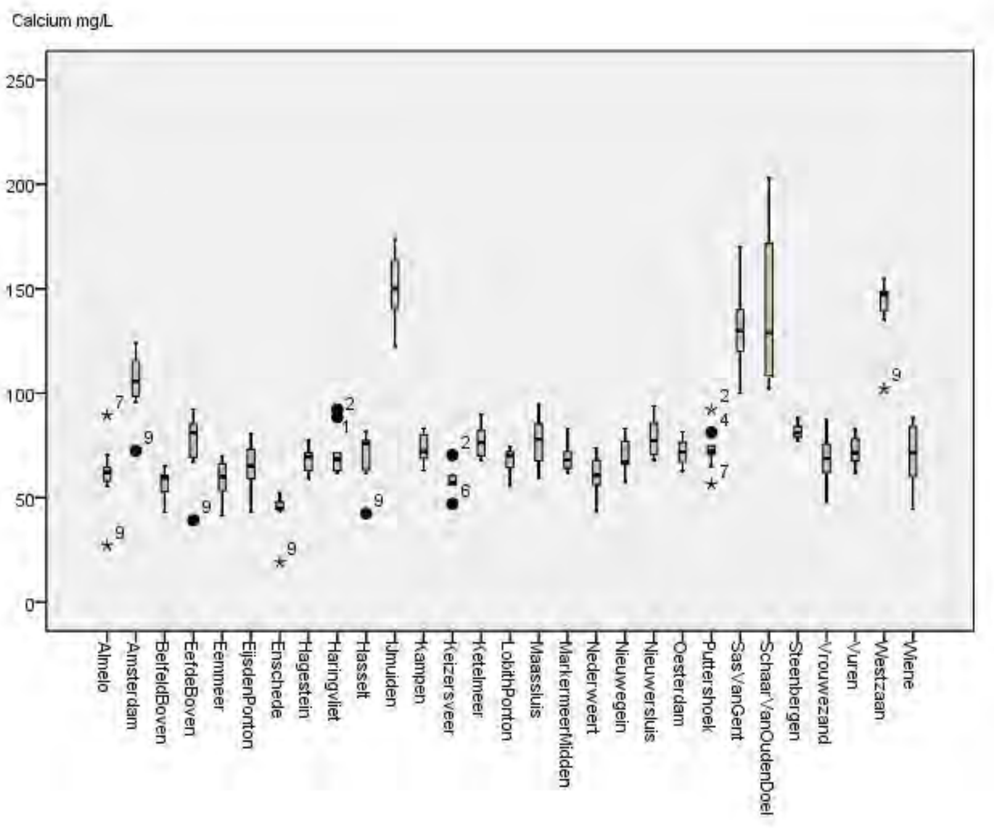


Figure 5.14: Distribution of calcium concentration per monitoring station in Dutch surface waters in the period 2001-2010.

To further analyse the effect of water hardness, the monitoring locations were plotted individually (Fig. 5.14). The graph illustrates the completely different conclusions that would be drawn when applying the differing sets of physiological tolerance data to the situation found in Dutch surface waters. Most of the samples taken from monitoring stations contained calcium concentrations below 100 mg/l indicating that the hatching success of silver carp eggs would be lower than the 3-5% suggested by Gonzal *et al*. (1987). However, the proximity of the monitoring station data sets to the 50 mg/l level suggests hatching success approaching the maximum 29-42% suggested by Rach *et al.* (2010). These statements are obviously completely contradictory. Further examinations of the literature highlight more conflicting evidence. In an American survey that examined water hardness data from over 3,000 stream and river sites across the contiguous United States, nearly all areas with bighead and silver carp reproduction were characterised by hard-water eco-regions (Whittier & Aitkin, 2008). Exceptions occurred in some soft-water regions with rivers originating in hard-water regions.

Table 5.5: Overview of experimental data relating water hardness to hatching success in the bighead carp (Hypopthalmichthys nobilis).

water hardness ($CaCO_3$ mg/l)	hatching success (%)	reference
29	47	Chapman & Deters (2009)
43	35	Chapman & Deters (2009)
80	37	Chapman & Deters (2009)
153	46	Chapman & Deters (2009)
259	39	Chapman & Deters (2009)

In an experiment by Chapman & Deters (2009), fertilized eggs of bighead carp were exposed to waters with a wide range of hardness and dissolved-solid concentrations. Hatching rate and egg size were not significantly affected by the different water qualities (table 5.5). Chapman & Deters (2009) concluded that these results, combined with the low hardness of the Yangtze River (the primary natal habitat of *Hypophthalmichthys*-species), suggest that managers and those performing risk assessments for the establishment of *Hypophthalmichthys*-species should be cautious about treating low hardness and dissolved-solid concentrations as limiting factors. However, anecdotal evidence contradicts these results. Chaudhuri (1979) reported that fish farmers suffered poor survival of bighead carp because of soft water. Additionally, water hardness may have an effect on the survivorship of hatchlings and although data is limited authors have stated that hard water may cause poor survival of bighead carp larvae Chaudhuri (1979).

It should be noted that anecdotal observations of an invasive species within it's native range could mislead assessments of it's impact and distribution when that species is introduced to a new ecosystem with a potentially unique mix of physical and biological conditions not present in the native range Rach *et al*. (2010). Therefore, comparisons of hatching rate with water hardness within the Asian carp's native range are also brought into question. Additionally, the origin, for example geographical location or culture, and resultant genetic variation of different populations of Asian carp may influence the physiological tolerance of test subjects and may explain differences

between experimental results. All data on hatching success and water hardness was obtained from North American and Chinese studies. Therefore, transferability to the European situation is uncertain. Unfortunately, there is a lack of data regarding the tolerance of the large scale silver carp to water hardness, however, physiological tolerances to water hardness are expected to be similar to the silver carp (Kolar *et al.*, 2007). It is recommended that further research is undertaken with test subjects originating from European populations to rule out uncertainty related to genetic variation between European, North American and Chinese populations. Additional research supplementing existing data for the bighead carp and research into the tolerance of the large scale silver carp to varying levels of water hardness is also recommended.
From the data collected it is reasonable to assume that there are at least certain populations of silver carp and bighead carp whose colonisation would not be limited by the levels of surface water hardness typically found in the Netherlands.

5.4 Summary and conclusions

The potential limiting effects of the environmental parameters discussed are summarised for five locations representative of different water bodies and types in tables 5.3 and 5.44.

Table 5.3: Potential limiting effects of environmental parameters on the bighead carp in the Netherlands.

		River Rhine at Lobith	Lake Markermeer	River Meuse at Belfeld, Limburg	River Meuse at Maassluis	River Oude Maas
hydrology-temperature match	spawning		not applicable**	not assessed	not assessed	not assessed
temperature	spawning					
	minimum young					
	maximum young					
	feeding					
	adult maximum					
dissolved oxygen						
chlorphyll a[#]						
water hardness[*]						
salinity	growth					
	max / min young					
	max / min adults					
	spawning					
total						

Individuals may adapt by increasing the percentage of zooplankton in their diet

* *Data on physiological tolerance is conflicting therefore some populations may not be limited*

** *Stagnant water*

- No limitation
- Measurements fall outside optimal range
- Measurements fall outside minimum or maximum tolerances
- Measurements fall outside maximum and minimum tolerances but for a limited period
- Inter-annual inconsistency (limits breached in some years but not others)

Regarding all environmental factors and locations assessed, the minimum temperature is absolutely limiting for young bighead carp. The yearly minimum temperature data is not consistent, however, with a minority of years exhibiting temperatures that do not exceed the physiological minimum. The minimum temperature for feeding is also exceeded at all locations but only for short periods in the winter and therefore the effects on fish biomass maybe limited. Levels of chlorophyll-a and water hardness maybe limiting to bighead carp survival and reproduction. However, bighead carp are opportunistic feeders and increase the percentage of zooplankton in their diet at times when phytoplankton concentrations are low (Kolar et al., 2007). Data and information obtained from the literature regarding water hardness as a limiting factor in reproduction is conflicting suggesting that there are at least some populations of bighead carp whose reproduction would not be limited by levels of water hardness typically found in the Netherlands. Therefore it cannot be concluded that the presence of soft water or low chlorophyll-a concentration would prevent reproduction at the locations examined. The total scores indicate that there is no location where the chance of colonisation of bighead carp can be eliminated totally. Minimum winter temperatures will cause a degree of mortality to young bighead carp in a majority of years at all locations, however. Maassluis exhibits a reduced chance of colonisation primarily due to elevated salinity and lower than optimum dissolved oxygen levels.

The analysis of hydrology-temperature match could not rule out the possibility of spawning of the bighead carp in the Dutch Rhine. No year within the period 1989 to 2010 exhibited conditions that would prevent spawning for most scenarios analysed. For the four velocity scenarios derived from observations of suitable spawning conditions found in literature, only the most extreme scenario (2.3 m/s) consistently ruled out the possibility of spawning for the bighead carp. Minimum flow velocities for spawning were exceeded in all years examined for all other velocity scenarios. Similarly, 17 out of 22 of the years examined showed increases in discharge of over 1000 m3/s during periods of suitable water temperature for spawning. Therefore, it is unlikely that the current hydrological characteristics and temperature regime in the river Rhine at Lobith will prevent spawning.

Silver carp are generally more tolerant than bighead carp of cold conditions (Kolar *et al.*, 2007) and this is reflected in the temperature section of table 4. The silver carp is more likely to successfully reproduce and survive in the temperature profile experienced currently in the Netherlands. Colour categories for the silver carp and chlorophyll a are similar to that of the bighead carp. However, it should be taken into account that the silver carp is primarily planktivorous and while it may adapt to low levels of phytoplankton by increasing the amount of zooplankton in its diet, the consequences of low concentrations of phytoplankton may be more significant for this species. Data and information obtained from the literature regarding water hardness as a limiting factor in reproduction of bighead carp is conflicting and suggests that there are at least some populations whose reproduction would not be limited by low levels of water hardness. It is assumed that this variability in sensitivity to water hardness also holds for silver carp. Therefore, it cannot be concluded that the presence of relatively soft water would prevent reproduction at the locations examined. The total scores indicate that there is no location where the chance of colonisation of silver carp can be fully eliminated. Similarly to the bighead carp, the river mouth at Maassluis exhibits a reduced chance of colonisation primarily due to elevated salinity and lower than optimum dissolved oxygen levels.

Table 5.4: Potential limiting effects of environmental parameters on the silver carp in the Netherlands.

		River Rhine at Lobith	Lake Markermeer	River Meuse at Belfeld, Limburg	River Meuse at Maassluis	River Oude Maas
hydrology-temperature match	spawning		not applicable**	not assessed	not assessed	not assessed
temperature	spawning					
	maximum young					
	feeding					
dissolved oxygen						
chlorphyll a[#]						
water hardness[*]						
salinity	maximum young					
	spawning					
total						

\# *Individuals may adapt by increasing the percentage of zooplankton in their diet*

* *Data on physiological tolerance of bighead carp is conflicting. Assuming similar variability in tolerance to water hardness of bighead and silver carp it is also likely that some populations of silver carp may not be limited by water hardness of rivers and large lakes in the Netherlands*

** *Stagnant water*

- No limitation
- Measurements fall outside optimal range
- Measurements fall outside minimum or maximum tolerances
- Measurements fall outside maximum and minimum tolerances but for a limited period
- Inter-annual inconsistency (limits breached in some years but not others)

The analysis of hydrology-temperature match could not rule out the possibility of spawning of the silver carp in the Dutch Rhine. No year within the period 1989 to 2010 exhibited conditions that would prevent spawning for the 0.3 m/s minimum flow velocity scenario. However, a minimum spawning flow velocity of 3.0 m/s would rule out spawning for all years examined. Due to the higher temperature requirement needed to induce spawning behaviour in the silver carp, discharge increases of sufficient magnitude fell within the time period of sufficient water temperature less frequently. Only 9 out of the 22 years examined showed increases in discharge of over 1000 m^3/s during periods of suitable water temperature. Even so, significant increases in discharge of over 500 m^3/s were witnessed in 11 of the remaining 13 years. Therefore, even though conditions are less favourable in comparison with the bighead carp, it is unlikely that the current hydrological characteristics and temperature regime will limit silver carp spawning in the river Rhine at Lobith.

In summary, temperature requirement and a need for a coinciding and sufficient increase in discharge for spawning will, in all likelihood, not prevent reproduction of the bighead and silver carps in the river Rhine at Lobith. However, there are other locations, such as Lake Markermeer and possibly the river Meuse, where these requirements are not met. If spawning were to occur, there are sites where limiting factors such as temperature, dissolved oxygen, food supply and salinity may limit growth and increase morbidity and mortality for individuals of both species. The only location examined where an absolute limitation on survival occurs is related to the juvenile bighead carp and temperatures is Lake Markermeer. This conclusion should be considered with respect to the spatial temperature variation that occurs within rivers and lakes. Temperature measurements were recorded at a single depth only, therefore the possibility of refuges existing at depths where temperatures were not measured cannot be excluded. Evidence predicting the future effects of climate change on the possibility of bigheaded carp establishment is contradictory. It is expected that the frequency and extent of rises in flow velocities during peak discharges in late spring and summer may slightly decrease compared to the current situation. However, the frequency of a temperature-flow velocity match for spawning might slightly increase due to prolonged periods with suitable water temperature. Therefore, it is assumed that the overall effect of climate change on spawning ability will be negligible and spawning ability in future will be more or less similar to the current situation. However, increases in water temperature, resultant food availability and changes in hydrological regime resulting from climate change may increase the growth and survival potential for existing bigheaded carps.

6 The probability of spread

Bighead carp and silver carp are both mobile species showing spawning migrations and dispersal in search of good feeding grounds. This mobility is reflected in the rapid invasion of the Mississippi River Basin. Bighead carp was reported in the Mississippi River for the first time in the 1980s and by 2004 most of the basin has been colonized. The silver carp was detected earlier in the Mississippi River in the later 1970s and also colonized most of the basin in 2004 (Kolar *et al*., 2007).

If the bighead carp or silver carp becomes established in the Netherlands it is very likely that it will quickly disperse in to all suitable habitats in the Netherlands.

7 Impact

7.1 Ecological impact

Impact on plankton

The **silver carp** has proven in experiments to reduce zooplankton densities in lakes, reservoirs and ponds, together with a shift towards smaller species of plankton. Effects are especially notable when refuge for the zooplankton are linfrequent or absent.

The impact on the phytoplankton is more complicated due to the interactions between silver carp and the herbivorous zooplankton. By reducing zooplankton densities it reduces also the grazing pressure by the herbivorous zooplankton. When this reduction is not compensated by the grazing of the silver carp, this might result in an increase of chlorophyll *a*/phytoplankton biomass and a reduced water clarity. This effect has been shown in several studies in both mesocosms and natural systems (Kolar *et al*., 2007).

An increase of algae is possible because of the size selective grazing of the silver carp, only ingesting particles of more the 7-10 µm (Vörös *et al*., 1997). Therefore the grazing pressure of the silver carp will reduce densities of larger species, including nuisance blue-green algae, but smaller species of e.g. green algae might actually become more abundant (Spataru & Gophen, 1985; Kucklentz 1985; Leventer 1987; Milstein *et al*. 1988; Smith 1989; Costa-Pierce 1992; Vörös *et al*. 1997).

The impact of **bighead carp** on plankton communities is in comparison with the silver carp much less studied, mainly because bighead carp are much more effective at feeding on zooplankton than algae and are therefore of less interest for controlling algae, although they are known to reduce densities of blue-green algae like *Microcystis* in at least some instances (Kolar *et al*., 2007; Cooke *et al*., 2009). Based on their feeding on larger plankton species it can be expected that at larger densities bighead carp will cause a shift towards smaller zooplankton species and can decrease total zooplankton biomass. In pond experiments Cooke *et al*. (2009) showed that in the presence of bighead carp densities of *Daphnia* sp. decreased and densities of copepods increased.

When the zooplankton density is reduced this might affect the phytoplankton as grazing pressure becomes reduced. When nutrients are not limiting this can result in an increase of phytoplankton density. The few studies done on the impact of bighead carp on phytoplankton in ponds showed variable results with in some cases an increased density of algae and in other cases no difference or a decrease. These difference are influenced by differences in both density and species composition, with bighead carp being more efficient at higher densities and when predating larger species (Kolar *et al*., 2007; Cooke *et al*., 2009).

Impact on benthic macroinvertebrates

Changes in plankton communities can potentially affect filter feeding macroinvertebrates such as freshwater mussels or dreissenids. Actual studies on the competition between bigheaded carp and freshwater mussels or dreissenids are absent. But as the latter are capable of retaining much smaller particles then bigheaded carp and are typical benthic feeders (Dillon, 2000) effects can be expected to be relatively small.

Impact on other fish species

By reducing plankton densities or changing species composition of the plankton, introduced bigheaded carp might affect other pelagic fish species with a planktivorous diet. Also fish species that are not planktivorous in the adult stage might be affected if they are pelagic planktivorous in earlier life stages (Conover *et al.*, 2007). In North America there is e.g. concern that the paddlefish, a large filter feeder native to the Mississippi River Basin, might be negatively affected by the still growing numbers of both bighead carp and silver carp (Kolar *et al.*, 2007).

Figure 7.1: The North American Paddlefish and the South Asian catla, two large planktivorous species that might be effected by bigheaded carp. Photo's: Illinois Department of Natural Resources & AFP.

Speculative reports of decline of indigenous fish species that are thought to be (partly) due to the introduction bigheaded carp are coming from India, Middle East and China. The establishment of silver carp in the Gobindsagar reservoir (India) in 1971 is thought to be at least partly responsible for the decline of species like catla (*Gibelion catla*) and rohu (*Labeo rohita*) (Shetty *et al.*, 1989; Petr, 2002). Especialy catla is highly dependable on zooplankton, also when adult. The rohu is planktivorous in earlier life stages and becomes a herbivore in the adult stage.

In the Aral Sea Basin the introduction of Asian carp and water manipulation for irrigation are thought to be the primary causes in the decline of fish biodiversity. Around the introduction of both bighead carp and silver carp the Aral Sea Basin harbored around 43 species of fish, in the 1980's only 22 species could be found (Pavlovskaya, 1995).

Also translocations of bigheaded carp in China are thought to be responsible for the decline of several, mainly planktivorous fish species. This includes species such as sharpbelly (*Hemiculter leucisculus*), barbless carp (*Cyprinus pellegrini*) and *Anabarilius grahami,* all rather small (<30 cm), pelagic species (Kolar *et al.*, 2007)

Figure 7.2: Two planktivorous species thought to have declined because of introductions of bigheaded carp: Anabarilius grahami (left) & the sharpbelly (Hemiculer leucisculus). Photo's: CAFS.

In an experiment with high (10 000 individuals age 2/ha) stocking of silver carp in Lake Grunz (Germany) both pike perch and perch were probably affected by the decline of pelagic zooplankton densities. In both species the survival of the fry and small juveniles was lowered because these are at least partly pelagic planktonophage. Other species with littoral feeding fry and bottom feeding habitats as an adult were not affected. Both sunbleak (*Leucaspius delineatus*) and bleak (*Alburnus alburnus*) were insufficiently studied to allow statements about the impact of the decline in pelagic zooplankton (Barthelmes, 1984).

Potential impact in the Netherlands

When densities of bigheaded carp are sufficiently high to reduce pelagic zooplankton to such an extent that it becomes a limited resource, several Dutch fish species might be affected. Typical pelagic zooplankton feeders in all life stages are e.g. bleak (*Alburnus alburnus*), sunbleak (*Leucaspius delineatus*), European smelt (*Osmerus eperlanu*) and twaite shad (*Alosa fallax*). The sunbleak is Red Listed as vulnerable, the twaite shad as disappeared. The European smelt is of great importance for several bird species in Natura 2000-areas.

With bigheaded carp only occupy large river systems and connected waters potential impact is limited to these waters. Because plankton densities in Dutch rivers are limiting (see §5) for bigheaded carp, potential densities are expected to be low. In the Lake Markermeer plankton densities are not limiting and potential densities are high.

The risk of impact is expected to be zero for most water systems, low for large river systems and medium to high for the Lake Markermeer and comparable lakes that have open connections with large rivers.

7.2 Vectors for parasites and diseases

One of the major problems in the transfer of (alien) fish, such as the bigheaded carp, is the possibility these fishes act as vectors for alien disease. Well known examples of introduced, harmful 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 European carp. Both disease were introduced in Western-Europe with fish transports of respectively eel and European carp (Lazard & Dabbadie, 2003).

Also with the import of silver carp and bighead carp there are risks of introducing and/or further spreading alien fish diseases in the Netherlands. For background information on six of these species (table 7.1) we refer to appendix 2. One species, the Chinese pond mussel, that is known to use fish species such as bigheaded carp as a host in the larval stage only, is discussed in more detail in §7.3. Especially the risk of introducing not yet in the Netherlands recorded, harmful parasites like the Asian tapeworm and the zoonotic parasite *Clonorichis sinensis* is a matter of concern, even when is acknowledged that presented information in the appendix is mainly from aquacultural practices and not from wild fish populations.

Table 7.1: Selected disease causing organisms for which bigheaded carp can be a vector

species	disease
Koi herpesvirus (KHV)	Koi Herpes Virus Disease (KHVD).
Rhabdovirus carpio	Spring Viraemia of Carp (SVC)
Sinergasilus polycolpus	-
Asian tapeworm *Bothriocephalus acheilognathi*	
Chinese liver fluke *Clonorchis sinensis*	
Aphanomyces invadans	Epizootic Ulcerative Syndrome (EUS)

Clearly such parasites and diseases are not limited to the bigheaded carp. Species like European carp, grass carp, black carp or Chinese sucker are potential host for most of the parasites and diseases mentioned for the bigheaded carp. This has especialy implications for prevention or management of these parasites and diseases, see also §9.

7.3 Chinese pond mussel (*Sinandonta woodiana*)

The Chinese pond mussel (*Sinanodonta woodiana*) is a freshwater mussel of the family Unionidae. It is probably only native in the Amur and Yangtze River basins, but has already in early times become widespread in East and South-East Asia. The first European records of the Chinese pond mussel originate from Hungary and Romania in the 1960's and 70's. After these first introductions the species has become widespread and is now known from more then 15 countries, including neighboring Belgium. This suggest that also in the Netherlands establishment is possible.

Figure 7.3: Chinese pond mussel purchased from a garden shop in the Netherlands. Photo by Menno Soes (Bureau Waardenburg).

The Chinese pond mussel has a life cycle typical for Unionidae with a parasitic larval stage: the glochidia. These glochidia attach to fins and gills of the host fish. Most introduced European populations of the Chinese pond mussel are thought to be due to the stocking of large cyprinids, including bigheaded carp, with these glochidia attached to their gills or fins (Pou-Rovira *et al*., 2009).

<u>Chance of entry:</u>
Especially fish from Eastern Europe might act as a vector because here the Chinese pond mussel is often kept in fish ponds together with e.g. large cyprinids, including bigheaded carp (P. Veenvliet, pers. comm.). So the chance of entry of the Chinese pond mussel by using bigheaded carp as a vector is high.

Other ways of entry are specimens sold for garden ponds and from neighboring countries. The chance of entry is high for garden ponds. The chance of entry for neighboring countries is in the present situation low, but might increase when it becomes more firmly established in Germany and Belgium.

<u>Possible impact of the Chinese pond mussel in the Netherlands:</u>
The Chinese pond mussel can reach high densities and is quite resistant to eutrophic conditions. Because of this the Chinese pond mussel might have a <u>positive</u> effect on the water clarity in eutrophic waters, comparable with e.g. *Dreissena*- and *Corbicula*-species (Dillon, 2000).

The Chinese pond mussel has a higher reproduction rate, a higher growth rate and is able to face pollution and hypoxia better than indigenous Unionidae (Sîrbu *et al*., 2005). Due to this, this species is a potential threat to native unionids in the Netherlands as it has the potential to outcompete these species when resources or space becomes limiting. In larger rivers and lakes this would include the already threatened *Pseudanodonta complanata*. Although such concerns have been uttered repeatedly (e.g. Pou-Rovira *et al*., 2009; Popa *et al*., 2007), no actual studies on this competition have been published.

Experiments offering the Chinese pond mussel as a host showed that the Chinese pond mussel is unsuitable for the European bitterling. Although the European bitterling did lay eggs in the Chinese pond mussel during the experiments, most of them were discarded by the mussel almost immediately. Long term experiments showed that no larvae survived when being incubated in the gills of the Chinese pond mussel (Reichard *et al*., 2007). The consequence of this is that when the Chinese pond mussel would become more abundant and replaces indigenous species this would <u>negatively</u> effect the reproduction of the European bitterling in the Netherlands.

7.4 Economic impact

When bigheaded carp become established they might effect commercial fishing both negatively and positively.

<u>Negative impact</u>
When commercialy important species such as European smelt or pike perch actually become reduced in their stocks, commercial fisheries will be negatively affected.

<u>Positive impact</u>
When large stocks of bigheaded carp are present, like in the Danube River system, commercial fisheries might benefit from the increased harvest. In the Netherlands this is unlikely as market prices are too low to make it profitable to harvest bigheaded carp. This especially because people in Western Europe do not eat cyprinids and high transportation costs are involved to reach those consumer markets that actually eat bigheaded carp (e.g. Eastern Europe or China).

7.5 Social impact

Both bighead carp and silver carp are sensitive to sound and electric fields. They react strongly to these stimuli with escape responses. This includes the passing of boats. Especially silver carp will jump out of the water in response to this. Because silver carp is a large fish, collisions with especially fast going watercrafts can be disastrous. In the USA reports of seriously injured boaters and water-skiers and severely damaged watercrafts are becoming more frequent (Kolar *et al.*, 2007).

Because of this river stretches with abundant silver carp are becoming less attractive for water recreation.This has both local economic and social effects that might also be expected in the Netherlands.

Figure 7.6: Silver carp jumping out of the water in response to a passing a boat. Photo: AP Photo.

8 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.

Both silver carp and bighead carp score 15 points in the Fish Invasiveness Screening Kit (FISK). According to this result both species belong not to the group of high-risk species (score > 18) (Copp *et al.*, 2009). This low score is mainly due to the reproductive tolerance of the species to the Dutch climate that has been scored intermediate and the uncertainty of the actual impact of these species.

Table 8.2 compares available risk classifications of the silver carp in several European countries, where risk assessment protocols in force have been applied in their national context. Moreover, these data are compared with the Fisk/FI-ISK score. Verbrugge *et al*. (2010, 2011) gives a detailed description of the applied assessment protocols. The available risk classifications show dissimilarities when compared between countries. Silver carp are expected to pose probable high risks in other European countries. These dissimilarities cannot be attributed to a single determining factor (Verbrugge *et al.*, 2011). Differences in classifications may be related to the different (number of) criteria in risk protocols as well as variability in a national context (i.e. invasibility of ecosystems) and in the use of literature by experts (i.e. expert judgment). Therefore, risk classifications from other countries and regions should always be applied with caution.

Table 8.2: Comparison of available risk classifications of the silver carp (Hypophthalmichthys molitrix) in several European countries, where risk assessment protocols in force have been applied in their national context.

country	risk classification	reference
Germany	probable - unlikely risk (Grey list)	Nehring *et al*. (2010)
Austria	probable - unlikely risk (Grey list)	Nehring *et al*. (2010)
Ireland	medium risk	Invasive Species Ireland (2007)
UK-Fisk/FI-ISK	high risk	Copp *et al.* (2009)

9 Risk Management

9.1 Early detection

Bigheaded carp have proven to be relatively difficult species to catch with standard monitoring methods. Therefore, the detection with these methods is unreliable when numbers are (still) low. In North America an alternative method has been developed using so-called environmental DNA. This method uses the presence of suspended sloughed tissues with DNA that can be relatively easily sampled. Species specific primers have been developed that produce, in a PCR, fragments of species specific sizes. When, for example, DNA of the bighead carp is present, the PCR will produce fragments with a length of 312bp. For extra certainty these fragments can be sequenced for confirmation of the fragment actually being the species specific fragment. This new method has proven to be more reliable and cost efficient in detecting both silver carp and bighead carp (Jerde *et al.*, 2010).

9.2 Prevention of entry

Obviously, the prevention of fish entries and further spread prevents later problems. Prevention seems a straightforward tool to impede further expansion of bigheaded carp in Europe, however, considering the diversity of the (un)intentional trade in ornamental fish, the actual implementation can be rather complicated. Different types of prevention act on different levels within an introduction pathway. Prevention consists of communication and legislation, for sources of fish this includes international trade. Education is the primary tool for preventing deliberate introductions. Several prevention procedures are discussed here and are based on the different sources and motives that were identified in chapter 4.

<u>Pet trade</u>
The banning of species from trade can be achieved either by legislation or by means of an agreement with the pet trade. Both legislation and agreements have certain advantages and disadvantages.

Beside concerns about releases of bigheaded carp into the wild, animal welfare can also be considered as a legitimate motivation to remove these species from the pet trade. Both species are unsuitable for almost every garden pond as their requirements cannot be met (see also chapter 4).

For comparison, the UK list of species covered by the “The Prohibition of Keeping or Release of Live Fish (Specified Species) Order 1998, made under the Import of Live Fish (England and Wales) Act 1980” includes the bigheaded carp. According to this list both silver carp and bighead carp are actually included. This legislation is considered effective in keeping new species out for the most part but less effective for ensuring that existing non-native species do not get into the wild due to human releases (G. Copp, pers. com.).

Deliberate releases

The motives underlying ornamental fish introductions have been identified in chapter 4 and include a lack of interest, overcrowding of ponds or dislike because of aggressive behaviour towards other, more appreciated fish species. In all cases, education is the only possible remedy for reducing the amount of such introductions. Specific campaigns are needed to reach potential 'releasers'. Pet stores and garden shops can play a role in preventing the release of ornamental fish. A drawback of public education is that it is hard to maintain. Without active maintenance, the effects of education will quickly fade away.

A possibility for providing good information is including an information leaflet (huisdierenbijsluiter) when, for example, bigheaded carp are actually purchased. Information leaflets have already been provided digitally for many species by the Landelijk Informatie Centum Gezelschapsdieren (LICG, www.licg.nl). However, for bigheaded carp they are not yet available. Such an information leaflet could clearly describe the negative impact of introductions and the legal aspects of doing so.

Creating insight in stocking practices

For creating an effective policy on the general stocking of fish and in particular bigheaded carp, information about the species and the numbers stocked in public waters are an important prerequisite. Such information is currently not available (Soes & Broeckx, 2010).

Reporting stockings beforehand to a central organisation could create better insight in stocking practices. This may not only serve to aid policies on exotic species, but may also have use in the prevention of fish diseases, especially if the origin of fish is recorded.

In the case of bigheaded carp this would be profitable as illegal stockings, which might be planned by people who are ignorant of the fact that it is illegal to stock this species in public waters, can be prevented. The chance of such illegal introductions are real as these species have already been stocked in several instances, see §4.7.

Preventing introductions by contaminated stocks

Contaminated fish stocks are important vector for several fish species. E.g. the stone moroco has probably been introduced and further spread in Europe by contaminated grass carp stocks. Also contaminated stocks of trout have been reported to be a vector for this species.

Bighead carp, silver carp and their hybrid are, at least in Eastern Europe, often kept together in aquaculture. Contamination of stock becomes in such circumstances more likely, also for stocks that are transported to the Netherlands.

Most important for the prevention of contaminated stocks is the awareness of the people involved. When stocks arrive they can be checked for possible contaminations and if such are present these can be removed to prevent the entry of unwanted species.

Preventing escapes from urban waters, garden ponds, etc.
It is legal to stock, for example, bigheaded carp in private, isolated waters. But it is stated in both the Dutch Flora and fauna law and the Fisheries law that such waters should be isolated from public water systems in such a way that escapes are prevented. Care should be taken that these waters do not become flooded with high waters.

9.3 Prevention of spread

It has been proven that bigheaded carp can easily disperse into rivers and associated waters following establishment at a certain locality, see chapter 6. Preventing their spread in such large water systems is extremely difficult, especially because of the economic importance of these water systems.

In North America there is great concern about the possible impact of silver carp and bighead carp entering the Great Lakes (Buck *et al.*, 2011). With the population in the Mississippi River basin being the most likely source for colonization of the Great Lakes, efforts have been made to isolate the Great Lakes from the Mississippi River basin for these species. The Great Lakes are connected with this basin through the Chicago Sanitary and Ship Canal (CSSC). To accomplish this the Electric Dispersal Barriers have been installed to prevent interbasin transfer of fish. The barriers, located approximately 25 miles from Lake Michigan in the CSSC, are formed of steel electrodes that are secured to the bottom of the CSSC. The electrodes are connected to a raceway, consisting of electrical connections to a control building. Equipment in the control building generate a DC pulse through the electrodes, creating an electrical field in the water that discourages fish (incl. bigheaded carp) from crossing. In total three barriers have been installed. The first one has been operational since 2002, the second since 2009 and the last since 2011. The last two barriers, including operating costs, cost more than 30 million US dollars, (Buck *et al.*, 2011; Vroman, 2011).

These electrical barriers have probably failed to prevent silver carp and bighead carp from entering the Great Lakes. In 2010 a bighead carp was caught by a commercial fisherman beyond the barriers (Vroman, 2011; Jerde *et al.*, 2010). With eDNA techniques silver carp have already been detected in the Calumet Harbor in Lake Michigan and bighead carp were detected beyond the electrical barriers at a distance of 13 kilometers from Lake Michigan (Jerde *et al.*, 2010). After these findings, efforts have been made to close the CSSC totally. Economic interests and juridical problems have so far prevented this plan being implemented (Vroman, 2011).

In Europe, such expensive measures will face the same problems and are also likely to be in opposition to fish conservation measures as such barriers also prevent the migration of indigenous species, which conflicts with the ecological restoration of the European river systems.

9.4 Eradication and physical control methods

In countries where exotic species have established populations researchers have experimented with a variety of physical controls to eradicate or reduce such populations. The following control methods have been applied to reduce or eradicate established populations of exotic fishes and might be applicable to bigheaded carp.

Eradication by piscicides
One of the possibilities for eradicating unwanted fish populations is the use of pesticides, which are more or less selective for fish: piscicides. Of these piscicides only rotenone has proven itself well enough to be reliable in its application (Clearwater *et al.*, 2008) and extensive manuals and risk assessments are available for this piscicide (e.g. Finlayson *et al.*, 2000; Turner *et al.*, 2007).

Rotenone is a natural toxin that can be obtained from several tropical Leguminosae species and has been used for centuries as a selective fish poison and more recently as a commercial insecticide. It is highly toxic to fish, larvae of amphibians and other aquatic life, but has low toxicity to adult amphibians, birds and mammals. Also fish eggs are succeptible (Ling, 2003). Mangum & Madrigal (1999) found that after a large scale rotenone treatment in the Strawberry Reservoir and River in Utah 21% of the invertebrate taxa were still missing after five years. Such outcomes are strongly influenced by recolonisation possibilities, a factor that should be carefully assessed beforehand when the use of rotenone is considered.

Rotenone is non-persistent in the environment, being quickly broken down by light and heat. It does not accumulate in animals and is readily metabolised and excreted. Rotenone persistence in natural waters varies from a few days to several weeks depending on the season. The half-life of rotenone is longest in winter but may decrease to as little as a few hours in summer.

In recent years, rotenone has more often been used to remove pest or non-native fishes to allow the recovery of indigenous stocks or for research on fish population structure and abundance (Bettoli & Maceina 1996). Rotenone has been used successfully to eliminate exotic trout in Australia (Sanger & Koehn 1997; Lintermans 2000) and to eradicate limited populations of carp and mosquito fish (Sanger & Koehn 1997). Both silver carp and bighead carp are moderately sensitive to rotenone and there is also some experience applying it against these species (Chapman *et al.*, 2003; Kolar *et al.,* 2007).

Eradication of fish with rotenone has a varied success depending on the type of environment and the amount of effort expended in achieving complete dispersal of the toxicant throughout a lake or drainage. The effectiveness of treatment decreases as water bodies and catchments increase in size. Dispersing toxicant in marginal zones with abundant plant growth can also present practical difficulties. Complete coverage is sometimes difficult to achieve, and because of the rapid loss of rotenone in such areas through chemical decay and adsorption to plants and sediment, fish may find refuge long enough to evade poisoning.

The application against bigheaded carp will in general be problematic as these species only establish themself in large water systems with an abundance of other fish species. Also, rotenone was, at least in more recent times, not been applied in the Netherlands. Rotenone is currently unlikely to be used because of the general negative attitude in water management towards pesticides, concerns about animal welfare and the lack of regional eradication projects using rotenone.

<u>Eradication by fishing</u>
Fishing is in the case of bigheaded carp, probably the only method to reduce established populations in numbers. For creating sustainable fisheries only commercial fishing is likely to succeed. Fishing for bigheaded carp is a specialised fisheries needing its own gear that is not yet available in the Netherlands. Also the market for selling caught fish needs to be created.

<u>Forbidding release of captured fish by recreational fishermen</u>
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 forbidden by law to release caught common 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 aforementioned legislation about 11% of carp were released after capture by recreational fishermen (Graham *et al.*, 2005). These recreational fishermen probably released their caught carp for ethical reasons. Australian internet forums clearly showed a lot of debate on the necessity of killing captured carp. Especially inexperienced fishermen who cause considerable animal suffering are considered a problem (D.M. Soes, pers. obser.).

In the Netherlands bigheaded carp are not an appreciated game fish. But the catch and release of coarse and game fish has been highly promoted and the killing of fish, even for consumption, is becoming rare. This gives little ground for installing legislation or policy, which involves the killing of fish such as bigheaded carp. Also a discussion during a recent meeting of the Vissennetwerk (3-6-2010) clearly showed that such legislation or policy would receive little support.

9.5 Disease prevention

The basic European Community legal provision on the prevention of the import and further spread of fish diseases is Council Directive 2006/88/EC on animal health requirements for aquaculture animals, and on the prevention and control of certain diseases as amended by Commission Directive 2008/53/EC. This legislation has to be implemented in national legislation by each member state of the European Union, including the Netherlands. This legislation focuses on a limited number of fish diseases that are considered to be of great economic risk to European aquaculture or fisheries. A overview of this legislation is given in appendix 4.

Of course, to avoid any transmission, the avoidance of the transport of live fish would be best, but this is unrealistic. To decrease the chance of introducing (new) fish diseases the quality/health of the stocked fish may be considered to be the main key. The sources of the imported fish could be e.g. checked for parasites and diseases, and accompanied by a health certificate at transport. Additionally, people involved in fish transfers may be educated in the risks of introducing (new) diseases when stocking fish. Furthermore awareness may be stimulated when fish health, including the transmission of the diseases, is a significant part of fish stock management plans.

Furthermore, we are not sure whether we are in the Netherlands not yet infected with some alien pathogens, as currently they are not screened for. This greatly hampers the recognition of certain fish diseases as being of special interest to preventive measures. We would need to screen our freshwater wild fish populations on a more regular basis for parasites, bacteria and viruses to gain such knowledge.

10 Conclusions

Conclusions probability of entry

The chances of entry from the possible pathways are summarized in table 4.1. From this table it is clear that the chance of entry of the largescale silver carp is close to zero. For bighead carp, silver carp and their hybrid, stocking should be considered the most important pathway, especially as numbers involved are potentially high.

The most likely scenario's for stocked bigheaded carp to escape suitable water systems is stocking in waters that are flooded by rivers or stocking in open water systems.

Conclusions probability of establishment

The analysis of hydrology-temperature match reveals that potential of spawning of the bighead and silver carp in the Dutch Rhine river distributaries cannot be ruled out. However, if spawning were to occur, there are other environmental factors that will limit establishment and invasiveness of both species. Temperature regime, dissolved oxygen, food supply and salinity of most large water bodies are expected to limit the growth and condition and to cause morbidity and mortality for individuals of both species.

The overall effect of climate change on spawning ability is expected to be negligible. Future increases in water temperature, resultant food availability and changes in hydrological regime resulting from climate change may increase the growth and survival potential of Asian bigheaded carps.

Conclusions probability of further spread

If the bighead carp or silver carp becomes established in the Netherlands it is very likely that it will quickly disperse in to all suitable habitats in the Netherlands.

Conclusions impacts

<u>Ecological impact</u>

- Both bighead carp and silver carp reduce zooplankton communities at higher population levels and alter the species composition with smaller species becoming dominant;
- Both bighead carp and silver carp do not normally reduce the densities of phytoplankton, but do alter the species composition with smaller species becoming dominant;
- It cannot be excluded that other planktivore fish or large bivalve species will be negatively affected when bighead and/or silver carp become established in the Netherlands;
- Both species of bigheaded carp and their hybrid are known vectors of several alien parasites and diseases, this includes the Chinese pond mussel. Several of these organisms have the potential to establish in the Netherlands, but of the potential impact of these organisms little is known.

Economic impact

- Negative impact: When commercially important species such as European smelt or pike perch stocks are reduced, commercial fisheries will be negatively affected.
- Positive impact: In the Netherlands it is unlikely that commercial fisheries might benefit from the increased harvest as market prices are too low to make it profitable to harvest bigheaded carp.

Social impact

Because of the escape responses of silver carp (jumping out of the water), coalitions with especially fast going watercrafts are of concern. Because of this river stretches with abundant silver carp are becoming less attractive for water recreation. This has both local economic and social effects that might also be expected in the Netherlands.

Conclusions risk management

Established populations of bigheaded carp are only expected in large open water systems. Eradication or management of populations densities in such systems is complicated to say the least. So management is more likely to be successful at the prevention level. In the Netherlands such prevention would best focus on the prevention of deliberate stockings or accidental stockings by contaminated stocks of another species.

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Appendix 1-4

Appendix 1: likelihood of bighead carp and silver carp spawning in the Rhine at Lobith

Table 1: Likelihood of bighead carp spawning in the Rhine at Lobith.

year	Period where adequate temperature for spawning achieved	Flow velocity scenarios (m/s) / temperature match				Rising hydrograph / temperature match	Potential for spawning
		0.6	0.9	1.2	2.3		
1989	07/05-03/11	+	+	+	-	+	++/-
1990	31/04-22/10	+	+	+/-	-	+/-	+/--
1991	10/05-16/10	+	+	+/-	-	+	+/-
1992	13/005-11/10	+	+	+/-	-	+	+/-
1993	22/04-16/10	+	+	+	-	+/-	+/-
1994	28/04-17/10	+	+	+	-	+	++/-
1995	23/05-31/10	+	+	+	-	+/-	+/-
1996	20/04-18/10	+	+	+	-	+	++/-
1997	13/05-21/10	+	+	+	-	+	++/-
1998	9/05-04/10	+	+	+	-	+	++/-
1999	01/05-16/10	+	+	+	-	+	++/-
2000	27/04-16/10	+	+	+	-	+	++/-
2001	08/05-02/11	+	+	+	-	+	++/-
2002	09/05-04/10	+	+	+	-	+	++/-
2003	26/04-11/10	+	+	+	-	+	++/-
2004	24/04-09/10	+	+	+	-	+	++/-
2005	17/05-24/10	+	+	+	-	+	++/-
2006	30/04-29/10	+	+	+	-	+	++/-
2007	17/04-16/10	+	+	+	-	+	++/-
2008	03/05-16/10	+	+	+	-	+	++/-
2009	26/04-13/10	+	+	+	-	+	++/-
2010	21/05-14/10	+	+	+	-	+	++/-

Table 2: Likelihood of silver carp spawning in the Rhine at Lobith.

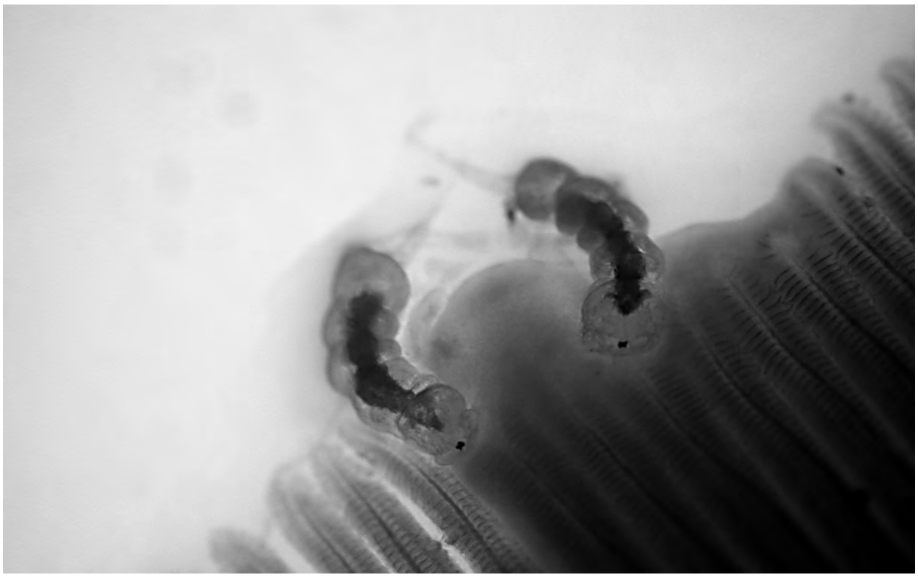
year	Period where adequate temperature for spawning achieved	Flow velocity scenarios (m/s) / temperature match		Rising hydrograph / temperature match	Potential for spawning
		0.3	3.0		
1989	19/05-29/09	+	-	+/-	+/-
1990	04/05-18/09	+	-	+	++/-
1991	01/06-30/09	+	-	+	++/-
1992	15/05-03/10	+	-	+/-	+/-
1993	28/04-15/09	+	-	+/-	+/-
1994	19/06-14/09	+	-	+/-	+/-
1995	21/06-17/09	+	-	-	+/--
1996	04/06-12/09	+	-	+	++/-
1997	17/05-03/10	+	-	+	++/-
1998	12/05-13/09	+	-	+/-	+/-
1999	30/05-02/10	+	-	+/-	+/-
2000	07/05-02/10	+	-	+	++/-
2001	17/05-12/09	+	-	+/-	+/-
2002	25/05-24/09	+	-	+/-	+/-
2003	28/05-25/09	+	-	-	+/--
2004	03/06-23/09	+	-	+/-	+/-
2005	08/06-30/09	+	-	+	++/-
2006	13/06-05/10	+	-	+	++/-
2007	24/04-11/09	+	-	+	++/-
2008	19/05-21/09	+	-	+/-	+/-
2009	20/05-03/10	+	-	+/-	+/-
2010	02/06-23/09	+	-	+	++/-

Appendix 2: Background information of several parasites and diseases.

1 - *Sinergasilus polycolpus*

Sinergasilus polycolpus is a well known and pathogenic parasitic copepod restricted to the bigheaded carp. Reports from grass carp are incorrect as in this species only the related *S. major* occurs. *S. polycolpus* is indigenous in China. Outside China this species is introduced in Hungary (as *S. leini*, a junior synonym), Serbia, Montenegro, European part of Russia and Central Asia. Here it is only recorded from silver carp and bighead carp, both in aquacultural facilities and in natural waters (Danube).

It is found on the gills of these species, where it can cause serious pathological changes. Female copepods cause clubbing and fusing of the gill filaments and in some cases deep indentations where the tips of the damaged filaments had broken off. In severe cases it can result in mortality. Such mortality is not only reported from carp ponds, but also from a resevoir in China (Molnar &. Szekely, 2004; Cakic *et al.*, 2004; Wang *et al.*, 2002).



Sinergasilus lieni from a silver carp gill. Photo Molnar &. Szekely (2004).

<u>Chance of entry:</u>
With *S. polycolpus* being present in Eastern Europe, the main source for bigheaded carp in the Netherlands, the chance of entry for this species is high.

<u>Possible impact in the Netherlands:</u>
So far *S. polycolpus* has only been recorded from bigheaded carp. Because none of the indigenous cyprinid species in the Netherlands has a comparable gill structure to

bigheaded carp, it is highly unlikely that indigenous fish species in the Netherlands might be affected.

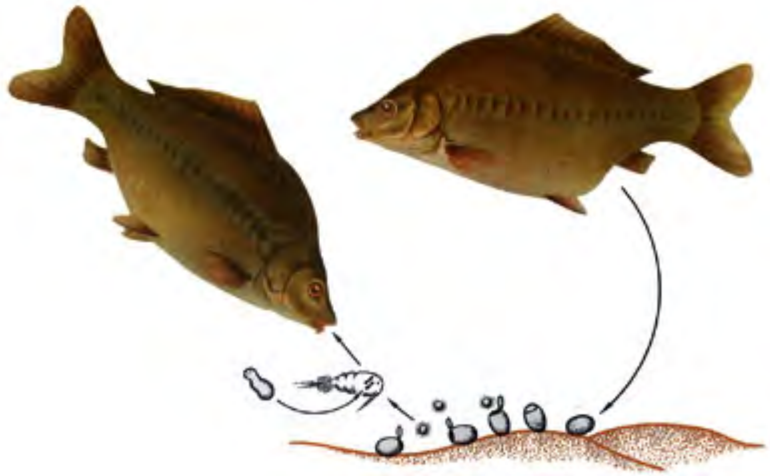
2 - Asian tapeworm (*Bothriocephalus acheilognathi*)

The Asian tapeworm *Bothriocephalus acheilognathi* is a cestod with an original range from the Amur River throughout much of China. It is also found in Japan, but probably this is the result of an early introduction (Kolar *et al.*, 2007). Being associated with commercially important species it has been widely introduced and become established in Europe, North America, South America, South Africa, Southeast Asia and Australia (Liao, 2007; Salgado-Maldonado & Pineda-Lopez, 2003). In Europe it is at least known from carp farms in Great Britain (Andrews *et al.,* 1981), from carp pond hatcheries in Germany (Körting, 1974), France, Italy and from farmed or wild carp from most Eastern European countries (Salgado-Maldonado & Pineda-Lopez, 2003). The parasite has so far never been found in freshwater fish species in the Netherlands, but evidence is not strong, as there have not been surveillance schemes in place.

The total number of known host species of *B. acheilognathi* is reported to be 102 in 14 families and 7 orders of freshwater fishes around the world (Salgado-Maldonado & Pineda-Lopez, 2003). Kolar *et al.* (2005) also described the parasite in a great variety of fishes from at least six orders, including sturgeons, live bearing fishes, sunfishes and catfishes. In China the Asian tapeworm is mainly reported from large cyprinids such as carp, grass carp and silver carp, but also other fish species, such as the carnivorous fish species yellow cheek (*Elopichthys bambusa*) and long spiky-head carp (*Luciobrama macrocephalus*) and the non-indigenous mosquito fish (*Gambusia affinis*) and swordttail (*Xiphophores hellerii*) (Liao, 2007).

This cestod becomes up to 20 centimeter long and has a relatively simple life cycle with only one intermediate host. This intermediate host can be various species of cyclopedia copepods that are common in almost any water body. Final hosts get infected by ingesting these copepods or, in the case of larger piscivorous species, by eating infected prey fish (Hansen *et al.,* 2007; Piasecki *et al.*, 2004). The parasite is thermophilic, and its development from eggs to coracidium takes only a few days in temperatures between 16 and 25˚C (Salgado-Maldonado & Pineda-Lopez, 2003).

Inside its final host the Asian tapeworm settles in the intestinal tract where it feeds on the nutrients by absorbing them directly through the body wall. The adult worms are hermaphroditic and produce fertile eggs by self-fertilization. The eggs are shed into the water with the fecal material of the host. Outside the host the larvae of the tapeworm hatch and after ingestion by a cyclopoid copepod settle in the body cavity of this intermediate host, completing the life cycle. The free-swimming larvae, called coracidia, are consumed by cyclopoid copepods (tiny crustaceans). They then burrow into the copepod's haemocoel (body cavity), where they develop into a second larval stage called a procercoid. This process also depends upon water temperature; larvae become able to infect their final host in 11-18 days at 29-31ºC, and in 49 days at 20ºC (Marcogliese, 2008).



Life cycle of the Asian tape worm. Taken from Salmo.ru.

Infected fish might be affected severely, with reports in aquaculture of mortality rates of up to 100%. The Asian tapeworm causes this damage by competing for nutrients with its host, blocking the intestinal tract, causing intestinal inflammation and/or damaging the surface of the intestinal tract (Han *et al.*, 2010). Typical noticeable effects of bothriocephaliasis are loss of weight, reduction of growth rate, weakened swimming and higher susceptibility to other diseases (Salgado-Maldonado & Pineda-Lopez, 2003). Deleterious effects of the Asian tapeworm are in general more common in small fish species and juvenile fish. In larger specimens of silver carp or bighead carp the adverse effects are known to be minimal (Kolar *et al.*, 2007).

The impact of the Asian tapeworm on an ecological level is hardly studied, although there are regular expressed concerns about the settlement of this parasite in populations of endangered fish species, e.g. Crucian carp (*Carassius carassius*) in the UK and several species of North American cyprinids (www.lambeth.gov.uk; Kolar *et al.*, 2007).

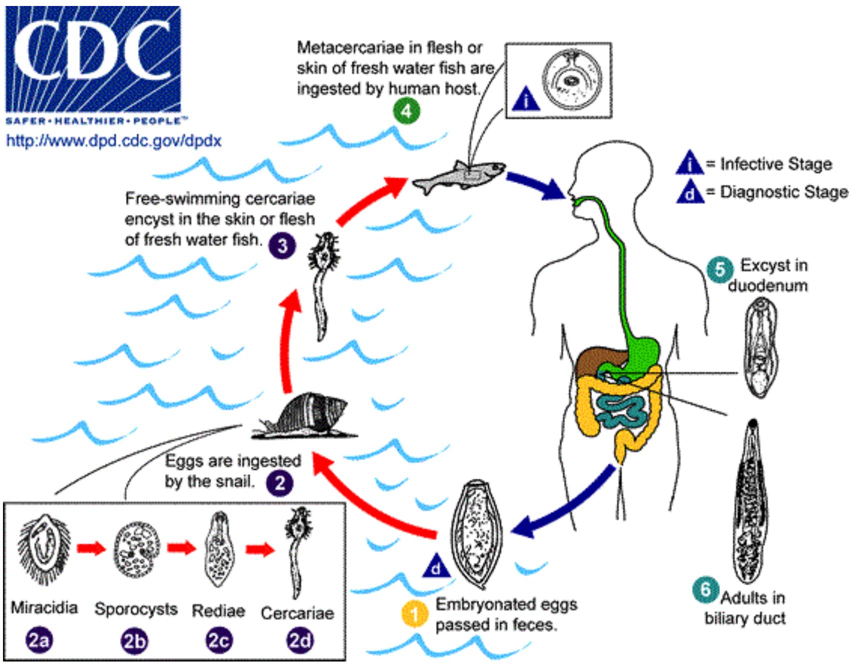
Chance of entry:
With the Asian tapeworm being present in Eastern Europe, the main source for bigheaded carp in the Netherlands, the chance of entry with bigheaded carp for this species is high.

Possible impact in the Netherlands:
The Asian tapeworm is known to cause in aquaculture serious deleterious effects to a variety of fish species. Although the impact it can have on natural systems is largely unknown, the Asian tapeworm should be taken as a potential risk for freshwater fish species in the Netherlands, especially of the family Cyprinidae.

3 - Chinese liver fluke *(Clonorchis sinensis)*

The trematode *Clonorchis sinensis* (Chinese liver fluke) is a parasite of fish and man and some other organisms, native to Japan, China, Taiwan, and Southeast Asia, currently infecting an estimated 30,000,000 humans. It is a zoonotic parasite, and resides in the human liver, most commonly in the gall bladder and common bile duct. The zoonosis is a significant problem in the mentioned regions, when raw or undercooked fish is consumed. In the Netherlands it is an uncommon disease imported by humans that have spend time in East-Asia (www.parasitologie.nl).

Chinese liver flukes have a complicated life cycle that involves several different types of animal hosts. Understanding this life cycle is an important part of controlling the spread of the parasite. In fish it is a parasite of a wide range of other fish species, including silver carp and bighead carp (Chen *et al.*, 2010).



The Chinese liver fluke discharges its eggs into the bile ducts and into the host animal's waste. From there, the eggs make their way into bodies of fresh water, where they are ingested by snails. The snail is the initial host for the fluke. Several species of snail can act as a host, including snails of the genus *Bithynia*. This genus has also representatives in the Netherlands (*B. tentaculata, B. leachii*). Once inside the snail, the egg hatches into a form called the miracidium, a simple organism with two eye spots and primitive sensory organs. Miracidia may also hatch into the water and swim free until they find an appropriate snail.

Inside the snail, the miracidium develops into several other forms. First, it becomes a sporocyst, a hollow sack with a developing larva inside. Eventually a form of the fluke called a redia emerges from the sporocyst. This form looks like a simple worm and lacks an intestine or esophagus. This form continues to develop until it becomes the cercaria, a stage that looks like a small adult fluke with a tail. Once the fluke reaches this stage, it bores its way out of the snail host and swims freely again.

Chinese liver fluke cercariae swim through the water until they find an appropriate fish to serve as their second intermediate host. These creatures then bore into the fish's body, forming a parasitic attachment to the fish. The cercariae create a cyst in the muscle of the fish, becoming metacercariae. It loses its eye spots and tail and becomes rounded.

Chinese liver fluke reaches its adult form only after ingestion by its final host–a human being. Once a human ingests the flesh of a fish containing metacercariae, the acid-resistant cyst passes through the stomach and into the small intestines. From there, the liver fluke moves through the bile tract to the liver, which is its final habitat. After about a month, the fluke matures and begins to produce eggs.

Chen *et al.* (2010) investigated many fish species in the Pearl River Delta of China for Chinese liver fluke: The results demonstrated a high incidence of *C. sinensis* infection in freshwater fishes and shrimps within Pearl River Delta region and a great difference in the infection rate among different collection sites and different fish species. Among the tested fish species were silver carp (9.5% positive) and bighead carp (21.6% positive). Tilapia was also positive (4.5%), as was goldfish (14.4%), but common carp (0%) was not.

Zhang *et al.* (2007) investigated the infection in humans and in fish: Among 1,473 people examined, 70 (4.75%) were found infected with Chinese liver fluke. By counting eggs per gram feces (EPG), it was found that the intensity of infection in males was stronger than that of females, and the average EPG was 41.87 in all populations. Snails, 1.15%, were infected with cercariae of Chinese liver fluke. The average infection rate of freshwater fishes of 15 species with metacercariae of *C. sinensis* was 16.97%, and the carps reached the highest infection rate (40.74%).

Phan *et al.* (2010a) tested fish from wild sources and from fish farms in the Red Delta, Vietnam for the parasite. He found that these fish groups were equally infected (64-68%), especially for the edible fish species. Of the silver carp 82.7% was infected. Phan *et al.* (2010b) tested nurseries of fish for the parasite in the same area, and concluded, that at nurseries of fish prevention strategies must address aquaculture management practices, to minimize the risk of distributing infected juveniles to grow out ponds, and subsequently to markets for human consumption.

<u>Chance of entry:</u>
With the Chinese liver fluke being absent in Eastern Europe, the main source for bigheaded carp in the Netherlands, the chance of entry with bigheaded carp is low.

[One large Asian species sold for garden ponds, the Chinese sucker (*Myxocyprinus asiaticus*), is said to be only available as wild caught fish from China. because of this, the species is a serious potential vector for Chinese liver fluke. See also §2 for more information on the Chinese sucker]

Possible impact in the Netherlands:
In the Netherlands freshwater fish are not or uncommonly eaten raw. The risk of humans becoming affected by the Chinese liver fluke originating from Dutch freshwater fish is low even when this species of fluke becomes common in the Netherlands. Information of the possible impact on other (intermediate) hosts is not available.

4 - *Aphanomyces invadans*

Epizootic ulcerative syndrome (EUS), caused by the oomycete *Aphanomyces invadans* (syn. *A. piscicida*), is a serious, newly emerging disease, diagnosed in over 60 freshwater and estuarine fish species of various fish families in Asia, Australia, North-America, and Africa. The disease is exotic to the European Union, and it is notifible for the EU and the OIE, see also 9. There is no therapy for EUS, nor is there a vaccine available (OIE, 2009).

The genera *Aphanomyces* is a member of a group of organisms commonly known as the water moulds. Although long regarded as a fungus because of its characteristic filamentous growth, water moulds are actually not a member of the Eumycota, true fungi, but is classified with diatoms and brown algae in a group called the Stramenopiles.

The early signs of the disease include loss of appetite and fish become darker. Infected fish may float near the surface of the water, and become hyperactive with a very jerky pattern of movement. Red spots may be observed on the body surface, head, operculum or caudal peduncle. Large red or grey shallow ulcers, often with a brown necrosis, are observed in the later stages. Large superficial lesions occur on the flank or dorsum. Most species other than striped snakeheads and mullet will die at this stage. In highly susceptible species, such as snakehead, the lesions are more extensive and can lead to complete erosion of the posterior part of the body, or to necrosis of both soft and hard tissues of the cranium, so that the brain is exposed in the living animal (OIE, 2009).

The silver carp and bighead carp are sofar not present at the list of susceptible fish species for EUS (EFSA, 2008). In the EFSA document (EFSA, 2007) on vector species, the silver carp and bighead carp are not mentioned as possible vectors for EUS. However, Phan Thi Van *et al.* (2002) mentions EUS in bighead carp in Vietnam. It is not clear whether this report has been rejected or not been considered by the EFSA working group on susceptible fish species.

Chance of entry:

The risk of introducing EUS into Europe via imports of live fish is currently being investigated by an ad hoc group of experts from the EFSA. The outcome is expected autumn 2011. Although this study is not ready yet, in general it can be assumed, that both silver carp and bighead carp are potential passive vectors for EUS without clinics, when originating from an EUS infected farm.

Possible impact in the Netherlands:

EUS is a serious disease that is not indigenous to the Netherlands, with the potential to effect probably most species of native fish. Its actual effects on both aquaculture and wild fish species is currently being investigated by an ad hoc group of experts from the EFSA. The outcome is expected autumn 2011.

5 - Spring Viraemia of Carp Virus (SVCV)

Spring viraemia of carp (SVC) is a rhabdovirus infection capable of inducing an acute haemorrhagic and contagious viraemia in several carp species, among which bighead carp and silver carp, and some ictalurid fish species (OIE, 2009). SVC is present in the Netherlands since decades, with a low incidence. We have seen outbreaks in wild carp with an incidence of once in about 5 years (CVI, unpublished data).

Chance of entry & possible impact in the Netherlands:

SVCV is already present in the Netherlands. Nevertheless, the release of silver carp and bighead carp in especially isolated water bodies could further spread SVC in wild cyprinid fish populations.

6 - Koi Herpesvirus (KHV)

Koi herpesvirus (KHV) is member of the family Herpesviridae, and causes Koi Herpes Virus Disease (KHVD). This disease has been mainly recorded in common carp (*Cyprinus carpio carpio*) and koi carp (*Cyprinus carpio koi*). Koi Herpes Virus was first isolated from fish cultured in Israel and USA respectively in 1998 and reported by Hedrick *et al.* (2000). KHV is notifiable for the OIE, and since Aug 2008 also for the EU.

KHV is at least since 1996 present in Europe. The global occurrence of KHV has been assessed via a questionnaire in 2009 (Haenen & Olesen, 2009): Up to 2009 KHV had been detected in 30 countries: (* = in closed systems; # = in wild carp): Austria*, Belgium*, Canada#, China*, Costa Rica*, Czech Republic*, Denmark*, France*, Germany*#, Hong Kong*, Indonesia*#, Ireland*, Israel*, Italy*, Japan*#, Luxembourg*, Malaysia*, the Netherlands*, New Zealand*, Poland*#, Singapore*, Slovenia*, S-Africa*, S-Korea*, Sweden*, Switzerland*, Taiwan*, Thailand*, UK*#, and USA*#. KHV was suspected in 3 countries: India*, Guatemala*, Russia*. In the Netherlands thus far all KHV outbreaks have been reported from closed facilities, i.e. indoor import farms and outdoor ponds, without direct contact to open water with one exception: there has been one detection of KHV in November 2008 in a lake.

The disease occurs naturally at temperatures between 17°C and 26°C with an incubation period of 7-21 days depending on water temperature. Morbidity is often 100% with mortality up to 90% at higher temperatures. Behavioural signs of disease include lethargy, fatigue, disorientation, erratic swimming and frequent ventilation (gasping). Fish can die within hours of the first signs appearing, but at lower temperatures the course of the disease is more protracted (Walster, 1999). The most consistent gross clinical sign of disease is an irregular discolouration of the gills consistent with moderate to severe gill necrosis. Other commonly reported clinical signs include anorexia, enophthalmia (sunken eyes), fin erosion, superficial haemorrhaging at the base of the fins, pale, irregular patches on the skin associated with excess mucus secretion and also decreased production of mucus in patches, leaving the epidermis with a sandpaper-like texture. Internal gross pathological signs are inconsistent but enlarged anterior kidney, in early stages of the disease a swollen spleen, and a flaccid and mottled appearance of the heart have been reported (Haenen *et al.*, 2004).

Although silver carp and bighead carp are not yet recognized as being susceptible to KHV, Bergmann (EAFP Conference, 2007) presented data from his research on KHV and concluded, that among others bighead carp and silver carp could be experimentally infected with KHV. However no mortalities or clinical signs were observed in bighead carp and silver carp. This means that these species might be vectors for KHV, without showing clinical sings. Thus far this observation has not been confirmed by other laboratories.

<u>Chance of entry:</u>
With the Koi Herpesvirus being present in Eastern Europe, the main source for bigheaded carp in the Netherlands, the chance of entry with bigheaded carp is high.

<u>Possible impact in the Netherlands:</u>
The Koi Herpesvirus is not known to affect native fish species in the Netherlands, but can cause high mortality in European carp populations. This species is both valuable for commercial and recreative fisheries.

Koi with KHVD: enophthalmus and gill necrosis (CVI, Lelystad).

Appendix 3: Results of the Risk identification conform the Fisk method.

	Fish Invasiveness Scoring Kit (G.H. Copp, R. Garthwaite & R.E. Gozlan)		
		Latin name:	*Hypophthalmichthys nobilis*
			Hypophthalmichthys molitrix
		Common name:	bighead carp
			silver carp
		Assessor:	Menno Soes/Rob Leuven
Question ID		**Risk query:**	
		Biogeography/historical	**Reply**
1	1,01	Is the species highly domesticated or cultivated for commercial, angling or ornamental purposes?	Y
2	1,02	Has the species become naturalised where introduced?	Y
3	1,03	Does the species have invasive races/varieties/sub-species?	Y
4	2,01	Is species reproductive tolerance suited to climates in the risk assessment area (1-low, 2-intermediate, 3-high)?	2
5	2,02	What is the quality of the climate match data (1-low; 2-intermediate; 3-high)?	2
6	2,03	Does the species have broad climate suitability (environmental versatility)?	Y
7	2,04	Is the species native to, or naturalised in, regions with equable climates to the risk assessment area?	Y
8	2,05	Does the species have a history of introductions outside its natural range?	Y
9	3,01	Has the species naturalised (established viable populations) beyond its native range?	Y
10	3,02	In the species' naturalised range, are there impacts to wild stocks of angling or commercial species?	Y
11	3,03	In the species' naturalised range, are there impacts to aquacultural, aquarium or ornamental species?	N
12	3,04	In the species' naturalised range, are there impacts to rivers, lakes or amenity values?	Y
13	3,05	Does the species have invasive congeners?	Y
14	4,01	Is the species poisonous, or poses other risks to human health?	N
15	4,02	Does the species out-compete with native species?	?
16	4,03	Is the species parasitic of other species?	N
17	4,04	Is the species unpalatable to, or lacking, natural predators?	N
18	4,05	Does species prey on a native species (e.g. previously subjected to low (or no) predation)?	N
19	4,06	Does the species host, and/or is it a vector, for recognised pests and pathogens, especially non-native?	Y
20	4,07	Does the species achieve a large ultimate body size (i.e. > 10 cm FL) (more likely to be abandoned)?	Y
21	4,08	Does the species have a wide salinity tolerance or is euryhaline at some stage of its life cycle?	N
22	4,09	Is the species desiccation tolerant at some stage of its life cycle?	N
23	4,10	Is the species tolerant of a range of water velocity conditions (e.g. versatile in habitat use)	Y
24	4,11	Does feeding or other behaviours of the species reduce habitat quality for native species?	?
25	4,12	Does the species require minimum population size to maintain a viable population?	?
26	5,01	Is the species a piscivorous or voracious predator (e.g. of native species not adapted to a top predator)?	N
27	5,02	Is the species omnivorous?	N
28	5,03	Is the species planktivorous?	Y
29	5,04	Is the species benthivorous?	Y
30	6,01	Does it exhibit parental care and/or is it known to reduce age-at-maturity in response to environment?	Y
31	6,02	Does the species produce viable gametes?	Y
32	6,03	Does the species hybridize naturally with native species (or uses males of native species to activate eggs)?	N
33	6,04	Is the species hermaphroditic?	N
34	6,05	Is the species dependent on presence of another species (or specific habitat features) to complete its life cycle?	N
35	6,06	Is the species highly fecund (>10,000 eggs/kg), iteropatric or have an extended spawning season?	Y
36	6,07	What is the species' known minimum generation time (in years)?	6
37	7,01	Are life stages likely to be dispersed unintentionally?	N
38	7,02	Are life stages likely to be dispersed intentionally by humans (and suitable habitats abundant nearby)?	N
39	7,03	Are life stages likely to be dispersed as a contaminant of commodities?	Y
40	7,04	Does natural dispersal occur as a function of egg dispersal?	Y
41	7,05	Does natural dispersal occur as a function of dispersal of larvae (along linear and/or 'stepping stone' habitats)?	Y
42	7,06	Are juveniles or adults of the species known to migrate (spawning, smolting, feeding)?	Y
43	7,07	Are eggs of the species known to be dispersed by other animals (externally)?	N
44	7,08	Is dispersal of the species density dependent?	?
45	8,01	Any life stages likely to survive out of water transport?	N
46	8,02	Does the species tolerate a wide range of water quality conditions, especially oxygen depletion & high temperature?	Y
47	8,03	Is the species susceptible to piscicides?	Y
48	8,04	Does the species tolerate or benefit from environmental disturbance?	N
49	8,05	Are there effective natural enemies of the species present in the risk assessment area?	Y
		Outcome:	Evaluate
		Score:	15
		Biogeography	11
		Score partition: **Undesirable attributes**	4
		Biology/ecology	0
		Biogeography	10
		Questions answered: **Undesirable attributes**	10
		Biology/ecology	23
		Total	43
		Aquacultural	7
		Sector affected: **Environmental**	17
		Nuisance	2

Appendix 4: Background information on legislation.

<u>General</u>

In the field of aquaculture and aquaculture products (European Commission, 2011 online), the basic European Community legal provision is Council Directive 2006/88/EC on animal health requirements for aquaculture animals, and on the prevention and control of certain diseases as amended by Commission Directive 2008/53/EC. Part of the 2006/88/EC is for most parts applicable for aquaculture, but partly also on ornamental fish, and in general this directive is important to prevent fish disease.

Council Directive 2006/88/EC lays down:

- 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 provisions of Directive 2006/88/EC are applicable to fish, molluscs and crustaceans at all their life stages reared in a farm or mollusc farming area, including any aquatic animal from the wild intended for a farm or mollusc farming area.

An outbreak of a disease affecting aquatic animals can quickly take on epizootic proportions, causing mortality and disturbances on a scale liable to reduce severely the profitability of aquaculture. It is therefore important that control measures are taken when the presence of such a disease is suspected so that immediate and effective actions can be implemented as soon as its presence is confirmed. Such measures are aimed at preventing the spread of the disease, in particular by carefully controlling movements of aquaculture animals and products thereof liable to spread the infection.

The diseases of Community importance and the susceptible species included in Directive 2006/88/EC are listed in Part II of Annex IV. Those diseases are classified in two categories:

1 - **Exotic diseases or diseases of special importance which have never been detected in the Community**. For fish are included: EHN (Epizoötic Haematopoetic Necrosis) and EUS (Epizootic Ulcerative Syndrome).

Community policy with regard to those diseases is the swift eradication as a first option.

When one of those diseases is suspected, the official services must initiate official investigations to confirm or rule out its presence. No movements of aquatic animals, whether dead or alive, are allowed without the authorisation of the official service. When the presence of the disease is confirmed, aquaculture animals should be harvested as soon as possible to avoid the spread of the disease.

2 – **Non-exotic diseases** or important diseases that have been detected in the Community. For fish are included: KHV (Koi Herpesvirus), VHS (Virale Haemorrhagic Septicaemia), IHN (Infectious Haematopoietic Necrosis) and ISA (Infectious Salmon Anemia).

Community policy with regard to those diseases is either to contain them or to eradicate them in the long term.

Where aquatic animals are suspected of being infected with a non-exotic disease an official investigation must be initiated to confirm or rule out the presence of the disease. Disease-free areas will lose their status as free from the disease until it is proven that the disease is eradicated.

Article 43 of Directive 2006/88/EC may be used as legal basis to control diseases not listed in Part II Annex IV that constitutes a significant risk for the animal health of aquaculture or wild aquatic animals in a Member State.

<u>Preventive measures</u>
Directive 2006/88/EC is focused on disease prevention. It introduces a system of authorisation of aquaculture production businesses and certain processing establishments. To be authorised, they have to comply with certain minimum requirements as regards traceability, implementation of good hygiene practices and risk-based health surveillance. This new system would provide a complete overview of the aquaculture industry which would assist in the prevention, control and eradication of aquatic animal diseases.

Once the aquaculture production businesses and authorised processing establishments are authorised, Member States shall establish a publicly available register. This provision is implemented by Commission Decision 2008/392/EC implementing Council Directive 2006/88/EC as regards an Internet-based information page to make information on aquaculture production businesses and authorised processing establishments available by electronic means.

Another important preventative measure is the obligation for all farms and mollusc farming areas to implement a risk-based surveillance scheme. This scheme aims to detect:

- Increased mortalities;
- Diseases listed in Part II of Annex IV to the Directive.

Commission Decision 2008/896/EC on guidelines for the purpose of the risk-based animal health surveillance schemes provided for in Council Directive 2006/88/EC ensures a consistent approach amongst Member States in this regard.

Placing on the market and imports

Directive 2006/88/EC governs any placing on the market within each Member State, between different Member States and imports into the European Union. In general terms, this means that aquaculture animals and products from both within the EU and from third countries must broadly fulfill similar animal health requirements before they can be moved.

The main principle of these regulations is that aquaculture animals which are intended for a Member State, zone or compartment declared free of or under a surveillance or an eradication programme as regards a listed disease must originate from a Third Country, Member State, zone or compartment declared disease free if the animals are susceptible or may act as vector for that disease.

Consequently, whether a movement is in compliance with the animal health placing on the market/import rules will be mainly determined by the following three factors:

- The health status at the place of destination as regards the diseases listed in Part II of Annex IV to the Directive. The relevant issue would be whether the place of destination has been declared free of or is under a surveillance or an eradication programme.
- The species in question. The relevant issue would be whether the animal of the consignment are susceptible or regarded as vector species to the diseases listed in Part II of Annex IV to the Directive.
    - Susceptible species are listed in Part II of Annex IV to the Directive;
    - Vector species and the conditions under which these species shall be regarded as vectors can be found in Annex I to Regulation (EC) No 1251/2008.
- The health status at the place of origin.

As a general rule, when the consignment contains susceptible/vector species and the place of destination has been declared free of or is under surveillance or eradication programme, freedom at the place of origin is required.

Detailed rules can be found in the following implementing measures:

- Commission Regulation (EC) No 1251/2008 implementing Council Directive 2006/88/EC as regards conditions and certification requirements for the placing on the market and the import into the EU of aquaculture animals and products thereof and laying down a list of vector species, which is amended by, a.o.:
    - Commission Regulation (EC) No 719/2009 amending Regulation (EC) No 1251/2008 as regards the list of third countries and

territories from which certain crustaceans and ornamental aquatic animals may be imported into the EU;

- Commission Regulation (EU) No 1143/2010 amending Regulation (EC) No 1251/2008 as regards the period of application of the transitional provisions for certain ornamental aquatic animals intended for closed ornamental facilities

• Commission Regulation (EC) No 1252/2008 derogating from Regulation (EC) No 1251/2008 and suspending imports into the EU from Malaysia of consignments of certain aquaculture animals;
• Commission Decision 2008/946/EC implementing Council Directive 2006/88/EC as regards requirements for quarantine of aquaculture animals
• Commission Decision 2010/221/EU approving national measures for limiting the impact of certain diseases in aquaculture animals and wild aquatic animals in accordance with Article 43 of Council Directive 2006/88/EC, which is amended by, a.o:
    - Commission Decision 2010/761/EU amending Annexes I and II to Decision 2010/221/EU as regards approved national measures by Hungary and the United Kingdom for spring viraemia of carp.

A Guidance document (last updated 9 March 2010) has been drafted to provide an introduction into the animal health requirements for placing on the market, import and transit of aquaculture animals according to Council Directive 2006/88/EC and Commission Regulation (EC) No 1251/2008.

<u>National legislation in place</u>
The national legislation on fish diseases can be found in the Fisheries Law (Visserijwet: http://www.st-ab.nl/wetten/0343_Visserijwet_1963.htm), which is based on the EU legislation. Handling fish should be furthermore according to the Gezondsheids- en Welzijnswet voor Dieren (GWWD) (http://www.st-ab.nl/wetten/0095_Gezondheids-_en_welzijnswet_voor_dieren_Gwwd.htm), which also deals with fish diseases.

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